United States Patent

Kawaguchi et al.

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[54] **APPARATUS FOR THE MANUFACTURE OF ALUMINUM STRIP CONDUCTORS**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **72/234**, 72/245, 72/237

[51] **Int. Cl.** **B21d 1/02**

[58] **Field of Search**........72/234, 199, 245, 226, 163, 72/237

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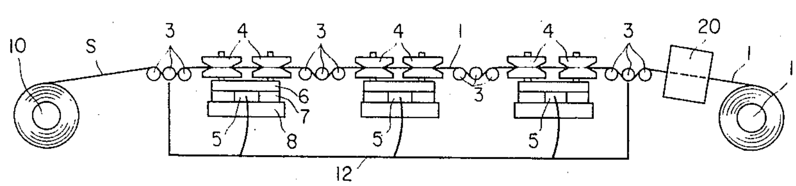
[57] **ABSTRACT**

This invention relates to apparatus for reshaping both edges of an aluminum strip of 0.2–3.00 mm. in thickness into rounded smooth edges adapted for an electric conductor. The edge of the strip has irregular burrs resulting from slitting of the aluminum strip of commercial width. In operation, the strip is pulled from its coiled supply, through a three-roll assembly, engaged with the groove of the reshaping rolls, through a cleaning chamber, and finally to a recoiler to be coiled again. The reshaping roll is urged by fluid pressure toward the edge so as to treat it with a relatively weak force in order to prevent the roll from damaging the strip.

5 Claims, 15 Drawing Figures



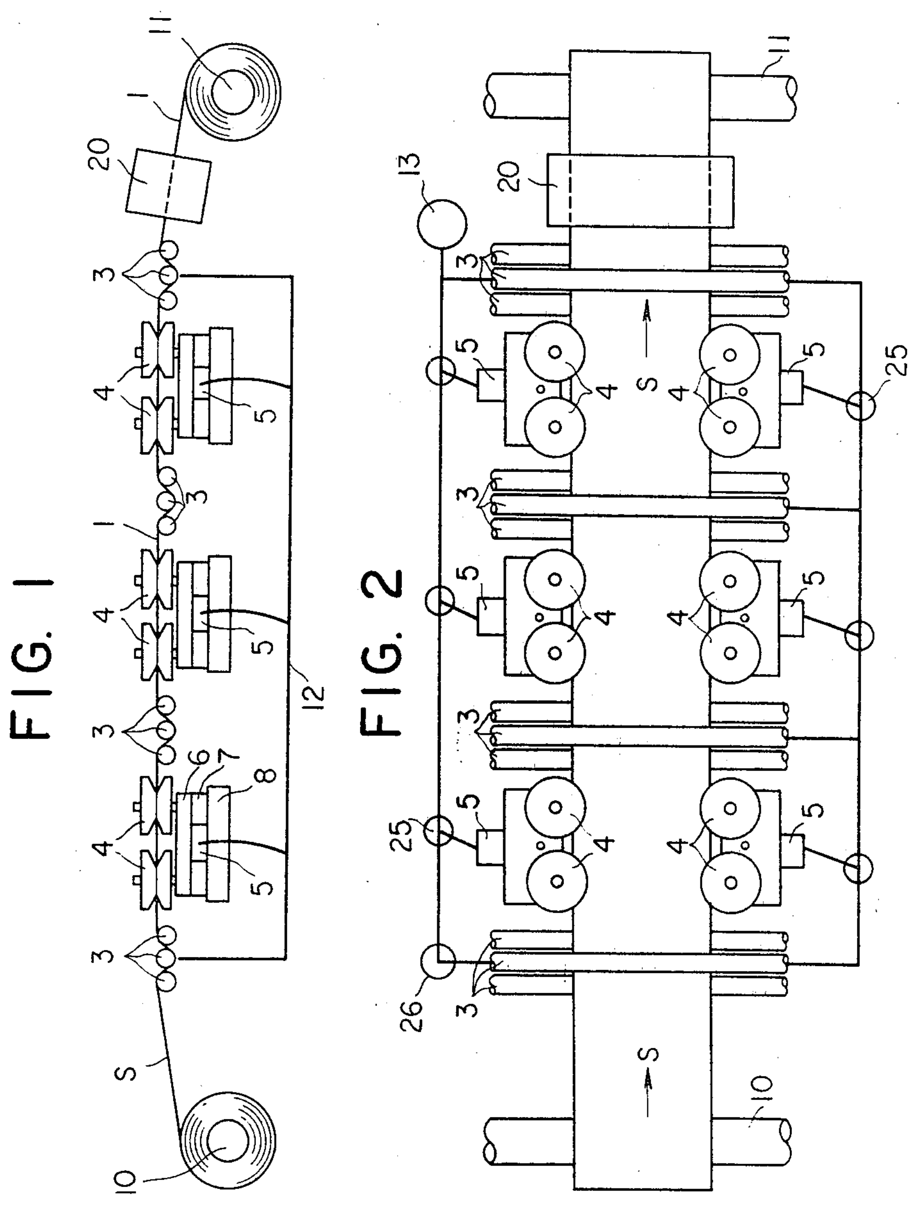


FIG. 1

FIG. 2

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FIG. 3

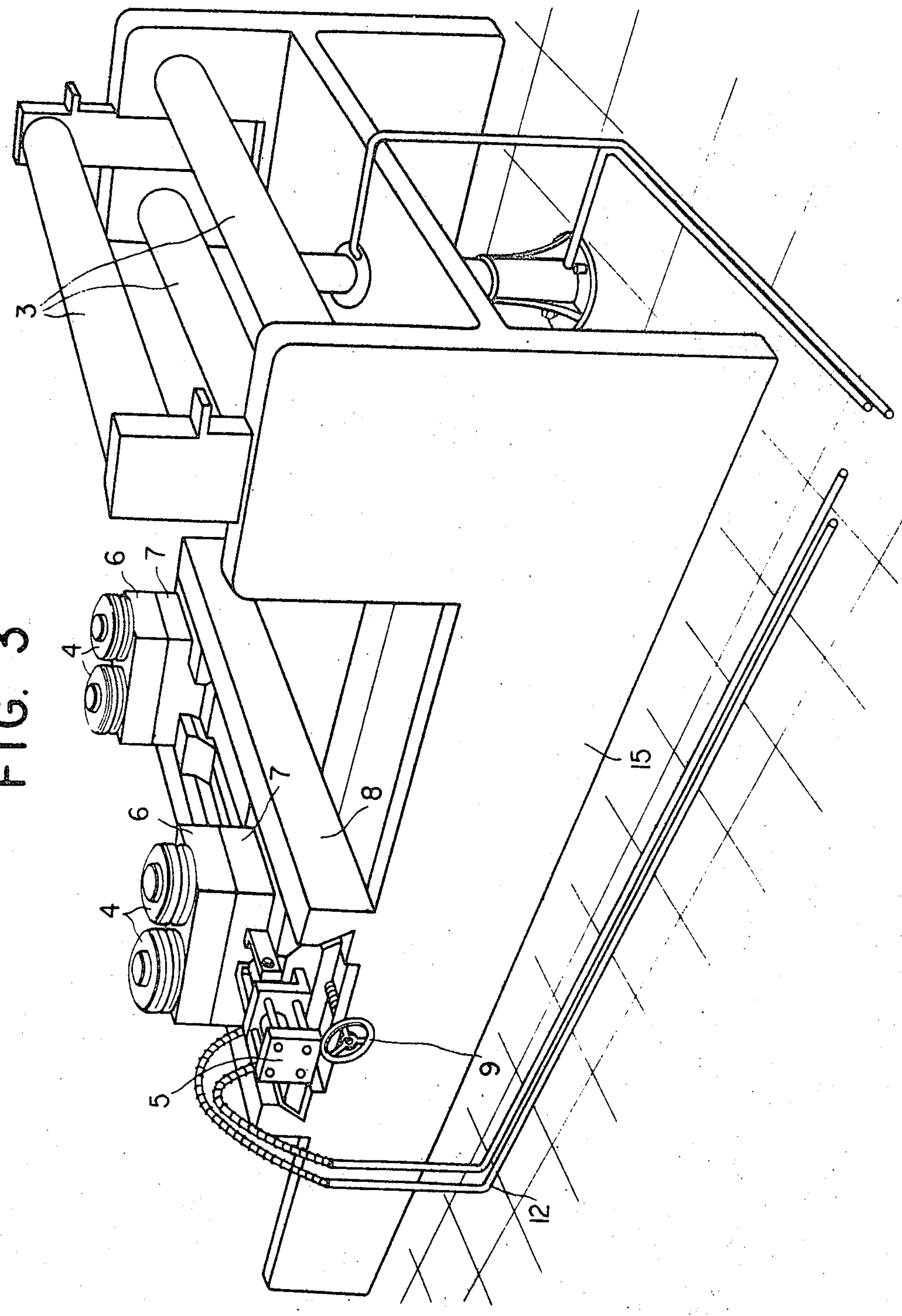

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FIG. 4

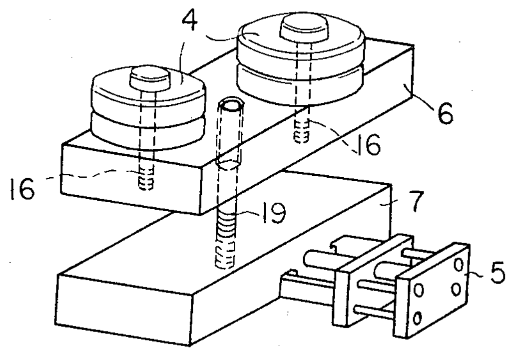


FIG. 5

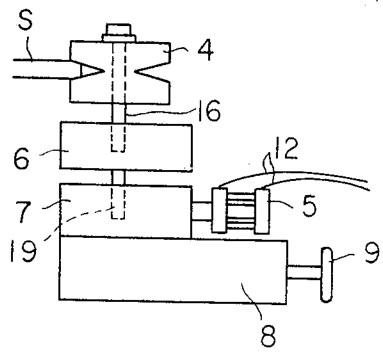


FIG. 6

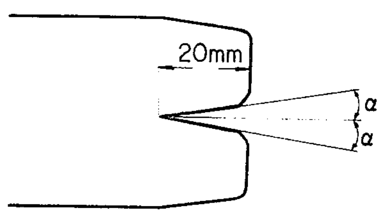
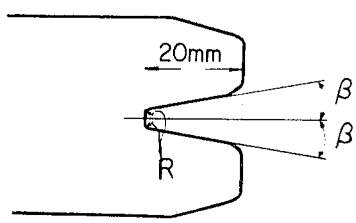


FIG. 7



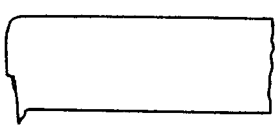


FIG. 9

FIG. 10

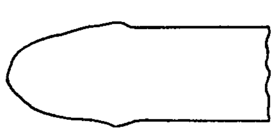


FIG. 11

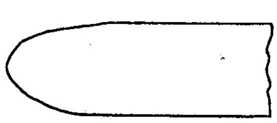


FIG. 12

FIG. 8

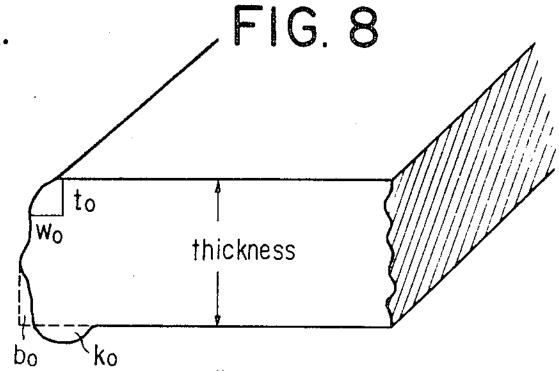


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FIG. 13

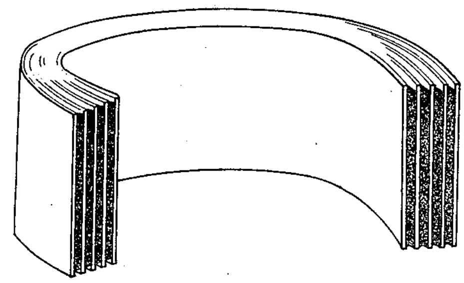


FIG. 14

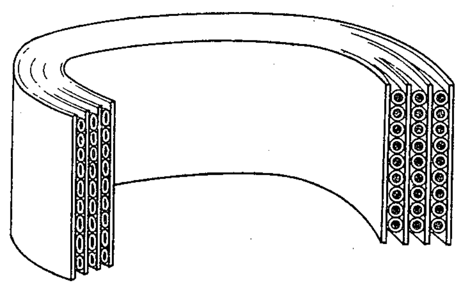
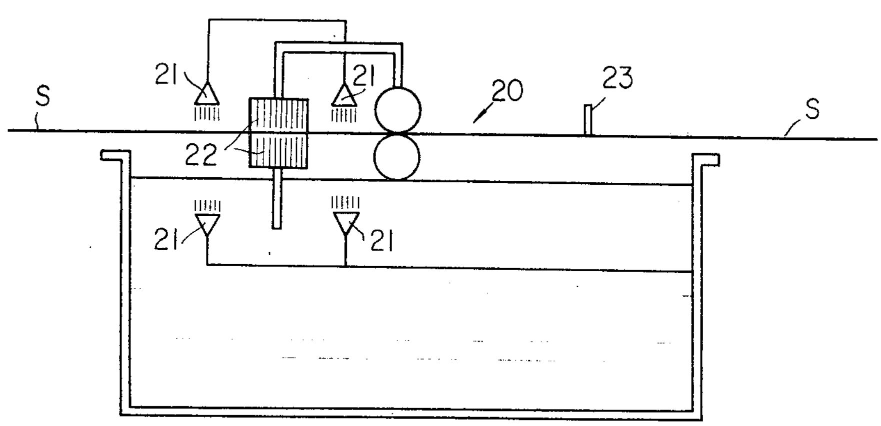


FIG. 15



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APPARATUS FOR THE MANUFACTURE OF ALUMINUM STRIP CONDUCTORS

This invention relates to an apparatus for the manufacture of an aluminum strip conductor, more particularly, to the apparatus for the manufacture of a high purity aluminum strip conductor adapted for an electric transformer and other electromagnetic devices.

In recent years, the copper resources all over the world have dwindled so noticeably that a great deal of aluminum is used as a substitute metal for copper. In point of resources, aluminum is much more abundant than copper, so aluminum is used as one of principal industrial metallic materials. In accordance with the invention, when the aluminum strip conductor is employed as a material for electromagnetic coils or windings for electric transformers and other electromagnetic devices, it is a common practice to form a coil wound with an aluminum strip in place of the coil wound with round aluminum wire.

While the common coil is wound with round copper wire, the coil of this invention is wound with an aluminum strip wider than wire. Thus, there is a considerable difference between aluminum and copper. The use of aluminum strip for coils has several advantages as follows: 1) Electric conductivity of aluminum is about 61 percent that of copper while its weight is one-third that of copper, hence the weight of aluminum with the same electric resistance is about half that of copper; 2) Rapid winding is possible, because aluminum is softer and more workable than copper so that the form of a coil is easily made 3) Better heat transfer. In the copper wire wound coil, its cooling surface is limited to a wire at every end of a layer, but in the strip wound aluminum coil, it is cooled by a cooling agent at every end of a layer, its cooling effect is high; 4) Less need for an electric insulating material. In case the same D.C. resistance is required, the cross section area of aluminum should be 1.6 times as big as that of copper, but it will be covered by the strip wound aluminum coil of a good design. Voids and thick insulating layers heretofore observed in the conventional coil wound with copper wire are eliminated owing to the low voltage between layers as well as the absence of inner cuts resulting from roll winding. As a result, the strip wound aluminum coil of the good design has almost the same space factor as that of the coil wound with copper wire, because in the former there is less space occupied by the insulating material; and 5) in view of the above features, the price of good-designed strip wound aluminum coils can be reduced by 5–10 percent from that of an electrically equivalent coil wound with copper wire, and aluminum's future availability is much better than copper so that price stability of the finished price is maintained.

In general, at present, a plurality of aluminum strip conductors of a width, e.g., in the range of 80–800 mm. are obtained by slitting an elongated aluminum sheet or strip of commercial width. As a result, sharp projections or burrs of microscopic dimensions are formed on the edges of the aluminum strip. In order to obtain a good aluminum strip conductor, these burrs must be removed to provide rounded smooth edges thereon, because when a coil is produced by coiling the aluminum strips with an electric insulation material, such as, insulation paper, interleaved between the turns, the irregular burrs tend to damage the paper so that a completed coil would be a bad one. An electric transformer having the coil produced from the aluminum strip conductor therein includes a pole transformer and a welding transformer rated 15–100 kVA (kilovolt-ampere), both of which show good results. Accordingly, the range of application of the aluminum strip conductor is widening to a transformer rated 500–1000 kVA.

Various methods for modifying the edge portions of such slit strips into rounded smooth edges for use in the coil of electromagnetic devices have been suggested as, for example, the mechanical brushing of the irregular edges, the controlled melting of those edges to provide convex smooth edges, or the chemical treatment of the edges to provide convex smooth edges.

The present invention contemplates to overcoming the above problem providing a mechanical process in which convex smooth edges are obtained by subjecting the irregular burrs to a mechanical working operation including an improved reshaping roll.

It is therefore an essential object of the invention to provide an improved apparatus for reshaping the burred edges of an aluminum moving strip in which the burrs resulting from slitting of an aluminum strip of commercial width are treated in a rapid, easy, and inexpensive manner.

It is an additional object of the invention to provide a high purity aluminum strip conductor having rounded smooth convex edges which will not damage the electric insulating material and adapted for an electromagnetic device.

It is still another object of the invention to provide two kinds of the reshaping roll for conditioning the edges of aluminum strip, one roll having a V-shaped groove and the other having a U-shaped groove.

It is still another object of the invention to provide a fluid pressure working process in which a relatively thin aluminum strip is treated by fluid pressure in a satisfactory manner, and in which bucking is effectively prevented.

Other objects and advantages will become more apparent when the following description is considered in connection with the accompanying drawings, in which:

FIG. 1 is a diagrammatic view showing a section of a preferred embodiment of the apparatus for reshaping the edge portions of an aluminum strip conductor together with its operation.

FIG. 2 is a top plan view of FIG. 1 together with its pneumatic system.

FIG. 3 is a perspective view of the essential parts of the apparatus of the invention.

FIG. 4 is a perspective view of a set of reshaping rolls and a fluid pressure means.

FIG. 5 is a side view of FIG. 4 together with a slide means with its feed handle.

FIG. 6 is a vertical section of a reshaping roll having a V-shaped groove which is to be engaged with an edge portion of aluminum strip wherein the groove forms equal angles α above and below the horizontal center line of the roll.

FIG. 7 is a vertical section of another reshaping roll having a U-shaped groove which is to be engaged with an edge portion of aluminum strip wherein the groove forms equal angles β above and below the horizontal center line of the roll, showing a rounded apex of the angle β.

FIG. 8 is a perspective view of an enlarged edge portion of aluminum strip showing several locations which are described in the text.

FIG. 9 shows an enlarged view of an example of an edge portion of strip immediately after slit.

FIGS. 10–12 show how the edges are reshaped by the rolls of the invention, and FIG. 12 shows a finished edge.

FIG. 13 is a perspective view of the strip wound aluminum coil, partly in section, showing the undarkened portion as an insulating material.

FIG. 14 is a perspective view of a coil wound with round copper wire, partly in section, showing an insulating material around the round copper wire.

FIG. 15 is a section of a degreasing and cleaning chamber wherein the aluminum strip conductor processed by this invention is cleaned prior to the final recoiling step.

In accordance with a preferred embodiment of the invention, the purity of aluminum to be processed is 99.0 percent , preferably 99.5 percent or more, and we adopt such aluminum materials as of 0.20–3.00 mm. in thickness and 80–800 mm. in width. It is to be understood that these values are exemplary and this invention should not be limited by them. Particularly, in the width, an aluminum sheet of less than 80 mm. or more than 800 mm. is satisfactory for carrying out our invention.

The invention provides a process and apparatus for reshaping the edge portions of aluminum strip just slit by causing them to be engaged with an improved reshaping roll while moving the strip continuously under tension. Referring more particularly to FIG. 1, a coiled supply 10 of an aluminum strip having rough edges as well as the above range of dimensions is mounted at one end of the apparatus. The invention can treat the rough edges of materials other than aluminum in accordance with the selection of a suitable reshaping roll. The aluminum strip S removed from the supply 10 passes through a three-roll assembly 3 consisting of three rolls, the number of which will not be limited. An intermediate roll of the three-roll assembly can be elevated by utilizing the fluid pressure system, which is shown in FIG. 3 in connection with FIG. 2. In mounting the strip on the apparatus, it is seen that it can be easily done if the intermediate roll is elevated so as to provide a sufficient space therebetween. As an example, each roll of the three-roll assembly is made of a cylindrical body of carbon steel, about 75 mm in diameter and about one meter, in length the surface of which is treated with a suitable agent. The three-roll assembly 3 serves to prevent the aluminum strip from buckling prior to causing it to be engaged with the reshaping roll 4. However, it is arranged that the three-roll assembly 3 will not be able to impart a noticeable stress to the aluminum strip. In addition, the three-roll assembly is not given a particular force. The construction of the three-roll assembly is known in the art. As shown in FIGS. 1 and 2, the three-roll assembly 3 is provided at four locations: before the first reshaping roll, between the first and second reshaping rolls, between the second and third reshaping rolls, and after the third reshaping roll 4, respectively. They are of the same construction, and the intermediate roll can be elevated up and down by means of a fluid pressure system. When the strip S passes, the intermediate roll descends down to a space between two rolls so that the three rolls are then in parallel. The strip S travels through the three-roll assembly in a zigzag path.

Then the strip S engages with the groove of the reshaping roll 4. In FIGS. 1 and 2, pairs of reshaping rolls 4 are provided in a vertical position to the plane of the strip at three locations along both edges of the strip. It is seen that the total number of reshaping rolls 4 is 12. It is understood that the total number of reshaping rolls will not be limited.

It is arranged that the reshaping rolls can be moved transversely across the width of the strip S. In accordance with the width of the strip to be treated, the reshaping rolls on opposite edges of the strip can be moved toward and away from each other (FIG. 2). To this end, slide means 8 is provided (FIG. 3). This slide means 8 is known in the art and it is operated by a feed handle 9 connected to a feed screw.

FIG. 3 shows two essential parts of the apparatus, the three-roll assembly 3 and the reshaping roll 4. As shown in the drawing, the reshaping roll 4 is constructed as a two-roll unit to which fluid pressure is applied. However, the reshaping roll may of a single roll, the details of which will be described hereinafter. The reshaping roll 4, an upper block 6, a lower block 7, slide means 8, and a fluid pressure piston-and-cylinder 5 are shown in FIGS. 3 and 4. In FIG. 4, each of the rolls is rotatably mounted by means of a pin 16 with a suitable bearing (not shown) on the upper block 6, to which the pin 16 is secured. In addition, the upper block 6 is pivotally mounted on the lower block 7 around a stud bolt 19 secured thereto. In other words, the diameter of the bolt 19 is somewhat less than a central bore of the upper block 6 so that the block 6 can be removed from the lower block 7 while swingable.

The lower block 7 is connected to the slide means 8 of known construction, the description of which is omitted.

The reshaping roll 4 of the above construction is connected to the fluid pressure piston-cylinder 5 which urges the roll 4 toward the edge of the aluminum strip. In this case, it is arranged that fluid pressure may read about 0.7–1.4 kg./ cm^2. at a pressure control means 25 (FIG. 2). If the fluid pressure at 25 shows the above range, it follows that, a working force of about 30–70 kg will be produced at the reshaping roll depending upon the size and capacity of piston-cylinder. However, it is very difficult to determine accurately an actual surface area of one edge portion of strip, so the above contact pressure per unit area is a mere conjecture. It seems that at least the fluid pressure of 10 kg./ mm^2. (per sq. millimeter) may be produced.

The present inventors have discovered based on an extensive experiment that the working force applied to the edge of a strip is satisfactory when the fluid pressure control means 25 indicates in the range of 0.7–1.4 kg./ cm^2. (per sq. centimeter). In reference to the fluid, we have adopted air from an economical point of view, but it is to be understood that any working fluid other than air, for example, oil may be used.

As an example, the reshaping roll has dimensions of 120 mm. in diameter and 60 mm. in height in this preferred embodiment, but this dimension will be exemplary, not limiting.

Referring to the reshaping roll, a single roll adapted for reshaping instead of two rolls shown in the drawing may be used. In the case of the single reshaping roll, a single block instead of the upper and lower blocks mentioned above may be employed. Other necessary means therefor would be obvious to any one skilled in the art.

The aluminum strip S moves toward a recoiler **11** while being treated by a series of reshaping rolls. In this apparatus, a driving force for advancing the strip is given only by a pulling force of the recoiler **11**. A recoiling speed of the strip is about 4.5–90 m./min., in which case the tension of the strip is at most 2,000 kg. at the speed of **4.5** m./min. This tension is obtained by the difference of power between two motors, one motor for the uncoiler **10** is 22 kW/hr. while the other for the spool **11** is 30 kW/hr. This is exemplary, not limiting.

The strip having completely reshaped edges enters a degreasing and cleaning chamber **20** of known construction in FIG. **15**, in which the strip S is sprayed on both sides thereof with a degreasing solvent, such as, trichloroethylene, from a group of spray nozzles **21** to remove rolling oil which remains from the previous rolling operation from ingot to sheet, chips, turnings and kerosene as a lubricant in this invention. The strip treated with solvent is subjected to brushing by a circular brush **22** mounted on the roll, passes through a pair of rubber rolls, and is wiped off by a rubber wiper **23**. Thus, the cleaned strip is coiled on the recoiler **11**. However, the chamber **20** does not form a part of the invention.

The operation of the apparatus of the invention has been described in the foregoing, and the fluid pressure system and circuit utilized in this invention is known in the art, but it will be mentioned briefly hereinbelow.

We have described the use of air as well as oil as a working fluid hereinbefore. In this invention, the intermediate roll of the three-roll assembly as well as the reshaping roll, the essential part of the apparatus can be moved by the use of air pressure. As shown in FIG. **2**, the first set of reshaping rolls (two on both sides, four in all) is provided with a pressure control means **25** and the second and third sets are also provided with the same means **25**, respectively. The pressure control means **25** is known in the art and provided with an air filter (not shown). In addition, four units of the three-roll assembly are installed in the apparatus, and a single pressure control means **26** with an air filter is provided. An air compressor **13** supplies compressed air through a conduit **12** to a number of units desired.

As described above, the aluminum strip S is engaged with the groove of each reshaping roll **4**, and any strip having a width in the range of 80–800 mm. can be accommodated in this apparatus. In engaging both edges of the strip with the reshaping roll **4**, they are set at a location distant about **20** mm. from the edge. To this end, the slide means **8** is moved by the feed means **9**. Then, compressed air is supplied to the air cylinder **5** connected to the lower block **7** to urge it, whereby compressed air is transmitted to the upper block **6** which is pivotally mounted about the bolt **19** on the block **7**. As described hereinbefore, thus, the reshaping roll **4** is urged toward the edge of strip engaged into the groove thereof to treat it. The reason why the upper block **6** on which the reshaping rools **4** are mounted is swingably mounted on the lower block **7** is to avoid an excessive pressure which may be by chance applied to the edge of strip through the reshaping roll **4**. We have found it after many experiments.

The standard shown below, and with reference to FIG. **8**, for treating the edge of the aluminum strip has been also determined as satisfactory from extensive research. The locations, t_0 , w_0 , k_0 , and b_0 of the edge portion shown in FIG. **8** should be in the range specified:

LOCATION	STANDARD
t_0	above 0.0511 11 = T
w_0	above 0.10 × T
k	above 0.005 × T
b_0	above 0.10 × T

In the above, T is the thickness of the strip.

In order to treat the edge portion of the aluminum strip within the above standard or requirements, we have invented two kinds of a reshaping roll shown in FIGS. **6–7**. One reshaping roll **4** in FIG. **3** is a steel roll, which, as an example, has a diameter of **120** mm., and a height of 60 mm. It has a groove about 20 mm. deep around the horizontal center line thereof. The reshaping roll of FIG. **6** refers to a V-shaped groove roll while that of FIG. **7** to a U-shaped groove roll. In FIG. **6**, the V-shaped groove forms an angle α above and below the horizontal center line of the roll while the U-shaped groove in FIG. **7** forms an angle β above and below the same line, but its apex forms an arc.

The angles and the radius of the arc are shown below as exemplary. These values have been obtained after many experiments. The angle α lies in the range of 1°–30 while β 1°–20°. The radius R within the angle α at 20 mm. from the side of the roll in FIG. **7** lies in the range of 0.05–0.7 mm. We have conducted many experiments based on the following values of R :

R = 0.05 mm.	R = 0.30 mm.
R = 0.1 mm.	R = 0.4 mm.
R = 0.15 mm.	R = 0.5 mm.
R = 0.2 mm.	R = 0.6 mm.
R = 0.25 mm.	R = 0.7 mm.

The value R can be combined with any angle within the angle β, hence the number of combinations may be more than 100.

The arrangement of three sets of reshaping rolls **4** on both edges of strip is shown in FIGS. **1–2**, and the arrangement of reshaping rolls having V-shaped and U-shaped grooves in the above sets is shown as exemplary in Table 1.

TABLE I

Article Size thickness ×width		1st Set 1st V-roll	2nd V-roll	2nd Set 3rd V-roll	4 U-roll	3rd Set 5th V-roll	6th V-roll
0.27×150mm.	A.	5°	10°	5°	3°	2°	1°
	R.			0.10	0.08		
0.8×370mm.	A.	5°	10°	5°	3°	2°	1°
	R.			0.35	0.3		
1.8×375mm.	A.	5°	10°	5°	3°	2°	1°
	R.			0.85	0.80		
375							

A. = angle
R. = radius

As shown in Table I, the first roll having a V-shaped groove has the angle 5° and the second 10°. Generally speaking, the rolls to follow have smaller angles. In treating the edge, the rough edge of FIG. **9** was treated to the condition of FIG. **10** by the first and second rolls, then to that of FIG. **11** by the third and fourth rolls, and finally to the completed condition of FIG. **12** by the fifth and sixth rolls.

In treating an aluminum strip having a thickness in the range of 0.27–0.38 mm., it has been found that the edge of such strip was treated satisfactorily for the purpose in view by the following arrangement of reshaping rolls without the third and fourth rolls having the U-shaped groove:

TABLE II

Thickness, mm.	1st Set 1st V-roll	1st Set 2nd V-roll	2nd Set	3rd Set 5th V-roll	3rd Set 6th V-roll
0.27 –0.38	5°	10°	absent	3°	1°

Many combinations of reshaping rolls other than the above example are feasible, and we are conducting our research on the arrangement of combinations of rolls.

In view of the fact that a leading portion of aluminum strip is initially pulled from the uncoiler, then through the three-roll assembly, engaged with the series of reshaping rolls, through the cleaning chamber, and finally to the recoiler to be wound in the operation of the apparatus, it is seen that some of the leading portion of strip may be thrown away as scrap, because some portion may not be treated. Several methods have been proposed to prevent some of the leading portion of strip from becoming scrap, but nothing about them is described.

As is well known, aluminum is softer than steel, and aluminum strip to be treated in this invention has a thickness in the range of 0.2–3.00 mm. In treating both edges of the strip, special attention should be paid that the reshaping roll and its force of application may neither damage aluminum nor remove excess metal. To this end, in this invention, the fluid pressure system particularly, air pressure, is employed to apply a working force to the reshaping roll. The pneumatic system has been proved to be an ideal means for applying a force required to work both edges of strip of the above range of thickness.

As an inexpensive oil which is both easily available and effective for reshaping the edge of the strip, commercial kerosene having a specific gravity of 0.790–0.850 and a boiling point between 150°–250°C. has been found to be satisfactory on the results of experiment, and its consumption about 0.5 liters per ton of aluminum strip.

In the foregoing, we have described the preferred embodiments of our invention, but it will be obvious to any one skilled in the art that various changes and modifications may be made therein without departing from the spirit and scope of the invention.

We claim:

1. In an apparatus for reshaping the edges of an aluminum strip conductor wherein said strip is moved from a supply roll to a recoil roll while said edges are pressed by a plurality of grooved reshaping rolls, said apparatus including a base frame, at least one pair of reshaping roll assemblies mounted in opposing fashion on said base frame and movable thereon toward one another to press said strip therebetween; the improvement wherein said at least one pair of reshaping roll assemblies comprises a first pair of reshaping roll assemblies, each of the rolls of which have therein a V-shaped groove with angles of 1°–30° above and below the horizontal center line thereof; and a second pair of reshaping roll assemblies, each of the rolls of which have therein a U-shaped groove with angles of 1°–20° above and below the horizontal center line thereof; and forming an arc at the apex thereof having a radius of from 0.05–0.7 mm. at a predetermined distance from the edge of said roll; each of said reshaping roll assemblies comprising slide means mounted on said base frame for movement in a direction transverse to the movement of said strip, a lower block mounted on said slide means and movable in said direction, fluid pressure means operably connected to said lower block for sliding said lower block in said direction, a stud bolt pivotally mounted in said lower block and extending upwardly therefrom, an upper block attached to said stud bolt and mounted above said lower block, said rolls rotatably mounted on said upper block, whereby said rolls of each of said reshaping roll assemblies may be selectively pressed against said edges of said strip.

2. The improvement claimed in claim **1**, wherein said first pair of reshaping roll assemblies is positioned upstream of said second pair of reshaping roll assemblies, and further comprising a third pair of reshaping roll assemblies positioned downstream of said second pair of reshaping roll assemblies, said third pair having rolls with V-shaped grooves similar to those of said first pair.

3. The improvement claimed in claim **1**, wherein said fluid pressure means comprises pneumatic means.

4. The improvement claimed in claim **1**, wherein said fluid pressure means comprises hydraulic means.

5. The improvement claimed in claim **1**, further comprising fluid pressure control means connected to said fluid pressure means for supplying pressure in the range of 0.7–1.4 kg/cm^2 to said rolls.

* * * * *