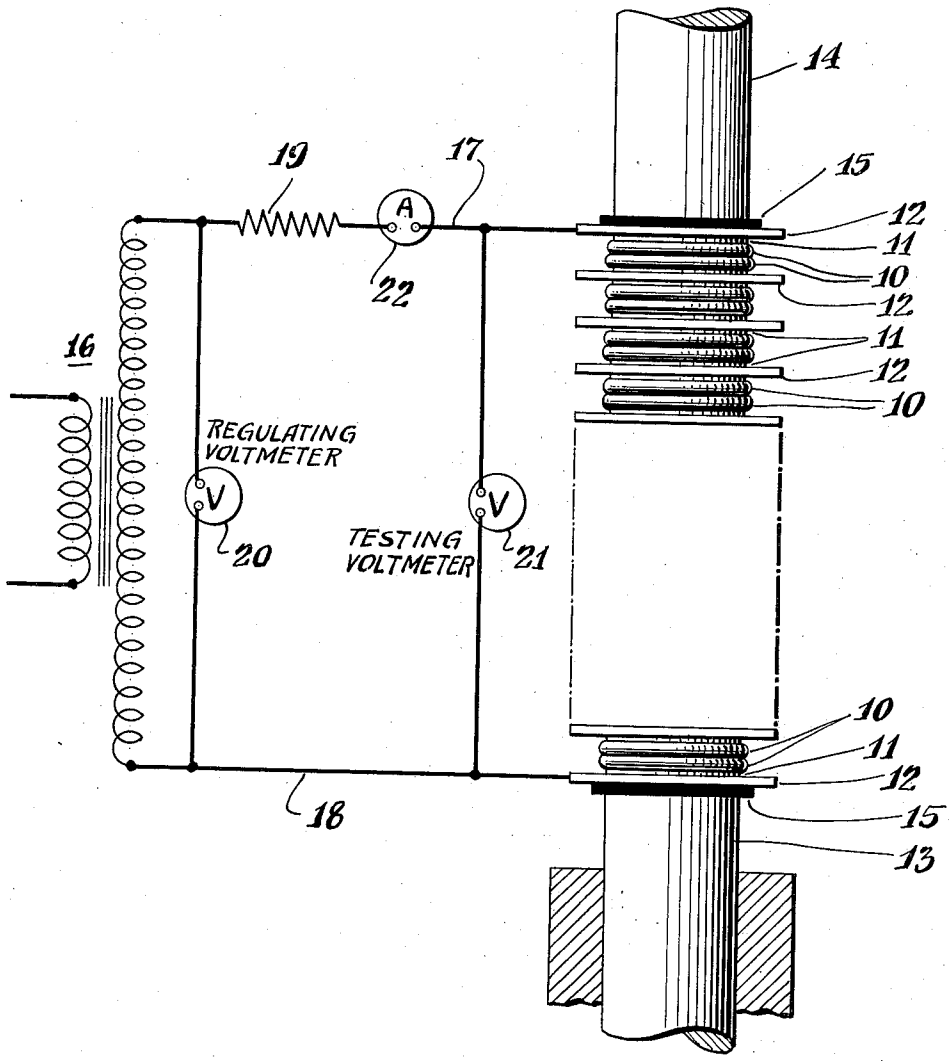
May 1, 1945. F. D. WILLIAMS, JR 2,375,181

RECTIFIER FORMING

Filed March 25, 1941



INVENTOR

Fred D. Williams, Jr.

BY

ATTORNEY

Patented May 1, 1945

2,375,181

UNITED STATES PATENT OFFICE

2,375,181

RECTIFIER FORMING

Fred D. Williams, Jr., New Rochelle, N. Y., assignor to Samuel Ruben, New Rochelle, N. Y.

Application March 25, 1941, Serial No. 385,100

10 Claims. (Cl. 175—366)

This invention relates to dry disc rectifiers and the method of making the same.

An object of the invention is to improve such rectifiers and the methods of making the same.

Other objects of the invention will be apparent from the following description and accompanying drawing taken in connection with the appended claims.

The invention comprises the features of construction, combination of elements, arrangement of parts, and methods of manufacture and operation referred to above or which will be brought out and exemplified in the disclosure hereinafter set forth, including the illustrations in the drawing.

In the drawing:

The figure of the drawing is a diagrammatic illustration of the preferred method of forming rectifier junctions.

This invention has its principal application in the manufacture of rectifiers comprising discs or washers formed of copper compounds, such as cupric sulphide, and contacting layers of a film forming electro-positive metal such as magnesium, reacted at their common contacting faces to comprise a rectifying junction. In place of copper sulphide, other compounds of elements of the sulphur group such as the selenides of copper may be used and in place of the metal layer compounds or alloys of the film forming electro-positive metals may be used, for instance, magnesium silicide. Rectifiers of the type contemplated are shown and described in Ruben Patent #2,198,843 and co-pending Ruben application Serial No. 385,055, filed concurrently herewith.

In the manufacture of such rectifying junctions, for instance a cupric sulphide-magnesium junction, the sulphide disc is ground or otherwise prepared with a plane surface after which it is placed in contact with the magnesium disc which may have been previously coated or filmed with a thin layer of oxide or other magnesium compound. The contacting discs are subjected to an electric potential across the contact junction to produce a controlled reaction at the interface and consequent formation of a rectifying film or layer between the discs. This step is called "forming" or "preforming" of the rectifier.

Heretofore, the pressure applied to the discs during the forming process has commonly been obtained by the use of a bolt and tightening nut passing through the discs or washers. The pressure attained in such cases has been generally limited to 3,000 pounds per square inch or less.

I have discovered that rectifying junctions of increased current capacity, improved stability, higher efficiency, longer life and greater moisture resistance are obtained by forming rectifying junctions under controlled pressure conditions substantially higher than those heretofore used. This is apparently due in part to the exclusion of oxygen from the junction and retention of sulphur in the junction during the forming process and probably also to a resulting higher density of the junction layer obtained with higher pressures. Another factor contributing to the advantages of the process is found in the more intimate contact secured by cold flow of the magnesium under the combined influence of the pressure applied to the assembly and that generated at the point of reaction.

Some advantage is apparent with pressures above 5,000 pounds per square inch but the advantage becomes much greater at pressures of 10,000 pounds per square inch and higher, I contemplate, therefore, that the permissible range of pressures coming within the purview of my invention may extend from 5,000 pounds per square inch to 30,000 pounds per square inch while the preferred range of pressures is between 10,000 and 20,000 pounds per square inch.

Referring to the drawing which illustrates a preferred arrangement for preforming the junctions, cupric sulphide discs 10 are assembled in contact with thin filmed magnesium discs 11 between heat radiator plates 12. The assemblies are preferably arranged as follows: first a heat radiator plate 12, then a filmed magnesium disc 11, then a pair of cupric sulphide discs 10 back to back, then another filmed magnesium disc 11, then another radiator plate 12 after which the cycle is repeated until a stack of sufficient height is produced.

The assembled stack is placed between the moveable plunger 13 of an hydraulic ram and the pressure support 14 of said ram, with a pair of insulating discs 15 between the ram parts and the stack to insulate the stack therefrom.

The power for forming the junctions is supplied from a transformer 16 the two ends of the secondary of which are connected by conductors 17 and 18 respectively to the two end radiator plates 12 of the stack. A series resistance 19 is included in conductor 17 to regulate the current.

Pressure is applied to the stack by the hydraulic ram until the junction pressure between the discs is within the range of values mentioned above (i. e. 5,000 to 30,000 p. s. i. or preferably 10,000 to 20,000 p. s. i.) and the forming current is applied and maintained until meters in the

circuit indicate that the junctions are completely formed.

After the junctions have been completely formed, it will be found that the magnesium discs adhere strongly to the cupric sulphide discs thereby forming an integral junction unit. This adherence is obtained by controlling the reaction to produce an effect similar to welding at the interface. High pressures of the order mentioned are very helpful in maintaining the uniformity and increasing the density of this reaction layer. After removal from the preforming assembly the individual junction units may be tested and reassembled to make any one of various types of rectifiers by assembling with interposed non-polarizing discs and radiator plates to form full wave, half wave or three phase rectifiers as desired. Any number of units may be placed in series or parallel to make rectifiers of the desired voltage and current capacity. The completed rectifiers may be held together by a bolt passing through concentric apertures in the disc assembly and a nut may be tightened upon the bolt against a spring washer to apply pressure to the assembly, as shown, for example, in the above mentioned Ruben patent.

The advantages of my invention are chiefly realized in the forming process and the preferred range of pressures need not be maintained in the finished rectifier assembly. Some advantage in respect to lower inverse current and higher surge rating may be realized by operation at pressures less than that maintained during forming. According to another aspect of my invention, therefor, it is contemplated that the pressure applied to rectifiers during operation shall be lower than the pressure used during the preforming operation, and may be of a value of 3,000 pounds per square inch, for example, or even somewhat less.

In initial comparison tests between rectifiers made from junctions formed at 10,500 pounds per square inch, 5,250 pounds per square inch and by the conventional method of the prior art which amounts to about 3,000 pounds per square inch, it was found that in testing the rectifiers at 135% of full load without sealing or ageing those formed at 10,500 pounds per square inch showed no sparking during operation while those formed at 5,250 pounds per square inch showed a slight sparking under similar conditions and those formed by methods of the prior art showed noticeable sparking together with instability of operation. This demonstrates that the current limit has been appreciably raised by forming under high pressures. After several days of shelf life without sealing, the inverse current at 6 volts D. C. was found to amount to over 5 amperes with rectifiers formed by prior art methods while it amounted to only about 2 amperes with rectifiers formed at 5,250 and 10,500 pounds per square inch. From this result it will be apparent that the rectifiers formed by conventional methods were more subject to moisture effects than those formed under higher pressures and would probably be less satisfactory after long periods of shelf life.

After 35 days of shelf life without sealing the rectifiers formed by prior art methods showed still higher inverse current and at that time the rectifiers formed at 5,250 pounds per square inch had also developed an inverse current of higher than 5 amperes while those formed at 10,500 pounds per square inch remained with a comparatively low inverse current of 2 to 3 amperes. This indicates that while some benefit may be obtained at 5,000 pounds per square inch, the best results will be obtained at 10,000 pounds per square inch or more. It will be appreciated that in these tests the rectifiers had been stored without sealing whereas in actual practice the rectifiers are sealed promptly after forming. Hence, the above tests are, in effect, accelerated ageing tests for the elements, which are extremely susceptible to moisture effects. It is also found that the rectifiers formed at the higher pressures exhibited an increase in efficiency. This increase is more noticeable on 3 phase circuits due to the better form factor.

While a preferred pre-forming arrangement is illustrated in the drawing, it is contemplated that in some cases other arrangements may be used such as a half-wave forming arrangement wherein all of the rectifying junctions are placed in similar orientation so as to effect a half-wave rectification of the A. C. forming current or a similar half-wave assembly in conjunction with a D. C. supply and suitable means for impressing this D. C. in the form of unidirectional impulses.

While preferred practice consists of using magnesium with an insulating or semi-insulating film it is to be recognized that under certain forming conditions a satisfactory rectifying junction may be made without the aid of this film.

While the present invention, as to its objects and advantages, has been described herein as carried out in specific embodiments thereof, it is not desired to be limited thereby but it is intended to cover the invention broadly within the spirit and scope of the appended claims.

What is claimed is:

1. The method of producing a rectifier which comprises forming a rectifying junction of high moisture resistance and electrical efficiency between a dense solid electrode composed of a compound of copper with an element selected from the group consisting of sulphur and selenium and a filmed electro-positive metal electrode, which comprises placing said electrodes in contact and applying a pressure of 5,000 to 30,000 pounds per square inch to the junction and applying an electric forming potential across said junction while maintaining said pressure to produce a reaction resulting in a rectifying layer at said junction, and continuing said forming at said pressure until substantially the entire junction area is so formed, then relieving said pressure and assembling said electrodes and associated junction together with terminal and clamping means for operation as a rectifier, said clamping means applying a pressure to said junction substantially less than the pressure applied during the forming operation.

2. The method of producing a rectifier which comprises forming a rectifying junction of high moisture resistance and electrical efficiency between a dense solid cupric sulphide electrode and an electrode of filmed magnesium metal, which comprises placing said electrodes in contact and applying a pressure of 5,000 to 30,000 pounds per square inch of contact area thereto, applying an electric forming potential across the junction to produce a reaction resulting in a rectifying layer at said junction and continuing said forming at said pressure until substantially the entire junction area is so formed, then relieving said pressure and assembling said electrodes and associated junction together with terminal and clamping means for operation as a rectifier, said clamping means applying a pressure to said junction

substantially less than the pressure applied during the forming operation.

3. The method of producing a rectifier which comprises forming a rectifying junction of high moisture resistance and electrical efficiency between a dense solid cupric sulphide electrode and an electrode of magnesium filmed with an oxide film, which comprises placing said electrodes in contact and applying a pressure of 10,000 to 20,000 pounds per square inch of contact area thereto, applying an electric forming potential across the junction to produce a reaction resulting in a rectifying layer at said junction and continuing said forming at said pressure until substantially the entire junction is so formed, then relieving said pressure and assembling said electrodes and associated junction together with terminal and clamping means for operation as a rectifier, said clamping means applying a pressure to said junction substantially less then the pressure applied during the forming operation.

4. The method of forming a rectifying punction of high moisture resistance and electrical efficiency between a dense solid non-porous cupric sulphide electrode and a thin filmed magnesium electrode which comprises placing said electrodes in contact, placing a hard backing behind said magnesium electrode and applying a pressure to the assembly and applying an electric forming potential across said junction to produce a reaction resulting in a rectifying layer at said junction and continuing said forming until substantially the entire junction area is so formed, said pressure being maintained sufficient to produce cold flow of said magnesium under the effect of the forming reaction during said forming.

5. The method of forming a rectifying junction of high moisture resistance and electrical efficiency between a dense solid non-porous cupric sulphide electrode and a thin electrode of magnesium filmed with an oxide film, which comprises placing said electrodes in contact and placing a hard backing behind said thin magnesium electrode and applying pressure to the assembly, applying an electric forming potential across the junction to produce a reaction resulting in a rectifying layer at said junction and continuing said forming until substantially the entire junction is so formed, said pressure being maintained sufficient to produce cold flow of said magnesium under the effect of the forming reaction during said forming.

6. The method of producing a rectifier which comprises forming a junction of higher moisture resistance and electrical efficiency between a dense solid electrode composed of a compound of copper with an element selected from the group consisting of sulphur and selenium and an electrode of a filmed electropositive metal by placing said electrodes together in contact and applying pressure thereto in a hydraulic press, and applying an electric forming potential across the junction to produce a reaction resulting in a rectifying layer at said junction, and subsequently removing the electrode-junction unit produced from said hydraulic press and assembling said unit together with terminal means under pressure of a clamping bolt and nut.

7. The method of producing rectifiers which comprises forming junctions of higher moisture resistance and electrical efficiency between dense solid electrodes composed of a compound of copper with an element selected from the group consisting of sulphur and selenium and filmed electropositive metal electrodes by producing a multiplicity of unit assemblies of copper compound electrodes in contact with electropositive metal electrodes, forming a stack of said assemblies and applying pressure to said stack in a hydraulic press, and applying an electric forming potential through said stack to produce a reaction resulting in rectifying layers at said junctions, and then removing said unit assemblies from said press and reassembling them with auxiliary parts to produce a rectifier.

8. The method of forming a rectifying junction of high moisture resistance and electrical efficiency between a dense solid electrode composed of a compound of copper with an element selected from the group consisting of sulphur and selenium and an electrode of filmed electro-positive metal, which comprises placing said electrodes in contact and applying a pressure of 10,000 to 20,000 pounds per square inch of contact area thereto, applying an electric forming potential across the junction to produce a reaction resulting in a rectifying layer at said junction and continuing said forming at said pressure until substantially the entire junction area is so formed, then relieving said pressure and assembling said electrodes and associated junction together with terminal and clamping means for operation as a rectifier, said clamping means applying a pressure to said junction substantially less than the pressure applied during the forming operation.

9. The method of producing a rectifier which comprises forming a rectifying junction of high moisture resistance and electrical efficiency between a dense solid cupric sulphide electrode and an electrode of filmed magnesium which comprises placing said electrodes in contact and applying a pressure of 10,000 to 20,000 pounds per square inch of contact area thereto, applying an electric forming potential across the junction to produce a reaction resulting in a rectifying layer at said junction and continuing said forming at said pressure until substantially the entire junction is so formed, then relieving said pressure and assembling said electrodes and associated junction together with terminal and clamping means for operation as a rectifier, said clamping means applying a pressure to said junction substantially less than the pressure applied during the forming operation.

10. The method of forming a rectifying junction of high moisture resistance and electrical efficiency between a dense, solid, non-porous electrode composed of a compound of copper with an element selected from the group consisting of sulphur and selenium and a thin electrode of filmed readily deformable electro-positive metal which comprises placing said electrodes in contact and placing a harder backing behind said thin electro-positive metal electrode and applying a pressure to the assembly and applying an electric forming potential across said junction to produce a reaction resulting in a rectifying layer at said junction, and continuing said forming until substantially the entire junction area is so formed, said pressure being maintained sufficient to produce cold flow of said electro-positive metal under the effect of the forming reaction during said forming.

FRED D. WILLIAMS, JR.