July 27, 1954 A. G. GETZ 2,684,707

MEANS FOR AND METHOD OF CORRUGATING METAL STRIP

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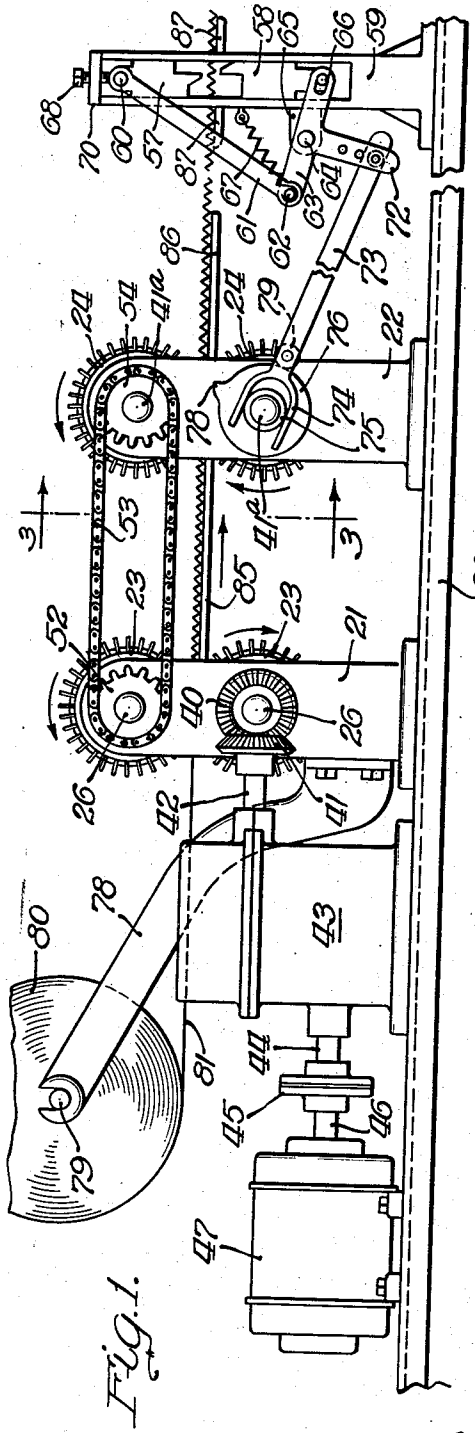


Fig. 1.

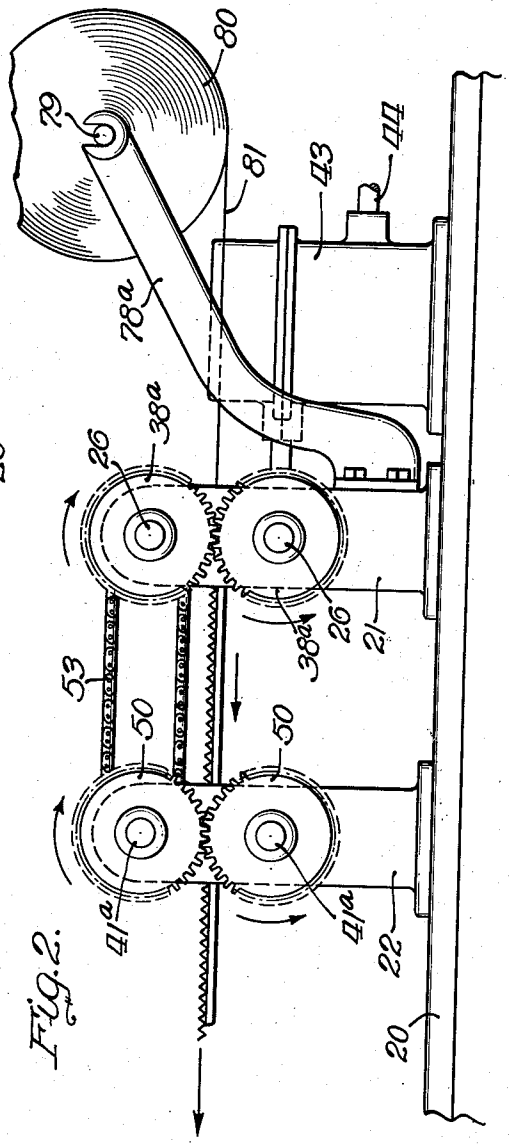


Fig. 2.

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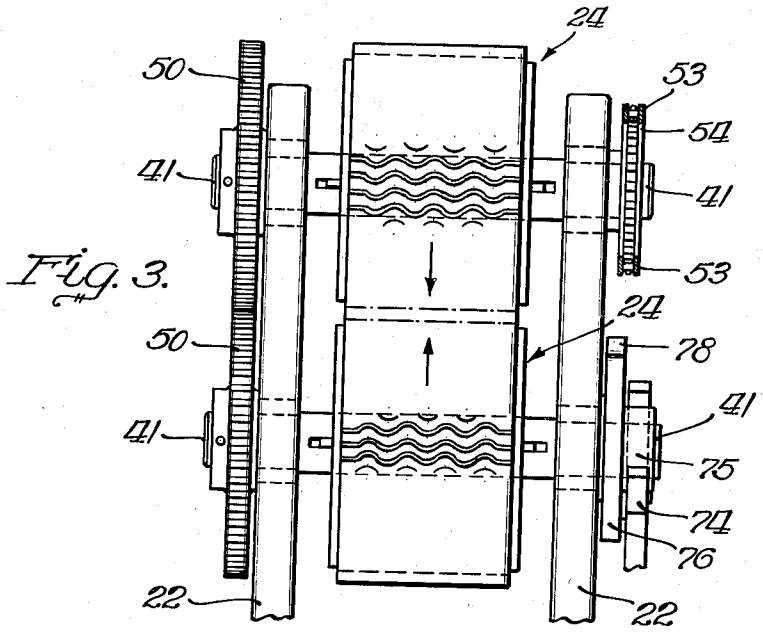


Fig. 3.

Fig. 4.

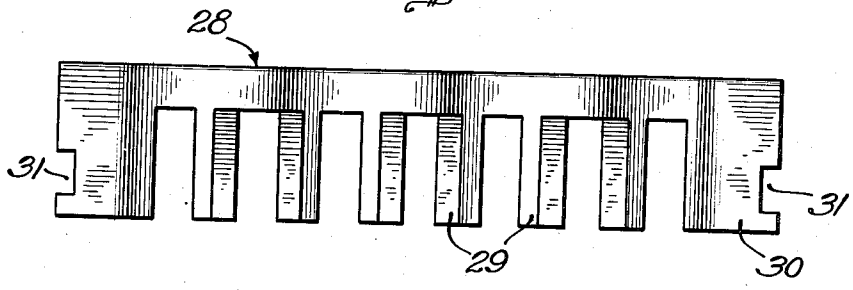
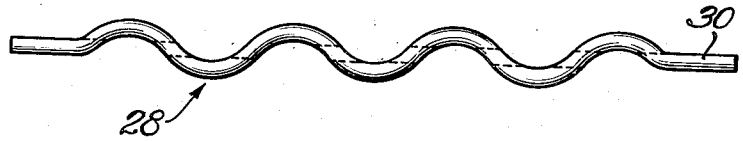


Fig. 5.



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MEANS FOR AND METHOD OF CORRUGATING METAL STRIP

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Fig. 6.

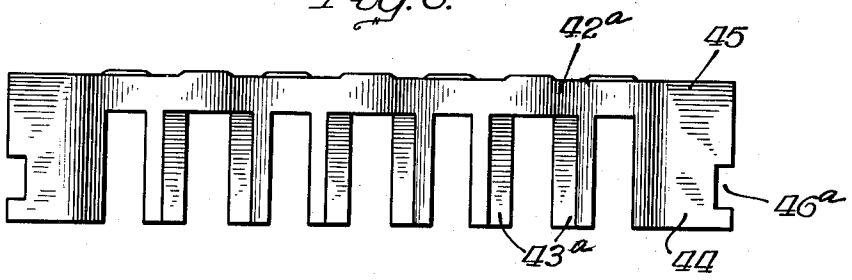


Fig. 7.



Fig. 8.

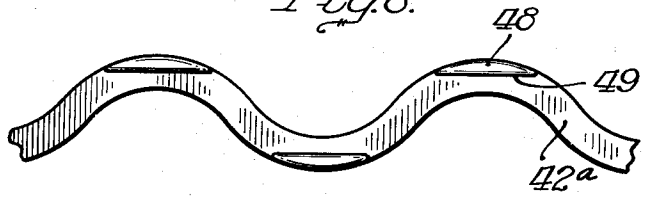
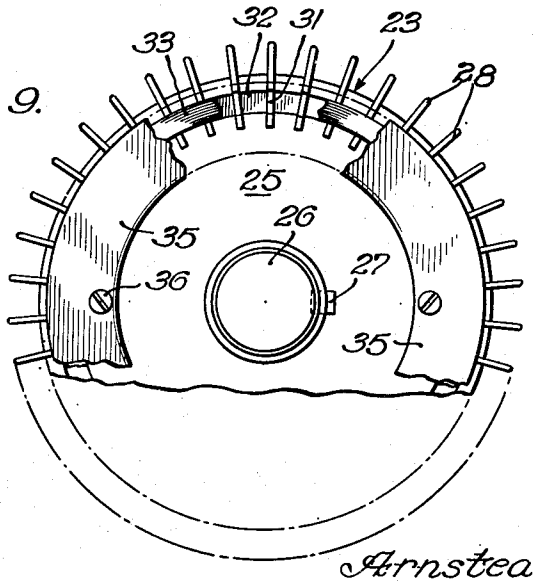


Fig. 9.



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MEANS FOR AND METHOD OF CORRUGATING METAL STRIP

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Fig. 10.

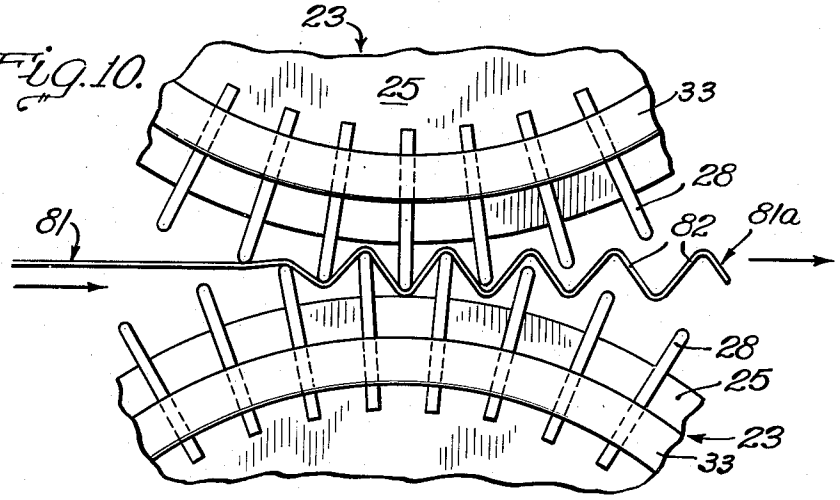


Fig. 11.

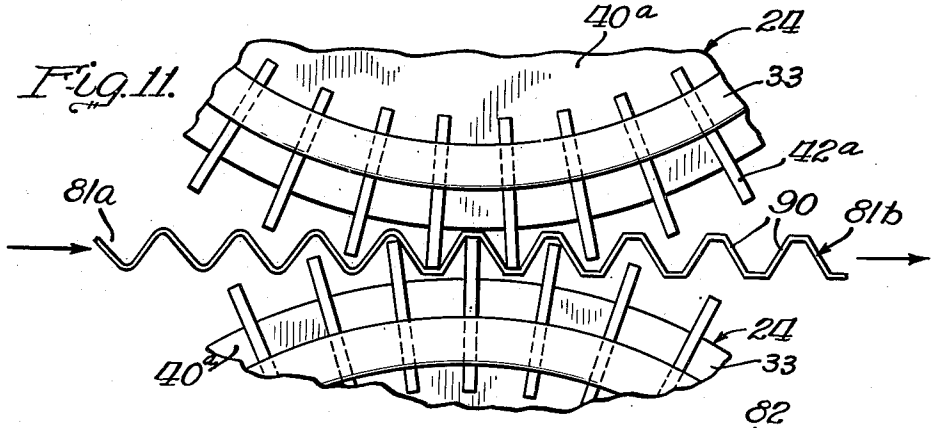


Fig. 12.

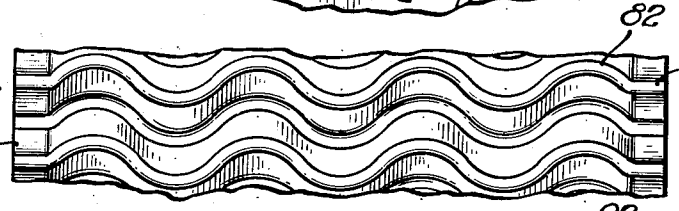
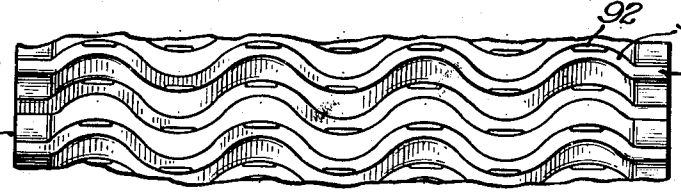


Fig. 13.



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MEANS FOR AND METHOD OF CORRUGATING METAL STRIP

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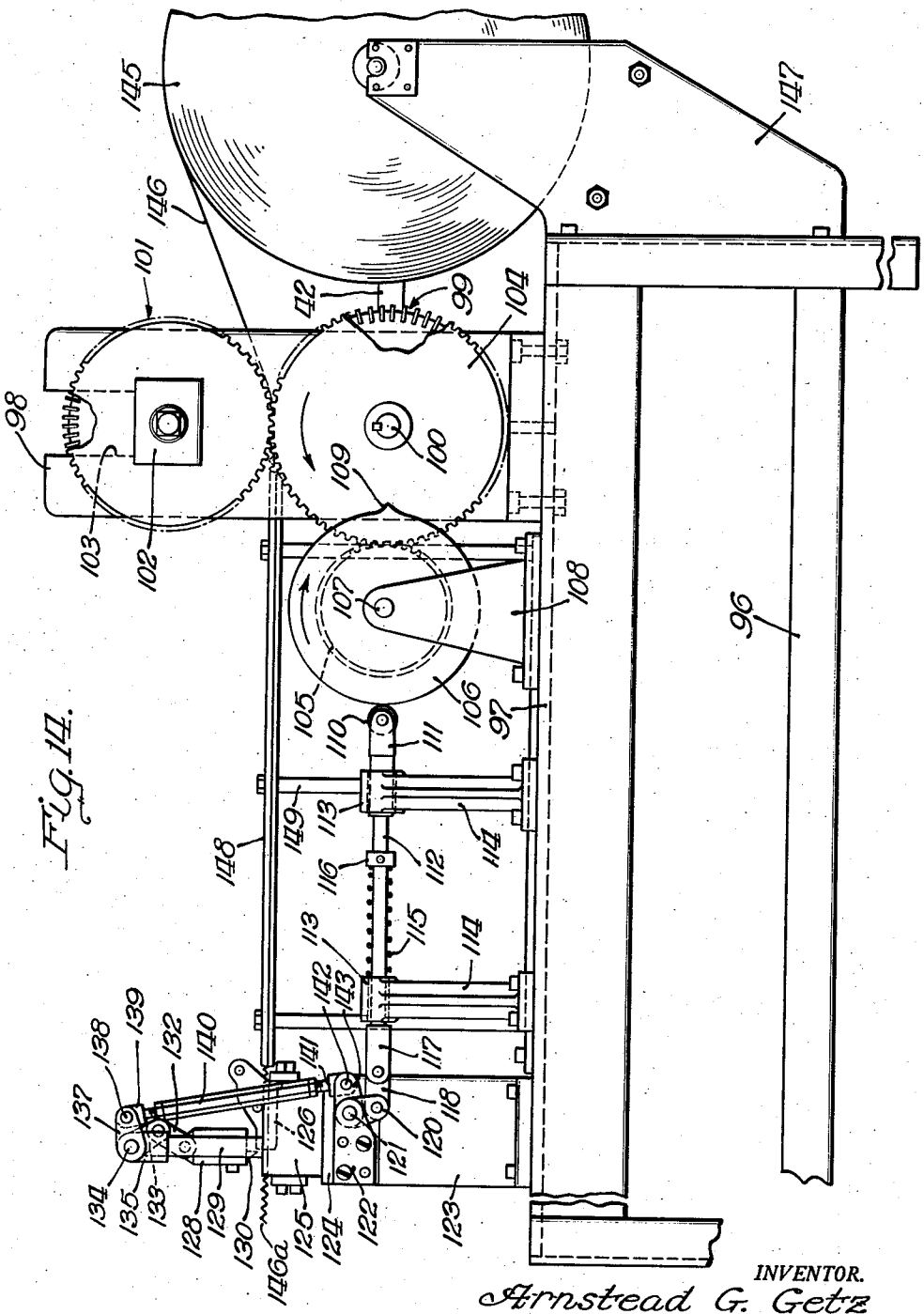


Fig. 11.

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Fig. 15.

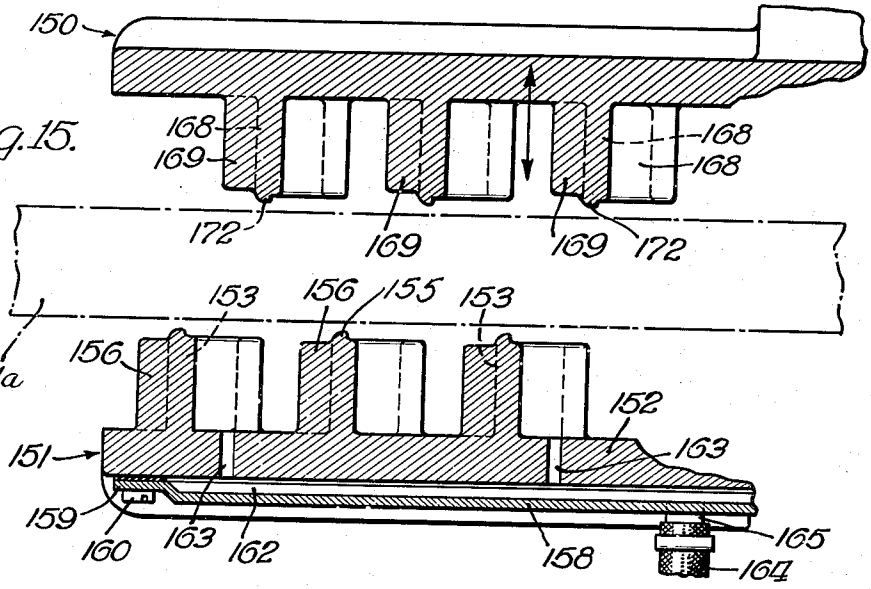
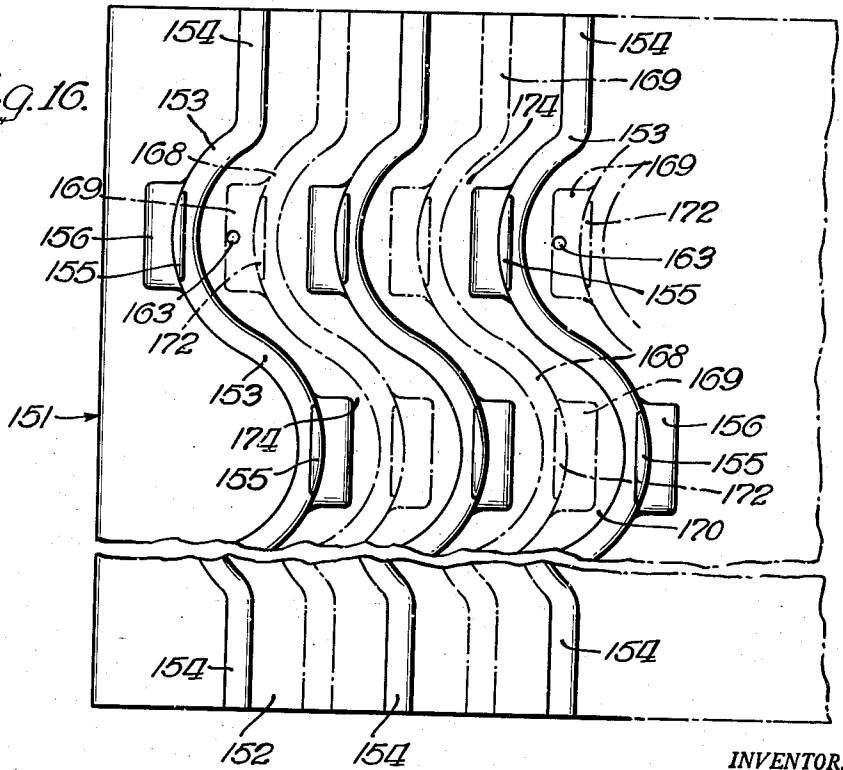


Fig. 16.



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MEANS FOR AND METHOD OF CORRUGATING METAL STRIP

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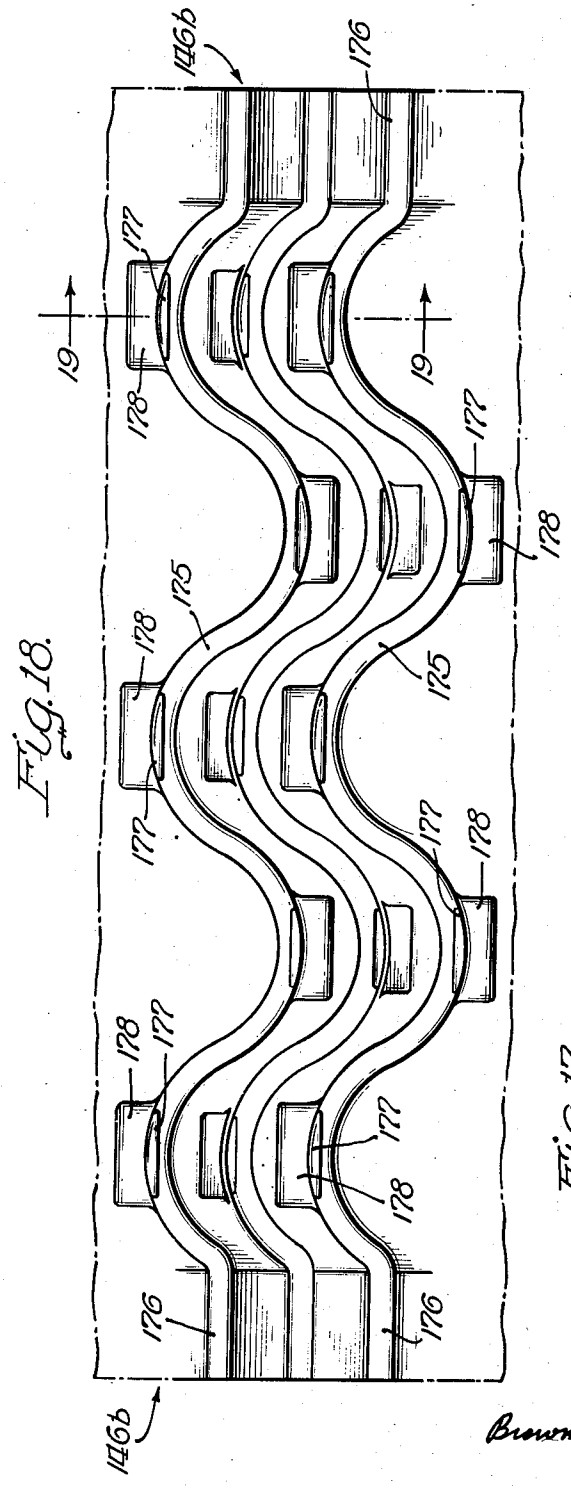


Fig. 18.

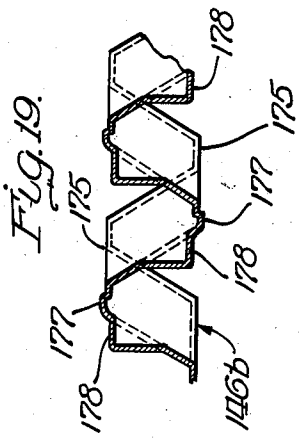


Fig. 19.

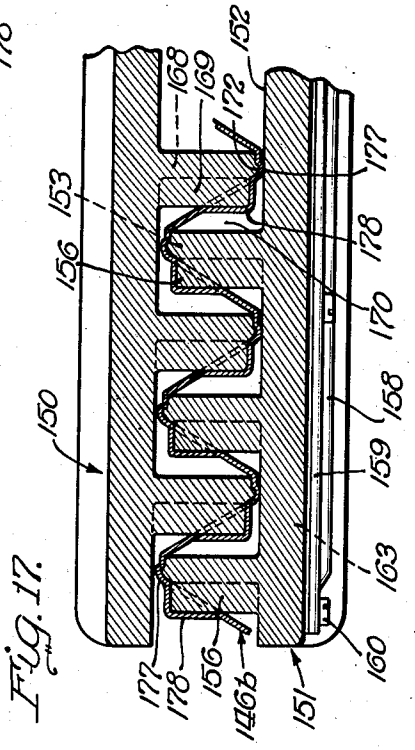


Fig. 17.

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UNITED STATES PATENT OFFICE

2,684,707

MEANS FOR AND METHOD OF CORRUGATING METAL STRIP

Arnstead G. Getz, Lakewood, Ohio, assignor to The Bishop & Babcock Manufacturing Company, Cleveland, Ohio, a corporation of Ohio

Application March 23, 1951, Serial No. 217,228

9 Claims. (Cl. 153—77)

1

This invention relates to cores for heat exchange units such as automobile radiators and heaters, and has to do with means for and a method of corrugating metal strip to be used in such cores for forming the air passages thereof.

It is known, in constructing cores of the character referred to, to provide metal strips formed with corrugations or projections, usually of straight line contour, which strips when assembled in the core define between them air passages having interior projections for imparting turbulence to the air and assuring contact thereof with the metal of the core. The strips are formed of quite thin metal, such as electrolytic copper having a thickness of approximately .0035" and, under present practice, usually are formed to desired shape by subjecting them to pressure between opposed forming surfaces conforming to the desired contour of the ultimate form of the strip. During such forming operation the thin metal strip is subjected to considerable pressure between relatively moving opposed forming surfaces and is frequently torn or ruptured in the forming operation. That results in objectionable waste of metal and also necessitates care in designing the final form of the strip so as to reduce, as far as possible, wastage. As noted, the final form of the strip usually is so designed that the corrugations or projections thereof are defined by straight lines, with a view to reducing tearing of the strip and resultant wastage to a minimum. It has been attempted to produce strips having projections or corrugations defined by curved lines but, in general, the resultant wastage, due to rupture and tearing of the metal, when using the present methods above referred to, has been so great as to be prohibitive.

My invention is directed to the production of corrugated metal strip of desired final form without incurring the wastage of metal which occurs under the present practice above referred to. It is directed particularly to the production of corrugated metal strip provided with corrugations which are undulatory lengthwise, without subjecting the strip to forming pressure between opposed forming and pressure applying surfaces such as would be apt to cause rupture or tearing of the metal, as occurs under the present practice above referred to. I form the strip to approximately final form by pulling it about forming members or ribs extending in alternately opposite directions beyond the plane of the metal strip being operated upon, and spaced apart a distance materially greater than the thickness

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of the metal strip so as to avoid subjecting it to pressure between opposed forming surfaces. When the strip has been preformed in the manner stated, it is subjected to a final forming operation similar to the preforming operation, the height and spacing of the forming elements or ribs used in the preforming operation being so related to the height and spacing of the forming elements or ribs used in the final forming operation as to render available for the latter operation adequate metal such that any objectionable stretching or thinning of the metal in the final forming operation is avoided. In both the preforming operation and the final forming operation the strip is at no time subjected to forming pressure between opposed forming surfaces thereby eliminating risk of rupture or tearing of the metal strip from that cause. The preforming operation is accomplished by opposed members, conveniently corrugating rolls, provided with spaced apart forming elements or ribs of such height and spacing that, in the rotation of the rolls, the ribs of each thereof enter midway between the ribs of the other roll with clearance therebetween materially greater than the thickness of the metal strip. Preferably, the ribs are of undulatory formation lengthwise. During rotation of the rolls, the metal strip is drawn between them and is pulled about the ribs in contact with the radially outer edges only thereof so as to be formed into corrugations also of undulatory formation lengthwise, the metal strip being at no time subjected to forming pressure between opposed forming surfaces. The preformed metal strip passes from the preforming members or rolls to the final forming members, preferably also two opposed corrugating rolls similar to the preforming rolls but having the forming elements or ribs thereof of slightly less height and greater spacing than the ribs of the preforming rolls, to avoid any objectionable stretching of the metal in the final forming operation, as above explained. In certain cases it is desirable to provide the corrugations of the finally formed strip with lateral bosses or projections, to increase the air turbulence and metal contact in the core embodying such strips. In such cases the final forming operation preferably is performed in opposed flat dies having forming elements or ribs similar to those of the corrugating rolls just referred to but provided with lateral projections or bosses for forming bosses or projections in the corrugations of the finally formed strip. In the method of my invention, as will be understood from what has been said,

the metal strip is pulled about the forming elements or ribs of the corrugating members so as to conform to the shape thereof, but is at no time subjected to forming pressure between opposed forming surfaces, thereby eliminating risk of tearing or rupture of the strip from that cause, as has been explained above. Further objects and advantages of my invention will appear from the detailed description.

In the drawings:

Figure 1 is a side view, partly broken away, of a metal strip corrugating machine embodying my invention;

Figure 2 is a side view of the machine of Figure 1, as seen from the side opposite to that shown in Figure 1, with certain parts shown in the latter figure omitted;

Figure 3 is a sectional view, on an enlarged scale, taken substantially on line 3—3 of Figure 1;

Figure 4 is a side view, on an enlarged scale, of one of the forming elements or ribs of the preforming rolls shown in Figure 3;

Figure 5 is a plan view of the rib shown in Figure 4;

Figure 6 is a side view, on an enlarged scale, of one of the ribs of the final forming rolls;

Figure 7 is a plan view of the rib of Figure 6;

Figure 8 is a fragmentary plan view, on an enlarged scale, of the rib of Figure 7;

Figure 9 is a fragmentary end view, on an enlarged scale and partly broken away, of one of the preforming rolls and its associated shaft;

Figure 10 is a fragmentary semi-diagrammatic view, on an enlarged scale, showing in end view the two preforming rolls and metal strip passing between them;

Figure 11 is a view similar to Figure 10 but showing the final forming rolls;

Figure 12 is a fragmentary face view of the preformed corrugated metal strip produced by the preforming corrugating rolls;

Figure 13 is a fragmentary face view of the corrugated metal strip produced by the final forming corrugating rolls;

Figure 14 is a side view of a modified form of metal strip corrugating machine embodying my invention, used for effecting the preforming operation on the metal strip;

Figure 15 is a fragmentary side view of two opposed dies suitable for performing the final forming operation on the preformed strip produced by the machine of Figure 14, the dies being shown partly broken away and in section;

Figure 16 is a fragmentary plan view of the lower die of Figure 15;

Figure 17 is a fragmentary lengthwise sectional view, on an enlarged scale, of the dies of Figure 15 closed on the metal strip therebetween;

Figure 18 is a fragmentary face view, on an enlarged scale, of the finally formed corrugated metal strip produced by the dies of Figure 15; and

Figure 19 is a sectional view taken substantially on line 19—19 of Figure 18.

The machine shown in Figure 1 comprises a suitable base or table 20 to which are secured two pairs of spaced uprights 21 and 22. Upper and lower preforming rolls 23 are rotatably mounted in the uprights 21, aligned lengthwise of table 20 with upper and lower final forming rolls 24. As is shown more clearly in Figure 9 each of the preforming rolls 23 comprises a cylindrical body 25 having an axial bore for reception of a shaft 26 on which body 25 is suitably secured, conveniently by means of keys 27. Body 25 is provided with a

plurality of lengthwise slots uniformly spaced circumferentially thereof and opening through the ends and the outer circumferential face of body 25. The slots in body 25 receive forming elements or ribs 28, shown more clearly in Figures 3, 4 and 5, which are of undulatory formation lengthwise and are straight and of substantially uniform thickness radially of body 25 of roll 23. The ribs 28 preferably are formed of cold rolled steel and are milled off for the major portion of their height to provide spaced fingers 29 extending downward from the rib 28, between end fingers 30 of materially greater extent lengthwise of rib 28 than the fingers 29 and straight lengthwise of rib 28, the outer or upper portions of the fingers 30 providing straight terminal extensions of the rib 28. Each of the fingers 30 is provided, in its outer edge, with a rectangular notch 31 which registers with a rectangular annular groove 32 in the end of the roll body 25. A locking ring 33 fits snugly in groove 32 and in the notches 31 of fingers 30, thus locking the ribs 28 tightly in position in the roll body 25. The ring 33 is retained in position by an annular plate 35 seating thereon and on the end of body 25 and secured to the latter in a suitable manner, conveniently by means of screws 36. As will be understood, there is a locking ring 33 and plate 35 at each end of body 25 of roll 23. The end portion of shaft 26 of each of the rolls 23 is of reduced diameter and is rotatably mounted in suitable bearings 38, mounted in the uprights 21, as is shown more clearly in Figure 3.

The ribs 28 are all of the same effective height and project radially outward beyond body 25 of the respective rolls 23 a distance appreciably less than the space between the bodies 25 of rolls 23, and are rounded at their outer edges, as shown more clearly in Figure 10. The rolls 23 are relatively off-set angularly so that in the rotation thereof the ribs 28 of each roll 23 enter midway between the ribs 28 of the other roll, with considerable clearance therebetween. Meshing spur gears 38a, secured on the corresponding ends of shafts 26 of rolls 23, assure that both thereof will be rotated at the same speed, the gear ratio being appropriate to that end, while maintaining the proper angular relation between the rolls and also assuring that they will be rotated in opposite relation. Accordingly, when either of the preforming rolls 23 is rotated, the other roll will also be rotated at the same speed and in opposite relation, and the ribs 28 of the rolls will enter between each other as above explained, these ribs being of such height that the ribs of each roll at all times clear the ribs of the other roll during rotation of the rolls, as will be understood from what has been said.

A bevel gear 40 is secured on shaft 26 of the lower roll 23, at the opposite end thereof from the spur gear 38a, and meshes with a bevel gear 41 secured on shaft 42 of a speed reducing unit 43 of suitable known type, mounted on table 20 to one side of one of the uprights 21. A second shaft 44 of unit 43 is driven, through a suitable coupling 45 of known type, by shaft 46 of an electric motor 47 mounted on table 20. It will be clear, from what has been said, that when the motor 47 is in operation the two preforming rolls 23 are driven at the same speed and in opposite relation, it being understood that the unit 43 is selected to drive the rolls 23 at appropriate speed.

The final forming rolls 24 are similar to the preforming rolls 23 and a brief description thereof will suffice. Each of the rolls 24 comprises a

cylindrical body 40a keyed on a shaft 41a rotatably mounted in bearings in the uprights 22. The body 40a is provided with lengthwise slots opening through its ends and its outer circumference and receiving final forming elements or ribs 42a projecting radially beyond body 40a. Referring to Figures 6 to 8, inclusive, the ribs 42a preferably are formed of cold rolled steel, are of undulatory formation for the major portion of their length, and are milled off at opposite sides to provide spaced fingers 43a aligned with relatively wide end fingers 44a straight lengthwise of rib 42a, the upper portions of which provide straight continuations or terminal elements of the rib 42a. Each of the fingers 44a is provided with a rectangular notch 46a in its outer edge, these notches 46a receiving locking rings fitting therein and in annular recesses in the ends of body 40a, held in position by retaining plates secured to the ends of body 40a, as in the preforming rolls 23.

The upper or radially outer edge of each rib 42a is flat, as shown more clearly in Figures 6 and 11, and each undulation of rib 42a is provided at the outer side thereof with a boss or projection 48 of approximately semi-elliptical shape in plan having an inner face 49 straight lengthwise of rib 42 and an outer face conforming to the curvature of the corresponding undulation of rib 42. The effective height of ribs 42a, that is the extent to which they project beyond the body of roll 40a, to the flat upper edges thereof, but not including the bosses 48, is less than the effective height of the ribs 28 of the preforming rolls 23 by an amount equal to the height of bosses 48, the effective height of ribs 42a at the bosses 48 being equal to the effective height of the ribs 28 of preforming rolls 23; as will be clear from Figures 4, 6, 10 and 11. Also, the ribs 42a of the final forming rolls 24 are spaced somewhat further apart than the ribs 28 of the preforming rolls 23, as shown in Figures 10 and 11, for a purpose which will appear later.

The effective height or radial extent of the ribs 42a beyond bodies 40a of the final forming rolls 24 is appreciably less than the distance between bodies 40a, as shown in Figure 11. The final forming rolls 24 are angularly off-set one half the distance between adjacent ribs 42a thereof so that the ribs of each roll, during rotation thereof, enter midway between the ribs of the other roll with clearance therebetween materially greater than the thickness of the metal strip operated upon. As will be understood from what has been said, the spacing and radial extent of the ribs 42a is such that there is at all times, during rotation of the rolls, ample clearance between the ribs thereof to guard against subjecting the metal strip to pressure between the ribs, which is also true of the preforming rolls, as above noted.

Meshing spur gears 50 secured on the ends of shafts 41a, adjacent one of the uprights 22, assure that the rolls 24 will be driven at the same speed and in opposite direction and that the angular relation therebetween will be maintained. A sprocket wheel 52 is secured on shaft 26 of the upper preforming roll 23, at the opposite end thereof from spur gear 38. This sprocket wheel 52 has driving connection, through a sprocket chain 53, to a similar sprocket wheel 54 secured on shaft 41a of the upper final forming roll 24 at the end thereof opposite to spur gear 50. It will be seen that when the preforming rolls 23 are driven, the final forming rolls 24 are also driven, the rolls of each pair being driven at the same speed and in opposite relation and the rolls of both pairs being driven at the same speed and in the same relation, that is, the upper rolls are driven at the same speed and in the same direction and the lower rolls are driven at the same speed as the upper rolls and in the opposite direction relative thereto.

The two pairs of rolls are aligned for reception between them of the metal strip being operated upon. As the finally formed metal strip passes beyond the final forming rolls 24, it is cut to length by suitable cut-off means. Conveniently, two opposed cut-off blades 57 and 58 are slidably mounted in slotted uprights, one of which is shown at 59, secured to table 20 in spaced relation transversely thereof. The upper blade 57 is pivoted at each end thereof, at 60, to a link 61 pivoted at its lower end, at 62, to the inner end of a lever 63 pivoted at its mid-point, at 64, on a bracket 65 secured to upright 59 and extending rearwardly therefrom. The forward end of lever 63 is connected, by a pin and slot connection 66, to the lower blade 58. A tension spring 67 is anchored at its lower end to pivot 62 and at its upper end to upright 59. This spring 67 tends to straighten the toggle comprising the link 61 and the inner arm of lever 63, thus urging the upper blade 57 upward, such upward movement of blade 57 being limited by stop screws, one of which is shown at 68, threaded through a cross piece 70 connecting the upper ends of the uprights 59.

The lever 63 is provided with a downwardly extending arm 72 having a series of openings for adjustably attaching thereto the forward end of a rod 73 provided at its rearward end with a fork 74 fitted about hub 75 of a cam disc 76 secured on shaft 41a of the lower final forming roll 24, at the opposite end thereof from the spur gear 50. The disc 76 is provided with a nose 78 disposed to contact a roller 79 carried by rod 73, for moving the latter forward. In the forward movement of rod 73 the blades 57 and 58 are moved toward each other and are effective for severing the metal strip passing therebetween, as will be clear. When the nose 78 passes out of contact with the lever 79, the blades 57 and 58 are returned to their normal positions shown in Figure 1, by the tension springs 67, and the rod 73 is moved rearward into position with the roller 79 disposed for contact by nose 78, as shown. It will be seen that the cut-off means is operated in timed relation to the rotation of the rolls, the timing being such that the finally formed strip passing from the rolls 24 is cut into lengths of predetermined and desired extent.

Two bracket arms 78a, slotted from their upper ends, are secured to and extend upwardly and rearwardly from the uprights 21. The arms 78a receive the ends of a shaft 79a rotatably mounted therein and carrying a roll 80 of metal strip or ribbon 81 of appropriate width and thickness, this metal strip commonly being quite thin, as above noted. In the operation of the machine the metal strip 81 is drawn from the roll 80 and passes between the pairs of rollers 23 and 24 and thence through the cut-off means, as will be clear. Preferably, the arms 78a are provided with friction surfaces contacting the sides of the roll 80 effective for preventing free running thereof while not imposing sufficient drag on the roll to cause objectionable tensioning of the metal strip 81, thus assuring that the metal strip is drawn

smoothly from the roll as required in the operation of the machine.

As the metal strip 81 passes between the preforming rolls 23 it is pulled about the ribs 28 thereof, as shown diagrammatically in Figure 10, and is corrugated transversely, the crests of the corrugations thus produced being rounded as shown. It will be noted that there is considerable clearance between the ribs and the metal strip pulled thereabout, and that at no time is the metal strip subjected to forming pressure between opposed relatively moving pressure applying surfaces. The metal strip 81 conforms to the lengthwise formation of the ribs 28 as it is pulled thereabout, and the preformed strip leaving the rolls 23 is provided with corrugations 82 of substantially V cross section and of undulatory formation transversely of the strip for substantially the full width thereof, except for terminal elements 83 which are straight transversely of the strip; as shown in Figure 12. By avoiding subjecting the strip to pressure between opposed forming surfaces, I eliminate risk of tearing and rupture of the strip from that cause, thereby eliminating wastage while also rendering it possible to corrugate the metal strip at comparatively high speed with resultant increase in production.

The preformed strip 81*a* passes from the preforming rolls 23 over a supporting shelf 85 mounted between the pairs of uprights 21 and 22 and extending therebetween. From the final forming rolls 24 the strip passes over a second shelf 86 supported between the uprights 22 and thence over two spaced shelves 87 carried by the uprights 59. In the passage of the preformed strip 81*a* between the final forming rolls 24, the crests of the corrugations 82 thereof are flattened, the corrugations are slightly spread or opened up, and the bosses 48 move corresponding areas of the corrugations outward beyond the flattened crests. The resultant finally corrugated strip 81*b* is provided with transversely extending corrugations 90 of undulatory formation for the major portion of their length and having straight terminal elements 91 transversely of the strip, the corrugations 90 being provided at the outer side of each undulation thereof with a boss or projection 92 of relatively slight height having an inner surface straight transversely of the strip. By having the forming elements or ribs 42[a] of the rolls 24 of less effective height than the ribs 28 of the preforming rolls 23, I render available adequate metal for forming the corrugations to final shape between the rolls 24 in the manner stated without subjecting the metal to appreciable or detectable stretching, thereby avoiding thinning of the metal to any objectionable or detectable extent. In the final forming rolls, as in the preforming rolls, the metal strip is formed by being pulled about the forming elements or ribs and is at no time subjected to forming pressure between opposed pressure applying forming surfaces, particularly during relative movement thereof. In that manner, I further guard against tearing or rupture of the metal strip with the advantages above noted.

In some cases it is desirable to provide the corrugated metal strip with projections or bosses in the side walls of the corrugations, to increase air turbulence and metal contact. I preferably provide, for that purpose, a machine for preforming the metal strip and cutting it to desired length, and shape the preformed corrugated strip to final form by separate means. In Figure 14 I have shown a machine comprising a suitable frame 96 supporting a table 97 on which are mounted two uprights, one of which is shown at 98, spaced apart transversely of the table. A lower preforming roll 99 is keyed on a shaft 100 rotatably mounted in the uprights 98, and an upper preforming roll 101 is secured on a shaft rotatably mounted in flanged bearing blocks 102 seating in slots 103 extending from the upper ends of the respective uprights 98. The rolls 99 and 101 are similar to the preforming rolls 23 of Figures 1 and 2 and are geared together by spur gears in the same manner as the latter rolls and need not be further described. The lower roll 99 is driven by shaft 42 of a speed reduction unit (not shown) through bevel gearing, in the same manner as the lower roll 23 of Figure 1, but the bevel gearing is located at the same end of roll 99 as the spur gear on shaft 100 thereof for driving the upper roll 101, it being understood that the two spur gears are at the far ends of the rolls 99 and 101 as viewed in Figure 14.

A spur gear 104 is keyed on the near end of shaft 100, as viewed in Figure 14, of roll 99. This spur gear 104 meshes with a spur pinion 105 secured to the inner face of a cam disc 106, both rotatably mounted on a stub shaft 107 secured in the upper end of a standard 108 suitably secured to table 97. Disc 106 is provided with a radially projecting element or nose 109, disposed to contact a roller 110 mounted in a slotted head 111 at the inner of a horizontal rod 112, slidably mounted through sleeves 113 at the upper ends of posts 114, mounted on table 97 and spaced from standard 108 in the direction of travel of the metal strip through the machine. A compression spring 115, disposed about rod 112 and confined between a collar 116 fixed thereon and the sleeve 113 more remote from standard 108, urges rod 112 toward the right so as to hold roller 110 in contact with the cam disc 106. The rod 112 is provided at its outer end with a slotted head 117 connected by a link 118 to one arm of a two armed lever 120 rockably mounted at 121 in a bracket 122 secured to an upright 123 mounted on bed 97. As will be understood, there are two uprights 123 spaced apart transversely of bed 97 and connected at their upper ends by a cross plate 124. A block 125 is mounted on plate 124 and carries a suitable knife 126 adjustable fore and aft thereon by known means. A knife holder 128 is slidably mounted between side guide members 129 extending upward from block 125. An upper knife 130 is mounted in the holder 128 and cooperates with the lower knife 126 for cutting to desired length metal strip passing therebetween. The knife holder 128 is connected at its midlength, by a link 132, to the lower end of an arm 133 fixed on a cross shaft 134 rockably mounted in bearing blocks 135 fixed on the upper ends of the side guides 129. An arm 137 is fixed on the near end of shaft 134, as viewed in Figure 14, and is pivoted at 138 to a clevis 139 at the upper end of a turn buckle 140. A clevis 141 at the lower end of turn buckle 140 is pivoted at 142 to the upper arm 143 of the lever 120. The lower preforming roll 99 rotates counterclockwise, as viewed in Figure 14, the upper roll 101 and the cam disc 106 rotating clockwise. When nose 109 of disc 106 contacts roller 110 the rod 112 is forced toward the left, thus pulling down the turn buckle 140 and thereby straightening the

toggle comprising link 132 and arm 133, thus moving the knife 130 downward into cooperating relation to the knife 126, for severing the metal strip therebetween, as will be understood from what has been said. The gear ratio is, of course, such that the metal strip is cut to the desired length.

A roll 145 of metal strip or ribbon 146 is rotatably mounted in the slotted upper ends of bracket arms 147 secured to and extending upwardly from the end of frame 96 adjacent rolls 99 and 101. Strip 146 is led from roll 145 between the rolls 99 and 101 and thence between strip guides 148, mounted at the upper ends of posts 149 mounted on table 97, there being two guides 148, as will be understood, receiving the transversely straight side marginal portions of the preformed corrugated strip. The guides 148 extend from the rolls 99 and 101 to within a short distance of the block 125, over which the corrugated strip passes as it leaves the guides 148. The preformed corrugated strip leaving the rolls 99 and 101 is similar to the strip leaving the rolls 23 of Figures 1 and 2 and shown in Figure 12, and need not be further described here. This strip, as noted, is cut into suitable lengths as it passes between the blades 126 and 130.

The cut lengths of preformed metal strip are shaped to final form between upper and lower dies 150 and 151, respectively, which are flat or straight lengthwise. The lower die 151, which may be stationary, comprises a body portion 152 and a plurality of substantially parallel ribs 153 projecting upwardly therefrom and of undulatory formation lengthwise, that is, transversely of body 152, for the major portion of their length, being provided with terminal elements 154 which are straight transversely of body 152. The ribs 153 are generally similar to the ribs 42^a of the final forming rolls 24 of Figures 1 and 2, have flat upper edges, are provided with upwardly extending bosses or projections 155 of substantially semi-elliptical shape at the outer sides of their undulations, have an effective height, not including the bosses 155, less than the ribs of the rollers 99 and 101 by the height of the bosses 155, and are spaced apart a distance somewhat greater than the distance between the ribs of the rollers 99 and 101, in the same manner as the ribs 42^a of the final forming rolls 24 of Figures 1 and 2 are spaced relative to the ribs 28 of the preforming rolls 23.

The ribs 153 of die 151 are further provided, at the outer sides of the undulations thereof, with bosses or projections 156 of substantially rectangular shape in plan, merging smoothly at their sides into the undulations of the ribs 153 and having rounded corners, the faces of the bosses 156 away from the undulations of the ribs 153 being flat and substantially perpendicular to body 152 of the die 151. The tops or upper faces of the bosses 156 are nearly flush with the upper edges of the ribs 153.

A cover plate 158, provided with an upwardly off-set flange 159, is secured to the under face of die 151, conveniently by screws 160, there being a sealing gasket 161 between flange 159 and the under face of die 151. Plate 158 defines, with die 151, an air chamber 162 from which restricted passages or ducts 163 extend upwardly through body 152 and open into the spaces between the ribs 153, one of such ducts being shown and it being understood that any suitable number thereof appropriately disposed may be provided. Air under appropriate pressure may be admitted to the chamber 162 through a hose 164 secured to a nipple 165 opening through plate 158 and secured thereto in a suitable manner, conveniently by welding. By admitting air under pressure to the chamber 162 the finally formed strip in the die 151 may readily be raised and removed therefrom, as will be clear from what has been said.

The upper die 150 may be moved toward and away from the lower die 151 in any suitable known manner. It is similar to the die 151 with the exception that it is not provided with the cover plate 158 and the ducts 163. Upper die 150 is provided with ribs 168 the same as the ribs 153 of lower die 151. The ribs 168 are spaced apart the same distance as the ribs 153 of lower die 151 and the ribs of each of the two dies 150 and 151 are off-set relative to the ribs of the other die one-half the distance between two adjacent ribs so that, when the dies are closed, the ribs of each thereof extend midway between the ribs of the other die with substantial clearance therebetween, materially greater than the thickness of the metal strip.

Referring further to Figures 16 and 17, I have shown in Figure 16 two of the ribs 168 of the upper die 150, in dot-and-dash lines, in the position which they occupy between adjacent ribs 153 of the lower die 151, when the dies are closed. It will be noted that the laterally projecting bosses 169 at the outer sides of the undulations of the ribs 168 are aligned with the inner or concaved sides of the undulations of the ribs 153 of the lower die, with clearance 170 therebetween materially greater than the thickness of the metal strip. In the final forming operation the preformed metal strip $146a$ is placed in the lower die 151 and the dies are then closed by downward movement of the upper die 150. In the closing movement of the dies the sides of the corrugations of the preformed metal strip are pulled or bent around the bosses 156 and 169 of the ribs 153 and 168, respectively, of the lower and upper dies 151 and 150, so as to be shaped thereabout. The bosses 155 of ribs 153 bend upward corresponding areas of the crest of the upwardly extending corrugations of the preformed metal strip, and bosses 172 of ribs 168 bend downward corresponding areas of the crests of the downwardly extending corrugations of the preformed metal strip $146a$. Referring further to Figure 17, when the dies 150 and 151 are closed, the bosses 156 of ribs 153 of the lower die 151 are disposed in alignment with the inner or concaved sides of the undulations of ribs 168 of the upper die, with clearance 170 therebetween materially greater than the thickness of the metal strip.

It will be seen that, during the final forming operation, the metal strip is shaped about the ribs and the bosses thereof by pulling or bending of the metal thereabout, and without at any time subjecting the metal of the strip to forming pressure between opposed pressure applying relatively moving forming surfaces. That avoids rupture or tearing of the metal strip with the advantages above noted. Further, since the preforming elements or ribs are of greater effective height than the final forming elements or ribs, adequate metal is available for shaping the preformed strip to desired final form, the final forming operation being mainly a simple bending operation in which the walls of the corrugations of the metal strip are deflected and shaped about

the bosses of the ribs without appreciable stretching of the metal. In that manner, objectionable thinning of the metal is avoided.

The finally formed metal strip produced by the dies of Figures 15 to 17, inclusive, is shown in Figures 18 and 19. This finally formed metal strip is provided with corrugations 175 extending transversely of strip 146b and of undulatory formation lengthwise for the major portion of their length, the corrugations 175 having terminal elements 176 straight transversely of strip 81c. Bosses 177 of approximately semi-elliptical shape in plan project from the crest of the ribs or corrugations 175, at the outer sides of the undulations thereof, and bosses 178 project laterally from the outer or convexed sides of the undulations of the corrugations. The bosses 178 are of substantially triangular shape in vertical section, as shown in Figure 19, and those of each corrugation extend oppositely to those of the next adjacent corrugation, it being noted that the base of the respective bosses 178 is substantially flush with the crest of the associated rib or corrugation 175.

If desired, instead of reforming the preformed metal strip produced by the machine of Figure 14 between the flat dies 150 and 151 of Figures 15 and 16, to form the bosses 178 on the corrugations 175, the reformed strip produced by the machine of Figures 1 and 2 may be subjected to a further reforming operation between the dies 150 and 151. If that procedure is followed, which may be desirable in certain cases as simplifying the die forming operation, the metal strip is subjected to a preforming operation and then to two successive reforming operations, as will be clear from what has been said. In either case, the height of the corrugations produced in the preforming operation is such as to assure that the metal rendered available by reduction in height of the corrugations in the first or succeeding reforming operation is adequate for performance of that operation without stretching of the metal. When the corrugated metal strip is reformed in the dies 150 and 151, to form the bosses 178, the operation is to a considerable extent a simple bending operation, though some stretching of the metal, but not to an objectionable extent such as to risk rupture thereof, occurs.

The finally formed lengths of metal strip are used in constructing cores of heat exchangers, such as automobile heaters and radiators. In my copending application, Serial No. 142,796, filed February 7, 1950, I have disclosed a cellular core for heat exchangers, in which metal strip formed as herein disclosed is used to advantage to provide the cooling air passages. Opposed lengths of metal strip, corrugated as shown in Figure 13 of the instant application, are positioned between water wall strips defining between them water passages, the latter strips having transverse ribs upon which the corrugations of the air passage strips seat, being positioned thereon by the bosses 82 of Figure 13. The opposed corrugated air passage strips define between them undulatory air passages which impart high turbulence to air flowing therethrough, as well as large area of contact between the air and the metal, thereby attaining high efficiency in heat transfer. I have found that by providing the corrugated metal strip for the air passages with laterally projecting bosses, such as the bosses 178 of Figures 18 and 19 of the instant application, the efficiency of the core can be materially increased, due to resultant increase in air turbulence and in area of contact of the air with the metal.

It will be understood that changes in detail may be made, both as to the apparatus and the method of my instant invention, and I intend to include all such variations, as fall within the scope of the appended claims, in this application in which the preferred forms only of my invention have been disclosed.

I claim:

1. In a machine for corrugating metal strip of predetermined thickness, a pair of spaced parallel preforming rolls and a pair of spaced parallel final forming rolls parallel with and disposed to receive preformed metal strip from said preforming rolls, the rolls of each pair respectively having a plurality of substantially uniform thickness and uniformly spaced lengthwise ribs of undulatory formation lengthwise and being relatively off-set angularly approximately one half the distance between adjacent ribs of the respective rolls, the spacing and effective height of the ribs of the rolls of each pair of being such that in the rotation thereof the ribs of each roll enter substantially midway between the ribs of the other roll to approximately the final depth of the desired corrugations with clearance therebetween materially greater than the thickness of the metal strip, the height of the ribs of the preforming rolls being greater than the height of the ribs of the final forming rolls to provide metal for final forming of the strip without objectionable stretching thereof, and means for rotating the rolls of each pair at the same speed and in opposite relation while rotating the corresponding rolls of said pairs at the same speed and in the same relation.

2. The method of corrugating metal strip which comprises, preforming the strip in a single operation to provide in the strip transverse corrugations of undulatory formation lengthwise and V-shape in cross section by bending the strip over and between spaced preforming elements and without subjecting the strip to forming pressure between opposed relatively moving forming surfaces, and bending the corrugations of the resultant preformed strip over and between spaced final forming elements similar to said preforming elements and substantially paralleling said corrugations and thereby forming the crests of the latter to desired final shape and size without subjecting the corrugations to forming pressure between opposed relatively moving forming surfaces while maintaining the continuity of the corrugations of the preformed strip and the V cross section of the corrugations produced in the preforming operation.

3. The method of corrugating metal strip which comprises, preforming the strip in a single operation by pulling and bending it in alternately opposite directions over and between rounded spaced preforming elements of undulatory formation lengthwise, thereby producing in the strip corrugations of undulatory formation lengthwise and V shape in cross section and of a height approximating the desired final height thereof without subjecting the strip to forming pressure between opposed relatively moving forming surfaces, and bending the corrugations of the resultant preformed strip between final forming elements similar to said preforming elements and spaced apart a distance approximately the same as the distance between the crests of adjacent preformed corrugations of the strip and thereby shaping the crests of the corrugations of the preformed strip to desired

final form and height without subjecting the preformed strip to forming pressure between opposed relatively moving forming surfaces while maintaining the V cross section of the corrugations produced in the preforming operation.

4. The method of corrugating metal strip which comprises, preforming the strip in a single operation by pulling and bending it in alternately opposite directions over and between spaced preforming elements of undulatory formation lengthwise, thereby producing in the strip corrugations of undulatory formation lengthwise and V-shape cross section having rounded crests and of a height approximating the desired final height thereof without subjecting the strip to forming pressure between opposed relatively moving forming surfaces, and bending the corrugations of the resultant preformed strip between flat forming elements similar to said preforming elements and spaced a distance apart approximately the same as the distance between the crests of adjacent preformed corrugations and thereby flattening the crests of the corrugations without otherwise materially altering the shape or height thereof and without subjecting the preformed strip to forming pressure between opposed relatively moving forming surfaces.

5. In a machine for corrugating metal strip of predetermined thickness, a pair of spaced parallel preforming rolls having a plurality of uniformly spaced ribs of substantially uniform thickness and of undulatory formation lengthwise and having rounded radially outer edges, said rolls being relatively off-set angularly approximately on half the distance between adjacent ribs of the respective rolls, the spacing and effective height of the ribs of each roll being such that in the rotation thereof the ribs of each roll enter substantially midway between the ribs of the other roll to a depth approximately the same as the final depth of the desired corrugations with clearance between said ribs such that corrugations of V-shape in cross section will be formed in metal strip passed between said rolls without subjecting the metal strip to forming pressure between opposed forming surfaces, a pair of spaced final forming rolls parallel with said preforming rolls and disposed to receive from the latter preformed metal strip, said final forming rolls having a plurality of uniformly spaced ribs of substantially uniform thickness and of undulatory formation lengthwise and having flat radially outer edges, said final forming rolls being relatively off-set angularly approximately one half the distance between adjacent ribs of the respective final forming rolls, the spacing and effective height of the ribs of each final forming roll being such that in the rotation thereof the ribs of each final forming roll enter substantially midway between the ribs of the other final forming roll to a depth the same as the final depth of the desired corrugations and contact the corrugations of the preformed metal strip at the crests only of the corrugations thereof thereby flattening such crests without subjecting the metal strip to forming pressure between opposed forming surfaces while maintaining the cross sectional V-shape of the corrugations formed by said preforming rolls, and means for rotating the rolls of each pair at the same speed and in opposite relation while rotating the corresponding rolls of said pairs at the same speed and in the same relation.

6. In means for corrugating metal strip of predetermined thickness, a pair of opposed preforming members each having a body portion and spaced substantially parallel ribs projecting therefrom toward the other member and of undulatory formation lengthwise, said members being relatively off-set approximately one half the distance between adjacent ribs of the respective members, said ribs being so spaced and of such effective height that the ribs of each member will enter substantially midway between the ribs of the other member with clearance therebetween such that corrugations of V-shape in cross section will be formed in metal strip passed between said members in the relative cooperating movement thereof without subjecting the metal strip to forming pressure between opposed forming surfaces, and a pair of opposed final forming members each having a body portion and substantially parallel ribs similar to and of approximately the same spacing and effective height as the ribs of said preforming members whereby said ribs of said final forming members contact the crests only of the corrugations of the preformed metal strip and form the crests to desired final shape without otherwise altering the shape of the corrugations produced by said preforming members and without subjecting the metal strip to forming pressure between opposed forming surfaces.

7. In means for corrugating metal strip of predetermined thickness, a pair of spaced preforming rolls each comprising a body and a plurality of lengthwise ribs thereon projecting outward therebeyond and uniformly spaced circumferentially of said roll, said ribs being of undulatory formation lengthwise, and of such effective height and spacing that in the rotation of said rolls the ribs of each roll enter substantially midway between the ribs of the other roll and in cooperation therewith form in metal strip passed between said rolls corrugations of V-shape in cross section and of undulatory formation lengthwise without subjecting the metal strip to forming pressure between opposed forming surfaces, a pair of opposed final forming rolls parallel with said preforming rolls disposed to receive from the latter preformed metal strip, said final forming rolls having ribs similar to and of approximately the same effective height and spacing as the ribs of said preforming rolls whereby the ribs of said final forming rolls contact the crests only of the corrugations of the preformed metal strip and form the crests to desired final shape without otherwise altering the shape of the corrugations produced by said preforming rolls and without subjecting the metal strip to forming pressure between opposed forming surfaces, and means for rotating the rolls of each pair at the same speed and in opposite relation while rotating the corresponding rolls of said pairs at the same speed and in the same relation.

8. The method of corrugating metal strip which comprises, preforming the strip by bending it in alternately opposite directions over and between preforming elements of undulatory formation lengthwise and of uniform thickness, thereby producing in the strip corrugations of undulatory formation lengthwise and V-shape in cross section and of approximately the desired final height without subjecting the strip to forming pressure between opposed relatively moving forming surfaces, disposing the corrugations of the preformed strip over and between final forming elements similar to said preforming elements and of uniform thickness the same as the desired final width of the crests of the corrugations with said final forming elements contacting the cor-

rugations at the crest areas only thereof, and flattening the crests of the corrugations by pressure applied thereto solely by said final forming elements while retaining substantially unaltered the V cross section of the corrugations imparted thereto in the preforming operation.

9. The method of corrugating metal strip which comprises, moving the strip in one direction and during such movement bending it in alternately opposite directions over and between preforming elements of undulatory formation lengthwise having rounded working edges and of uniform thickness approximately the same as the desired final width of the crests of the corrugations, thereby producing in the strip corrugations of undulatory formation lengthwise having rounded crests and V shape in cross section and of approximately the desired final height without subjecting the strip to forming pressure between opposed relatively moving forming surfaces, during continued travel of the strip in said one direction disposing the corrugations of the preformed strip over and between

final forming elements having flat working edges and similar to said preforming elements and of uniform thickness the same as the desired final width of the crests of the corrugations with said final forming elements contacting the corrugations at the crest areas only thereof, and during such continued travel of the strip flattening the crests of the corrugations by pressure applied thereto solely by said final forming elements while retaining substantially unaltered the V cross section of the corrugations imparted thereto in the preforming operation.

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