# United States Patent [19]

**Hofer**

[11] **3,911,567**

[45] **Oct. 14, 1975**


[54] **METHOD OF MANUFACTURING AN ELECTRIC CONDUCTOR OF METAL STRIPS**


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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** ................ **29/628;** 29/470.1; 29/470.5; 29/472.3; 29/624; 174/99 E; 339/275 E

[51] **Int. Cl.**$^2$........................................ **H01R 43/00**

[58] **Field of Search** .... 29/470.1, 624, 470.5, 472.3, 29/628; 174/68 B, 71 B, 99 E, 86 R; 238/14.1, 14.11; 339/276 E, 276 RB, 275 E, 275 RB



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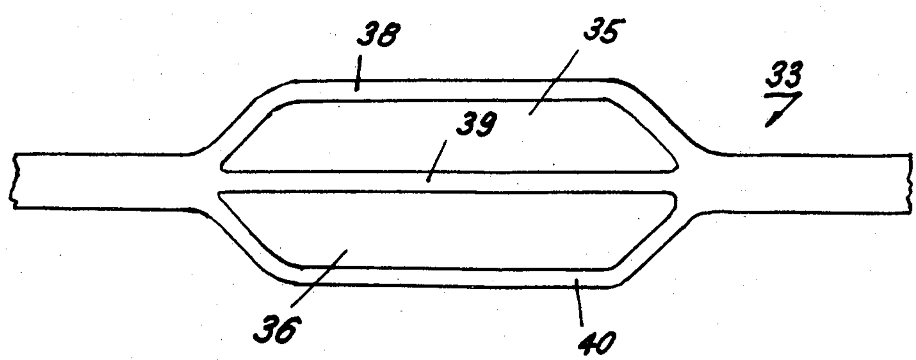
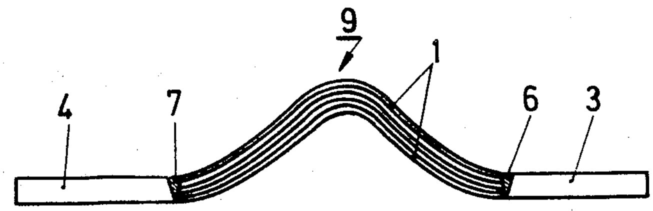
[57] **ABSTRACT**

Electric conductor formed of a plurality of metal strips or bars, with end portions of the strips being explosion welded together; means to maintain the spacing of the strips prior to welding; method for producing such conductors.

**20 Claims, 6 Drawing Figures**




PRIOR ART

FIG. 1

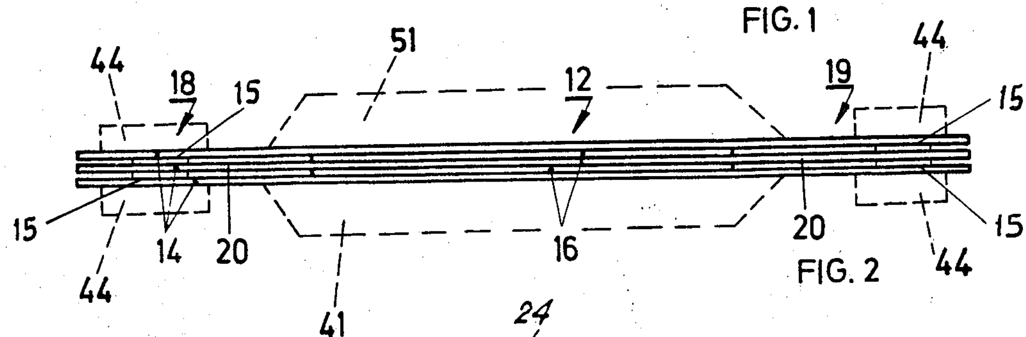



FIG. 2

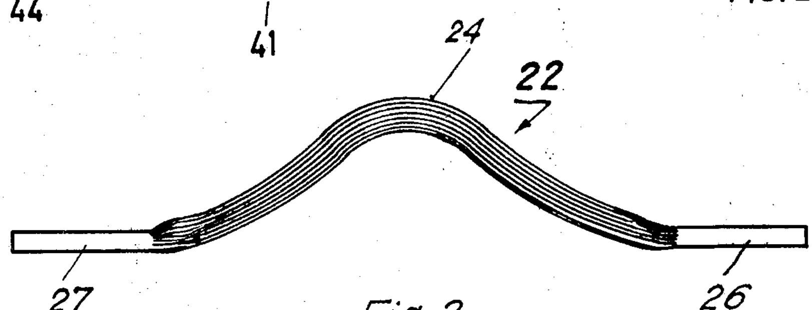



Fig. 3

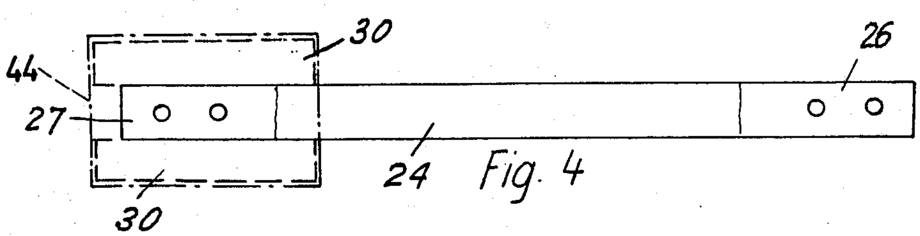



Fig. 4

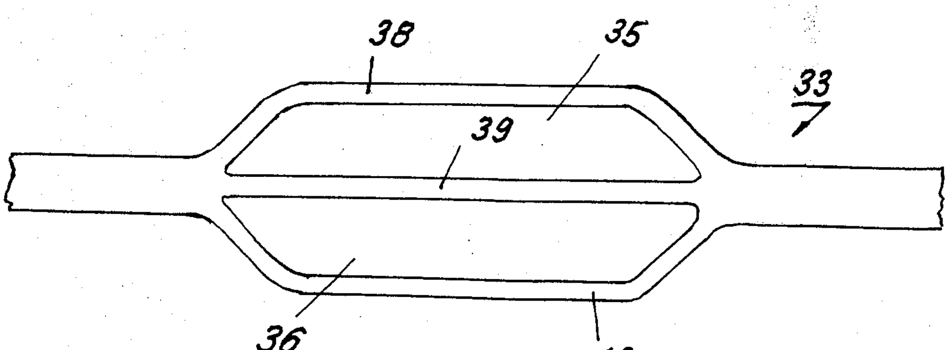



Fig. 5

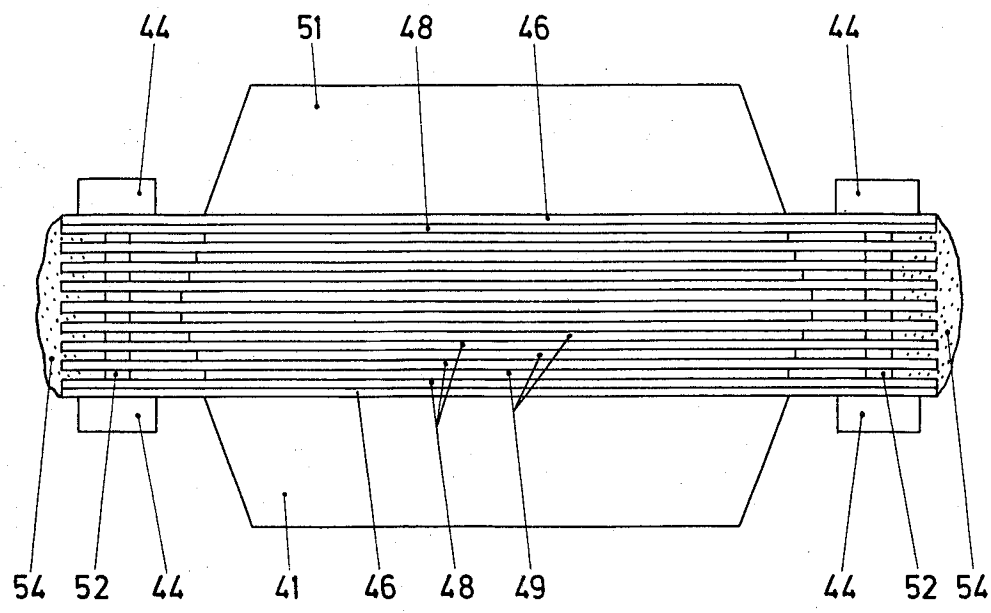



FIG. 6

# METHOD OF MANUFACTURING AN ELECTRIC CONDUCTOR OF METAL STRIPS

## BACKGROUND OF THE INVENTION

The present invention relates to an electric conductor comprised of metal sheets or bars, and particularly relates to such a conductor used for a thermal-expansion compensator or for a cooled bus bar. The invention also relates to a method of manufacturing such a conductor.

In one application for the invention, in order to compensate for the thermal expansion of a rigid electric conductor, such as a bus bar or pipe cable, a longitudinally self adjustable intermediate member must be installed. This is comprised, for instance, of a flexible cable or of a package of bent metal sheets.

In another use or a supplemental use for the invention, to provide for the cooling of a multilayer or multistrip electric conductor, the strips lying on the outside of a bundle of strips are bent laterally outwardly to create air-passage ducts between the outside and inside strips and the strips are welded together where they meet.

In a conductor comprised of a package of sheet-metal strips, aluminum or copper sheets of **0.3** – 1.5 mm. in thickness and about **40–150** mm. in width are used. The sheets are connected, usually by welding, at both ends to solid metal plates that are of the same width as the sheets and are of the same material. Such welding is very difficult, particularly in the case of aluminum, and in some cases can be effected only in the presence of an inert gas. However, even with proper welding, breaks in the sheets at the junction points frequently occur in operation.

Another known method for connection of the metal sheets to each other is based on the use of continuous metal sheets which are connected together at their end portions by means of rivets. This method has the disadvantage that the rivet connection between the individual sheets may fail to give a dependable electrical connection because of oxidation.

Similar problems arise in the production of flat conductors or bus bars which are subdivided for cooling.

## BRIEF DESCRIPTION OF THE INVENTION

The present invention avoids the above discussed disadvantages by creating a longitudinally expansible conductor formed from a plurality of metal sheets or bars that are joined at at least two locations by explosion welding.

It is the primary object of the present invention to provide a plural conductive strip electric conductor.

It is another object of the invention to provide such a conductor adaptable for thermal or the like ambient condition compensation.

It is another object of the invention to provide a method for producing such a conductor.

It is a further object of the invention to provide such a method incorporating an expansion welding technique.

The invention is now described by reference to the accompanying drawings, in which:

FIG. **1** is a schematic side view of a thermal compensator having a bundle of sheet-metal strips and plates welded to its two ends in accordance with the prior art;



FIG. **2** is a schematic side view of a bundle of sheet-metal strips with interspersed spacer inserts before explosion welding in accordance with the invention;

FIG. **3** is a schematic side view of a sheet-metal strip bundle with explosion-welded ends, in the form of a thermal-expansion compensator;

FIG. **4** is a schematic top view of the bundle of sheet metal strips shown in FIG. **3**;

FIG. **5** is a schematic side view of a bus bar in which cooling ducts have been produced and which was formed by the method of the invention; and

FIG. **6** is a schematic side view of an arrangement of metal sheets which are to be connected together by explosion welding and which are located in a pressing tool.

## DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** shows a thermal compensator for a conductor, as known in the prior art. This compensator is comprised of a bundle of sheet-metal strips **1.** At the ends of the bundle, plates **3** and **4** are welded at weld seams **6** and **7.** The bundle of sheet-metal strips **1** have compensation fold **9** in the region of their center in order to permit thermal expansion.

Thermal-expansion compensators or subdivided bus bars made from bundles of sheet-metal strips use aluminum, copper or some other relatively inexpensive metal which is a good electric conductor. The thickness of the metal sheets for compensators is preferably **0.3** to **1.5** mm. and for subdivided bus bars, cooling bodies, and the like, the thickness is preferably **1** to **10** mm. For a finished compensator, the sheet width is normally within the range of **40** to **150** mm., or more, and the sheet length varies within the range of **100** to **700** mm. or even longer for subdivided bus bars. The sheets for the compensators are normally cut from larger, flat sheet-metal panels of a length, for instance, of **2** m. and of a width for instance, of **50** cm.

The method for producing a thermal compensator according to the invention is now described.

In FIG. **2,** sheet metal strips **14,** also referred to as conductive sheets, are stacked in a bundle **12.** This is advantageously effected in an apparatus which is provided with stops.

Between neighboring strips **14** there is inserted a shorter length and width intermediate layer or spacer sheet **16** made, for instance, of steel or plastic. Spacers **16** do not extend out to the ends of strips **14** but are arranged in the central region of the strips. Thus, strips **14** extend beyond the spacers **16** at both ends.

In order to assure a gradual local transition from the tool body to the strips, the spacers are of unequal length and their lengths increase toward one side of the bundle or, for a symmetrical development, they increase from the top and bottom of the bundle toward the center. Conductive sheets **14** should extend parallel to each other at their free ends, or at least they should not contact each other over their entire free or unsupported portions. It is necessary to have uniform spacing of the sheet-metal strips **14** upon the subsequent explosion welding. To assure this spacing, the ends of the strips are separated by spacers **15,** a plurality of which together form a comb. A comb may be made of steel so that it might be reused, or it may be made of inexpensive and disposable material, for instance plastic.

With metal spacers, there is the danger of shearing of the separated strips, particularly the outermost sheet metal strips, at the ends of the spacers. This can be avoided by producing a damping by means of plastic or rubber bars serving as the spacers.

Bundle **12** of metal strips, which has been prepared in the above manner, is introduced into a suitable pressing tool, for instance, the bipartite tool, **41, 51** indicated in dashed lines. Herein, a compensation fold, like the fold shown in FIG. **3,** is produced and maintained.

To assure a smooth transition between the strips where they are combined to form a substantially homogeneous explosion welded body and the individual strips extending out of the body, more resilient intermediate inserts, made for instance of plastic, rubber or the like, are inserted between the strips in the region of points **20.**

In a third operation, the ends of the bundle of sheet-metal strips are converted by explosion welding by explosive charges **44,** indicated in dashed line in FIG. **2,** into compact plates, **26, 27** as shown in FIG. **3.** Compensator **22** of FIG. **3** is formed of sheet-metal strips **24.** The ends of the strips are welded together by explosion welding to form plates **26** and **27.** The explosion welding can be effected at each end of a compensator individually, or by the application and detonation of an explosive charge **44** on only one side of strips **24,** or by explosion on both sides of the bundle of strips **24.**

Although formation of a compensation fold prior to welding has been disclosed, it is also possible to first explosion weld the bundle of sheet-metal strips **12** and to then force out a compensation fold in the central region of the bundle after the explosion.

It should be emphasized that detonation of all of the explosive charges **44,** which may be two or four in number, must occur simultaneously. Detonation can be effected via a fuse leading to detonator caps. The corresponding pressing tool, which holds the strips prior to welding, protects them from damage in the explosion. However, if the bundle of sheet metal strips does not have a compensation fold at the time of the explosion, such protection by a pressing tool is not always necessary.

In a subsequent operation, spacers **16,** which have been inserted between the individual sheet-metal strips, are removed. The compensator is then squeezed in a press to even out the welded together parts. At the same time, corresponding undesirable edge parts can be cut off and/or fastening holes or the like can be produced in the strips (FIG. **4**). For the pressing of larger pieces, the press jaws preferably have fine transverse grooves. The grooves emboss the surfaces of the explosion welded body and assure good transmission of current after mounting.

Next, the compensator is bulged outwardly or is compressed in its longitudinal direction to obtain the desired length, for instance, a particular length at a predetermined temperature. During explosion-welding, to prevent the assembled strip ends from arching because the pressure produced by the explosion encounters less resistance at the peripheral edge lateral walls than in the centers of the strips, edge bodies **30** of metal or plastic and having a rectangular profile are pushed against the side edge surfaces of the sheet metal strips in the bundle, as shown in dashed line in FIG. **4.** The edge bodies must be of approximately the same thickness as the bundle of sheet-metal strips after the explosion welding. The edge bodies are thrown off by the welding explosion.

When welding is caused by detonation of only one explosive charge above one surface of an end of the sheet metal bundle, rather than by two charges above both of two opposite surfaces of the bundle as shown in FIG. **2,** there is a danger that the unexploded side will weld to the tool at individual points. One remedy is to coat the tool at the endangered places with a separating layer, like an oil, for instance a silicone oil. Another remedy is to place a separating layer of plastic, rubber or paper between the tool and the lowermost metal strip. In similar manner, a separating layer, such as a sheet of metal, plastic or rubber should be inserted between the uppermost strip and the explosive. Otherwise, an unattractive surface will be obtained, particularly with aluminum strips.

FIG. **5** shows a cooled tripartite or three layer conductor bar **33** having two cooling ducts **35** and **36** between the individual layers **38, 39** and **40** of bar **33.** The individual layers are connected on both sides of the cooling ducts **35** and **36** by explosion welding, according to the process described above.

FIG. **6** shows means for forming a plurality of stacked metal panels into a plurality of compensators. The bottom of a pressing tool is shown. It is developed from a solid steel piece. Its length and width correspond to the length and width of the sheet metal panels to be welded together, for instance **500** × 200 mm². On element **41** is placed plastic plate **46,** which protrudes beyond both sides of the pressing tool. On the bottom side of the tool along both sides of bottom part **41** are arranged explosive charges **44.** These extend over the entire length of plastic plate **46,** for instance, **2** m.

On plastic plate **46** lies a first sheet metal panel **48,** made, for instance, of aluminum, which protrudes on both sides beyond pressing tool part **41** by the same distance as plastic plate **46.** Metal panel **48** is followed by plastic plate spacer **49** corresponding in width to tool part **41.** On plate **49** rests another aluminum panel **48** of the same width as the first. In this way, up to **50** sheet-metal panels are stacked alternatingly with plastic plates **49.** The uppermost sheet metal panel **48** is followed by a plastic plate **46,** corresponding to lowermost plate **46.** Above upper plate **46** are two explosive charges **44** similar to the two bottom explosive charges **44.** As a termination, a top tool part **51** made from steel is applied. Bottom part **41** and top part **51,** which together form the tool, are forced together, by means of tie rods (not shown) located, for instance, at the four corners of the bottom and top parts **41, 51.**

In order to maintain the continuous spacing between the individual sheet-metal panels **48,** even in their outermost marginal regions, it is advantageous to insert spacer pieces or sheets **52,** formed, for example, of pieces of spring steel between panels **48.** These inserts extend along the entire length of panels **48** and are located along approximately the central longitudinal axes of the upper and lower explosive charges **44.** Sheet-metal spacer sheets **52** are replaced just before the detonation of charges **44** by a quick-setting frangible composition, for instance plaster of paris, which is applied between the sheet-metal panels to form fastening bridge **54.** After the application of fastening bridge **54,** sheet metal spacer sheets **52** are removed. Then the charges **44** are detonated. Welding of the aluminum sheets **48** occurs in the region between the opposing upper and lower explosive charges **44**. The plaster bridge flies off upon the explosion.

The tie rods of the pressing tool **41, 51** are now loosened, and the unitary block comprised of aluminum sheets **48** and plastic spacer plates **49**, is lifted out of pressing tool **41, 51**. The block is then divided into a plurality of thin, strip like arrangements by means of a plurality of circular or band saws moving through one pass. The saws are spaced a distance corresponding to the desired width for the compensators. In this way, for instance, **20** to **40** finished compensators of a width of **100** mm. to **50** mm. are obtained.

Depending on the desired shape for each compensator, the compensation fold is now shaped or pressed in a bipartite pressing tool. At the same time, the two welded ends are provided correspondingly with transverse grooves in order to make the contact surfaces more adherent. In addition to forming the grooves, it is also possible during the pressing to punch corresponding openings or holes in the ends of the compensator.

As the final operation, plastic spacer plates **49** are removed through the open side edges of the completed compensator.

The method which has been described in connection with FIG. **6** for the production of compensators is simple and economical, because very little sheet-metal waste is produced, and the construction of the welding device becomes extremely simple. Due to the relatively large starting dimensions, the handling is also much less time-consuming, since in a short time, a large number of such compensators can be produced by means of one explosion. Due to the possibility of welding such large sheets together, intermediate storing of the explosion-welded but as yet uncut panels is possible. The panels can later be cut as required into compensators of desired width.

Although the present invention has been described in connection with a number of embodiments thereof, many variations and modifications will now become apparent to those skilled in the art. It is preferred, therefore, that the present invention be limited not by the specific disclosure herein, but only by the appended claims.

I claim:

**1.** Method for producing an electric conductor, comprising:

providing a plurality of conductive metal strips;

disposing the strips one above the other to form a multilayer bundle;

placing an explosive charge at two spaced locations on the bundle of strips between the ends of the strips;

inserting spacers between the strips under the locations of the charges to maintain spacing of the strips; after the spacers are inserted under the locations of the charges, placing a spacing bridge at the ends of the strips to hold them separated at the locations and them removing the previously inserted spacers that had been inserted between the strips under the locations;

detonating the charges, exploding out the spacing bridge upon the detonation and explosion welding the strips in the bundle at the locations, thereby forming the strips into a solid plate where the detonated charges were located.

**2.** The method for producing an electric conductor of claim **1**, wherein the spacing bridge is formed of a quick setting, frangible composition.

**3.** The method for producing an electric conductor of claim **1**, wherein the explosive charges are placed at each end of the bundle of strips.

**4.** The method for producing an electric conductor of claim **1**, further comprising pressing against the top and bottom of the bundle of strips, thereby squeezing them together and defining transverse grooves in the strip bundle top and bottom by the pressing.

**5.** The method for producing an electric conductor of claim **1**, wherein the spacers are comprised of one of the group of materials consisting of metal sheets and plastic sheets.

**6.** The method for producing an electric conductor of claim **1**, further comprising subsequent to the detonating, dividing the welded strip bundle across both locations and forming a plurality of separated, welded conductors.

**7.** The method for producing an electric conductor of claim **6**, wherein the dividing comprises a plurality of sawing operations simultaneously performed on the bundle.

**8.** The method for producing an electric conductor of claim **1**, wherein each explosive charge is placed on at least one of the sides of the bundle at one of the respective locations therefor; and the explosive charges being all detonated simultaneously.

**9.** The method for producing an electric conductor of claim **8**, wherein there is an explosive charge on only one side of the bundle at each respective location therefor; providing a mold resting surface against which a first surface on one side of the bundle of strips is rested, and placing the explosive charge against a second surface on the opposite side of the bundle of strips.

**10.** The method for producing an electric conductor of claim **9**, further comprising interposing a separating layer between the first surface of the bundle and the mold resting surface to prevent attachment of the bundle to the mold resting surface upon the detonation.

**11.** The method for producing an electric conductor of claim **9**, further comprising interposing a protective separating layer between the second surface of the bundle and the explosive charge.

**12.** The method for producing an electric conductor of claim **8**, wherein an explosive charge is placed on both opposite sides of the bundle at each location.

**13.** The method for producing an electric conductor of claim **1**, further comprising bending the bundle of strips between the locations to define an expansion-contraction compensation fold.

**14.** The method for producing an electric conductor of claim **13**, wherein the bending of the bundle comprises forming a bulge between the locations.

**15.** The method for producing an electric conductor of claim **13**, wherein the bending of the bundle is performed by pressing the bundle to form a fold therealong.

**16.** The method for producing an electric conductor of claim **13**, wherein the bending is performed after the detonation.

**17.** The method for producing an electric conductor of claim **16**, further comprising subsequent to the detonating, dividing the welded strip bundle across both locations and forming a plurality of separated, welded conductors.

**18.** The method for producing an electric conductor of claim **13,** wherein the bending is performed before the detonation.

**19.** The method for producing an electric conductor of claim **1,** wherein before detonation, spacers are in-



serted between the neighboring metal strips in the central region of the bundle between the locations.

**20.** The method for producing an electric conductor of claim **19,** further comprising bending the bundle of strips between the locations to define an expansion-contraction compensation fold.

* * * * *

UNITED STATES PATENT OFFICE

# CERTIFICATE OF CORRECTION

Patent No. 3,911,567 Dated October 14, 1975

Inventor(s) Peter Hofer

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Cover Page, Column 1, at [30],

change "Sweden" to --Switzerland-- in both instances.

**Signed and Sealed this**

*second* **Day of** *March 1976*

[SEAL]

*Attest:*

**RUTH C. MASON**
*Attesting Officer*

**C. MARSHALL DANN**
*Commissioner of Patents and Trademarks*

UNITED STATES PATENT OFFICE

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[SEAL]

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**C. MARSHALL DANN**
*Commissioner of Patents and Trademarks*