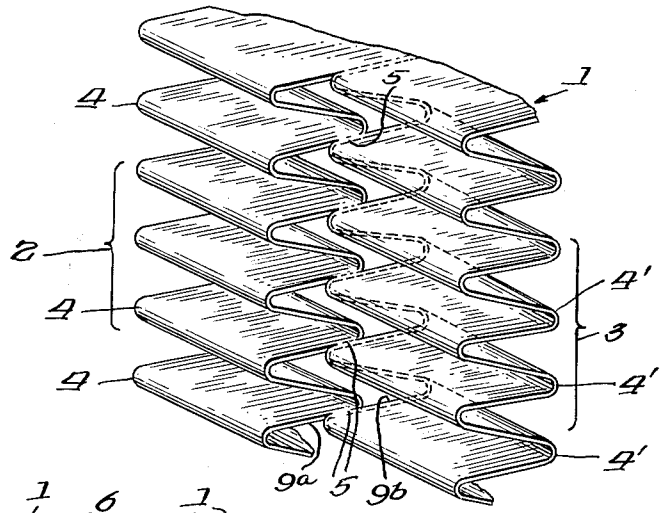
July 24, 1962 H. D. HUGGINS ETAL 3,045,979

STAGGERED SERPENTINE STRUCTURE FOR HEAT EXCHANGES AND METHOD AND MEANS FOR MAKING THE SAME

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Fig. 1.



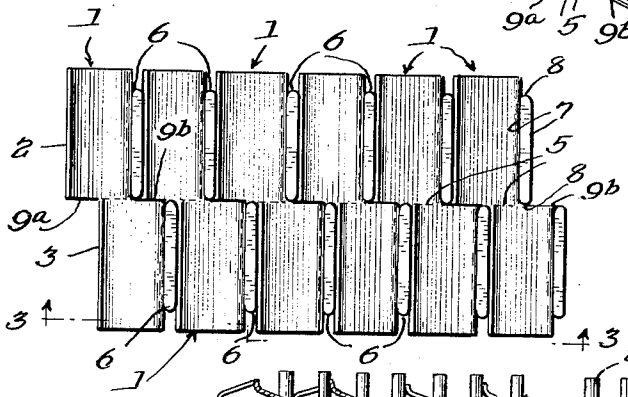
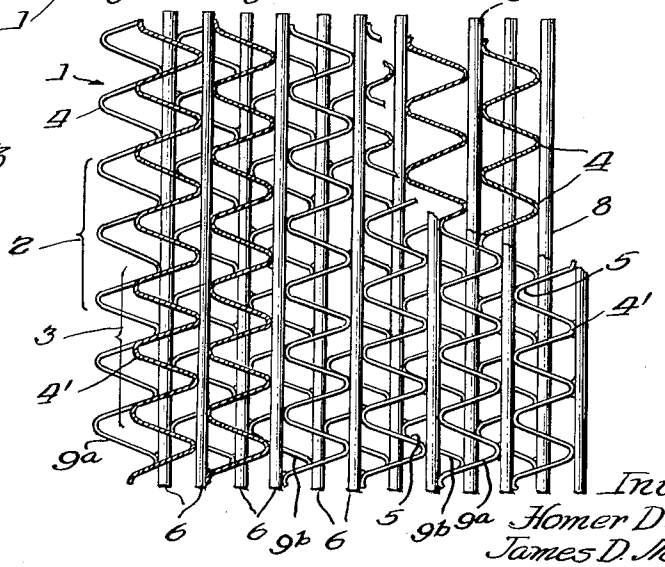


Fig. 2.

Fig. 3



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Fig. 4

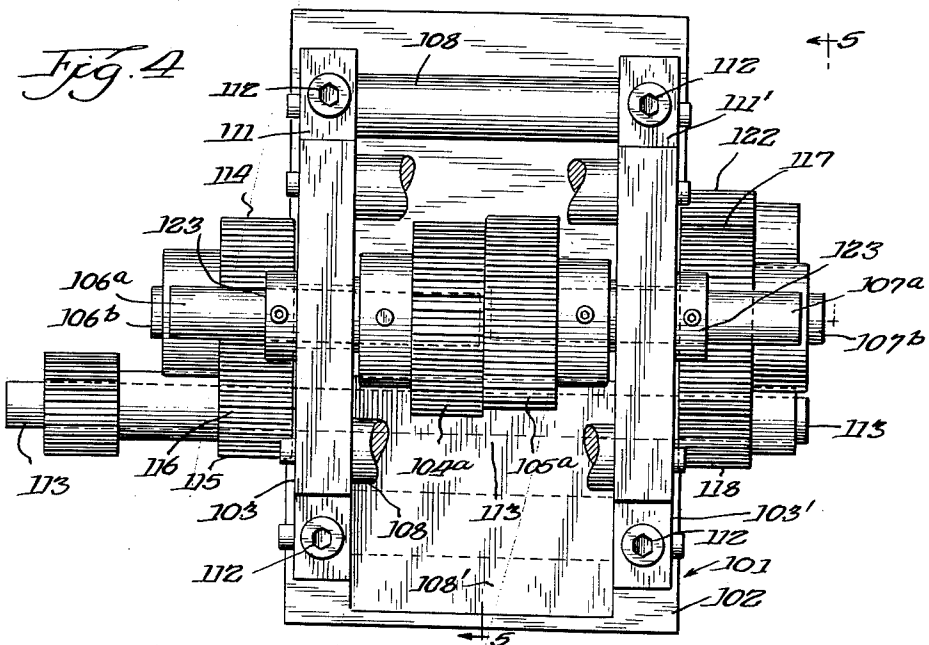
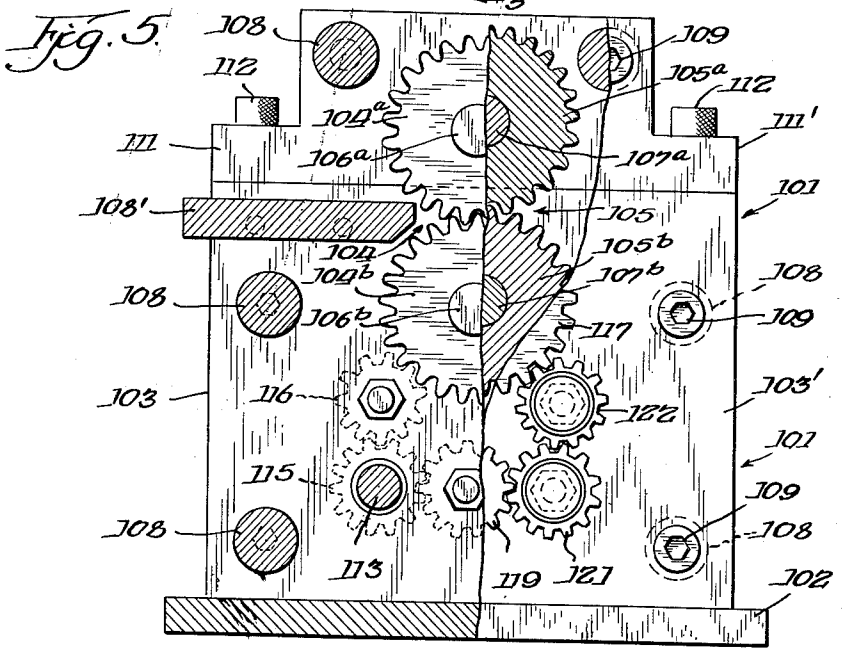


Fig. 5



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STAGGERED SERPENTINE STRUCTURE FOR HEAT EXCHANGES AND METHOD AND MEANS FOR MAKING THE SAME

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The invention relates generally to heat exchange structures, and more particularly to a novel fin member of generally serpentine or corrugated shape, particularly adapted for use as secondary heat exchange surface.

In the past, fins of serpentine type have been employed with the corrugations extending in continuous rows, forming a generally rectangular-shaped fin member which, for example, could be positioned between two parallel planes such as the parallel walls of a pair of fluid conducting tubes or elements, with the outermost loops or connecting portions of the corrugations extending in contact with the adjacent surfaces. Due to the continuously parallel arrangement of such fins, fluid-conducting elements such as flat sided tubes could not be positioned in staggered arrangement so that successive tubes in the direction of flow between any particular pair of fin elements were of necessity positioned in an in-line arrangement. To avoid an exact in-line arrangement, a very slight amount of tube offset or stagger has been achieved by a drawing of the metal of the fin member whereby a portion of the fin element is slightly offset with respect to another portion thereof, such a construction being illustrated in Patent Number 2,592,950, issued on April 15, 1952 to Stanislaus Przyborowski. However, as any drawing of metal introduces definite limitations as to the amount of forming that can be achieved without rupture of the metal and particularly in the case of fin members of the type hereinvolved which are normally fabricated from very light gauge metal, often having a thickness under .01 inch and even less than .005 inch, obviously a drawn offset must of necessity be very slight.

The present invention has among its objects the production of a novel fin structure of the serpentine or corrugated type which may be so provided with offset portions that a full or complete staggering of the fluid-conducting tubes or elements may be achieved, resulting in improved heat transfer characteristics of heat exchange structures embodying the present invention.

Another object of the invention is the production of such a fin structure wherein the amount of offset of one portion of the fin member relative to another portion thereof is limited only by the amount of material desired to be employed in connecting the two such portions so that an offset of well over one-half the width of the fin structure may be readily achieved, permitting the use of various staggered arrangements.

Another object of the invention is the production of such a fin structure and heat exchange structure employing the same wherein the fluid conducting tubes may be joined along at least one of their longitudinal edges to the fin structure as distinguished from prior structures wherein tubes were connected to the fin structures only along their side faces, and in which portions of the fin elements may be staggered with respect to other portions thereof for producing turbulence at specific desired points, etc.

Another object of the invention is the utilization of a novel method of producing a fin structure of the type described wherein the offset or staggering of the various portions of the fin structure is achieved as a result of the configuration produced in the forming operation and

not merely from the drawing of the material, also resulting in the elimination of limitations imposed by a drawing of the material.

A further object of the invention is the production of a novel apparatus for forming fin structures embodying the present invention, which apparatus may be of a continuously operated type, forming the fin member from a roll of strip metal in a single continuous operation.

Many other objects and advantages of the construction herein shown and described will be obvious to those skilled in the art from the disclosure herein given.

To this end my invention consists in the novel construction, arrangement and combination of parts herein shown and described, and more particularly pointed out in the claims.

In the drawings, wherein like reference characters indicate like or corresponding parts:

FIG. 1 is a perspective view of a portion of a fin element embodying the present invention;

FIG. 2 is a top plan view of a portion of a heat exchange structure embodying fin elements of the type illustrated in FIG. 1;

FIG. 3 is a front elevational view of the structure illustrated in FIG. 2, with portions thereof broken away to more clearly show the fin configuration and relationship;

FIG. 4 is a top plan view of a machine for forming the fin structure illustrated in FIG. 1; and

FIG. 5 is a sectional view of the machine illustrated in FIG. 4 taken approximately on the line 5—5 thereof.

The present invention contemplates the fabrication and use of a fin structure of the serpentine or corrugated type constructed from a single piece of material and provided with one or more offsets intermediate the edges of the fin structure at opposite ends of the respective corrugations. As illustrated in FIG. 1, the fin member **1**, comprises a pair of fin sections designated by the numerals **2** and **3**, each section having a plurality of respective serpentine folds or corrugations **4** and **4'** provided with a fin loop, with the corrugations **4** and **4'** extending in the same general direction. As illustrated in FIG. 1, the sections **2** and **3** may be laterally offset or staggered with respect to one another, providing an array of staggered corrugated fin sections, the adjoining ends of the respective sections lying substantially in a common plane extending substantially parallel to the planes including the outer edges of the fin sections. Also another plane within which the contiguous corrugations are affixed is perpendicular to the planes including the outer edges of the fin sections, and each of said first-mentioned other planes including the portion of one side of each adjacent fin loop is parallel to each other. The sections **2** and **3** are connected at their adjoining ends by relatively narrow connecting intermediate portions **5** contiguous to the fin loop so that the two sections are rigidly connected and may be formed from a single sheet of material.

A plurality of fin elements such as that illustrated in FIG. 1 may be assembled with a plurality of fluid-conducting tubes to form a heat exchange core, as for example, such as that illustrated in FIGS. 2 and 3 wherein a plurality of fluid conducting tubes **6** may be placed in engagement with the corrugations of cooperable fin members **1**, the tubes being illustrated as of elongated cross-sectional shape having parallel side walls **7** and relatively narrow end walls **8**, the inner end walls **8** of the respective tubes being positioned in engagement with the inner end edges **9***a* and **9***b* of the respective sections. The array of staggered fin sections comprises a plurality of the laterally offset sections of sheet metal fins which may be formed from very thin sheet metal. The fin sections which are corrugated are so formed that each corrugation constitutes a fin loop with the offset arrangement exposing the inner edges of said fin loops. The al-

ternate loop surfaces of corresponding fin loops of adjacent sections lie in the same plane and are integrally attached at overlapping portions of said sections. Following assembly of the fin members and fluid-conducting tubes, the elements may be bonded or otherwise secured in operative heat transfer relationship to form an integral core structure wherein each of the tubes are operatively engaged in heat transfer relation to the fin loops of the corresponding sections on opposite parallel side walls of the tube, and with one of the end walls of said tube being in contact with the edges of the fin loops of the adjacent offset section, the offset arrangement of said fin loops thereby providing a free passageway for air flow through said fin structure at each fin loop.

It will be noted that with this type of assembly, the tubes **6** of the front or lower row as viewed in FIG. 2 are laterally offset or staggered with respect to the rear or upper row, and/or adjacent row providing high heat transfer efficiency. The tubes of each row being staggered with respect to the tubes of an adjacent row to form uniformly spaced pairs of tubes in staggered relationship, and the array of staggered corrugated fin sections extend between and are attached to the staggered pairs of tubes. It will also be noted that the tubes **6** are in intimate contact with the fin members along substantially the entire periphery of the tubes with the exception of the outermost end edges of the tubes, thus contributing to the high efficiency of the structure. Referring to FIG. 3, it will be seen that the rear section **2** of each fin member is laterally staggered with respect to the front section other than those portions in alignment with the connecting portions **5** between the respective sections, so that the free body edges of each section are respecively directly in the air path through the core, which insures a break-up of heat transfer film along the surface of the corrugations and further contributes to the high efficiency of the structure. The aforesaid offset arrangement of said fin loops also provides a free passageway for air flow through said fin structure at each fin loop.

While we have illustrated the fin member **1** as comprising two sections, it is believed apparent that additional sections could be utilized, the latter being integrally connected in the same manner as that shown and the staggered relation may be varied to meet specific applications, as for example, said array of staggered fin sections to provide for effective offsetting or staggering of three or more rows of tubes whereby no two tubes would be in alignment. It will also be apparent to those skilled in the art that in some cases it may be deemed desirable to provide additional offsets adjacent the outer ends of the tubes whereby the latter may be bonded to the fin members completely around the periphery of the tube.

In fabricating fin members of the type illustrated in FIG. 1 from a single sheet of metal, the material is slit along a longitudinal line intermediate the side edges of the strip, defining the juncture of the adjacent sections, the respective slits being spaced by solid or unslit material which will ultimately form the connecting portions **5** of the completed fin member. The material on opposite sides of the line of slits comprising the respective sections may be deformed to provide a serpentine form with the corrugations of the one section generally extending at one side of the general plane of the undeformed strip and the corrugations of the other section generally disposed at the opposite side of such plane, thereby exposing the respective inner edges of the sections other than at the intermediate connecting portions **5**. In practice as hereinafter described in connection with applicants' preferred apparatus, it may be desirable to form the slits defining the inner edges of the respective sections simultaneously with the formation of the corrugations **4** and **4'** having fin loops.

Illustrated in FIGS. 4 and 5 is an apparatus for forming fin members such as that illustrated in FIG. 1 in a rolling operation which thus may be performed as a continuous operation on a roll of strip material.

Referring particularly to FIGS. 4 and 5, the reference numeral **101** indicates generally the base of a machine comprising a bottom member **102** and a pair of spaced substantially parallel uprights or standards **103**. Journaled in the respective uprights **103** are pairs of forming rollers or gears **104***a* and **104***b*, and **105***a* and **105***b*. As will be apparent from a reference to FIG. 5, the forming rollers or gears are carried by respective shafts **106***a* and **106***b*, and **107***a* and **107***b*, the shafts **107***a* and **107***b* being journaled in the upright **103'**, and the shafts **106***a* and **106***b* being journaled in the upright **103**, so that the respective pairs of gears and their associated shafts may be independently rotated relative to the other pair, the adjacent faces of the gears **104** and **105**, however, being positioned substantially in a common plane. The uprights **103** and **103'** may be operatively connected by suitable reinforcing members or bars **108** which may be secured in operative relation by suitable cap bolts **109** or the like. As illustrated, the uprights **103** and **103'** each may be made in two sections whereby an upper section **111** and **111'**, secured to their respective base sections by cap screws **112**, carry rollers **104***a* and **105***a*, whereby the latter rollers may be disassembled from the machine without disengaging the respective rollers from their shafts, etc.

The respective pairs of rollers may be operatively connected to a common driving shaft **113** through respective gear trains, the shaft **106***b* carrying a gear **114** which is operatively connected to a driving pinion **115** on the shaft **113** through an idler pinion **116**. In like manner the shaft **107***b* may be provided with a driving gear **117** connected to a driving pinion **118** on the shaft **113** through three idler pinions **119**, **121**, and **122**.

Collars **123** may be provided on the shafts **106***a* and **107***a* to maintain the structure in operative relation, and to provide adjustment in the relationship of the meshed teeth of one pair of forming rollers with respect to the other pair, at least one of the rollers **104***b* or **105***b* may be adjustably connected to its associated drive shaft **106***b* or **107***b*, as the case may be, whereby the adjustable pair of rollers may be rotated relative to the other pair and locked in operative position. It will be apparent to those skilled in the art that this adjustment will determine the amount of offset produced in the finished fin member.

While the specific structure illustrated in FIGS. 4 and 5 utilizes the intermeshing of the forming rollers to transmit motion from the lower roller to the upper roller of each pair, depending upon the particular formation of the forming teeth, it may be desirable in some instances to positively drive the upper shafts and their associated forming rollers, which could easily be achieved by substituting a like gear **114** or **118**, as the case may be, for the collars **123**, whereby the shafts **106***a* and **107***a* will be positively driven through such gear trains. Likewise, provision could be made for shifting the axes of one pair of forming rollers with respect to the other pair to provide an adjustment between it and the other pair. In the event additional offsets may be desired in the fin member, additional pairs of forming rollers may be provided, in which case it might be desirable to support one or more pairs of rollers on offset shafts, drive the intermediate, or if desired all of the rollers in the same or similar manner as the rollers **104***a* and **105***a*, are driven by the rollers **104***b* and **107***b*.

It will be apparent from the above description that the machine illustrated will efficiently produce fin structures of the type illustrated in FIG. 1, which if desired may be fabricated from a continuous roll of strip material, and following fabrication may be severed into any desired lengths.

It will be noted that we have provided a novel fin structure whereby core structures may be produced having

staggered tube arrangements, the structure being such that maximum flexibility of design may be achieved. Likewise, we have provided a novel method and means for producing fin members embodying the present invention.

Having thus described our invention, it is obvious that various immaterial modifications may be made in the same without departing from the spirit of our invention; hence, we do not wish to be understood as limiting ourselves to the exact form, construction, arrangement and combination of parts herein shown and described, or uses mentioned.

What we claim as new and desire to secure by Letters Patent is:

In a heat exchange structure, the combination of a plurality of fluid-conducting tubes arranged, from front to rear, in transversely extending rows, said tubes being of elongated cross-sectional shape having parallel side walls and relatively narrow end walls, the tubes of each row being staggered with respect to the tubes of an adjacent row thereby forming uniformly spaced pairs of tubes in staggered relationship, an array of staggered corrugated fin sections extending between and attached to said staggered pairs of tubes, said staggered array comprising a plurality of laterally offset sections of sheet metal fins, each of the corrugations constituting a fin loop, said offset arrangement thereby exposing the inner edges of said fin loops, the alternate loop surfaces of corresponding fin loops of adjacent sections lying in the same plane and being integrally attached at overlapping portions of said sections, each of the tubes being operatively engaged in heat transfer relation to the fin loops of the corresponding sections on opposite parallel side walls of the tube, and with one of the end walls of said tube being in contact with the edges of the fin loops of the adjacent offset section, the offset arrangement of said fin loops thereby providing a free passageway for air flow through said fin structure at each fin loop.

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