No. 815,729. PATENTED MAR. 20, 1906.

W. S. MOODY.

TRANSFORMER.

APPLICATION FILED DEC. 13, 1901.

2 SHEETS—SHEET 1.

Fig. 1.

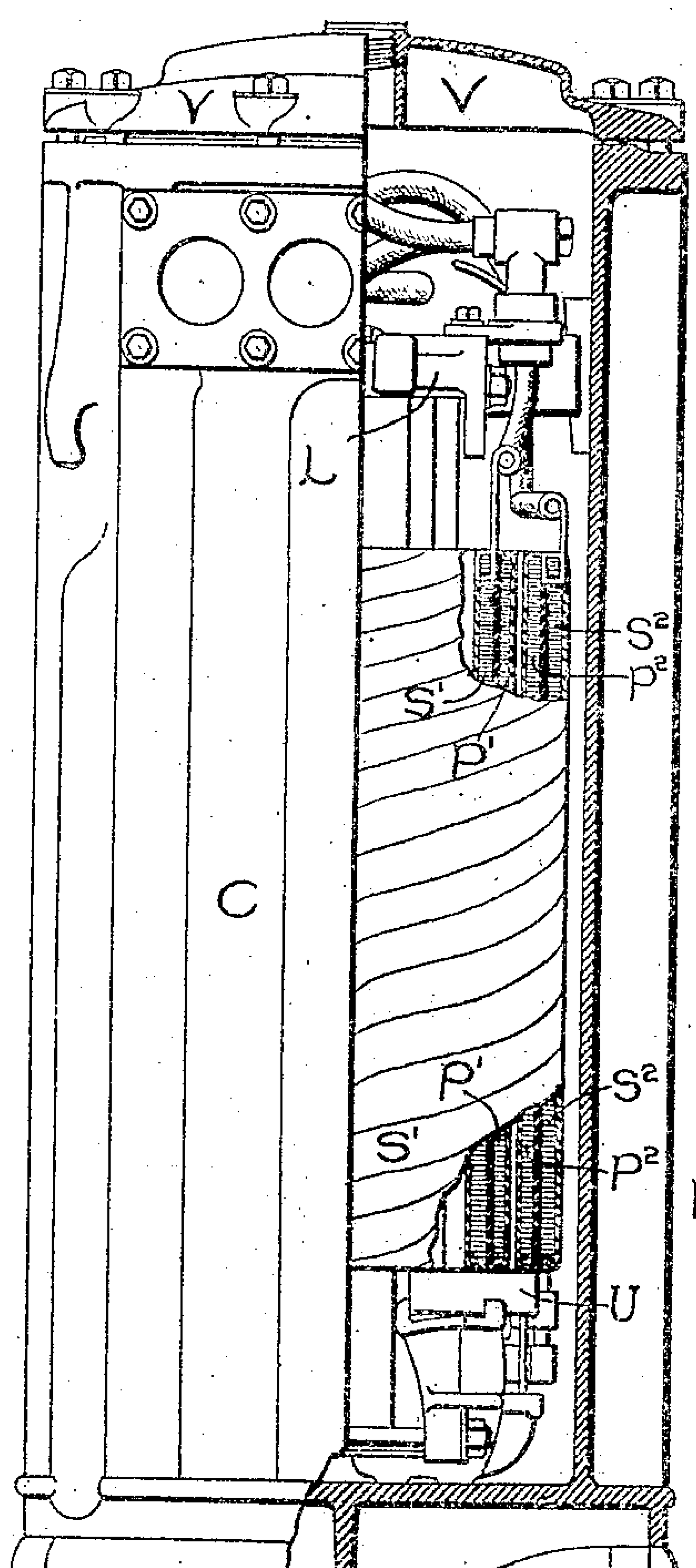


Fig. 5.

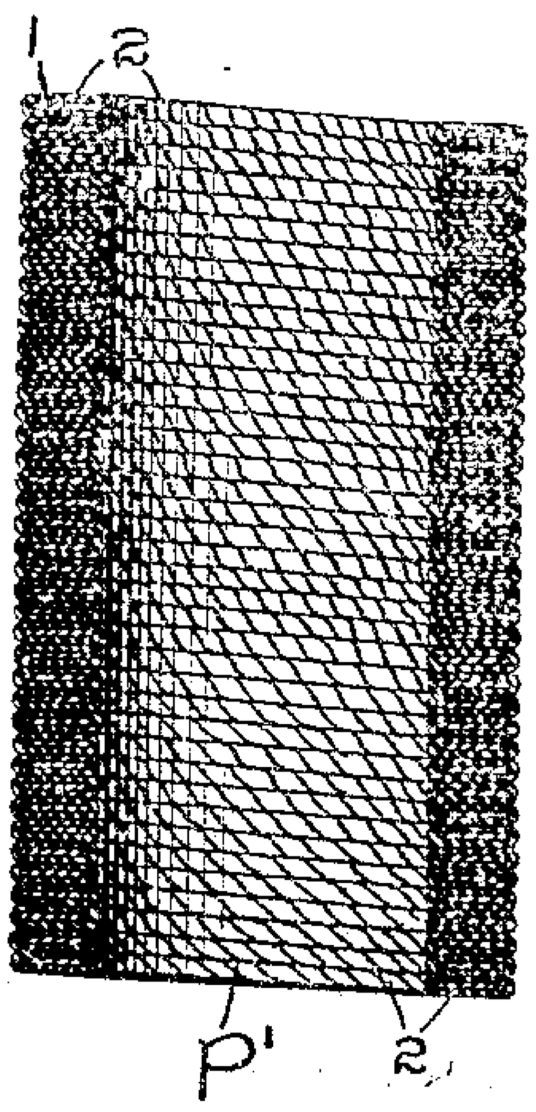


Fig. 6.

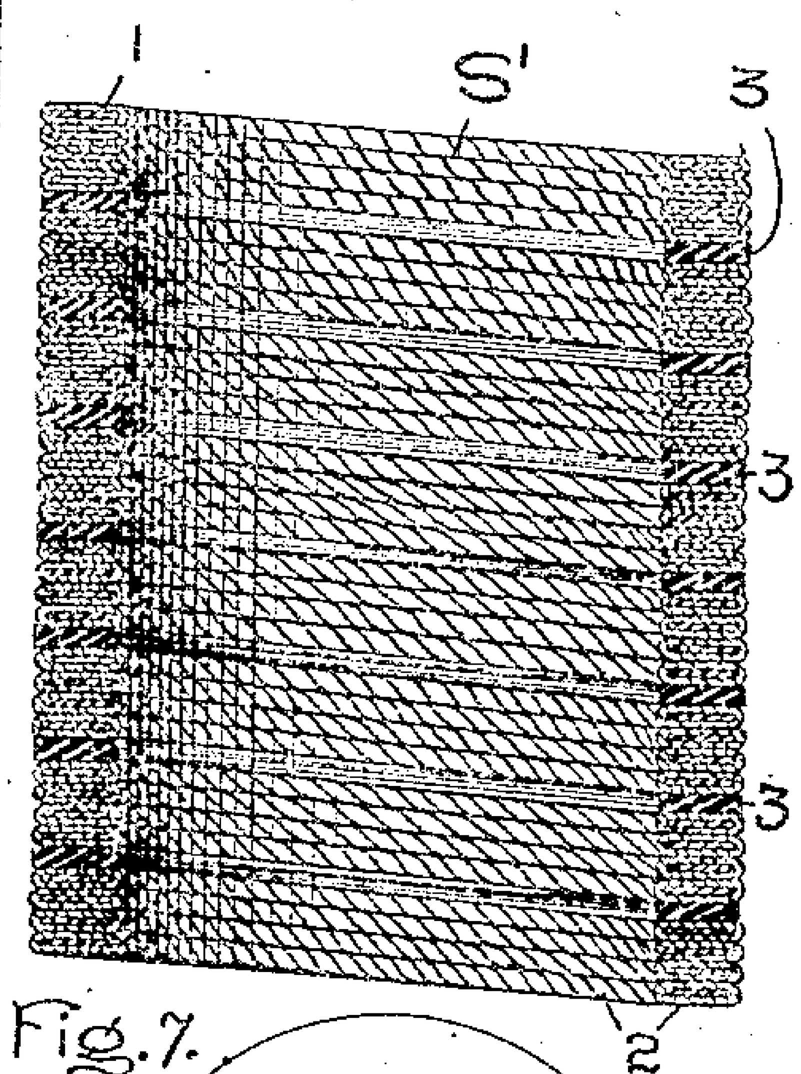


Fig. 7.

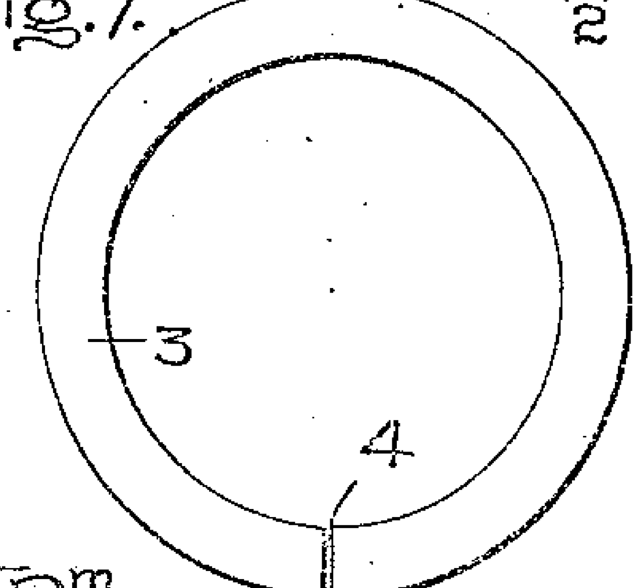
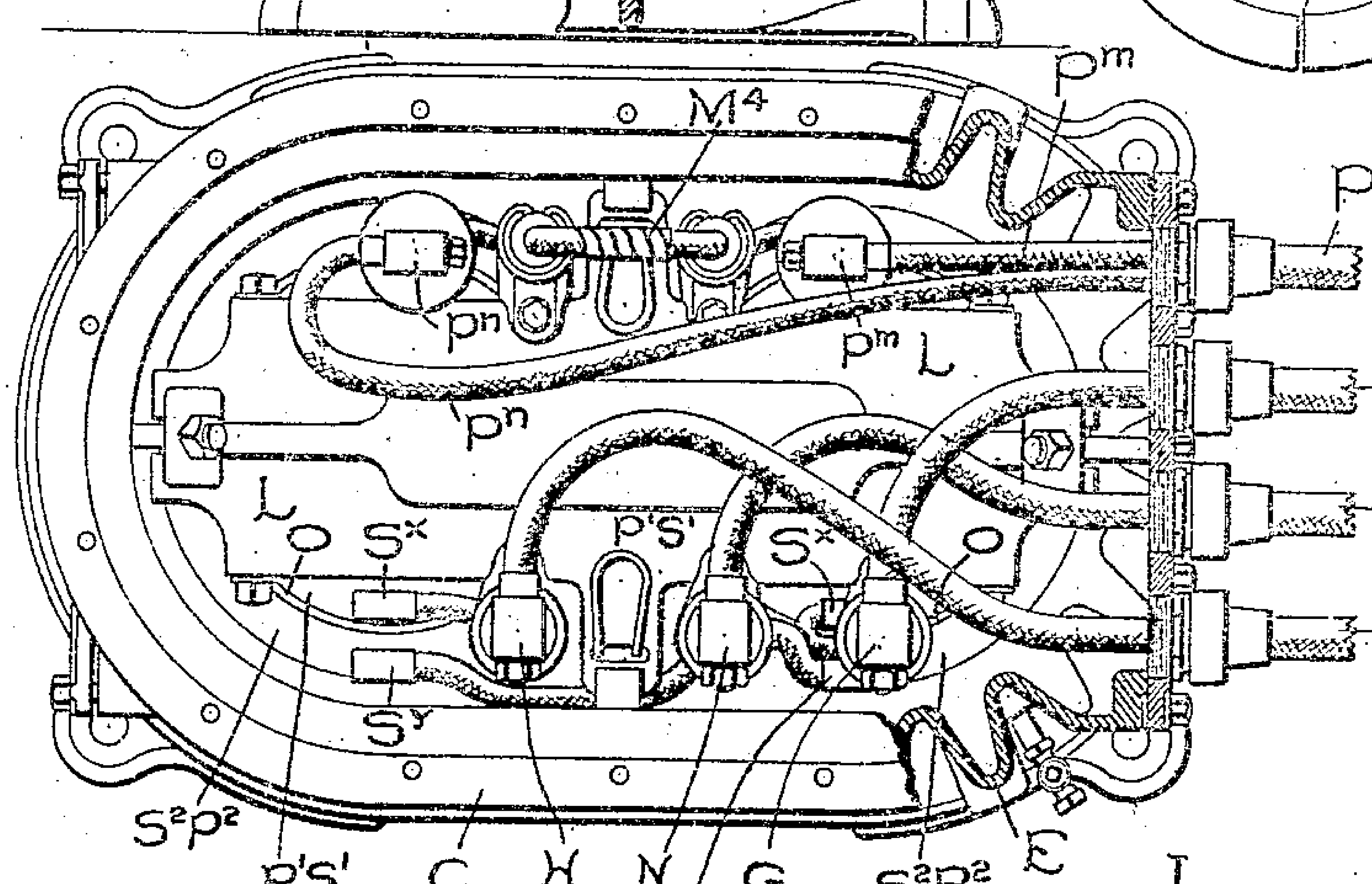


Fig. 2.



Witnesses:

Marcus L. Byng.

Benjamin B. Hull

Inventor:

Walter S. Moody,

by Albert G. Davis

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2 SHEETS—SHEET 2.

Fig. 3.

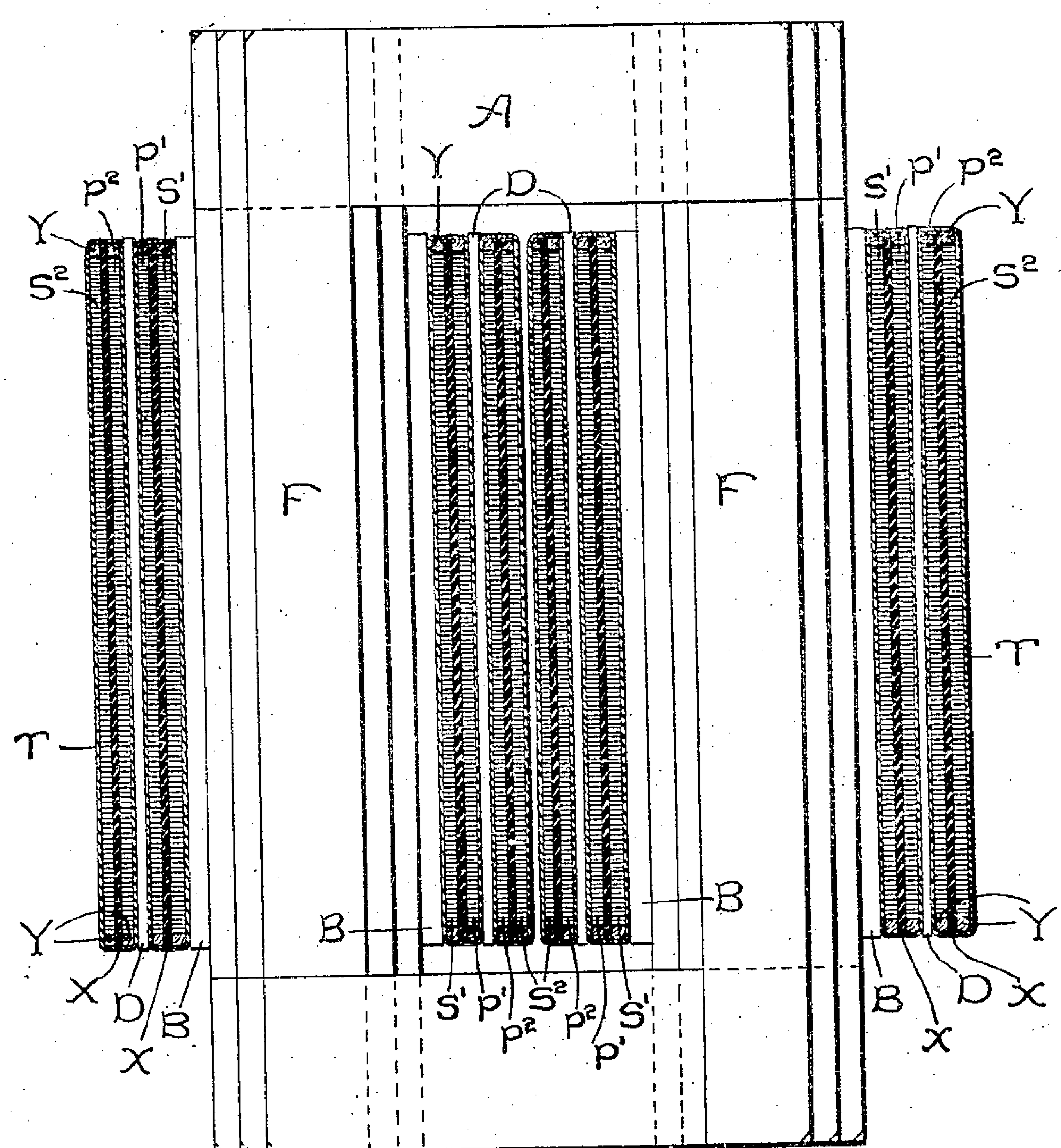
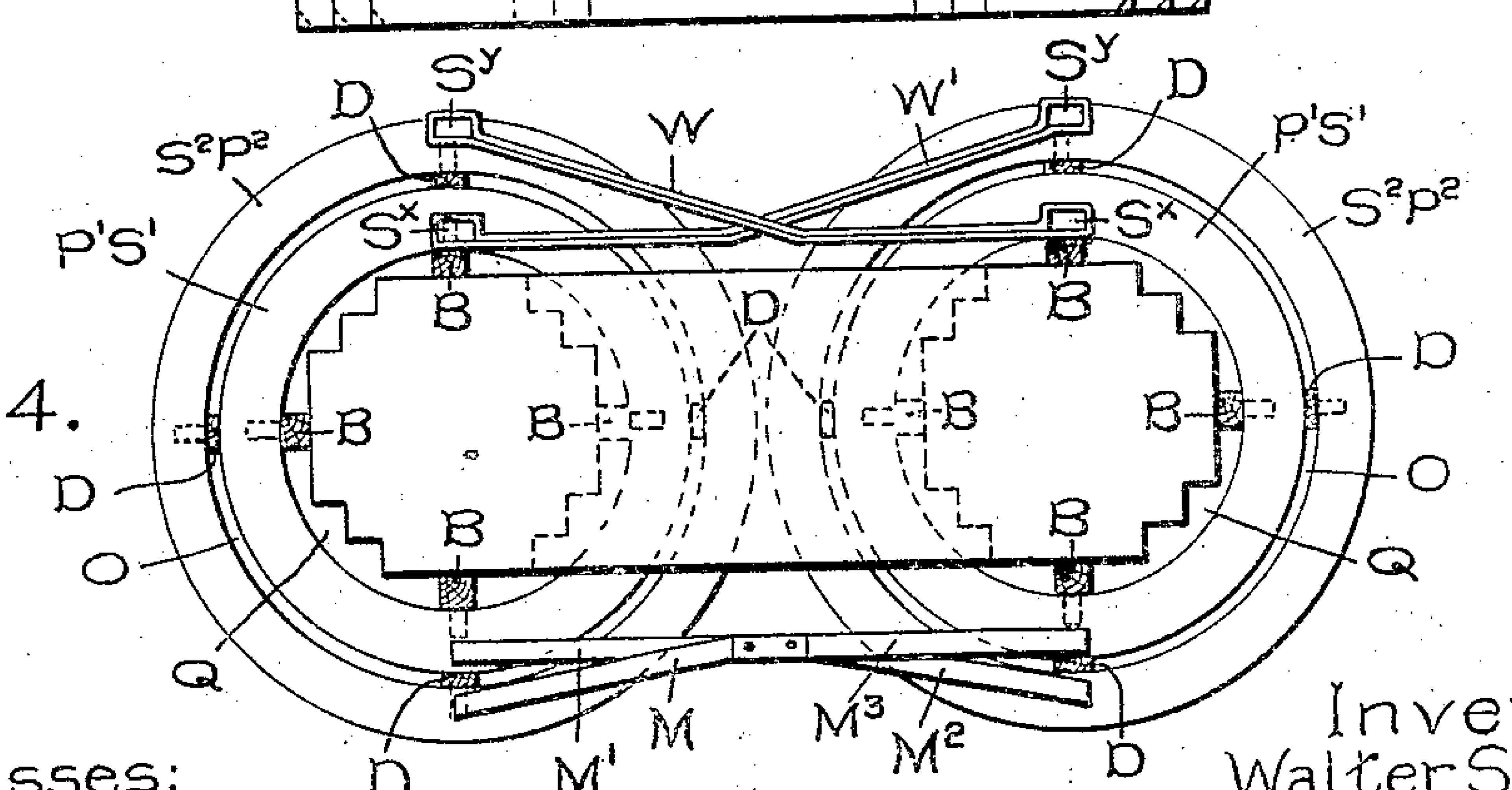


Fig. 4.



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UNITED STATES PATENT OFFICE.

WALTER S. MOODY, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

TRANSFORMER.

No. 815,729. Specification of Letters Patent. Patented March 20, 1906.

Application filed December 13, 1901. Serial No. 85,737.

To all whom it may concern:

Be it known that I, WALTER S. MOODY, a citizen of the United States, residing at Schenectady, county of Schenectady, State of New York, have invented certain new and useful Improvements in Transformers, of which the following is a specification

This invention relates to improvements in electrical apparatus for transforming from high to low potential, and vice versa.

The improvements consist in the peculiar construction and arrangement of the high and low potential windings whereby important advantages are obtained both in electrical operation and in mechanical structure.

Of the drawings, Figure 1 is an elevation of the transformer-casing, partly in section, to show the transformer itself inside the casing, a part of the transformer itself being also in section to show the construction and arrangement of the windings to which the invention relates. Fig. 2 is a top plan view of the casing with the cover removed to show the top of the transformer and the conducting-leads to both the high and low potential windings. Fig. 3 is an elevation of a core of one type of transformer to which the invention may be applied, the windings being shown in cross-section on the core. Fig. 4 is a bottom view of the core and windings of Fig. 3, showing the bottom conducting-leads. Fig. 5 is a vertical longitudinal section of a primary coil. Fig. 6 is a similar section of a secondary coil, and Fig. 7 is a plan of an insulating part.

The various features of the invention can be applied advantageously to the "core-type" transformers shown in the drawings, in which type the core constitutes a single magnetic circuit, and these features may also be employed with transformers of other types.

The windings are arranged as most clearly shown in Figs. 3 and 4, the inside cylinder comprising two coils, being separated from the outside cylinder, also comprising two coils, by an annular space O, Fig. 4, formed by the spacing-pieces D, Figs. 3 and 4, of insulation-impregnated wood or other suitable material. This space serves to insulate the outer surface of the inside cylinder from the inner surface of the outside cylinder and exposes a large extent of the surfaces of both cylinders to the cooling effects of air or oil or other cooling fluid in the casing surrounding the transformer. In practice the apparatus shown in Fig. 3 is usually immersed in a body of suitably-prepared oil contained in the cast-iron casing C of Figs. 1 and 2, the oil serving to insulate the windings from each other and from the core and casing and to absorb the heat generated in the windings and convey it to the cast-iron casing, whence it is dissipated into the outside atmosphere. The inside cylinder is separated from the legs F of the core A by an annular space Q, Fig. 4, formed by the spacing-pieces B, Figs. 3 and 4, of insulation-impregnated wood or other suitable material. The oil or other cooling fluid thus has free access to all parts of the core and to the inner surface of the inside cylinder and serves to insulate the latter from the core. Each cylinder comprises a high and a low potential coil, so that there are two high-potential windings and two low-potential windings concentrically arranged on a given part of the core. When as formerly there were only two windings—one of high voltage and one of low voltage—arranged concentrically on a given part of the core, it was necessary to employ thick insulation between them, owing to the great difference in potential between the last turns, and this thick insulation not only occupied valuable winding-space, but by causing the distance between the high and low potential coils to be considerable produced considerable reactance. With longer coils, where the total amount of copper in one coil could be closely associated with the total amount of copper in the other coil, there is less reactance between the windings; but even when the practical limit of length is reached the amount of insulation required to protect the low-potential winding from the high-potential winding is so great as to separate the windings to such an extent as to produce considerable reactance, besides occupying valuable winding-space. By the arrangement shown the reactance is much reduced, as the necessary insulation between the high and low potential coils comprising each cylinder is much less. The low-potential coil or secondary S′ of the inside cylinder lies nearer the core than the high-potential coil or primary P′ of the same cylinder, thus requiring less insulation (solid or fluid) between itself and the core than if the high-potential winding were located nearer the core than the low-potential winding. The secondary S^2 of the outside cylinder lies nearer the iron casing C, thus requiring less insulation (solid or fluid) between itself and the casing than if the high-potential winding were nearer the casing than the low-potential winding. The arrangement brings the two primary coils P′ P^2 next to each other, but separated from each other by the space O. This space is, in fact, a duct through the center of the high-potential winding and accomplishes the important result of providing insulation between parts of the primary which may have a great difference of potential. The space O also exposes half of the total primary winding to the cooling action of the oil or other fluid. A most important feature of this arrangement is that the space O produces the above beneficial results without increasing the reactance, which it would do if it were between a primary and a secondary coil. The location of the space between the two parts of the primary permits each primary and secondary coil to be located close together, separated only by the minimum amount of material required for adequate insulation. There are two important results attending the location of the two coils of the primary between the secondary coils. The first result is the lack of the necessity of placing thick insulation on both the inside and outside of the primary, which would take up valuable winding-space. The primary if placed next the core would have to be heavily insulated from both the core and secondary; but with the arrangement described it is necessary only to insulate the inside of the primary of the inner cylinder and the outside of the primary of the outer cylinder, since the space O serves to insulate the two primary coils from each other. The second important result is that the casing C can be made smaller, with a less space between it and the outside secondary than if the high-potential primary were nearest the casing. The construction of the coils is such as to obtain greatly-improved results both as to electrical operation and mechanical strength.

It has been customary to wind transformer-coils of insulated copper wires of circular cross-section, either winding the wire directly on the core in cases where the single-circuit core was composed of four bundles of sheet-metal laminations or winding the wire separately and slipping the coil over the core. The coils in the present case are constructed of a flat strip of copper or other suitable conductor, as shown in Figs. 5 and 6, which strip is formed into a barrel or cylindrical winding, as described, by winding the strip edgewise by means of the apparatus disclosed in the patent to John J. Frank, No. 771,902, October 11, 1904, or by any other winding apparatus suitable for the purpose. Such a winding has sufficient mechanical strength and rigidity to resist strains from handling during manufacturing, &c., which formerly changed the shape of the old-style coils, so that it was necessary in order to make possible the assembly of one coil over another to allow considerable difference in diameter between the two coils. The edge-wound coil is thus economical in radial transformer-space. It is also very economical in longitudinal winding-space, and it has been found that a much larger effective amount of copper can be wound in a given space by winding a strip on edge than by the old-style winding. The edge-wound coil also tends to reduce eddy-currents and leaves a large part of the coil exposed for ventilation.

The windings shown in Fig. 3 are made in practice in the following manner, taking, for example, the outside cylinder, comprising the coils P^2 and S^2: The coil P^2 is first wound on the mandrel of the proper winding apparatus. When this coil is to be the high-potential and low-current winding, it is composed, as shown in Fig. 5, of a single edge-wound copper strip 1. This strip is preferably covered before winding edgewise with ordinary cotton isulation 2, which not only serves to insulate the turns of the wound coil from each other, but also to insulate the edges of the turns from metallic parts in its proximity. The spaces thus formed between the turns serve to reduce eddy-currents. It is preferable that the edges of the turns of this high-potential coil be insulated, although it may not be absolutely essential in all cases—as, for example, if the coil be separated a sufficient distance from other metallic parts. The use of insulation over the edges makes possible a closer approximation of the high and low potential coils, thus not only economizing space, but reducing reactance and increasing the efficiency of the apparatus. The next step is the placing of the insulation X, Fig. 3, around the outside of the coil P^2, which is done without removing the coil from the mandrel of the winding apparatus. Thus insulation need not be as thick in proportion to the thickness of the coils as is indicated in the drawings, where it is exaggerated for clearness, and it need be only thick enough to properly insulate the high from the low potential winding. The insulation may consist of press-board, or one or two sheets of oil-silk, or of any other suitable material. In some cases the insulation X may be sufficient, so that the insulation 2, Fig. 5, on the edges of the high-potential turns may be dispensed with; but even in this case the turns of the coil must be suitably insulated from each other. After the insulation X has been properly secured in place, as by taping in the well-known manner, the coil S^2, composed, as shown in Fig. 6, of a plurality of copper strips in multiple with each other when it is to be the low-potential and high-current winding, is wound over the insulation X and the coil P^2 without removing the latter from the mandrel. The coil S^2 is wound over the coil P^2 so tightly that both coils, with the interposed insulation X, constitute a single rigid mechanical structure, which is not only very convenient to handle during the process of constructing the transformer, but also enables the high and low potential coils to be located so closely together that their mutual reactance is reduced to a minimum.

The bunches of parallel strips 1 of the coil S^2 are separated from each other by insulation in a novel manner. Rings 3, Fig. 7, of flat horn fiber or other suitable material are split, as shown at 4, and these rings are disposed in series along the length of the bunches, the end of one split ring adjoining the end of another split ring, so that, as shown in Fig. 6, the series of rings form a substantially continuous helix, which completely insulates the bunches of strips from each other.

Another important advantage of the edge-wound coil is that, owing to its smooth periphery, the insulation X, such as press-board, between the coils is not creased, as was formerly done by the wires or irregular insulation of the old-style coils. This is important, because the creasing of the press-board or other insulation seriously impairs its insulating qualities, while if it is not creased it may be of much less thickness, and valuable space can consequently be saved.

The copper strips of the low-potential coil S^2 are preferably covered with a cotton or other suitable insulation 2 before winding them on edge; but if they are wound bare the turns of the completed coil may be separated by independent insulating-strips, or by an applied varnish, or by an insulating glaze or enamel if the latter can be successfully placed on the strip so that it will not crack off when the strip is wound edgewise. The cotton covering of the several strips which compose one bunch is not essential as insulation, but serves to reduce eddy-currents. The inner cylinder, consisting of the primary P' and secondary S', with interposed insulation, is constructed in the same manner as the outer cylinder above described, except that the low-potential coil S' is wound first, and this cylinder may be slipped in place over a core-leg F without any enveloping insulation, if desired, as the low-potential winding S' will be sufficiently insulated from the core by the spacing-pieces B and by the oil or other fluid in the space Q formed by these pieces. I prefer, however, to wind each cylinder with cotton tape T, mainly for the purpose of holding the copper strips in alinement, although, of course, such tape will serve to a degree as an insulation. It will be noted that the insulation X extends down beyond the edges of the coils and that the space between this insulation and the spacing-pieces B and D is filled with wooden blocks Y. This construction is for the purpose of preventing leakage to the secondary from the high-potential primary and at the same time strengthening the projecting parts of the insulation X. Each leg F of the primary shown is similarly equipped with two cylinders. It will be noted that owing to the edgewise winding of the strip and to the peculiar arrangement of the coils each turn of all the coils is directly exposed, save for the cotton insulation 2 and the thin winding of tape T, to the cooling action of the oil or other cooling fluid in the casing.

The transformer shown in the drawings is especially adapted to three-wire service, and to this end I have shown the coil connections in accordance with my Patent No. 595,403, granted December 14, 1897, which discloses a means of obtaining automatic regulation when the loads on the two sides of the three-wire circuit are unbalanced. Other means may, however, be employed.

In accordance with my patent above noted the primary coils are all connected in series, as shown in Figs. 2 and 4 of the drawings. The circuit is from the main P^m of Fig. 2 down through the right-hand coil P' of Figs. 3 and 4, (the latter of which is a bottom view,) out through the end M^3 of the copper strip comprising said coil to the end M of the copper strip comprising the left-hand coil P^2, up through the latter coil to the top cross-conductor M^4 of Fig. 2, across to the right-hand coil P^2, Figs. 3 and 4, down through the latter to the end M^2 of the strip composing said coil to the end M' of the strip which composes the left-hand coil P', and up through the latter to the main P^n, Fig. 2.

The secondary line-terminals are shown in Fig. 2, G and H being the outside lines of the three-wire circuit and N the neutral. The secondary coil S' on one leg of the core is connected in series with the secondary coil S^2 on the other leg of the core across one side of the three-wire circuit, and the secondary coil S^2 on the former leg is connected in series with the secondary coil S' on the latter leg across the other side of the circuit. In Fig. 4 are shown the cross connection W', which joins the bottom leads S^x S^y and the connection W, which joins the bottom leads S^x S^y. The circuits may be traced as follows: from the line-terminal G, Fig. 2, to the top lead S^x of the right-hand inside coil S', down through this coil, Fig. 4, to the bottom lead S^x, across the bottom connection W to the bottom lead S^y, up through the left-hand outside coil S^2, Fig. 4, to the top lead S^y, and thence to the neutral terminal N. The other side of the circuit leads from the line-terminal H, Fig. 2, to the top lead S^x of the left-hand inside coil S', down through this coil, Fig. 4, to the bottom lead S^y of the right-hand outside coil S^2, up through this coil, Fig. 2, to the top lead S^y, and thence to the neutral terminal N.

The casing C may be of cast-iron and may have the wave shape E, as shown. The cover V is removably secured to the casing by suitable bolts, and when the cover is removed the entire apparatus, together with the supporting-clamps U and L, can be lifted out of the casing.

The term "cylindrical" employed herein is not intended to limit the shape of the coils to a true annular cross-section, but is intended to indicate merely the general barrel shape thereof.

What I claim as new, and desire to secure by Letters Patent of the United States, is—

1. In a transformer, the combination with the core, of a winding comprising a high and a low potential coil and arranged on the core, and a second winding also comprising a high and a low potential coil, said second winding being arranged outside the first, and separated therefrom by a cooling and insulating space.

2. In a transformer, the combination with the core, of a winding comprising a low and a high potential coil, said winding being arranged on the core and separated therefrom by a cooling and insulating space; and a second winding also comprising a low and a high potential coil, said second winding being arranged outside the first and concentric therewith.

3. In a transformer, the combination with the core, of a cylindrical winding comprising a low and a high potential coil, said winding being arranged on the core and separated therefrom by a cooling and insulating space; and a second cylindrical winding also comprising a high and a low potential coil, said second winding being arranged outside the first, and separated therefrom by a cooling and insulating space.

4. In a transformer, the combination with the core, of a cylindrical winding comprising a high and a low potential coil, said winding being arranged on the core; and a second cylindrical winding also comprising a high and a low potential coil, said second winding being arranged outside the first and concentric therewith.

5. In a transformer, the combination with the core, of high and low potential windings consisting of cylindrical coils arranged one outside the other, one of the windings being subdivided into mechanically separate adjacent coils separated by an annular cooling and insulating space.

6. In a transformer, the combination with the core, of high and low potential windings consisting of cylindrical coils arranged one outside the other, the high-potential winding being subdivided into two separate coils which are separated by an annular cooling and insulating space.

7. In a transformer, the combination with the core, of a cylindrical low-potential coil arranged on the core, a cylindrical high-potential coil surrounding said low-potential coil, a second cylindrical high-potential coil surrounding the first high-potential coil and separated therefrom by a cooling and insulating space; and a second cylindrical low-potential coil surrounding the second high-potential coil.

8. In a transformer, the combination with the core, of a cylindrical low-potential coil separated from the core by a cooling and insulating space, a cylindrical high-potential coil surrounding said secondary, a second cylindrical high-potential coil surrounding the first high-potential coil and separated therefrom by a cooling and insulating space; and a second low-potential coil surrounding said second high-potential coil.

9. In a transformer, the combination with the core, of a cylindrical winding mounted thereon and consisting of two cylindrical coils each composed of one or more edge-wound conducting-strips, said coils fitting one within the other to provide a single structure, and a second cylindrical winding constructed like the first, and separated therefrom by a cooling and insulating space.

10. In a transformer, the combination with the core, of a cylindrical winding mounted thereon consisting of an inside low-potential and an outside high-potential coil, each coil consisting of one or more edge-wound conducting-strips; and a second cylindrical winding surrounding the first and separated therefrom by a cooling and insulating space, said second winding consisting of an inside high-potential coil and an outside low-potential coil, each of which consists of one or more edge-wound conducting-strips.

11. In a core-type transformer, the combination with the core constituting a single magnetic circuit, of cylindrical windings disposed on different parts of said core, each winding comprising a low-potential coil and a high-potential coil; and other cylindrical windings also comprising each a low-potential coil and a high-potential coil, and arranged respectively outside the first windings.

12. In a core-type transformer, the combination with the core constituting a single magnetic circuit, of cylindrical windings disposed on different parts of said core, each winding comprising an inside low-potential coil and an outside high-potential coil; and other cylindrical windings comprising each an inside high-potential coil and an outside low-potential coil, and arranged respectively outside the first windings, the two high-potential coils of each set of cylindrical windings being separated by a cooling and insulating space.

13. A transformer-winding which comprises a cylindrical coil consisting of an edge-wound flat strip, an insulation covering for the exterior of the coil, and a second coil consisting of a flat strip wound edgewise over said insulation and forming therewith a unitary structure.

14. In a transformer, the combination with the core, of a cylindrical low-potential winding arranged next the core and consisting of one or more edge-wound flat strips, and a cylindrical high-potential winding consisting of one or more flat strips tightly wound edgewise over said secondary winding and forming therewith a unitary structure.

15. In a transformer, the combination with the core, of a winding comprising a cylindrical coil consisting of a single edge-wound strip, and a coöperating winding comprising a cylindrical coil consisting of a plurality of interconnected edge-wound strips.

16. In a transformer, the combination with the core, of a cylindrical low-potential winding arranged nearest the core, a cylindrical high-potential winding arranged outside of and concentric with said low-potential winding, the high-potential winding being divided into two coils separated by an annular space; and a low-potential winding arranged outside of and concentric with the high-potential winding.

17. A cylindrical coil composed of a plurality of insulated conducting-strips arranged side by side in a bunch and wound on edge.

18. In a stationary induction apparatus, the combination with the core, of a winding subdivided by an intermediate annular space, and a second winding divided into coils located inside and outside the first winding.

19. A coil for stationary induction apparatus which comprises one or more conducting-strips wound on edge, and a continuous insulating-helix comprising a series of split rings arranged end to end.

20. A plurality of insulated strip conductors arranged side by side and wound on edge so as to form a coil.

21. A plurality of strip conductors arranged side by side and wound into a coil, insulation between the strips, and heavier insulation between the turns of the coil.

In witness whereof I have hereunto set my hand this 11th day of December, 1901.

WALTER S. MOODY.

Witnesses:
BENJAMIN B. HULL,
MARGARET E. WOOLLEY.