Jan. 29, 1963 C. F. MANNING ETAL 3,075,893

ALUMINUM STRIP ELECTROMAGNETIC WINDINGS AND METHOD

Original Filed Feb. 9, 1955 3 Sheets-Sheet 1

Fig. 1.

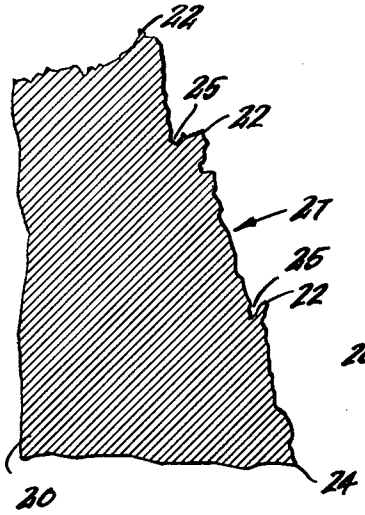


Fig. 2.

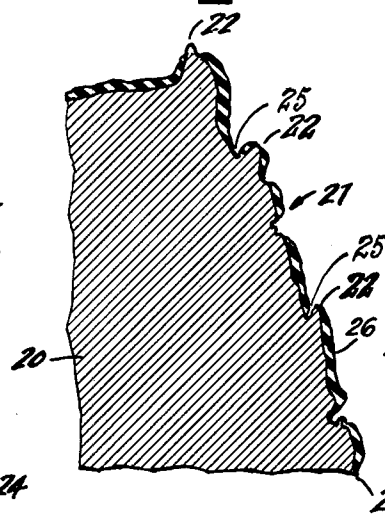


Fig. 3.

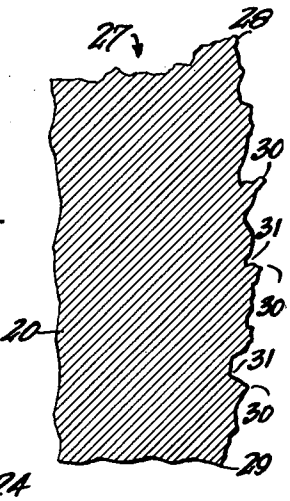


Fig. 4.

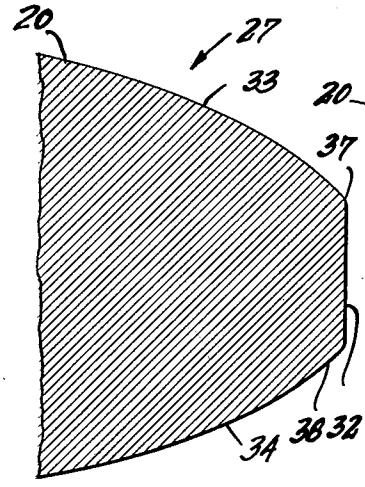


Fig. 5.

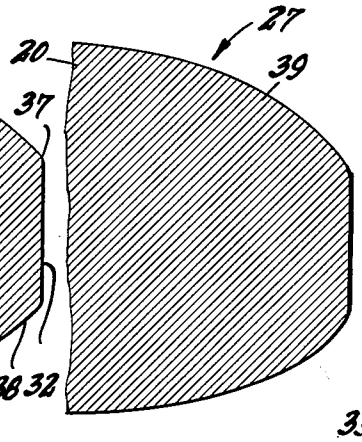
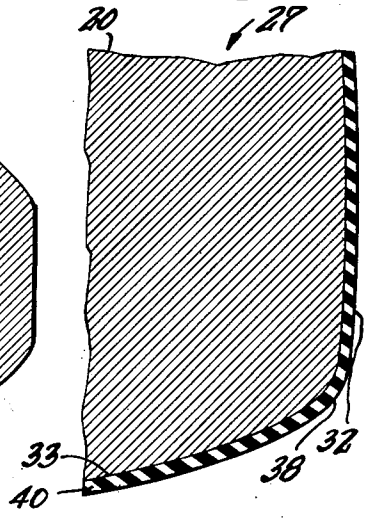


Fig. 6.



INVENTORS
Clarence F. Manning
Thorgen E. Lewis Jr. and
BY John Staley
H. Lee Helms
attorney

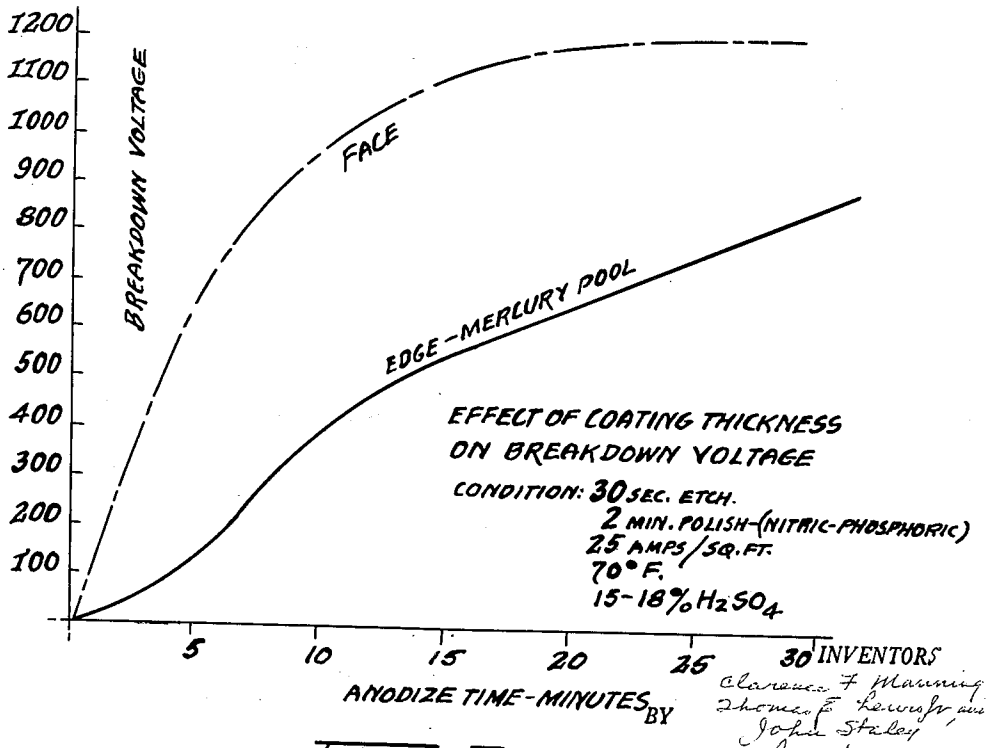


FIG. 7.

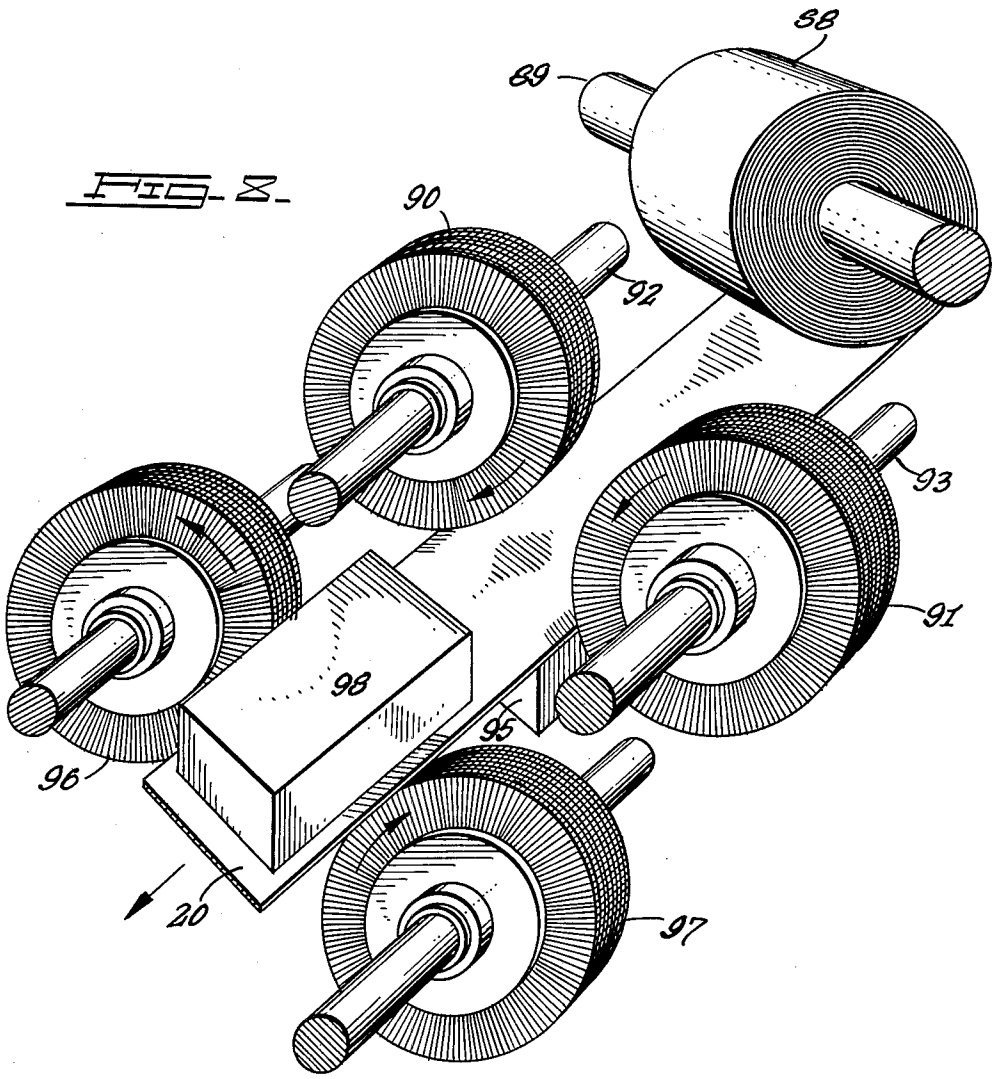
INVENTORS
Clarence F. Manning
Thomas E. Lewis, Jr.
John Staley
BY
H. Lee Helms
ATTORNEY.

Jan. 29, 1963 C. F. MANNING ETAL 3,075,893

ALUMINUM STRIP ELECTROMAGNETIC WINDINGS AND METHOD

Original Filed Feb. 9, 1955 3 Sheets-Sheet 3

FIG. 8.



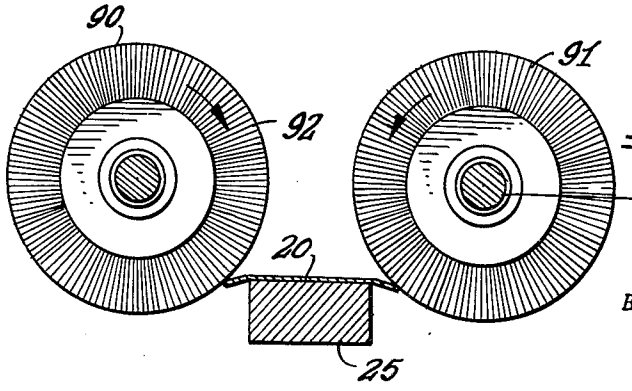


FIG. 9.

INVENTORS

BY

ATTORNEY.

United States Patent Office 3,075,893 Patented Jan. 29, 1963

3,075,893 ALUMINUM STRIP ELECTROMAGNETIC WINDINGS AND METHOD

Clarence F. Manning, Goochland County, and Thomas E. Lewis and John Staley, Chesterfield County, Va., assignors to Reynolds Metals Company, Richmond, Va., a corporation of Delaware

Continuation of application Ser. No. 487,057, Feb. 9, 1955. This application Nov. 9, 1959, Ser. No. 854,993
3 Claims. (Cl. 204—29)

For many years the desirability of aluminum foil and thin sheet electromagnetic coils or windings for transformers and other electromagnetic devices, has been recognized, but there are great difficulties in securing dielectric coatings which will not only satisfactorily insulate the surfaces of the strips, but which will provide adequate insulation for the edges of the foil strips. In cutting the strips from sheets of commercial width, sharp projections or burrs of microscopic dimensions are formed on the edges thereof. Attempts have been made to avoid the effects of the rough condition of the edges of the strips and produce coils therefrom by coiling the strips with paper interleaved between the turns to provide durable insulation and thereafter cut back into the metal the strip at its edges, by treating the coil with chemicals neutral to the paper insulation so as to leave between the outer edges of the turns overhanging or projecting edges of insulation.

Further attempts have been made to coat the edges with enamel coating, and to apply an oxide coating to aluminum strips, passing the strips through a bath, as for example, an electrolytic bath. All such attempts have failed because of lack of adequate insulation on the edges or the accumulation at the edges of the strips of applied insulation material, when such material as resins are used, such thickened edges preventing the strips from being made into coils in which the turns are symmetrically flat and the final coil sufficiently compact.

It has also been realized that an anodized film or aluminum coil strips provides many advantages over other applied insulation materials. Such inorganic anodic coating is not only more permanent insulation but also allows operation of the equipment at higher temperatures than organic insulations and lets it compete with the more expensive glass, mica, and other inorganic insulations. Anodic films also provide adequate insulation with a minimum of insulation thickness.

In arriving at the article and method, subject of the present application, it was first endeavored to treat the inevitable burred edges of aluminum foil, say 0.008", with an oxide film by both chemical and electrochemical processes, and also to coat the aluminum coil strips with enamel. These attempts were unsuccessful due to the lack of adequate insulation on sharp projections on the sheet. Attempts have been made to deburr the edges by melting them but an electric arc produced beading even when very close controls were employed. Such beading is undesirable due to resulting increased thickness of the edges and the space and insulation problems. Finally the method of the present invention arrived at success.

The present invention is based upon the inability of the oxidation method applied to slit thin aluminum strips for electromagnetic coils, such as used in transformers, to adequately provide dielectric oxide coatings on aluminum foil strips, even when slit from wider strips with great care, and inasmuch as microscopic burrs would ineviably be produced, and the solving of this problem after very extended experiments with various methods leading to the discovery that cut strips of aluminum foil of even 0.008" and lower, when produced with a smooth rounded edge, visible upon magnification, will enable uniform oxidation over the edges of the sheet as well as upon its major surfaces, and that the said rounded edges on the sheet may be produced mechanically, or preferably by a combined mechanical and chemical treatment of the said edges.

The invention will be described with reference to the accompanying drawings, in which:

FIGURE 1 represents a reproduction of a microphotograph of the right-hand edge portion of a cross section at a cut edge of a first specimen of an aluminum foil strip of 0.008" thickness, showing the burred edge obtained even after very careful slitting of the strip;

FIGURE 2 is a reproduction of a microphotograph of the specimen of FIG. 1 after anodizing, and showing that while the burrs are somewhat reduced in sharpness they still remain, so that the anodizing will not adequately insulate the edge as has been found in unsuccessful attempts to produce magnetic windings from such strip;

FIGURE 3 is a view similar to FIG. 1, showing the cross section through the right-hand edge of a second specimen cut strip of 0.008" thickness even after special attention is given to the slitting in order to minimize the burr;

FIGURE 4 is a view of the specimen of strip edge shown in FIG. 3 after mechanical rounding of the edge in accordance with the method of the present invention;

FIGURE 5 is a view of the same edge specimen shown in preceding FIGS. 3 and 4 after chemical polishing;

FIGURE 6 is a much more highly magnified view of the right-hand corner portion of the specimen shown in FIG. 4, a lesser amount of edge rounding having been applied than in FIG. 5 and after anodic coating;

FIGURE 7 is a chart showing the dielectric properties of an insulating coating applied to strips in accordance with this invention;

FIGURE 8 is a perspective view of a brush apparatus for mechanically treating the edges of the strips;

FIGURE 9 is a diagrammatic view illustrating the brushing operation with respect to action on the edges at the top of the strip.

Referring to FIG. 1 there is shown a highly magnified fragment representing a microphotograph of the right-hand edge of a strip **20** of aluminum carefully cut from a relatively wide strip or sheet by conventional slitting methods, the fragment being designated generally as **21**. In the normal course of the slitting operation, the reproduced microscopic sharply pointed projections such as **22**, a sharp corner **24** and sharply convergent pockets or recesses **25**, are found.

In accordance with methods heretofore used for insulating the cut strip, the fragment **21** of FIG. 1 is shown after treatment by an anodizing process in FIG. 2, the anodizing process producing an integrally formed coating of insulation **26**. In FIG. 2 the coating **26** is shown in a highly exaggerated manner for purposes of emphasis and diagrammatic illustration. In actual microphotographs, however, the actual coating is not clearly discernible. It will be noted that at the sharply convergent pockets or recesses **25** after anodizing as shown in FIG. 2 and at the remaining sharply pointed projections **22** and the corner **24**, the electrostatic field distribution during the anodizing process is such as to prevent the formation of any appreciable insulative coating.

As a result of this irregular distribution of the insulative coating **26**, any attempt to wind electromagnetic coils using anodized aluminum strips having the lateral edge configuration shown in FIGS. 1 and 2, will result in a structure in which the extreme lateral edges of the strip are effectively, if not actually, devoid of any insulation. This, of course, will result in short circuited turns even though the voltage per turn may be relatively low. FIGS. 1 and 2 clearly illustrate the inherent problems encountered in attempting to form an electromag-

netic winding using thin anodized aluminum strip material slit by conventional slitting methods and apparatus.

FIG. 3 is similar to FIG. 1 illustrating a fragment of the extreme right-hand edge of a different specimen of strip as produced by slitting apparatus. As in the case of FIG. 1, the fragment of the strip specimen is designated generally as **27** in FIG. 3 and comprises the usual sharp corners **28** and **29**, sharply pointed irregularities **30** and sharply convergent pockets or recesses **31**. Instead of proceeding directly to apply an electrically insulative coating to the specimen shown in FIG. 3, the edges of the strip **20** of which the fragment **27** is representative are first subjected to a special mechanical brushing process as described in greater detail below. This brushing process produces a relatively straight vertical-corner-edge **32** contiguous with smoothly rounded upper and lower edges **33** and **34**. The vertical edge **32** is joined to upper and lower rounded edges **33** and **34** at corners **37** and **38** respectively. The strip is then subjected to a chemical polishing process which lessens the corners **37** and **38** in the course of the chemical polishing process. In the condition shown in FIG. 5, the strip edge is ideal for anodizing as described in greater detail below.

Referring to FIG. 6, the edge rounding process has been applied to a lesser extent than in the case of FIG. 5. Only the lower right hand portion of the section is visible in FIG. 6 which is more highly magnified than FIG. 4. In FIG. 6 the fragment **27** is shown after anodizing and bearing a thin continuous coating **40** of electrically insulative material completely covering the surfaces of the strip.

Because of the smooth surfaces **32** and **33** and rounded corner **38** are effectively free from sharply pointed irregularities or sharply convergent pockets or recesses such as **30** and **31** in FIG. 3, a fairly uniform thickness of coating is obtained. The dielectric properties of this coating are sufficient at its points of minimum thickness to provide the required degree of electrical insulation. This may be seen at FIG. 7 as explained in greater detail below.

Referring now to FIGS. 8 and 9, the strip of aluminum **20** is shown after slitting wound in the form of a roll **88** mounted on a suitably braked or otherwise restrained mandrel shaft **89** from which it is pulled by conventional pulling and rewinding means (not shown), thereby keeping the strip **20** in continuous longitudinal movement under suitable tension.

A pair of oppositely revolving circular brushes **90** and **91** mounted on spaced parallel power driven shafts **92** and **93**, respectively, engage the lateral edge portions of the strip **20** at the upper surfaces thereof. The action of the brushes **90** and **91** is preferably symmetrical, the shafts **90** and **91** being individually driven at equal speeds from a common source of power by means of gearing or the like which has been omitted from the drawing for simplicity of illustration.

A fixed rectangular back-up block **95** is disposed beneath the moving strip **20** in engagement therewith at the location where its edges are engaged by the brushes **90** and **91**. The upper surface of back-up block **95** symmetrically supports the strip **20** for limiting transverse bending at its edge portions which are in contact with the brushes **90** and **91** and thereby permitting an appreciable amount of brushing pressure to be applied to the edges of the comparatively thin strip **20** without requiring an undue amount of tension in the strip.

After treatment of its upper edge surfaces by brushes **90** and **91**, the strip **20** proceeds to a second pair of oppositely revolving brushes **96** and **97** which brush the lower surfaces of the edge portions of the strip **20**. The brushes **96** and **97** are arranged similarly to the brushes **90** and **91** except that the back-up block **98** associated therewith is disposed above the strip **20** instead of beneath the strip as in the case of back-up block **95** associated with brushes **90** and **91**.

Only two pairs of brushes **90—91** and **96—97** have been shown. It is to be understood, however, that one or more further sets of brushes may be provided if desired. Ordinarily, two complete sets of brushes as shown in FIG. 11 will serve to remove the irregularities at the strip edges to an extent sufficient to prepare the strip for subsequent chemical polishing of its edges as described below.

In practice, satisfactory results have been obtained using brushes of approximately 12″ diameter with closely massed filaments, in the case of bronze filaments preferably about 0.005 in thickness and with an effective length of 3⅜″. In the case of brushes with fiber filaments it has been found satisfactory to employ a filament thickness of 0.010–0.025, with the same active filament length as in the case of the bronze filaments. The brushes with bronze filaments were operated at speeds of 400–600 r.p.m. bristles and 1500–1800 r.p.m. when using fiber filament brushes and any suitable abrasive, preferably of −200 mesh. The direction of rotation of each brush is such as to exert a force tending to deflect the strip transversely as indicated in FIG. 12, the brushing forces exerted by the two brushes of each pair being substantially equal and oppositely directed so that the strip is not pulled laterally in either direction. Preferably, the brushing force is exerted on the edges of the strip at an angle of approximately 45° with respect to the horizontal point of engagement with the edge of the strip **20** as shown in FIG. 12.

After brushing, the strip **20** is chemically and mechanically cleaned and thereafter rinsed with water, and the water rinse is followed by a chemical polishing in an aqueous solution of acid at 170–200° F. As an example, the solution may consist of a mixture of phosphoric and nitric acids consisting of 95% of H_3PO_4 at a concentration of 85% and 5% of HNO_3 at a concentration of 65%. The duration of the chemical polishing treatment is of the order of 1 to 2 minutes and the treatment need be applied only to the edge portions of the strip.

After the chemical polishing, the strip is rinsed with water and air dried.

After air drying, the strip is then subjected to an anodizing treatment, for example with sulphuric acid, using direct current at a current density of 25 to 30 amperes per square foot of total strip area to be coated, with the positive terminal connected to the strip. The bath may be an aqueous solution of sulphuric acid at a concentration of 15–18% and a temperature of about 70° F. The time of treatment may be about 6 to 13 minutes which causes the formation of an oxide coating integral with the strip and of sufficient thickness to serve as adequate insulation when the strip is wound into a roll for use as a transformer winding.

After completion of the anodizing treatment, the insulated strip may, if desired, be sealed by immersion in hot water at 200° F., and a further sealing with steam may be employed. The strip is then air dried. At this point it may be coated with silicone.

FIG. 7 is a graph showing the dielectric strength of a coating produced by the foregoing method both on the face of the strip and at its edges. As shown by the graph, the dielectric strength increases with increasing duration of the anodizing treatment. A test of the dielectric strength at the edges of the strip using a mercury pool electrode clearly shows the presence of a substantial and effective insulating coating as indicated by the lower curve.

After drying, the strip may be wound by means of conventional winding machinery into a transformer coil in the form of a roll of hollow cylindrical shape, a suitable silicone oil being applied as a lubricant during the course of the winding operation.

Connections are then made to the coil ends and the transformer thereafter assembled and tested in the usual manner.

Preferably the invention is practiced with aluminum of substantially pure grade commercially known as "2S", one quarter hard to full hard. Although it has been stated that the invention can be practiced on cut strips of aluminum of even 0.008" and lower thickness, it also can be practiced on strips of greater thickness, e.g., 0.015".

This is a continuation of our copending application, Serial No. 487,057, filed February 9, 1955, and now abandoned.

We claim:

1. The method of making an insulated electrical conductor, the steps comprising: slitting a thin sheet of aluminum to form a strip; brushing the edge portions of the strip to remove burrs formed in the slitting step and impart thereto a generally rounded cross-sectional configuration and a smooth surface finish; and anodizing the strip to provide both sides and the edges thereof with a thin continuous electrically-insulating film.

2. The method defined in claim 1 in which the sheet of aluminum is of the order of about 0.008" to about 0.015" thickness.

3. The method defined in claim 1 including the step, between the polishing and anodizing steps, of chemically polishing at least the edge portions of the strip.

References Cited in the file of this patent

UNITED STATES PATENTS

1,877,569	Falkenthal	Sept. 13, 1932
2,094,048	Siegel	Sept. 28, 1937
2,346,349	Baster	Apr. 11, 1944
2,374,449	Mulcahy	Apr. 24, 1945
2,493,609	Young	Jan. 3, 1950
2,538,317	Mason et al.	Jan. 16, 1951
2,590,927	Brandt et al.	Apr. 1, 1952
2,668,936	Robinson	Feb. 9, 1954