March 14, 1939. G. LEISCHNER 2,150,382

REGULATING TRANSFORMER

Filed June 11, 1937 4 Sheets-Sheet 1

Fig.1

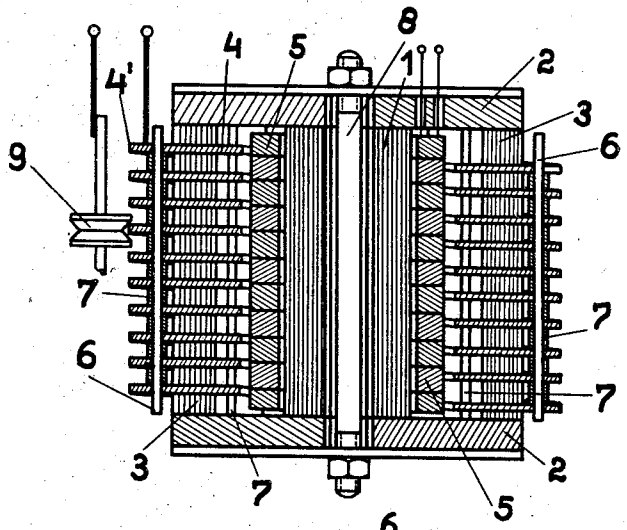


Fig.1b

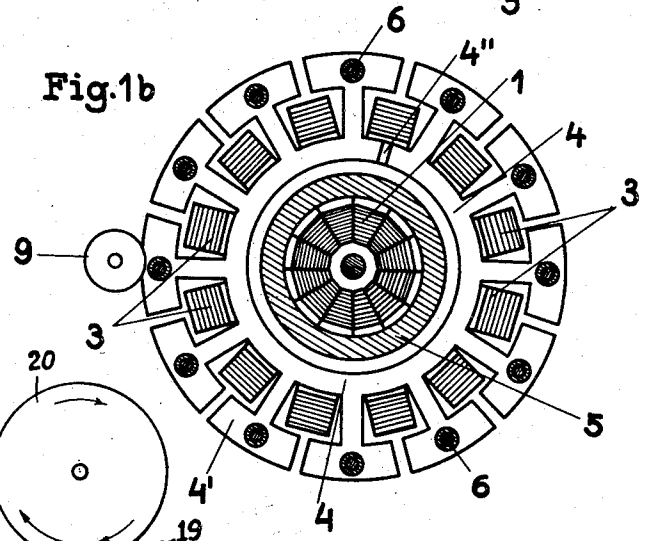
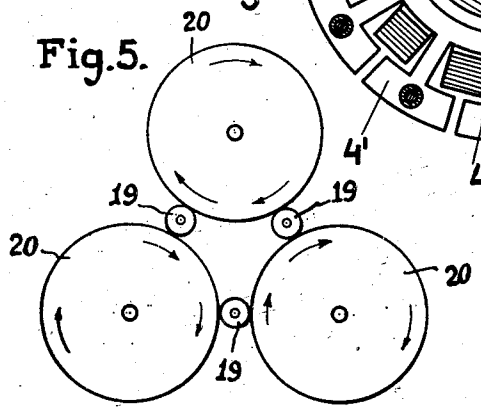


Fig.5.



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REGULATING TRANSFORMER

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Fig. 2

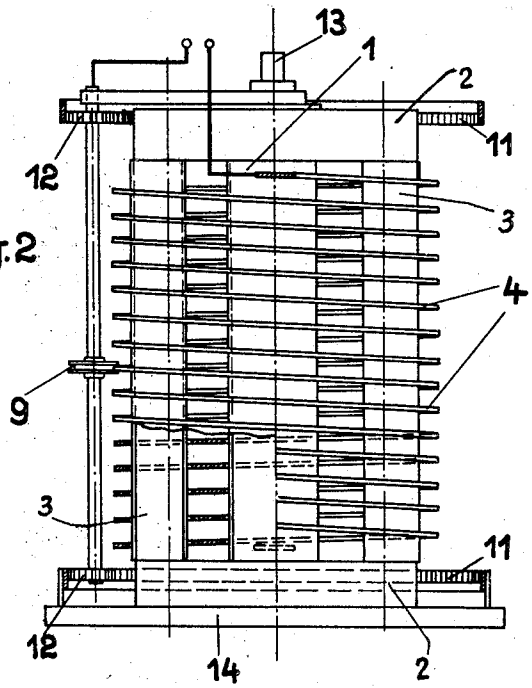

Fig. 2b

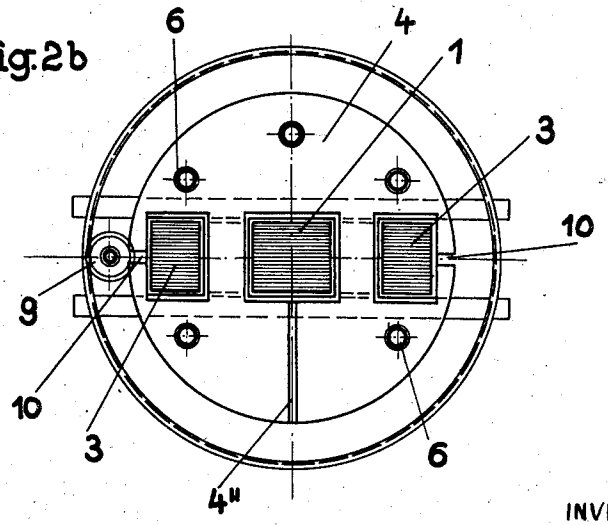

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Fig.3

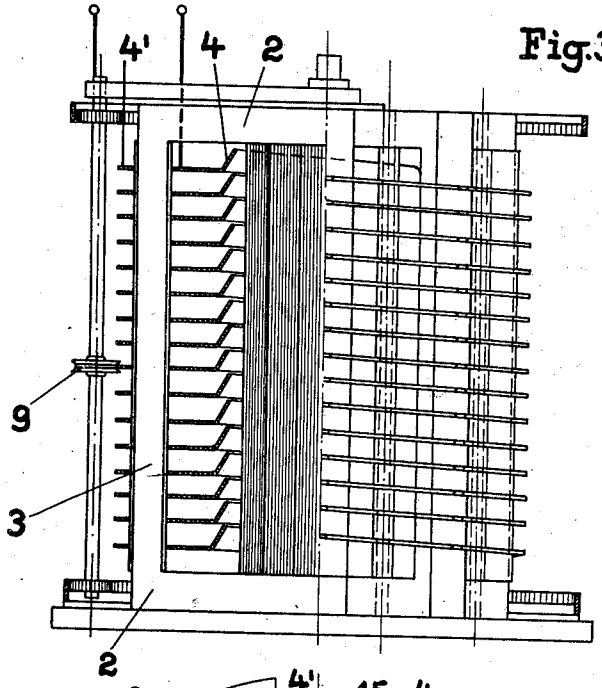
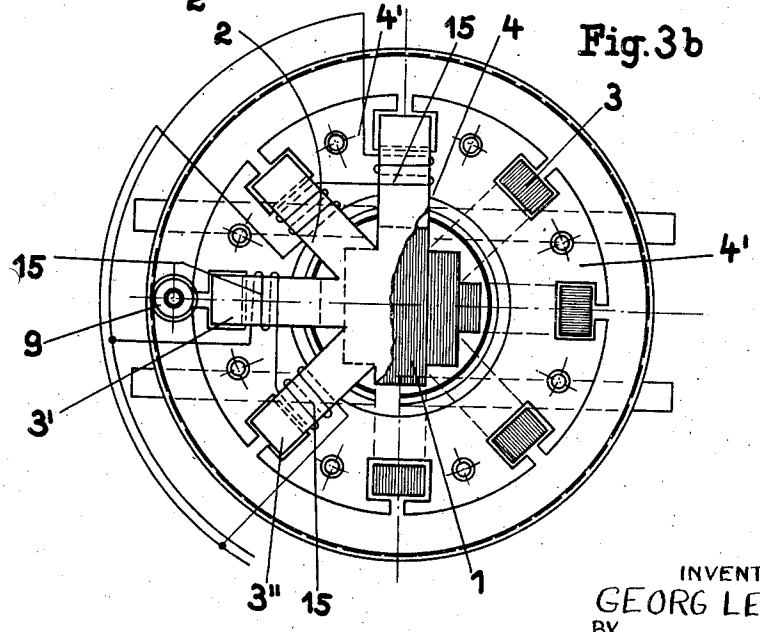


Fig.3b



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REGULATING TRANSFORMER

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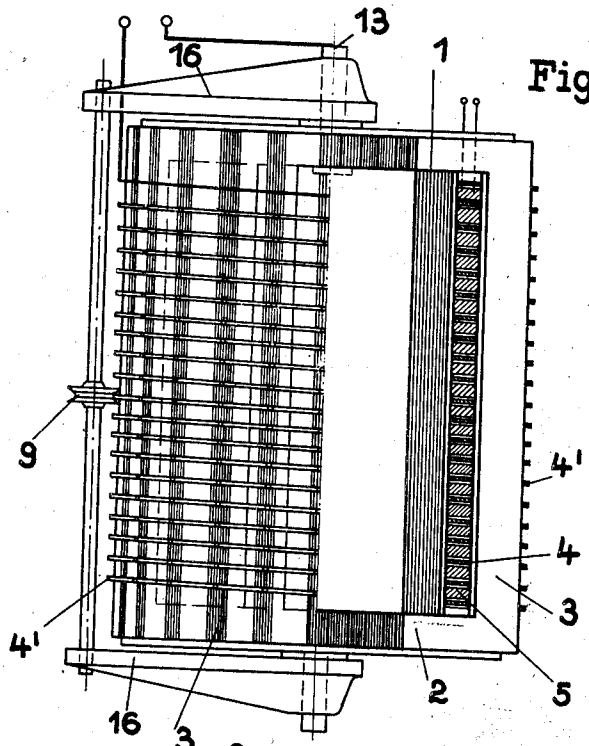

Fig.4

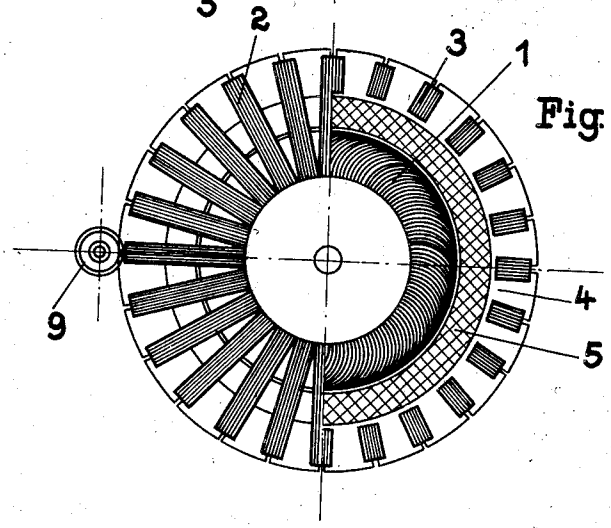

Fig.4b

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UNITED STATES PATENT OFFICE

2,150,382

REGULATING TRANSFORMER

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Application June 11, 1937, Serial No. 147,771
In Germany June 11, 1936

16 Claims. (Cl. 171—119)

The invention relates to a regulating transformer for the practically stepless regulation of potential with a set of brushes rotatable about the core of the transformer or with a rotatable winding.

In the case of the known transformers of this kind, the potential is varied substantially by a jump of an entire turn potential at each complete revolution of the brushes about the core. In order to avoid this potential jump and to produce an at least approximately continuous regulation of potential there has therefore already been provided in combination with the rotatable brushes a potential divider from which the regulated potential can be taken off.

The subject-matter of the invention is a regulating transformer by means of which there can be obtained an increase of the regulated potential that is approximately continuous or as finely graduated as desired without its being necessary to provide special potential dividers. According to the invention the iron core of this transformer is divided, and the regulating winding is applied to the core and, if required, provided with tappings led through between the limbs, for the time being traversed by a part of the exciting flux, so that on the shifting of the regulating brush along the winding the potential is varied by an amount which corresponds to only a fraction of the entire exciting flux and which may be made as small as desired and, consequently, only a fraction of the complete turn potential.

Specially advantageous is the construction of the transformer as a shell-type transformer the shell of which is divided into several separate return paths. The tappings of the regulating winding surrounding the main limb are then advantageously led outwards between these return paths and there formed as a spiral contact path which extends parallel to the regulating winding and along which then slides the brush, which is preferably rotatable about the transformer. In this way the transformer is given an extremely compact and closed form, which is particularly advantageous also as regards leakage losses.

In a particularly preferred constructional example of the invention the several regulating turns with tappings are constructed in the form of annular and slit metal sheets. Each metal sheet is connected at the slit with the succeeding metal sheet in such a manner that there results a helical turn arranged around the main core.

Some constructional examples of the invention are shown in the drawings, in which, Figure 1 is a vertical section through one form of construction embodying my invention; Figure 1b is a horizontal section through the construction shown in Figure 1; Figures 2, 3 and 4 are elevations, partly in section, and Figures 2b, 3b and 4b horizontal sections, respectively, showing three other embodiments of the invention, and Figure 5 is a diagrammatic illustration of a three-phase transformer system constructed in accordance with the invention.

In Figure 1, 1 denotes the core of the regulating transformer, which is in this case surrounded by twelve return paths 3. The laminated core 1 has the form of a hollow cylinder and is composed of separate (twelve) segments (Figure 1b). The connection with the return paths, which are likewise laminated in the direction of the radius, is effected by means of yoke plates 2, which may if required also be laminated. The yoke plates serve at the same time for holding together the entire iron core and are pressed together by means of a spindle 8.

The exciting winding 5 surrounds the core 1 and is in its turn surrounded by the secondary winding (regulating winding). The latter consists of metal discs 4, which are slit at 4'' and are in each case there electrically well connected with the succeeding sheet by welding (preferably by butt welding) or soldering or some other method. The sheets themselves are provided with tappings 4', which widen outwards and each two of which enclose one of the return paths 3. The annular sheet metal discs 4 with the tappings are advantageously stamped out of one and the same sheet, preferably copper or brass sheet, in a single operation.

The bolts 6 and the spacing pieces 7 serve for supporting and holding the several annular sheets, which extend collectively helically around the core. Between the several turns there is a comparatively large interspace through which the air can pass so that a good cooling of the transformer is ensured.

The widenings of the several tappings 4' located outside the core system produce a practically uninterrupted contact path which extends around the shell-type transformer spirally and along which travels the brush 9, which is preferably formed as a roller.

The primary winding 5 is, in the case of the constructional form according to Figure 1, divided into separate coils connected in parallelism (Figure 1a) in order to avoid too great leakage with the winding only partly switched in. This arrangement is specially advantageous in the case of transformers with comparatively long cores.

The coils are advantageously arranged in such a manner that there is always a primary coil in the immediate neighbourhood of a switching turn of the secondary winding. The transformer then behaves as if it consisted of a number of component transformers the primary windings of which are all connected together in parallel and are consequently mutually independent of the condition of loading of the secondary circuit.

The division of the primary cylindrical winding into separate disc coils is advantageous not only for the purpose of reducing the leakage to a minimum but also when it is a question of fixing the leakage to any desired value in accordance with the given conditions. This is essential particularly for welding transformers and also for variable choking coils. In this case special advantages attach to connecting all the coil ends of the primary winding to one terminal board or to a suitable switch for the purpose of connecting the coils of the primary winding according to requirements alternatively in groups, in series or in parallel.

The transformer constructed according to the invention is exceedingly safe as regards short-circuiting, and individual tappings can be short-circuited without difficulty during the regulating operation. In the case of the arrangement represented in Figure 1*b* each contact 4' corresponds to the twelfth part of the turn potential. In that case, where, as shown in the drawings the roller is just passing from one tapping to the other, a short-circuit current must occur. Now this current is itself very small, because it can be produced only by a twelfth part of the turn potential, and it is moreover further reduced owing to the fact that the flux produced by it compensates the exciting flux in the surrounding component limb and deflects it into the other component limbs. In the case of the subject-matter of the invention the flux deflection, owing to suitable dimensioning of the transformer, is advantageously allowed only to such an extent that an injurious increase of the potential drop of the entire regulating winding by the load current is practically avoided, even in the case of nonuniform loading of the transformer. Moreover, a possible small increase of the potential drop dependent on loading does not act injuriously on the total regulating potential curve because the entire transformer consists of a large number of regulating windings which surround the exciting flux and which are regulated successively, and, in addition, when the brush has revolved once around the transformer there is always produced again a symmetrical loading of the component cores.

It is advantageous to make the flux deflection possible when the exciting flux is divided into only a few, or for example two, component fluxes. Such an arrangement is represented in Figure 2. The transformer is in this case constructed as an auto-transformer. The exciting winding consists again of disc-shaped sheets 4 which are threaded over the core 1 and the return paths 3 and which are welded together at their slits 4'' and surround the iron core spirally (Figure 2). The sheets at their edge have gaps 10 (Figure 2*b*) which extend to the return paths 3 and between which there exists in each case half the turn-potential. When in this case the current-collecting brush 9 bridges the gap 10 directly, the half turn-potential in the short circuit surrounding one of the component return paths 3 produces a current. As, however, the corresponding limb 3 is blocked as regards the exciting flux by the short circuit, the short circuit current cannot be of an undue magnitude. In some circumstances it may then be advantageous to make the roller 9 of resistance material for the purpose of limiting the short-circuit current. This is particularly advantageous when deflection of the flux from one of the return paths into the other is to be opposed by a resistance and the short circuit current must consequently be reduced in another way.

Also in the case of the arrangement according to Figure 2, a loading-dependent potential drop at the ends of the regulating winding does not occur injuriously, because the loading of the component limbs and consequently the distribution of the exciting flux are always uniform after a complete revolution of the brush.

The transformer constructed according to the invention presents great advantage when flux deflection is rendered possible inasmuch as special load switches need not be provided in this case, and on the contrary, the current-collecting brush can regulate the load circuit directly.

The regulating operation itself takes place, in the case of the constructional example here represented, by rotating the entire transformer on the base-plate 14, for example, by means of a force applied to the axle 13. Through the toothed ring 11 and the toothed wheels 12 the rotary motion is transmitted to the roller brush 9, which thereupon, moving axially, rolls on the tappings of the secondary winding 4. It is particularly advantageous to arrange for the transformer to be fixed as a whole and the brush 9 only to move, the brush, for example, being fastened to a gallows-like support and moved around the transformer cores and thus shifted axially. As a guiding device for the brush there may serve the correspondingly formed regulating winding or its tappings.

A similar construction, likewise in auto-transformer connection, is shown in Figure 3. The turn potential is in this case divided into eight steps, and the core 1 has eight return paths 3. The core itself is composed of sheet-metal bundles stepped in relation to one another, and has essentially the form of a cross. The several return paths are arranged circularly about the core and have respective yokes 2, with which they are extended over the core 1 (Figure 3). The sheets of the return paths 3 have rectangular projections forming the yokes 2. When the transformer is constructed as two-winding transformers, there may be arranged around the core a special primary winding in a manner similar to that of Figure 1. The annular metal sheets 4 put together to form a spiral are here, as is shown in Figure 3*a*, placed substantially edgewise. The tappings 4', and may be also a larger or smaller annular edge of the sheets, extend substantially horizontally and at right angles to the parts of the sheets that are placed edgewise. This arrangement has the advantage that the distribution of the winding within the transformer is facilitated and that, moreover, the action of the skin effect can be suppressed in a favourable manner.

In order, in the case of this arrangement, when the several flux conductors are ununiformly loaded, to prevent an undue increase of the load-dependent potential drop at the regulating winding, it may be advantageous to arrange equalizing windings on the return paths which offer a resistance to a deflection of the exciting flux from the

loaded component limbs to the unloaded ones. It may be specially advantageous, particularly in the case of transformers for larger power, to apply the equalizing windings in such a manner that whilst a shifting of flux is possible within separate groups of at least two component limbs, flux deflection from these groups to the others is suppressed.

In Figure 3b the arrangement of equalizing windings is represented quite diagrammatically. For the sake of clearness the several coils **15** are shown only on four return paths (in Figure 3 they are omitted altogether). Each two of the equalizing coils **15** are connected in series but these groups of coils are all connected in parallel. The equalizing windings have the effect that the exciting flux must be distributed uniformly over all the groups (each of two component limbs). Within the groups the flux may, however, be shifted as desired. For example, in the case of the position shown of the roller brush **9**, the flux is deflected from the return path **3'** to the return path **3''**. The short-circuit current flowing around this limb **3'** is consequently limited. Conversely, when the tappings on the return path **3''** are short-circuited by the roller brush **9** the flux is deflected from this return path to the return path **3'**. A corresponding statement applies when the roller brush short-circuits the tappings on the other return paths. In the case of a short circuit, consequently, a flux deflection is always possible. On the other hand, in the case of ununiform loading of the regulating transformer, the load current will be able to deflect the exciting flux in each case at most out of one of the return paths **3**, so that an injurious rise of the load-dependent potential drop at the ends of the regulating winding does not occur.

Both the position and also the number of the turns of the equalizing windings is a suitable means for enabling the magnitude of the flux deflection to be adjusted. For example, the equalizing windings on the yokes **2**, will impede the flux shifting less than when the windings are arranged on the return paths **3**.

When the turn potential is divided so finely that in the case of the short-circuiting of separate tappings injurious currents can no longer occur, the possibility of flux deflection may in some circumstances be entirely dispensed with. The transformers of this kind frequently present special advantages because in this case there results an absolutely linearly rising and approximately perfectly continuous regulating-potential curve. A constructional example of this kind is represented in Figure 4. The main core **1** has in this case **24** return paths **3**, and the turn potential is consequently divided into 24 steps. Each return path **3** has its own yoke **2**. The yokes and the return paths are advantageously stamped out of one and the same metal sheet. Instead of the separate yokes **2** there may in some cases be used connected yoke plates of circular-disc form.

The laminated core **1** is formed as a hollow cylinder and the metal sheets are advantageously put together in involute form (Figure 4b). The regulating winding **4** is arranged around the core. The primary winding **5** is again divided into disc coils which are connected in parallel and of which each is located between the metal sheets **4** (Figure 4a). There thus results a particularly compact construction of the transformer. If required in this case also equalizing windings may be arranged on the return paths or on their yokes, and indeed all the coils of this winding are then advantageously connected in parallel so that a deflection of the exciting flux from one return path to the other is practically altogether impossible.

The guiding of the roller brush **9** is effected by means of two arms **16**, which are mounted on the central axle **13** of the transformer and are insulated in relation thereto. In smaller constructions of the transformer one of the arms may in some cases be omitted. It may be advantageous to use two current-collecting brushes and to shift them in opposite directions from the middle of the regulating winding. In the case of transformers in which the primary winding is formed as a cylindrical winding (of coils not connected in parallel), and also in the case of autotransformers, there then results the advantage that the leakage of the transformer is considerably reduced.

The regulating transformer constructed according to the invention, has, further, special advantages as a three-phase current transformer as is quite diagrammatically shown in Figure 5. In that case each part **20** corresponds to a transformer core according to Figures 1–4 for each phase of the three-phase current. The star point of the three-phase current transformer is formed by the contact rollers **19**. The potential regulation is effected by rotating the transformer cores **20** in the direction of the arrows (or in the opposite direction). For the supply of current there is necessary only one conductor for each of the transformer cores **20**. The conductors are connected through slip rings. Conductors to the contact rollers **19** moving along the winding axis may be dispensed with. There thus results a particularly advantageous and simple construction of the arrangement.

What I claim is:—

1. A regulating transformer having an iron core with a main limb and several magnetic return paths connected with the main limb and arranged in spaced relation around the main limb, a regulating winding surrounding the main limb and a current-collecting brush, the regulating winding being provided with tappings, the tappings extending between the return paths to the periphery of the transformer and there forming a helical contact-path which extends parallel to the turns of the regulating winding, and means mounting said brush in contact with said helical contact-path and permitting relative movement between the same.

2. A regulating transformer as recited in claim 1, in which means are provided for moving the current-collecting brush along said helical contact-path around the fixed transformer core.

3. A regulating transformer as recited in claim 1, in which the iron core is rotatable and the current-collecting brush comprises a contact-roller movably mounted on a stationary rod, said brush being responsive to rotation of the iron core to slide along the contact path and to move in the longitudinal direction of the winding.

4. A regulating transformer having an iron core with a main limb and several magnetic return paths connected with the main limb and circularly disposed in spaced relation around the main limb, a regulating winding surrounding the main limb and having tappings which extend between the return paths to the periphery of the transformer and form a helical contact path extending parallel to the turns of the regulating winding, a current collector, and means mounting said current collector for sliding movement along said

contact path, the current collector being constantly in contact with said contact path so that during its movement, before leaving one contact of the contact path, it has already reached the succeeding contact.

5. A regulating transformer having an iron core with a main limb and several magnetic return paths connected with the main limb and circularly disposed in spaced relation around the main limb, a regulating winding surrounding the main limb, and a movable current collector, the regulating winding comprising a helical sheet metal conductor having its turns located one above another and separated from one another by an interspace, each turn of said conductor having a plurality of projections which extend between the return-paths to the periphery of the transformer and there form with their edges a helical contact path, and means mounting said current collector for movement in contact with said helical contact path.

6. A regulating transformer according to claim 5, in which the helical sheet metal conductor forming the regulating winding comprises a plurality of sheet metal coil sections welded together at their abutting ends.

7. A regulating transformer according to claim 5, in which said projections forming the contact path are widened at the periphery of the transformer into segments of which in each case two successive ones approximately completely surround a return-path, the current-collecting brush being so dimensioned that during its movement, before leaving one segment, it has already reached the next.

8. A regulating transformer including an iron core with a main limb and several magnetic return paths connected with the main limb and circularly disposed in spaced relation around the main limb, a regulating winding surrounding the main limb and a movable current-collecting brush, the regulating winding comprising a helical sheet metal conductor having its turns located one over another and being bent at their inner edges substantially rectangularly so that the surface of the sheet at these bends extends approximately parallel to the axis of the core, each turn of said conductor having a plurality of projections on its outer edge which extend between the return-paths to the periphery of the transformer in such a manner that a return-path is located between each two successive ones of these projections, the projections forming with their edges a helical contact-path, and means mounting said current-collecting brush for movement in contact with said helical contact-path.

9. A regulating transformer having an iron core with a main limb and several magnetic return-paths connected with the main limb and circularly disposed in spaced relation about the main limb, an exciting winding, a regulating winding surrounding the main limb, and a movable current-collector, the regulating winding comprising a coiled metal sheet forming a helical winding, said exciting winding lying between the several turns of said metal sheet, each turn of said sheet having a plurality of radial projections which extend between the return paths to the periphery of the transformer and there form with their edges a spiral contact path, and means mounting said current-collector for movement in contact with said spiral path.

10. A regulating transformer comprising an iron core with a main limb and several magnetic return paths arranged in spaced relation around the main limb, an exciting winding, a regulating winding, and a current collector, the exciting winding and the regulating winding each including a plurality of turns located one over the other and surrounding the main limb, the exciting winding consisting of discs connected in parallel, the regulating winding having tappings which extend between the return paths to the periphery of the transformer and there form a spiral contact path which extends parallel to the turns of the regulating winding, and means mounting said current collector for movement in contact with said spiral contact path.

11. A regulating transformer comprising an iron core with a main limb and several magnetic return paths circularly disposed in spaced relation around the main limb, a regulating winding surrounding the main limb, and an equalizing winding located on the return paths, the regulating winding being provided with tappings which extend outwardly between the return paths to the periphery of the transformer and there form a helical contact-path which extends parallel to the turns of the regulating winding and along which may slide a current-collector.

12. A regulating transformer according to claim 11, in which the equalizing winding includes separate turns, one on each return path of the iron core; the total number of the turns being divided into groups of at least two turns, with the coils of each group connected in series and the several groups of turns placed in parallel with one another.

13. A regulating transformer comprising an iron core with a main limb and several magnetic return paths circularly disposed in spaced relation around the main limb, a regulating winding surrounding the main core, and a movable current-collector, the main limb of the iron core including a plurality of laminated sheets forming a core of cruciform cross-section, the return paths including laminated metal sheets, the regulating winding having a plurality of tappings which extend between said laminated return paths to the periphery of the transformer and there form a spiral contact-path which extends parallel to the turns of the regulating winding, and means mounting said current-collector for movement in contact with said spiral contact path.

14. A regulating transformer having an iron core, composed of laminated sheets, including a main limb and several magnetic return paths circularly disposed in spaced relation around the main limb, the main limb being formed tubularly and being composed of sheets bent into involute form, a regulating winding surrounding the main limb, the regulating winding being provided with tappings which extend between the return paths to the periphery of the transformer and there form a helical contact path which extends parallel to the turns of the regulating winding and along which may slide a current-collector.

15. A three-phase regulating transformer comprising three single-phase transformers, each single-phase transformer comprising an iron core having a main limb and several magnetic return paths arranged in spaced relation around the main limb and a regulating winding surrounding the main limb, the regulating winding having tappings which extend between the return paths to the periphery of the transformer and there form a spiral contact path extending parallel to the turns of the regulating winding, means mounting said three single-phase transformers for rotation about their respective axes, three current-collect-

ing brushes in the form of contact rollers each of which is located between two of the single-phase transformers and in contact with the said contact paths of these two transformers simultaneously, and means mounting the contact rollers for movement in the axial direction of the windings, the contact rollers forming together the star point of the three-phase transformer.

16. A regulating transformer as recited in claim 1, said mounting means comprising a rotatable shaft centralized with respect to said core, at least one arm secured to said shaft and extending radially therefrom, and means connecting said brush with said arm whereby to move the brush in contact with and along said spiral contact path upon rotation of said shaft.

GEORG LEISCHNER.

CERTIFICATE OF CORRECTION.

Patent No. 2,150,382. March 14, 1939.

GEORG LEISCHNER.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 4, first column, line 72, claim 9, after the word "spiral" insert contact; same page, second column, line 30, claim 12, for "coils" read turns; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 15th day of August, A. D. 1939.

Leslie Frazer

Acting Commissioner of Patents.

(Seal)