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Böstrom et al.

[11] **3,789,494**

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[54] **METHOD OF SPIRALLY WINDING STRIP TO PRODUCE PINNED UNITS**

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[21] Appl. No.: **246,655**

[52] **U.S. Cl.** ..... **29/423,** 29/157.3 R, 165/10, 242/7.02

[51] **Int. Cl.** **B23p 15/26,** B23p 17/00

[58] **Field of Search** ..... 29/157.3 A, 157.3 AH, 423, 29/157.3 R; 113/118 A; 242/7.02; 165/10

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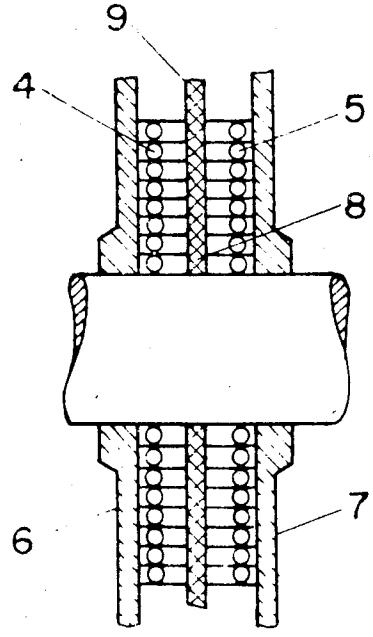
Assistant Examiner—D. C. Reiley, III
Attorney, Agent, or Firm—Larson, Taylor & Hinds

[57] **ABSTRACT**

A design of finned units, intended for example for thermal regenerators, heat exchangers or burners for liquid fuel. The finned units are manufactured by simultaneous spiral winding of a strip forming fins and a spacer element forming a distance between the fins. The spacer elements are wholly or partially removed when fixing elements have been introduced in a number of holes distributed about the circumference. The cross-sectional area of each fixing element is equal to or smaller than the cross-sectional area of the corresponding holes in the fins. As a consequence thereof each fixing element prevents movement of the fins exclusively in a plane perpendicular to said fixing element.

17 Claims, 15 Drawing Figures



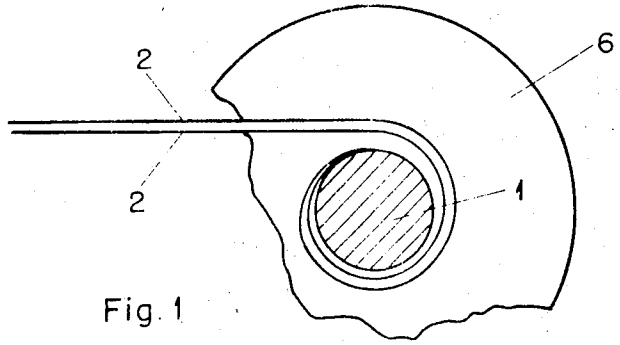


Fig. 1

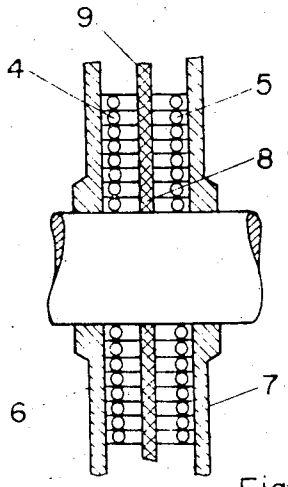


Fig. 2

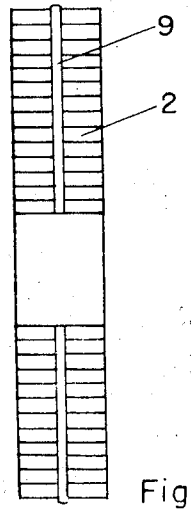


Fig. 3

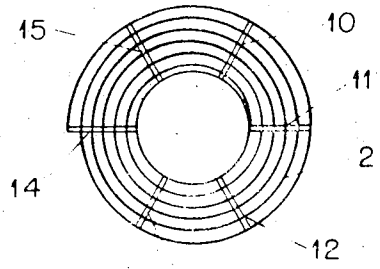


Fig. 4 13

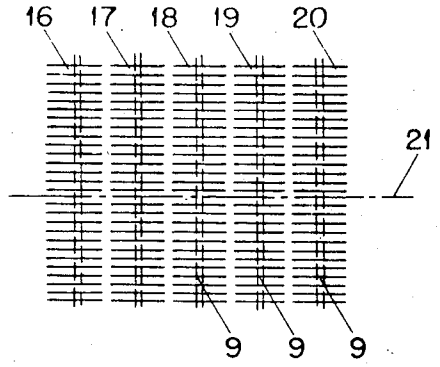


Fig. 5

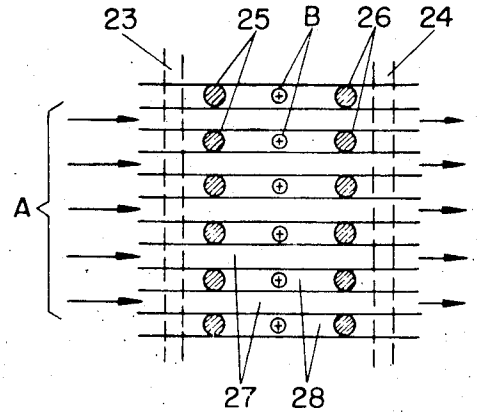


Fig. 6

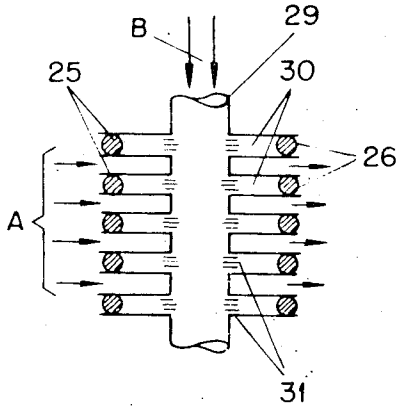


Fig. 8

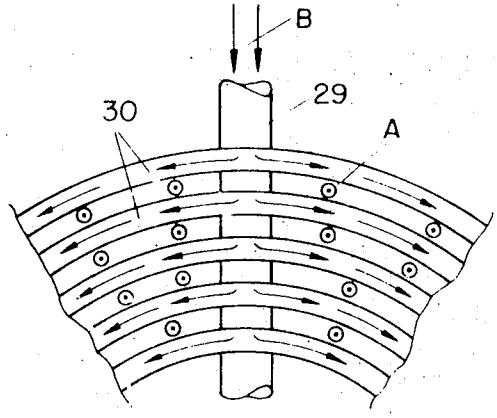


Fig. 7

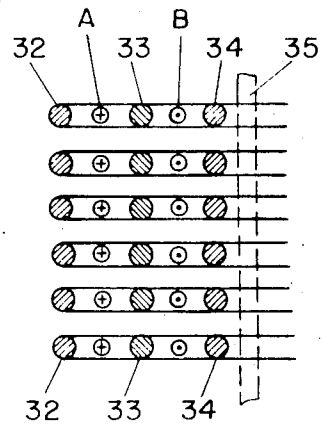


Fig. 9

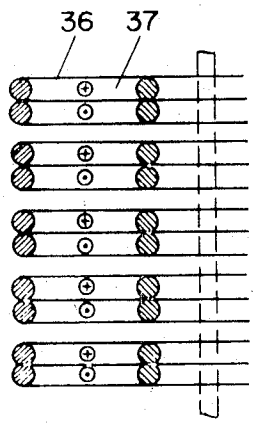


Fig. 10

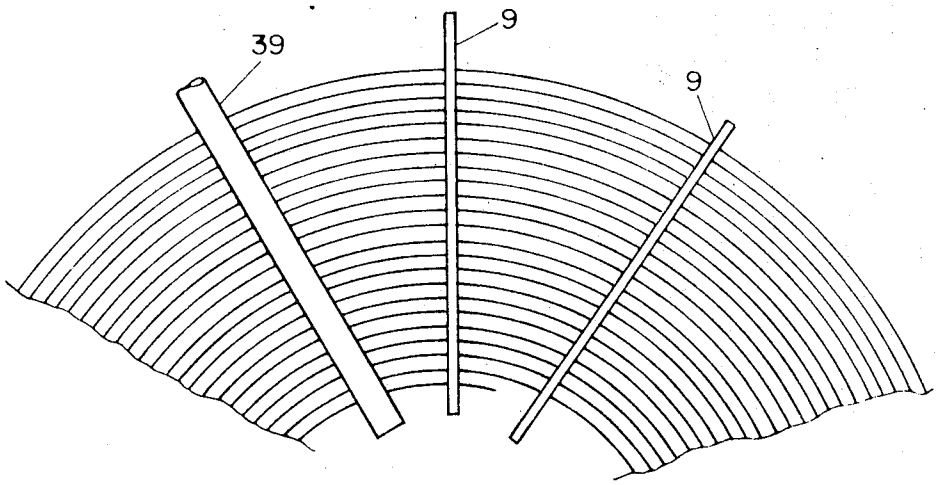


Fig. 12

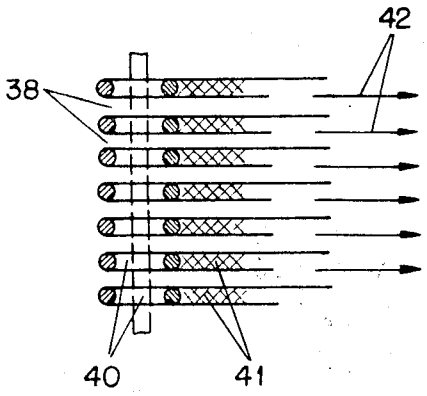


Fig. 11

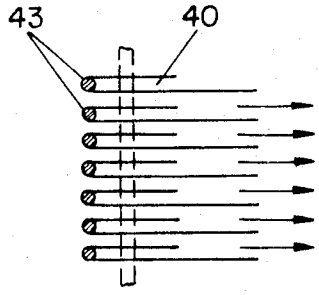


Fig. 13

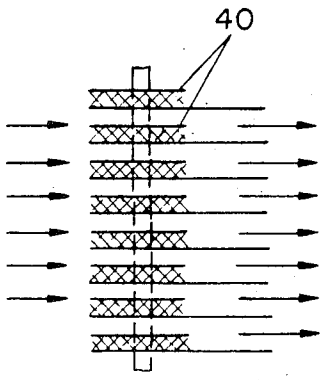


Fig. 14

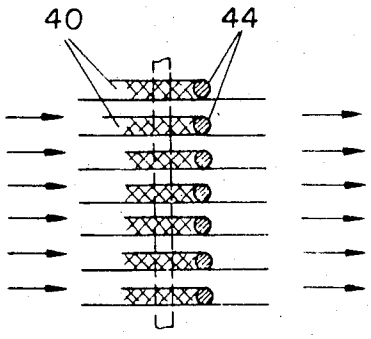


Fig. 15

METHOD OF SPIRALLY WINDING STRIP TO PRODUCE PINNED UNITS

The present invention relates to a method for the manufacture of finned units by winding of an elongated, for example strip material, achieving radial distance between the individual turns of the winding forming the fins, finned units manufactured according to the method and application of such finned units.

It has been known previously that finned units can be manufactured in that a substantially flat strip is wound up at the same time as a corrugated strip, so that this corrugated strip serves as a spacer element between the different turns of the flat strip. It has also been proposed previously that a finned unit can be manufactured in that a strip is wound up which is provided with spacer elements distributed over its length, for example in the form of prominences or projections on the strip.

The present invention has the characteristics which will be apparent from the following main claim and subsidiary claims.

Thus a finned unit is manufactured by winding of an elongated, for example strip material together with spacer elements so as to achieve a radial distance between the individual turns in the finned unit formed, the turns of the winding being fixed by means of guide elements, for example consisting of guide pins or other fixing elements in the direction perpendicular to the guide pins.

By application of the invention a finned unit of a strip material with small thickness can be manufactured, whereby the distance between the individual fins can be greater than, equal to or smaller than the thickness of the individual fins. The finned unit may be realized with great compactness, whilst it has great strength and dimensional rigidity, for example against compression in radial direction. By radial direction in this connection is meant a direction which is perpendicular to a tangent on the turn of the winding at a certain point. The turn of the winding at that point may be curved or flat.

The advantages which are obtained by a constant radial distance between the fins can be extraordinarily great in thermodynamical and also other applications. If the finned unit is used in heat exchanger devices a low pressure drop and at the same time effective heat transfer can be achieved. The thermal conduction from fin to fin, accordingly in radial direction of a near-circular spiral, can be made very small compared with the thermal conduction within a finned unit constructed with the help of corrugated strip, since here a large contact surface exists between the strips. It is thus possible by application of the invention to construct heat exchangers with a minimum radial conduction of heat through the strip material and guide elements, which can be of great value for example in cryotechnique, hot-gas engine technique.

As a consequence of the fact that the finned unit can be manufactured with extremely small and at the same time constant distance between certain fins, whilst between other fins a different, for example greater, constant distance can be achieved, a finned unit in accordance with the invention can be utilized for the manufacture of a burner for liquid fuel, the latter being sucked in by capillary action between the individual fins, whereupon it is evaporated and burnt. Hereby it

is possible for the oxidizer to flow in through one side of the finned unit. For such applications it may be appropriate partly to fill the space between certain of the fins with a fine-mesh net or other comparable elements for facilitating capillary pumping of the liquid fuel.

The invention is described in the following in connection with the enclosed drawing, where FIG. **1** shows in a sideview how a strip material and a spacer element are wound up, FIG. **2** shows the same in axial section, FIG. **3** shows an axial section through a finished finned unit and FIG. **4** such a finned unit in plan view. FIGS. **5 – 15** show different realizations of the finned unit in connection with the application of such finned units in various technical fields.

As can be seen from FIG. **1** a strip material **2** is wound up on a core **1,** which is driven by a motor not shown on the drawing, and at the same time with it a spacer element **3.** This spacer element, as is apparent from FIG. **2,** can be constituted of two wires **4** and **5.** These may, as in the embodiment shown, be placed during the winding up so that they come to lie near the edges of the strip material **2,** but they may also, for other applcations, be placed farther away from the edge. For the guiding of the strip material **2** during the winding up fixing parts **6** and **7** may be arranged on the core **1,** between which the winding up takes place.

When a sufficiently great number of turns of the strip material **2** has been wound up together with the spacer element **3,** so that the desired dimension on the unit has been achieved, the turns of strip are fixed mutually by means of guide elements so that a constant distance between the individual turns is maintained and so that the turns of fin are fixed against movement in tangential direction, in the first place at the guide elements. This may be accomplished as shown in FIG. **2** in that a number of holes **8** are drilled radially into the unit. Into each hole is introduced a pin **9** which has such dimensions in relation to the hole **8** in the strip, that the individual strips cannot shift tangentially at the pin **9.** If the different guide pins in the unit form angles with one another a fixing in radial direction of the corresponding portion of the strip is achieved. Fixing in radial direction can also be accomplished by a connection between pin and strip by means of soldering, glueing or the like. Possibly the drilling can be done in such a manner that the holes are flanged, with each flange around a hole made in this manner abutting against the neighbouring turn of the strip material. In the case of this realization pins **9** may in certain cases be dispensed with. As is apparent from FIG. **4** the fixing of the individual turns of this strip material can be done along a number of radial directions **10 – 15** distributed along the periphery, the number of such fixings depending on different factors such as the size of the finished finned unit, the thickness of the strip material, the field of application of the finned unit etc. Other possible realizations of the guide elements will be apparent from the further embodiments described in the following.

After the fixing of the individual turns has been accomplished, the whole or part of the spacer elements **3** may be removed, whereupon the finished finned unit in principle assumes the appearance as shown in FIGS. **3** and **4.** In the embodiment of the invention described here, when the spacer element **3** is formed by two wires **4** and **5,** which are wound up at the same time as the strip material **2,** the removal of the spacer element can take place quite simply through pulling the wires out of

the unit after the two fixing parts **6** and **7** have been withdrawn.

The desired mutual fixing of the fins can also be achieved by soldering of bands or wires transversely across the edges of the fins on one or both sides of the finned unit. It is also conceivable to accomplish the fixing by deformation of the fin edges in the form of radial splines on both sides.

The spacer elements which serve for maintaining a constant distance between the turns during the winding procedure and before the turns of fins have been fixed to one another, may consist, as previously mentioned, of wires which are wound up at the same time as the strip material. For certain fields of application the spacer elements may consist of a material which under the effect of heat, certain chemicals or in a similar manner can dissolve, leaving behind the finned unit. It is also conceivable that the material in the fins themselves can have similar properties, in which case the finned unit can be utilized as a mould. The formation of distance between the different turns during the winding procedure itself can also be achieved by winding two or more strip materials onto the core at the same time, the strip materials having such a mutual axial displacement on the core that a certain overlapping takes place, so that consequently one strip material with its edge serves as a spacer element for the neighbouring strip material during the winding up procedure. After the mutual fixing of the turns mentioned earlier has been achieved, for example by means of the drilling of radial holes and insertion into these of pins, the different finned units are obtained quite simply by separating the different windings from one another in axial direction.

FIG. **5** shows a number of finned units of the type previously described which have been combined to a thermal regenerator which may be used for example in a hot-gas engine or a refrigerating machine. In the latter case use is made of gas expansion with thermal regeneration. As is apparent from the figure a number of finned units **16, 17, 18, 19, 20** are arranged following one another in axial direction, consequently with a common axis **21.** The finned units are arranged following one another with a comparatively small axial separation. As in the embodiment described earlier each finned unit is provided with a number of guide pins **9.** A gaseous medium can be made to flow through the finned unit in axial direction and in alternating directions, that is to and fro, the gas pressure being variable according to a specified scheme, accomplished for example by means of a reciprocating piston. During the pulsating flow the gas exchanges heat with the matrix constituted by the finned units, whereby at the flow of the gas in one direction heat is given off from the matrix to the gas and at the flow of the gas in the opposite direction heat is given off from the gas to the matrix. In this application it is significant that the radial as well as the axial heat conduction is small so that the efficiency of the regeneration should remain high. By making use of the finned unit according to the invention this condition can be fulfilled. The finned unit can be formed of metal strip, whereby the separation in axial direction between neighbouring finned units can be appreciably less than the width in axial direction of the finned unit. For example at a width of the finned unit equal to 3 mm the separation between neighbouring finned units may be 0.2 mm. The axial separation between the individual finned units in the matrix may be accomplished by means of plastic nets or spacer elements not shown in the figure with low thermal conductivity, which have small contact surface with the finned units.

In the embodiments described until now it has been assumed that a sole strip material is wound up together with the spacer element to form a finned unit. A quicker construction of the finned unit can be achieved by simultaneous winding up of two or more strip materials together with the corresponding number of spaced elements. Finned units manufactured in this manner may be utilized in various manners, and in the following some possible fields of application will be described.

FIG. **6** shows a finned unit which can be utilized as a heat exchanger between two media. The finned unit has been formed by simultaneous winding up of two strip materials together with the corresponding number of spacer elements, so that constant distance is obtained between the individual turns. Subsequently in the previously described manner guide pins **23** and **24** were fitted so as to produce the aforementioned fixing of the individual fin turns. Finally the spacer elements between every other turn have been removed leaving behind the spacer elements **25** and **26** between the other turns. As a result ducts **27** running in axial direction were obtained and a spiral-shaped duct **28** running in tangential direction. One of the two media, here designated by A, flows axially through every other fin gap, whilst the other medium, here deisgnated by B flows in the other gap in a spiral-shaped track. The remaining spacer elements **25, 26** may be sealed in a suitable manner against the strip material. Depending on the material used for the strips and for the spacer elements such a seal can be made by means of soldering, cementing or in some other manner.

FIG. **7** shows likewise a heat exchanger between two media, and in this case the medium B enters radially through a pipe **29** and is distributed from this pipe to the different fin ducts **30.** In these ducts the medium flows a half turn to a second pipe, not shown on the drawing, which serves as a manifold. It is assumed that the medium A flows forward in axial direction through the finned unit. This said pipe **29** may also serve as a guide element for the fixing of the mutual position of the turns. The pipe **29** and the corresponding pipe on the other side of the finned unit may from the start be made of sintered pipes or bars which are inserted in the drilled holes in the finned unit. Subsequently the spacer elements between every other strip are removed whereupon the sintered pipe or bar is sealed on the outside by soldering, glueing, dipping in a metal bath etc. whereby at the same time the fin ducts **30** for medium B can be sealed.

FIG. **8** shows a section through the finned unit according to FIG. **7** in a projection which is perpendicular in relation to FIG. **7.** As is apparent from the drawing, the spacer elements **25, 26** have been left behind in the finned unit and it is assumed that these spacer elements have been sealed in a suitable manner against the fins so that closed ducts **30** are formed. As indicated by the short lines **31** these ducts are in communication with the interior of the pipe **29,** whilst the other part of the pipe **29** have been sealed in the manner described previously.

FIG. **9** shows a finned unit realized in accordance with the invention used as a heat exchanger according

to the counterflow principle, where two media A and B flow through the finned unit in opposite spiral directions. In this case three spacer elements **32, 33** and **34** were inserted between two neighbouring turns of the strip material and these spacer elements are left behind in the finished finned unit. As a result two spiral-shaped ducts are formed which are located next to one another in axial direction. Every other gap between the fins is open, and this has been accomplished as before by the corresponding spacer elements having been removed, and these gaps act as an insulation between fins separated in axial direction. The guide pins are suitably made of material with low coefficient of thermal conductivity. In the types of heat exchangers described here the heat exchange takes place between media A and B by heat conduction in axial direction of the finned unit.

FIG. **10** shows a finned unit realized in accordance with the invention which acts as a heat exchanger, where the heat exchanger takes place in radial direction. The finned unit has been manufactured by simultaneous winding of three strip materials together with the corresponding number of space elements. The spacer elements in every third gap have been removed, so that this gap stays open and serves as an insulating gap. The effectiveness of the insulation can be increased by filling this gap with insulating material or by evacuating it. Between the other fins, spiral-shaped ducts **36,37** are formed which each conduct their particular medium in opposite spiral-shaped tracks. An arrangement of this kind can be used advantageously as a counterflow heat exchanger in cryo-technical applications in which the thermal flux by conduction in the solid material from the hot to the cold side has to be kept to a minimum value.

FIG. **11** and FIG. **12** shows a finned unit which is given such a shape that it can serve as a burner for the combustion of a liquid fuel with a gaseous oxidizer, for example air. The finned unit has been formed by simultaneous winding up of two strip materials together with the corresponding number of spacer elements, whereby the spacer elements between every other turn have been removed, after the fixing of the fins, as described previously, has been performed. As a result ducts **38** running in axial direction have been formed through which air can be introduced under pressure. As is shown in FIG. **12,** the liquid fuel is introduced through a fuel pipe **39** which in the manner described previously is in communication with the gaps **40,** which are located between the gaps **38.** By means of capillary pumping the fuel is sucked into the gaps **40,** and these may possibly besides contain a metal net **41,** by virtue of which this capillary pumping is facilitated. The burnt gases are removed in the direction of the arrows **42** in FIG. **11.** Owing to heat conduction from the parts of the finned unit which are nearest to the burnt gases the fuel is evaporated in the higher portions of the fuel gaps **40** and flows together with air into the combustion zone. This effect, as indicated in FIG. **11,** can be supported in that certain fins are given a greater width in the direction towards the combustion zone. This burner gives an effective mixture of the fuel with air, complete combustion, a short burner in axial direction and great radial spread of the flame surface, all of which makes the burner very suitable for hot-gas engines, Rankin engines etc.

The strip which forms the fins in the burner according to FIG. **11** and **12** may be formed in a known manner so that the desired flame supporting properties are obtained, for example with protuberances, certain knurling or fluting, boring etc. Furthermore it is conceivable that the fuel pipe **39** (or the fuel pipes) can function at the same time as guide element corresponding to the guide pins **9.** The fuel feed may take place by capillary pumping from the centre of the finned unit, by pressure in separate conduits which lead to a number of feed points of various radii in the finned unit or by single filling of the capillaries.

FIGS. **13, 14** and **15** show by way of examples three possible variants of the burner. In the design according to FIG. **13** the capillary pumping of the fuel takes place without utilizing a metal net inserted in the gaps **40.** In the design according to FIG. **13** furthermore a spacer element **43** has been left behind, so that the gaps **40** are closed in the direction towards the incoming air and open in the direction towards the combustion zone.

In the design according to FIG. **14,** after the insertion of guide pins in the manner described previously, all spacer elements have been removed. On the other hand a metal net has been inserted in the ducts **40** in connection with the winding of the finned unit, which facilitates the capillary pumping.

In the design according to FIG. **15** the spacer elements **44** have been left behind so that the gaps **40** are open in the direction towards the incoming air. These gaps can moreover, as indicated in the figure, be filled with a metal net.

In the preceding text a number of different fields of application for finned units in accordance with the invention have been described. Further scopes of application are conceivable, such as directional elements for a gas or liquid flow, for example in wind tunnels, where a number of finned units may be used for changing the direction of a gas flow in a corner. The finned unit can also be used for the laminarisation of a flow, for rapid heating or rapid cooling of gases or liquids, where the strip in the finned unit can be heated by an electric current.

A further field of application for finned units realized in accordance with the invention is the storage of thermal energy whereby owing to insignificant radial heat conduction the losses are small, the generation of ultrastrong magnetic fields in that a pulsating electric current can be made to flow through the strip material wound in spirals. A finned unit formed by the simultaneous winding up of two strip materials can, after the spacer element has been removed, serve in electrical circuits as a capacitance, as a transformer or voltage transformer in general, with the possibility of air or liquid cooling in the gaps.

The finned unit in accordance with the invention can also be used in silencers.

The invention and its applications are not limited by the embodiments described here by various modifications are conceivable within the framework of the following claims. Thus the elongated material which is wound up at the same time as the spacer elements need not be a flat strip but can have any cross-section.

Furthermore the finned unit may be given a shape differing from a circular spiral when it is wound up, such as a triangular, square or rectangular spiral, and finned units shaped in another manner may be formed by a combination of finned units shaped in various

manners so that a configuration of the finned unit adapted to a certain purpose is obtained.

What is claimed is:

1. In a method for manufacture of finned units comprising simultaneously spirally winding at least one fin-forming strip and at least one spacer element such that the spacer element spaces adjacent turns of the strip radially, the improvement comprising securing the turns of the winding in this radially spaced relationship by passing elongate fixing elements through a number of radially aligned holes in the turns of said strip at plural locations about the circumference of the spirally wound strip, the cross sectional area of each fixing element within a range encompassing several successive strip turns being not greater than the cross-sectional area of the corresponding holes in the strip such that each fixing element prevents movement of the strip turns exclusively in a plane perpendicular to the fixing element, and removing at least part of said spacer element from between at least some of the adjacent turns of the strip.

2. Method as claim in claim **1** wherein the cross-sectional area of each fixing element within a range encompassing several successive strip turns is less than the cross-sectional area of the corresponding holes in the strip.

3. Method as claimed in claim **1** wherein enough of the spacer element is removed to provide axially open passages between some of the turns.

4. Method as claimed in claim **3** wherein at least two fin-forming strips and a corresponding number of spacer elements are wound about the same center at the same time and in the same radial plane, and at least one of said spacer elements is removed and one is retained.

5. Method as claimed in claim **4** wherein the spacer elements between every second turn are removed, the spacer elements between the other turns being retained in position.

6. Method as claimed in claim **5** wherein the retained spacer elements are axially spaced from each other in said other turns so as to form flow paths therein transverse to the axial flow paths formed by removal of said every second turn.

7. Method as claimed in claim **6** further comprising communicating the flow paths defined by the retained spacer elements with at least one radial pipe.

8. Method as claimed in claim **4** wherein the retained spacer element comprises at least two axially spaced spacer elements forming between them a flow passage.

9. Method as claimed in claim **8** wherein the retained spacer element comprises at least three axially spaced spacer elements forming between them at least two axially separated flow paths.

10. Method as claimed in claim **4** wherein three fin forming strips and three spacer elements are wound about the same center at the same time and in the same radial plane, and one of said spacer elements is removed and the other two are retained, the retained spacer elements each comprising two axially spaced spacer elements defining between them a flow path.

11. Method as claimed in claim **5** wherein the turns from which the spacer element is removed are open for fluid flow axially therethrough and the turns in which the spacer element is retained are communicated with a liquid fuel supply.

12. Method as claimed in claim **11** wherein capillary pumping means are provided in the turns which are communicated with a liquid fuel supply.

13. Method as claimed in claim **1** wherein at least two fin-forming strips are wound up at the same time about substantially the same center in different axial planes but with mutual overlapping relationship such that one strip serves as a spacer element for the adjacent strip.

14. Method as claimed in claim **1** comprising arranging a plurality of the finned units axially adjacent each other.

15. Method as claimed in claim **14** wherein the adjacent units are axially separated by appreciably less than the axial width of the individual units.

16. Method as claimed in claim **1** wherein said spacer element is in the form of a wire.

17. Method as claimed in claim **1** wherein at least two axially spaced spacer elements are wound with the fin-forming strip.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,789,494 Dated February 5,1974

Inventor(s) BERTIL INGEMAR BOSTROM, ET AL

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

On the cover sheet, insert -- [30] Foreign Application Priority Data Sweden 5298/71 April 23,1971--

Signed and sealed this 6th day of August 1974.

(SEAL)
Attest:

McCOY M. GIBSON, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

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* U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334.