June 14, 1932. M. A. LISSMAN 1,862,936

RECTIFYING APPARATUS

Filed Jan. 11, 1930 3 Sheets-Sheet 1

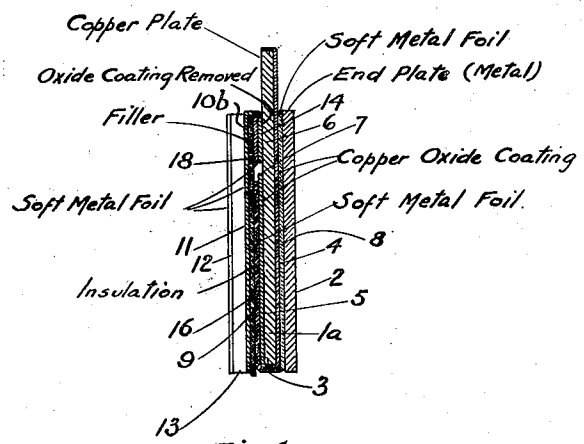


Fig 1.

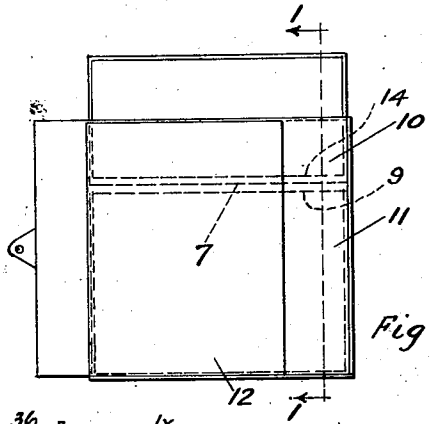


Fig 2

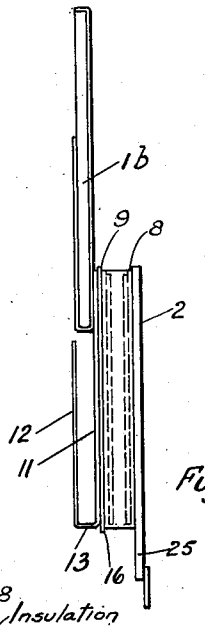


Fig 3

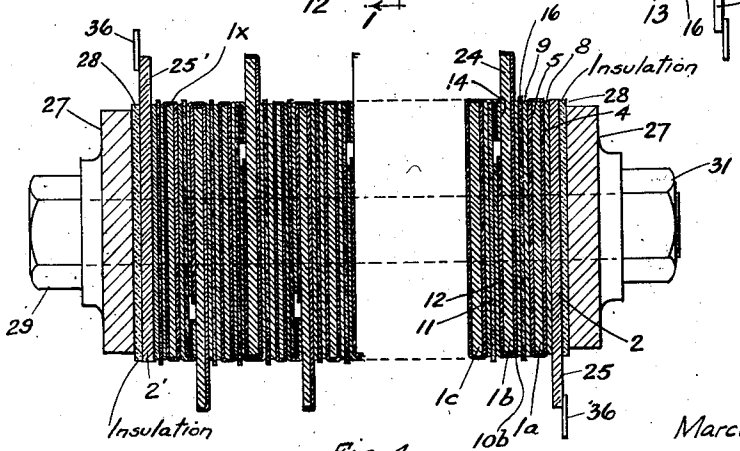


Fig 4.

INVENTOR.
Marcel A. Lissman.
BY Arthur P. Knight and
Alfred W. Knight
ATTORNEYS

June 14, 1932. M. A. LISSMAN 1,862,936

RECTIFYING APPARATUS

Filed Jan. 11, 1930 3 Sheets-Sheet 2

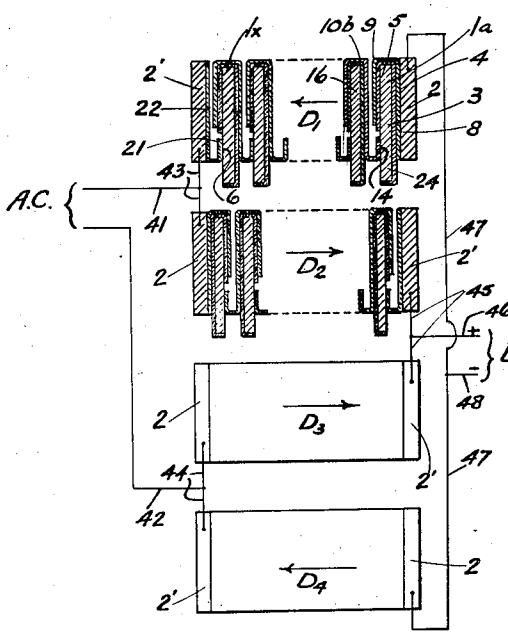


Fig. 6.

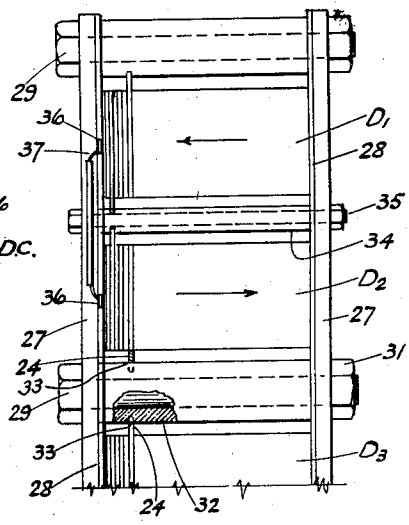


Fig. 5.

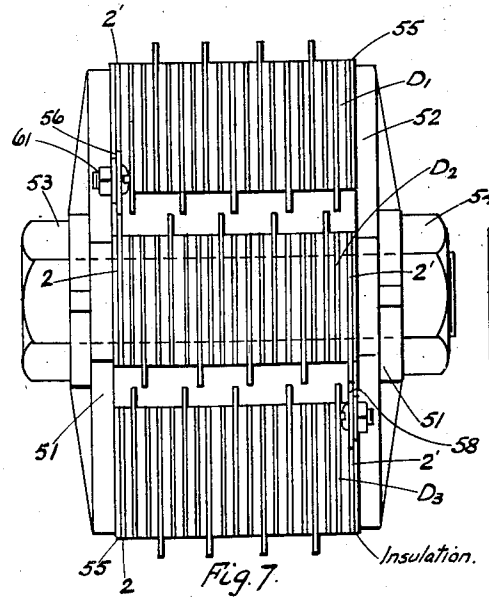


Fig. 7.

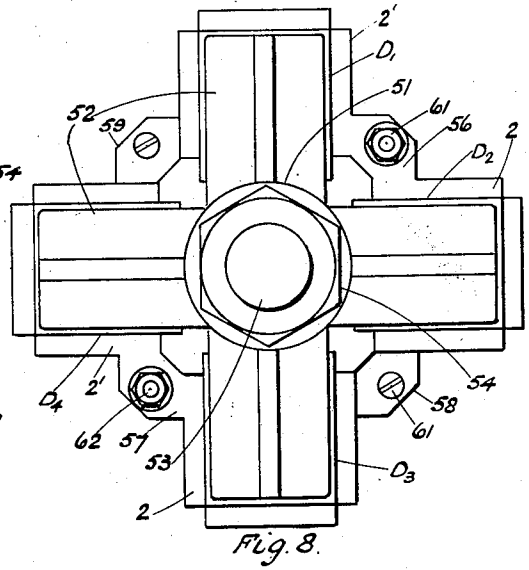


Fig. 8.

INVENTOR.

Marcel A. Lissman.

BY Arthur P. Knight and Alfred W. Knight

ATTORNEYS

June 14, 1932. M. A. LISSMAN 1,862,936

RECTIFYING APPARATUS

Filed Jan. 11, 1930 3 Sheets-Sheet 3

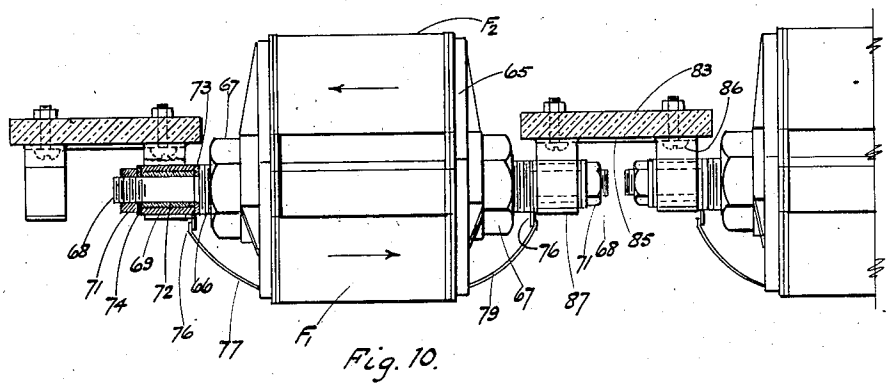


Fig. 10.

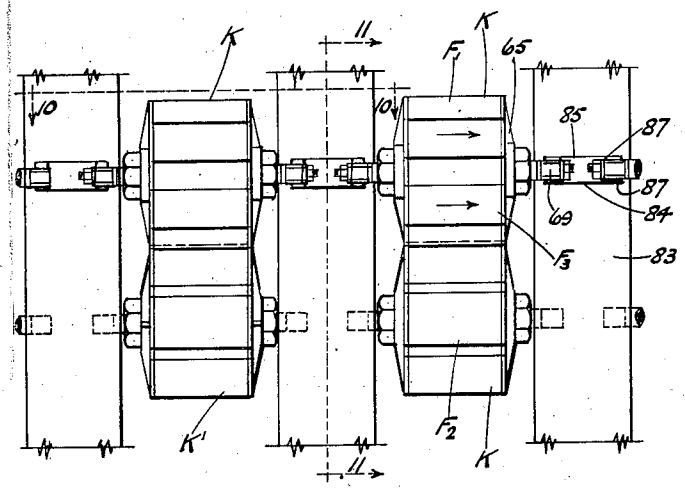


Fig. 9.

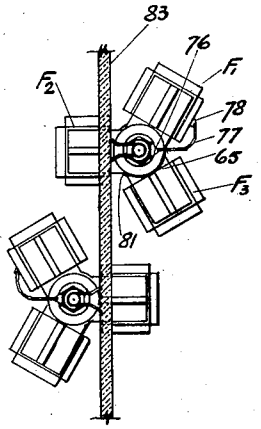


Fig. 11.

INVENTOR.
Marcel A. Lissman.
BY Arthur P. Knight and
Alfred W. Knight
ATTORNEYS

Patented June 14, 1932 1,862,936

UNITED STATES PATENT OFFICE

MARCEL A. LISSMAN, OF LOS ANGELES, CALIFORNIA, ASSIGNOR TO INTERNATIONAL PRECIPITATION COMPANY, OF LOS ANGELES, CALIFORNIA, A CORPORATION OF CALIFORNIA

RECTIFYING APPARATUS

Application filed January 11, 1930. Serial No. 420,130.

This invention relates to apparatus for rectification of alternating electric current, and particularly to rectifying apparatus of the asymmetric film type, such as the well known copper-copper oxide rectifier. Such rectifiers depend upon the asymmetrical conductivity of the surface between two closely contacting members, for example between a plate of copper and a layer or film of cuprous oxide formed thereon, in which case the resistance to flow of electric current from the oxide to the copper is many times less than the resistance in the reverse direction. The voltage which may be impressed across one such asymmetrically conductive interface without causing rupture or breakdown thereof is ordinarily relatively small, for example on the order of from 1 to 10 volts, but by connecting a suitable number of elements in series, any desired voltage may be handled satisfactorily.

The principal object of the present invention is to provide a rectifier construction which permits a large number of asymmetric solid contact rectifying elements to be assembled in a relatively short space and in series connection with one another, and which provides a maximum area of the asymmetrically conductive surface, such as the surface between the copper and the oxide coating, of each element.

A further object of the invention is to provide a construction adapted for rectification of relatively small electric currents at relatively high total voltage, in an apparatus of moderate size and low cost of manufacture and assembly.

A further object of the invention is to provide a simple and inexpensive means of assembling suitable numbers of such rectifying elements to form units of convenient size, and novel means for mounting and interconnecting such units.

A common type of copper oxide rectifier construction heretofore employed consists of a plurality of spaced apart copper discs or plates having an oxide coating or film on each face thereof, metal contact plates held in contact with the copper oxide coating at the respective sides of each copper plate, and separate connecting members for connecting each copper plate to the contact plates of an adjacent element, whereby the desired number of said elements are connected in series. In this form of construction the elements are ordinarily separated by air gaps which permit dissipation of heat to the air therebetween, and units of this type are well adapted to the rectification of relatively large electric current, due to the relatively high requirement for heat dissipation. The number of elements which may be assembled in a given space, however, with this form of construction, is relatively small, so that this form of construction is not well adapted to the rectification of relatively high voltages where a large number of elements must be connected in series. Furthermore, when the current to be conducted is relatively small, the heat dissipation requirements are much less and the spaced apart arrangement of the elements is not required.

Another type of construction which has been heretofore used comprises merely a stack of copper plates, each coated with copper oxide upon only one face, with alternate contact plates, such as lead washers, interposed therebetween, and an insulated bolt or other compression member extending longitudinally through the centers of all of the elements and serving to hold the same in tight engagement, with the respective contact plates establishing contact between the several copper plates and the oxide coatings of the adjacent plates. One disadvantage of this latter construction, however, is that each copper plate is coated with oxide at only one side, and the total available asymmetrically conductive surface, for a plate of a given size, is only one-half as great as in the construction first described.

As distinguished from the above described rectifier constructions, the construction of my invention provides for mounting, for example, a series of oxide-coated copper plates in close proximity to one another and without intervening air spaces, while at the same time permitting the use of plates coated with copper oxide over the major portion of both faces thereof, but with suitable provision for connection from a relatively small non-oxidized surface portion of each plate to substantially the entire surface of the oxide coat-

ing of the next plate, thus providing a relatively great number of elements in a given length and at the same time providing for utilization of the maximum asymmetrically conductive surface per element.

A preferred embodiment of rectifying apparatus of my invention, by means of which the above objects are accomplished, comprises essentially a plurality of copper plates arranged in a stack and each having a coating of cuprous oxide formed thereon in any suitable manner and extending over the major portion of both faces thereof, corresponding contact elements consisting preferably of soft metal foil, each of said contact elements extending over and in intimate contact with substantially the entire surface of the oxide coating at both sides of the corresponding copper plate and also having a portion extending in intimate contact with a non-oxidized surface portion of relatively small area on an adjacent copper plate, suitable insulating means interposed between the overlapping portions of the adjacent contact elements, and means compressing the entire stack so as to maintain tight engagement and intimate electric contact of the contact elements with the oxidized and non-oxidized surface portions of the copper plates. It will be seen that this construction takes advantage of the fact that the conductivity from the non-oxidized portion of the copper plate to the metallic conducting element in contact therewith is much greater than the conductivity between the copper oxide coating and the copper plate, even in the direction of relatively high conductivity, so that a contact of the contact element with a relatively small non-oxidized surface portion is capable of handling the same current flow as may be passed through the relatively large area of surface between the copper oxide film and the copper.

It will be understood that other asymmetrically conductive solid contact rectifying elements may also be mounted and assembled in a similar manner, such as silver-silver oxide elements, elements each comprising a plate of aluminum having a coating of sulphide thereon and a layer of cupric sulphide in contact therewith, or elements consisting of aluminum in contact with cuprous sulphide. However, for the sake of clarity, the following description will be directed particularly to rectifying apparatus of the copper-copper oxide type, it being understood that this is by way of example only.

The apparatus also comprises certain novel means for mounting the stacks of rectifying elements above described so as to form units of convenient size, and novel means for assembling and interconnecting these units, as hereinafter described.

The accompanying drawings illustrate embodiments of my invention and referring thereto:

Fig. 1 is a vertical section on line 1—1 in Fig. 2, showing an intermediate stage in the assembly of a stack of copper-copper oxide rectifying elements according to my invention.

Fig. 2 is a side elevation taken from the left side of Fig. 1.

Fig. 3 is an inverted plan view of Fig. 2, showing the manner of inserting the next copper plate in the stack.

Fig. 4 is a longitudinal section of a partly broken away stack of rectifying elements showing one form of means for compressing such stack to cause intimate contact between the elements thereof

Fig. 5 is a side elevation showing a number of stacks of rectifying elements mounted between suitable supporting and compressing means.

Fig. 6 is a diagrammatic representation showing a simple manner of connecting four stacks of rectifying elements according to my invention, so as to provide for full wave rectification thereby.

Fig. 7 is a side elevation of a simple construction of full wave rectifying unit for moderate voltages.

Fig. 8 is an end view from the left end of Fig. 7.

Fig. 9 is a side elevation showing a plurality of units connected in series and each comprises a plurality of stacks also connected in series.

Fig. 10 is a horizontal section on line 10—10 in Fig. 9.

Fig. 11 is a vertical section on line 11—11 in Fig. 9.

It should be stated, at the outset, that in certain figures of the drawings the rectifying elements, the contact elements and the insulating and spacing means are exaggerated in thickness, in proportion to their other dimensions, in order to show the shape and positions thereof more clearly. Also, in certain figures, some or all of the individual rectifying elements are not indicated, as this would involve a needless repetition of parts.

Referring to Figs. 1 to 3 inclusive, I have indicated at 2 an end plate, preferably of rectangular shape, and consisting of copper or any other suitable metal or conducting material, while the first rectifying element is indicated at 1*a*. Said rectifying element is shown as comprising a copper plate 3, preferably of rectangular shape and provided with a coating of cuprous oxide formed thereon in any suitable manner and extending over the entire contacting area of one face, as indicated at 4, and over the major portion of the other face, as indicated at 5. A relatively small portion of this last mentioned face, however, is free from copper oxide coating, as indicated at 6, the freedom from oxide

coating over this portion of the plate being secured in any suitable manner, as, for example, by first coating the entire exterior surface of the plate and then removing the oxide coating from this face of the plate above the point indicated at 7. Contact from the end plate 1 to the copper oxide coatings 4 and 5 over the major portion of the surface of both sides of the copper plate 3, is provided by means of a sheet of soft metal foil having a portion 8 lying between said end plate and the oxide coating 4, and bent in U-shape, and having the other side of the U extending, as indicated at 9, in contact with oxide coating 5 up to adjacent the upper edge 7 of said coating.

The contact element 10*b* for establishing connection between the uncoated portion of the copper plate 3 and the copper oxide coating of the next plate is shown as also comprising a sheet of thin soft metal foil, such as lead foil, also bent in U-shape, with the two arms of the U, indicated at 11 and 12 respectively, connected together by a web portion 13 and spaced apart sufficiently to receive the next rectifying element 1*b* therebetween, as shown in Fig. 3, said contact element also including a portion 14 bent over at one side of the portion 11 and engaging a portion of the exposed surface 6 of the copper plate of the first rectifying element 1*a*. Between the overlapping portions of the metal foil contact strips 9 and 11, there is interposed a sheet of insulating material 16 consisting, for example, of paper or the like of sufficient thickness and dielectric property to serve as an effective insulation against the potential difference between the adjacent rectifying elements. Also, in order to compensate for the absence of the copper oxide coating between the portion 14 of the contact element and the copper plate, suitable filling means is interposed behind said portion. For example, the insulating strip 16 may extend up behind the portion 14, and a filler or strip 18 of suitable material, such as paper or the like, may be placed between said insulating strip and said portion 14, said filler being of substantially the same thickness as the copper oxide coating, so that upon application of pressure to the stack of rectifying elements, said portion 14 will be pressed into tight engagement with the copper plate.

For the purpose of clearly illustrating the principle of this invention, reference may now be had to one of the stacks of rectifying elements shown in Fig. 6. In this figure the layers of insulating and filling material are omitted, in order to show more clearly the relative positions of the copper plates and the metal foil contact elements. Any desired number of rectifying elements, such as indicated at 1*a*, 1*b*—1*x*, may be assembled in the above described manner so as to form a stack of convenient length. The bare surface portion 6 of the last element is in turn connected by a metal foil contact element having a portion 21 in contact with the non-oxidized surface portion 6 of said rectifying element and a portion 22 making contact with the inner face of another end plate 2′. Referring to the uppermost stack of rectifying elements D_1 in Fig. 5, it will be seen that electric current will be permitted to pass therethrough substantially only in the direction indicated by the arrow applied thereto. Such current enters through the end plate 2, passes through the portions 8 and 9 of the first contact element to the copper oxide film indicated at 4 and 5, through said film to the copper plate 3 of the first element, thence through portion 14 of contact element 10*b* to the copper oxide film of the next element 1*b*, and so on through all of the elements of the stack in series. The voltage which may be impressed across such a stack of rectifying elements without causing breakdown of the film of copper oxide at any point is a function of the permissible voltage drop across each film and the number of elements in the stack.

While the construction of my invention is intended particularly for use with relatively small electric current flow, there will nevertheless be a certain amount of heat produced upon passage of current therethrough, and in order to facilitate dissipation of such heat and prevent over-heating of the elements I prefer to provide each of the copper plates with a projection or fin 24 projecting at least one side beyond the cross section of the stack proper, that is, beyond the area covered by adjacent contact elements. In Fig. 5, for the sake of clarity, I have shown these projecting fins 24 as all extending in the same direction from the stack, and it will be understood that it is within the scope of the invention to use such a construction. However, in order to increase the clearance between adjacent projections and thus increase the opportunity for dissipation of heat therefrom, I prefer to mount each copper plate with its projection extending in a different direction from the projection of each adjacent plate. A particularly advantageous construction is the one illustrated in Fig. 4, in which end plate 2 has a projection 25 extending downwardly, while the first rectifying plate 1*a* has its projection (not shown) extending at right angles to the projection 25, that is, either forwardly or rearwardly with respect to the plane of the drawings, the next rectifying plate 1*b* has its projection 24 extending upwardly, the next plate 1*c* again has a projection extending either forwardly or rearwardly and opposite to the projection of plate 1*a* and so on through the series. The other end plate 2′, in turn, has its projection 25′ extending at right angles to that of the last preceding rectifying element. At any one side of the stack, therefore, the successive projections are separated

by a distance equal to four times the interval between adjacent rectifying elements, thus providing ample space for circulation of air or other cooling medium between these projections to effect dissipation of heat therefrom.

In the particular construction shown, this angular displacement of the cooling fins of the successive rectifying elements is brought about by forming each of the contact elements with its bent over portion 14 connected to one of the edges of the portion 11 which is adjacent to the web 13, so that when such contact element is placed in proper relative position with respect to the preceding contact element, such elements are disposed at right angles to one another. Each rectifying element is placed with its extension 24 projecting out through the open side of the U of the corresponding contact element, thus causing the projections of the successive elements to be also disposed at right angles to one another. It will be understood, however, that this construction may be modified without departing from the invention.

All of the rectifying elements and contact elements of each stack may be compressed by any suitable means so as to cause intimate contact therebetween. In Figs. 4 and 5, the compressing means is shown as comprising thrust means such as bars 27 engaging insulating plates 28 which in turn engage the outer faces of the end members 25 and 25′, and bolt 29 and nut 31 serving to draw said thrust members toward one another and exert the desired compression upon the stack, so as to force the soft metal contact elements into intimate contact with the oxidized and non-oxidized surface portions of the copper plates.

In Fig. 4, the contact elements 10*b*, etc. and the insulating means 16 and 18 are also shown in their proper relative position between the rectifying elements, and it will be evident that, upon tightening nut 31, the entire stack may be compressed sufficiently to cause intimate conductive contact between substantially the entire area of the portions 11 and 12 of each contact element and the oxide-coated surfaces 4 and 5 of the corresponding rectifying element, and also between the portion 14 thereof and the non-oxidized surface portion 6 of the next rectifying element.

As shown in Fig. 5, a number of stacks, indicated at D_1, D_2 and D_3 may be mounted between common supporting and compressing means, including compressing bolts 29 at suitable intervals along the row. In this figure I have also shown guide means for maintaining the elements of each stack in proper alignment, such guide means being shown as comprising insulating sleeves 32 surrounding the respective bolts 29 between the bars 27 and engaging in suitably shaped notches 33 in the projections 24 of the adjacent stacks. Furthermore, if desired, additional guide means such as insulating sleeves 34 held in position by bolts 35 may be provided between the stacks, and similarly engaging therewith, where there are no compressing bolts 29.

Electrical connection to the opposite ends of each stack and between the successive stacks when a plurality thereof are to be connected in series may be provided in any suitable manner. In Figs. 4 and 5, for example, the projections 25 and 25′ of the respective end members are shown as provided with connecting lugs or terminal pieces 36 for connection of suitable electrical conductors thereto. In Fig. 5 the stacks D_1 and D_2 are shown as connected in series by means of wire 37 connecting together the terminal pieces 36 at the adjacent ends thereof, it being understood that when connected in this manner the rectifying elements of the respective stacks should be reversed in position so as to permit flow of current in one direction in the stack D_1 and in the reverse direction in the stack D_2, for example as indicated by the arrows applied thereto.

Fig. 6 illustrates an arrangement of four stacks of rectifying elements D_1, D_2, D_3 and D_4 for full wave rectification at moderate voltage. The rectifying elements in stacks D_1 and D_4 are so disposed as to permit passage of current only toward the left, while the rectifying elements in stacks D_2 and D_3 are so disposed as to permit passage of electric current only toward the right, as indicated by the arrows applied to the respective stacks. Two alternating current supply wires are indicated at 41 and 42, one of said wires being connected by wires 43 to the adjacent end members 2′ and 2 of stacks D_1 and D_2 respectively and the other of said wires being connected by wires 44 to the adjacent end members 2 and 2′ of stacks D_3 and D_4 respectively. At the other end, the end plates 2′ of stacks D_2 and D_3 are connected by wires 45 to a common output wire 46, while the end plates 2 of the remaining stacks D_1 and D_4 are connected by wires 47 to the other output wire 48. Upon application of alternating current of suitable voltage to the wires 41 and 42, direct current will be delivered through the wires 46 and 48 to any suitable load which may be connected therebetween, the oppositely disposed stacks of rectifying elements acting in the usual manner of full wave rectifying systems. During one half-wave the current will flow from wire 41 through stack D_2 to wire 46 and back through wire 48 and stack D_4 to the wire 42, and during the next half-wave the current will flow from wire 42 through stack D_3 to wire 46 and back through wire 48 and stack D_1 to wire 41.

A simple means of mounting four stacks of rectifying elements connected for full wave

rectification as above described, is shown in Figs. 7 and 8. In this case the four stacks of rectifying elements are compressed by means of end members 51, each provided with four arms 52 engaging the ends of the respective stacks, and by means of bolt 53 and nut 54 serving to draw said end plates toward one another. Suitable insulating members 55 are mounted between the end plates 2 and 2′ of the respective stacks and the arms of the thrust plates. In this case the end plates 2′ and 2 of stacks D_1 and D_2 are shown as connected together by a web plate 56, preferably formed integrally with said end plates. In a similar manner web plate 57 connects together the end plates 2 and 2′ of stacks D_3 and D_4, while at the other end the end plates 2′ of stacks D_2 and D_3 are connected together by web plate 58 and the end plates 2 of stacks D_1 and D_4 are connected by web plate 59. Suitable means such as binding posts 61 are mounted on the respective connecting members 56, 57, 58 and 59, for connection thereto of electrical input and output conductors corresponding to the wires 41, 42, 46 and 48 respectively of Fig. 6.

In Figs. 9 to 11 inclusive I have illustrated a type of rectifying unit provided with a plurality of stacks of rectifying elements all connected in series, and a simple means of mounting a number of such units for connection of all of the units in series, for the purpose of rectification at relatively high voltages. In this case each unit is shown as comprising three stacks of rectifying elements of the above described construction, indicated at F_1, F_2 and F_3 respectively, said stacks being compressed into tight contact throughout by means of three-armed thrust plates 65, insulated from the ends of the stacks by insulating plates such as above described, and held together by bolt 66 and nut 67 engaging the outer faces of the respective thrust plates. An advantage of this form of the invention is that the three point engagement of the thrust plates with the ends of the group of stacks insures that thrust plates will bear with equal pressure against the ends of all of the stacks, and thus provide tight compression in all of the stacks, due to the ability of said thrust plates to tilt slightly in any direction to compensate for slight differences in the length of the several stacks. Bolt 66 is shown as provided at each end with a threaded extension 68, which may advantageously be of reduced diameter, and upon each of said extensions a metal contact sleeve 69 is secured by means of nut 71, said sleeve being completely insulated from the bolt, as, for example, by means of insulating bushing 72 and insulating washers 73 and 74. Each contact sleeve 69 is shown as provided with a connecting lug 76 projecting outwardly therefrom.

Two of the stacks such as F_1 and F_2 are shown as having their elements so arranged as to provide for flow of current therethrough in the same direction, while the third stack such as Fig. 2 has its elements disposed so as to provide for flow in the reverse direction, as indicated by the arrows in Figs. 9 and 10. The connecting lug 76 at one end is connected by wire 77 to a connecting lug 78 on the adjacent end member of the stack F_1, while the connecting lug 76 at the opposite end is connected by wire 79 to a similar connecting lug on the adjacent end member of stack F_3. The ends of the stacks F_1 and F_3 opposite the ends to which are connected the wires 77 and 79 respectively, are connected to the adjacent ends of the stack F_2 by any suitable means such as small connecting webs, one of which is indicated at 81 in Fig. 11, said connecting webs being preferably formed integrally with the end plates. It may be seen, therefore, that all of the rectifying elements of all of the stacks of each unit are connected in series between the contact sleeves 69 at the opposite ends thereof. For example, from the contact sleeve at the left of unit shown in Fig. 10, the current may flow through wire 77 and stack F_1, thence through the connecting member (not shown) to the stack F_2 and through said last named stack, then through the connecting member 81, to the stack F_3 and through the stack F_3 and wire 79 to the contact sleeve at the other end of the unit.

The rectifying units are shown as mounted on upright supporting strips 83, preferably formed of insulating material. Said units may be mounted on said supporting strips in any suitable manner, for example by means of contact clips 84 in which the contact sleeves of two adjacent rectifying units may be removably inserted. Each of said clips is shown as comprising a flat plate portion 85 mounted upon the strip 83 by means of screws 86 and provided at each end with two resilient arms 87 having suitably curved portions forming a socket in which the contact sleeve 69 is adapted to be inserted by pressing the same inwardly whereupon it will be resiliently held between said arms. This construction provides, therefore, not only for supporting the rectifying units but also electrically connecting adjacent units in series. For example, in Fig. 9 the rectifying units indicated at K are shown as forming part of a horizontal row of units all connected in series, while the units K′ are shown as forming part of another row connected in series. In assembling large numbers of units of this type, alternate rows may advantageously be mounted on opposite sides of the supporting strips 83, as shown in Fig. 11, in order to conserve space by permitting the rows to be spaced as close together vertically as possible. By thus mounting and properly interconnecting a sufficient number of such

rectifying units, rectification of high voltage electricity may be obtained for any desired purpose, for example for the energization of electrical precipitation apparatus or other apparatus where high voltage unidirectional current is required. Advantages of this form of rectifying means when used for such purposes are sturdiness of construction and long life, freedom from moving parts, and elimination of high frequency oscillations such as inevitably occur with the so-called mechanical rectifiers, due to the actual completion and breaking of the electrical circuit between the fixed and moving contact parts of such mechanical rectifiers.

I claim:

1. An electric current rectifying apparatus comprising a longitudinally compressed stack consisting of a plurality of copper plates each having a coating of copper oxide formed over the major portion of both contact faces and also having a non-oxidized contact surface portion of relatively small area, a plurality of metal contact elements corresponding to the respective copper plates and each making contact with substantially the entire surface of the copper oxide coating on both faces of one of said copper plates and having a portion also interposed in the stack and making contact with the non-oxidized surface portion of an adjacent copper plate, insulating and spacing means interposed between adjacent copper plates and contact elements in such manner as to provide a compact stack adapted to transmit pressure throughout its length, and means compressing the entire stack longitudinally so as to hold the contact elements, solely by the pressure thus exerted thereon, in intimate contact with both the copper oxide coatings and the non-oxidized surface portions of the copper plates.

2. An electric current rectifying apparatus as set forth in claim 1, each of said copper plates being provided with a portion projecting from one edge thereof beyond the cross section of the stack to serve as a cooling fin, and the fins on adjacent plates projecting in different directions so as to increase the space therebetween.

3. An electric current rectifying apparatus as set forth in claim 1, said means compressing the stack comprising thrust members engaging the opposite ends of said stack and means extending outside the cross-section of the stack and holding said thrust members toward one another.

4. An electric current rectifying apparatus comprising a plurality of copper plates arranged in a stack and each having a coating of copper oxide formed over substantially the entire area of one contact face thereof and over the major portion of the other contact face thereof, a relatively small surface portion of said other face of each plate being free of copper oxide coating, a plurality of metal contact elements interposed between the respective copper plates and each having a U-shaped portion making contact with substantially the entire copper oxide coating on both contact faces of one of said plates and a portion bent over at one side of said U-shaped portion and making contact with the uncoated surface portion of an adjacent plate, and means comprising the entire stack so as to maintain intimate contact between the said portions of the contact elements and the copper oxide coatings and the uncoated surface portions of the copper plates.

5. An electric current rectifying apparatus comprising a plurality of substantially rectangular copper plates arranged in a stack and each having a coating of copper oxide formed over substantially the entire area of one contact face thereof and over the major portion of the other contact face thereof, said other contact face having a relatively small portion of its surface non-oxidized, a plurality of contact elements interposed between the respective copper plates and each having a U-shaped portion one arm of which makes contact with substantially the entire area of the first-named contact face of one of said plates and the other arm of which makes contact with substantially the entire oxide-coated portion of the other contact face of the same plate, and also having a portion bent over at one edge of the first-named arm of the U-shaped portion and making contact with the non-oxidized surface portion of the next copper plate, and means compressing the entire stack so as to maintain intimate contact between the contact elements and the copper plates.

6. An electric current rectifying apparatus as set forth in claim 5, and comprising in addition insulating members interposed between the overlapping portions of the adjacent contact elements.

7. An electric current rectifying apparatus as set forth in claim 5, and comprising in addition filling means between the non-oxidized surface portion of each copper plate and the next plate, of sufficient thickness to compensate for the absence of the copper oxide coating and maintain tight engagement of said non-oxidized surface with the corresponding contact element under the pressure caused by said compressing means.

8. An electric current rectifying apparatus comprising three stacks of asymmetric solid contact rectifying elements, each of said stacks comprising a plurality of such rectifying elements and a plurality of contact elements connecting said rectifying elements in series for passage of electric current in substantially one direction only through that entire stack, the elements of two of said stacks being disposed so as to permit current flow in a direction reverse to the flow of current in the third stack, common thrust members en-

gaging the opposite ends of all of said stacks and freely movable into tight three-point engagement therewith, compressing means extending outside the cross section of said stacks and holding said thrust members toward one another so as to tightly compress the stacks and maintain tight contact between the rectifying elements and contact elements throughout each stack, means electrically connecting one end of said third stack to the adjacent end of one of said two stacks, and means electrically connecting the other end of said third stack to the adjacent end of the other of said two stacks so as to connect all of said stacks in series with one another.

9. An electric current rectifying apparatus comprising a plurality of rectifying units, each of said units comprising three stacks extending side by side and each stack comprising a plurality of asymmetric solid contact rectifying elements and a plurality of contact elements connecting said rectifying elements in series for passage of electric current in substantially one direction only through the entire stack, each of said rectifying units further comprising means electrically connecting all of the stacks of rectifying elements of said units in series, common thrust members engaging the opposite ends of all the stacks of said units, compressing means extending outside the cross section of said stacks and holding said thrust members toward one another so as to tightly compress the stacks and maintain tight electrical contact between the rectifying elements and contact elements of each stack, contact members at the opposite ends of said unit and means electrically connecting the respective contact members to the opposite ends of the series of stacks of said unit, and said apparatus further comprising supporting means, and connecting clips mounted on said supporting means and provided with means for removably receiving the contact members of two adjacent rectifying units, said rectifying units being mounted with the adjacent connecting members of adjacent units removably inserted in the respective connecting clips, whereby said clips serve both to support said units and to electrically connect all of said units together in series.

In testimony whereof I have hereunto subscribed my name this 2nd day of January, 1930.

MARCEL A. LISSMAN.