

July 4, 1933.

C. SCHRADER ET AL

1,916,588

POWER TRANSFORMER AND MORE PARTICULARLY TO TRANSFORMERS
AND REACTORS FOR EXTRA HIGH VOLTAGE CURRENTS

Filed Nov. 9, 1931

5 Sheets-Sheet 1

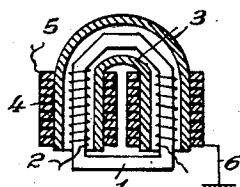


Fig. 1

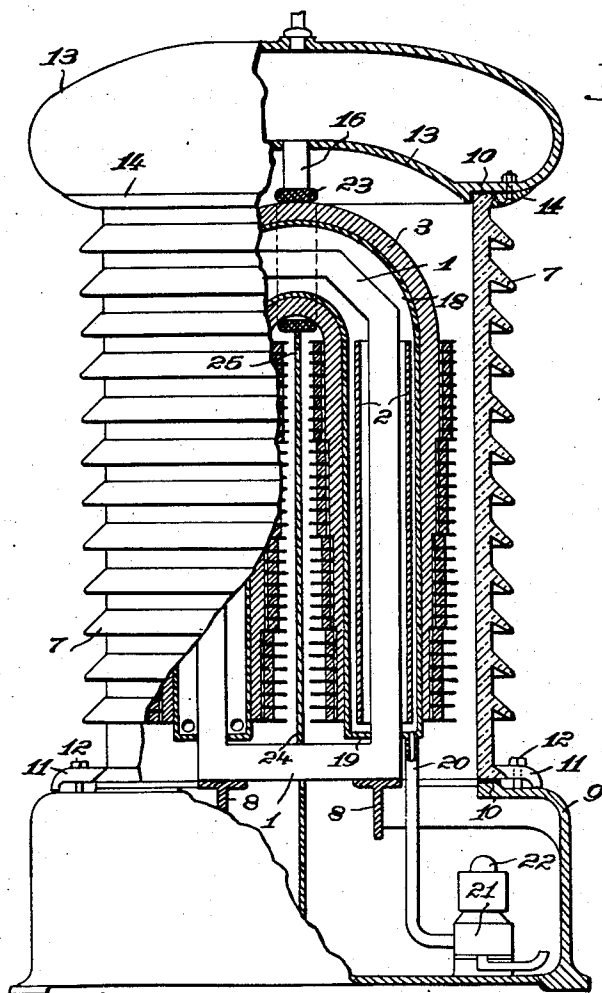


Fig. 2

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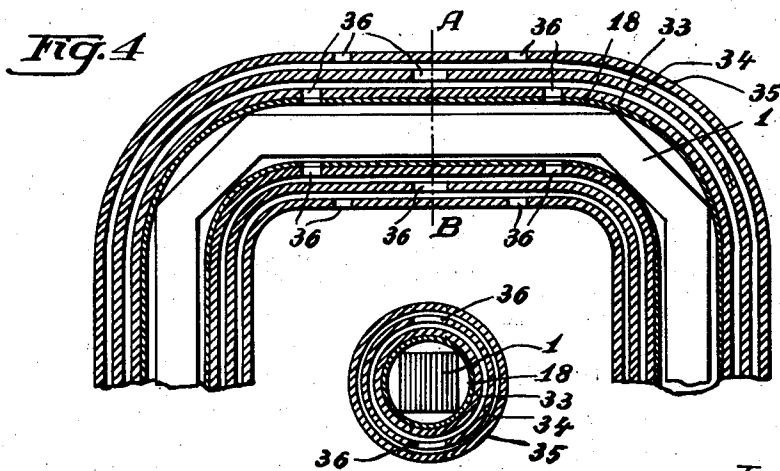
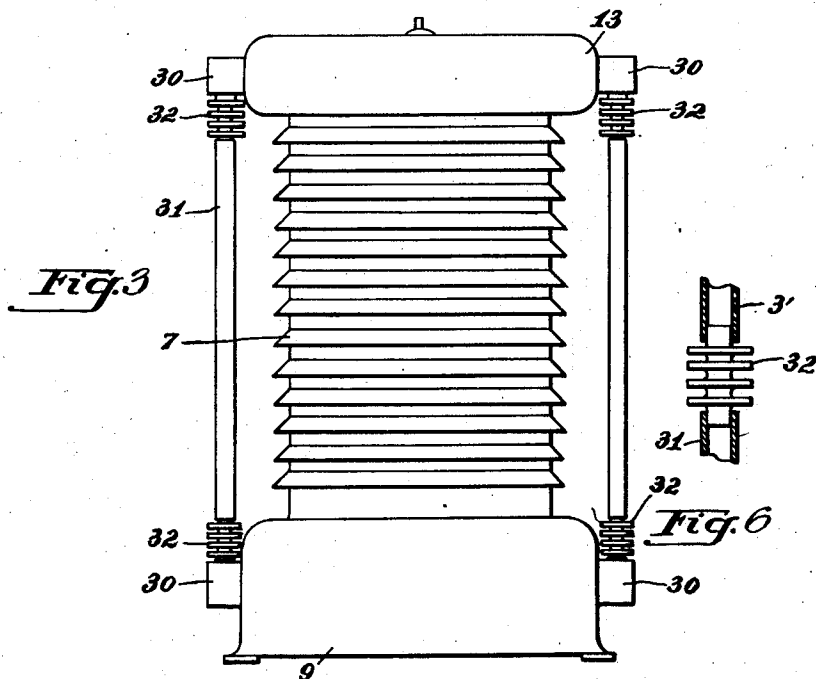
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5 Sheets-Sheet 2



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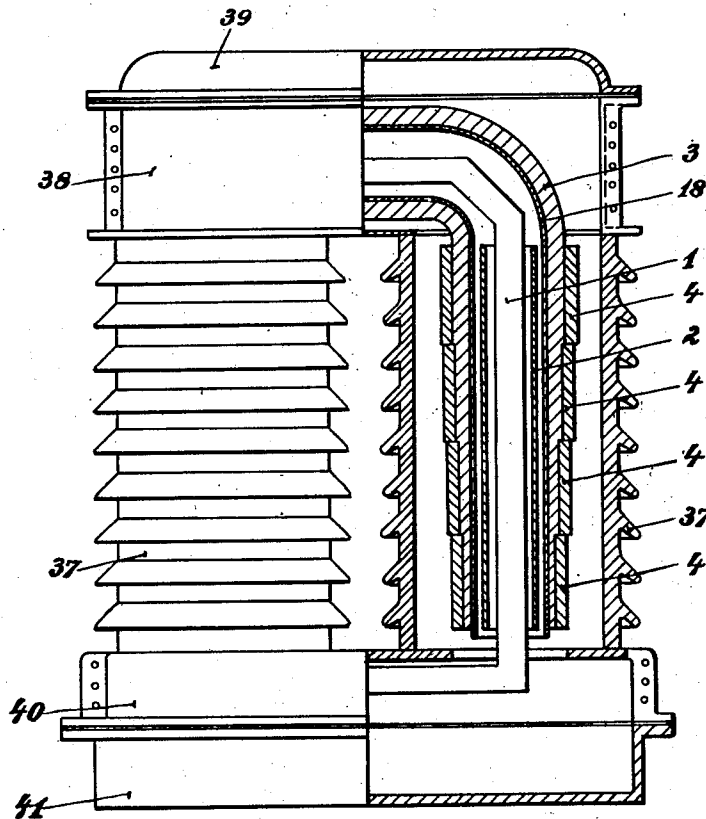
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5 Sheets-Sheet 3

Fig. 7



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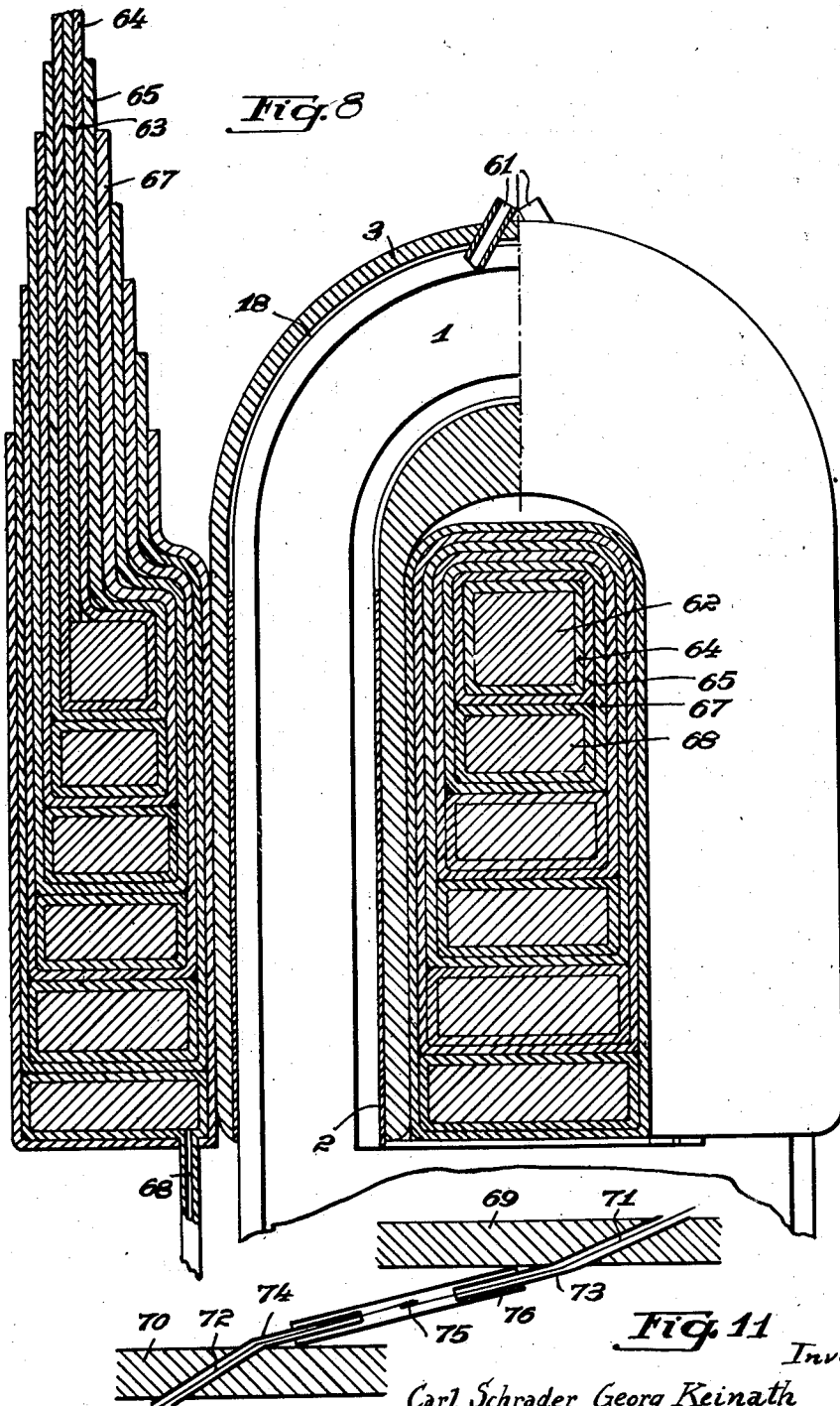
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5 Sheets-Sheet 4



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Fig. 9

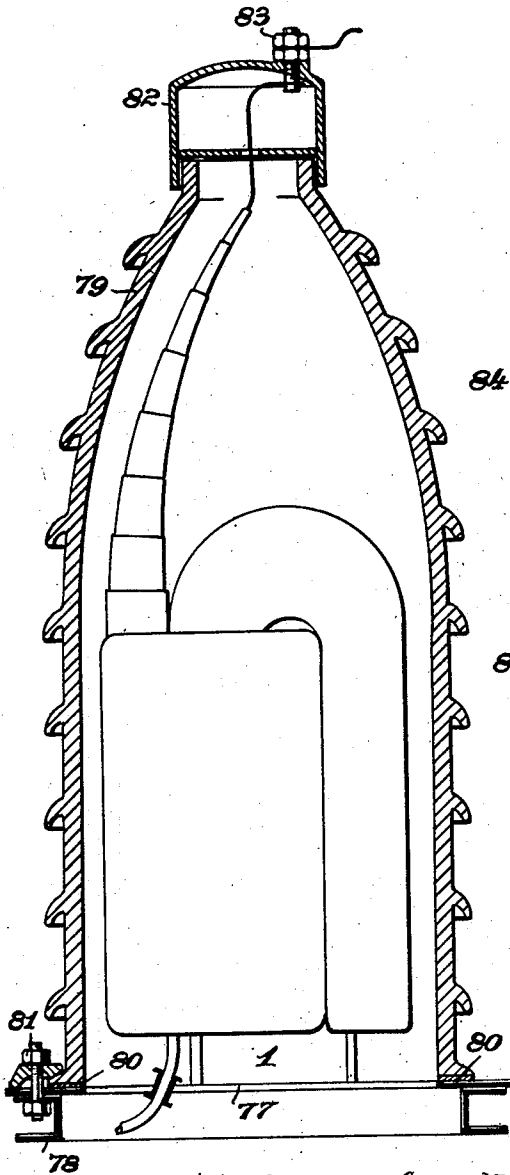
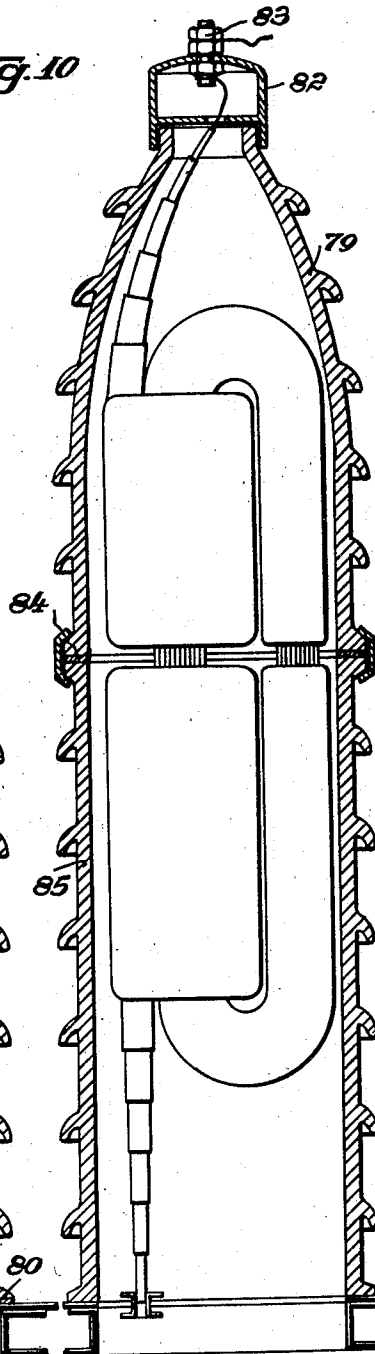


Fig. 10



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UNITED STATES PATENT OFFICE

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POWER TRANSFORMER AND MORE PARTICULARLY TO TRANSFORMERS AND REACTORS
FOR EXTRA-HIGH VOLTAGE CURRENTS

Application filed November 9, 1931, Serial No. 573,740, and in Germany November 12, 1930.

Our invention relates to power transformers, and more particularly to transformers and reactors for extra-high voltage currents. Hitherto it has been customary to subdivide such transformers into a plurality of stages or steps, in order to overcome insulation difficulties.

The object of our invention is to provide a power transformer of comparatively small proportions able to transform very high voltages in a single step or stage, and thus with a single iron core. Our invention consists in providing means each of which by itself permits of an increase in the service voltage beyond values permissible today, and which in their combination render possible an increase hitherto considered impossible in the voltages which a single transformer is able to handle.

An important feature or means employed to this end according to our invention consists in enclosing all the legs of the cores and one of the yokes which connect such legs, in an insulating envelope, so that only one of these yokes is clear of such insulating envelope. On this envelope the high tension winding or coil is arranged in such a manner that the voltage will diminish toward that yoke which has been left clear or exposed as stated.

Another feature or means relates to an improvement in the insulation of the high tension winding and consists in making said winding of a plurality of disc coils in axial succession, and in providing insulating envelopes which enclose each other and said coils, said envelopes being graded in such a manner that, as regards the individual disc coils, the number of the insulating envelopes enclosing such coils will increase with an increase of the voltage between the respective coils and the iron core. This arrangement of the insulation is indeed of advantage only when the amount of heat to be dissipated from the high tension winding is kept within certain limits, as is the case, for instance, with measuring transformers.

Three typical and satisfactory embodiments of our invention are illustrated by the accompanying drawings, in which

Fig. 1 is a longitudinal section through our improved transformer, in diagrammatic representation;

Fig. 2 shows a transformer of the design shown in Fig. 1 in greater detail, with parts in section;

Fig. 3 is a side elevation of a transformer having a particularly efficient cooling system; Fig. 4 is an enlarged vertical section through the core of the transformer shown in Fig. 3; Fig. 5 is a cross section through a portion connecting the legs of the transformer core; Fig. 6 is a vertical section showing one of the joints of the cooling pipes; Fig. 7 is a vertical section through a transformer each leg of which is enclosed in a separate insulator; Fig. 8 shows the active portion of a voltage transformer, the left hand half of the core with the coils thereon being shown in section and the right hand half of the core being shown in elevation; Figs. 9 and 10 are vertical sections illustrating complete transformers the active parts of which are built up according to Fig. 8, and Fig. 11 is a detail view illustrating the way in which the disc coils of the transformers are preferably connected with one another.

Like parts are indicated by like reference numerals throughout all the figures of the drawings.

Referring to Fig. 1 of the drawings, 1 is the iron core of the transformer on the legs of which is directly mounted the secondary or low tension winding 2. The core 1 is provided with a U-shaped insulating envelope or insulator 3, which surrounds or encloses both legs and the upper yoke of the iron core 1, while the lower yoke is clear or exposed. On the legs of this insulating envelope 3 is slipped the primary or high tension winding 4 consisting of disc coils stacked in axial succession. 5 is the high tension terminal of the primary winding which is connected with the core and grounded at 6. The disc coils on the two legs of the insulator are alternately connected to each other. The disc coils located next to the open ends of the insulator or insulating enclosure 3 thus have the lowest potential to the core, while the disc coils carrying the highest potential

relatively to the core are farthest away from the open ends of the insulator 3. Instead of connecting the coils upon the legs of the insulator in series, the coils on the individual legs may also be connected in parallel, it being understood that a correspondingly thinner wire and double the number of turns is then required. It is furthermore not necessary that both legs should carry windings, and one leg may be left without a winding, and the secondary winding as well as the primary winding may be mounted on one leg only. The insulator or insulating envelope is not changed thereby in any way.

The parts described above are housed within an insulating tubular case or tank 7 (Fig. 2). This tank is directly supported on two ribs 8 of the metal base 9 and may be secured to them by means of suitable angle irons, for example. The base 9 serves at the same time as an oil-tight seal for the tubular tank or case 7. The seal is effected by means of two annular surfaces on the two parts to be joined between which is placed a suitable packing 10 and which are firmly pressed together by clamps 11 and bolts 12. At the top the tank 7 is closed by a preferably dome-shaped metal cover 13. A tight seal is again obtained in a similar manner as at the base 9 by means of packing rings 10, but instead of the individual clamps 11 a split metal ring 14 is used. The cover 13 also serves as oil conservator or expansion vessel and is by a bore of the tubular extension 16 in communication with the interior of the tank or case 7. On both legs of the transformer core 1 is mounted the secondary winding 2 in such a way, that it is wound upon an insulating tube and this tube is then pushed over the core. A solid bushing or sleeve 18 is then placed over the core with the secondary winding, and preferably consists of a plurality of parts. This bushing may consist of metal and must in this case be split to avoid the formation of a short-circuit winding. The gap in the bushing may then be filled with a suitable dielectric material. The bushing 18 is preferably grounded or electrically connected to the part of the primary winding carrying the lowest potential, or to the secondary winding. The solid bushing 18 serves as a foundation or support for the insulating envelope 3, which may, for instance, consist of paper tapes wound on said bushing. This bushing 18, also serves for guiding the current of oil along the core and the secondary winding. For this purpose at least one end of the bushing is closed by a cover 19 from which an oil supply pipe 20 leads to an oil pump 21. The motor 22 of the oil pump 21 is preferably directly fed from the transformer. In this way greatest service reliability is attained, as the motor starts automatically as soon as the transformer is load-

ed. For feeding the motor either a special secondary low tension winding may be provided, or the motor could be supplied from the existing secondary low tension winding. The arrangement of the motor in the interior of the oil tank has the advantage that the entry of air into the oil circulation is effectively avoided. To keep leakage as low as possible, the insulating envelope 3 is repeatedly stepped towards its open end, so that the thickness of the insulation corresponds with the high tension potential at each particular point.

The high-tension side of the primary voltage coil is connected to a split ring 23 strongly rounded along the edges and consisting of brass, for instance, and which embraces the midportion of the insulating envelope 3, at the same time serving as a supporting member, particularly during the assembly of the transformer. For this purpose the ring is provided with the extension 16 which can also be employed for bracing the core against the cover 13. This ring 23 is connected to the primary line through the cover 13. A partition wall 24 consisting of insulating material, divides the tank into two compartments each of which contains one leg of the transformer. Openings 25 place the two compartments in communication. The partition wall serves for guiding the current of oil which is conveyed into the interior of the insulating envelope 3 by the oil pump 21 through the pipe 20 and there absorbs the heat of the core and the secondary winding. At the end of the insulating envelope 2 opposite the oil inlet the oil passes into the left-hand outer compartment, is by the aid of the partition wall 24 conducted upwards along the primary winding, absorbs the heat of the winding and passes through the opening 25 into the right-hand compartment in which it descends, while absorbing the heat generated in the right-hand side primary winding.

In Figs. 3 to 6 we have disclosed a particularly suitable manner of cooling the transformer by means of oil. The transformer, the interior design of which may be identical with the construction shown in Fig. 2, is enclosed by an insulator or tank 7 which at the bottom terminates into a base 9 and at the top in a cap or dome 13. The base 9 and the top 13 consist of metal and are according to our invention provided with lateral extensions or lugs 30 into which porcelain tubes 31 are adapted to be inserted in an oil-tight manner. Preferably the extensions 30 are so designed that straight porcelain tubes 31 may be employed since these are substantially cheaper in manufacture than bent tubes. Bent tubes, however, have the advantage of larger cooling areas, and are for this reason sometimes employed. To relieve the fragile insulating tubes as far as possible of mechanical stresses, elastic intermediate tubular

members 32 are arranged between their ends and the extensions 30, for example in the manner shown in Fig. 6. The guidance of the current of oil in the interior of the transformer tank or case varies within wide limits in accordance with the construction possibilities and the necessary heat discharge. A preferred design consists in forcing the oil in the open end of the insulating tube by means of a pump, allowing it to escape at the other open end of the insulating tube at the same height, conducting it along the primary coils of the transformer through the tank upward, and finally exposing it in the tubes 31 to the action of the cool outer air.

If comparatively small quantities of heat have to be discharged, as for instance in the case of instrument transformers, the oil pump may under certain conditions also be omitted, particularly if care is taken that the direction of the current of oil within the tank or case 7 is always upwards. For this purpose the insulating substantially U-shaped envelope may in its upper portion be provided with one or a plurality of outlet openings for the oil, so that the oil may enter the two open lower ends of the insulating envelope and leave it through the openings at the top. If the insulating envelope consists of a plurality of spaced concentric envelopes all the envelopes must be provided with openings in their upper parts. These openings are preferably displaced in relation to one another or staggered. An example of this is shown in Figs. 4 and 5. 1 is the core of the transformer which is surrounded by a split metallic envelope 18. 33, 34 and 35 are three further concentric insulating envelopes spaced apart so that an ample current of oil is able to pass through between them. In all the insulating envelopes are provided outlet openings through which the oil from the interior of the tube can issue. By tuning the areas of the openings in relation to one another the current of oil may be distributed in the desired ratio over the available parallel passages. In this arrangement it will as a rule be possible to dispense with an oil pump, as the temperature difference of the oil in the interior of the transformer and descending in the tubes 31 already ensures a sufficient circulation velocity. In special cases an oil pump may, of course, be provided in this design also.

In some cases it may be preferred to subdivide the isolating case or tank, to enable cases or tanks of smaller internal diameters to be employed, and also to reduce the contents of oil. A design of this kind is shown in Fig. 7 which represents a transformer each of the legs of which is enclosed in a separate tank or case. The right-hand side half of the transformer is here shown in cross-section, and the identical left-hand side in elevation. 1 is again the iron core of the

transformer, 2 is the secondary winding directly surrounding the core, 18 is a split metallic envelope or circular shield upon which is placed the high-tension insulation 3 tapering towards the ends, 4 is the primary winding, 37 the insulating tanks or cases in which are accommodated the vertical parallel legs of the transformer carrying the windings. The upper part of the transformer is formed by a cap rigidly connected with the insulating cases and consisting of two shells 38 with a cover 39. The two halves of the shell 38 abut against each other in the plane of the core and are electrically insulated against each other by an interposed layer of a dielectric. The cover 39 is likewise insulated against the two parts of the shell 38 by interpositional of an insulator. The base or socket of the transformer is constructed in a similar manner. This base also consists of two shell portions 40, which are designed similar to the shell portions 38 of the cap or dome and joined together in like manner, and a base-plate 41 which is likewise connected with the two shell portions 40 through the intermediary of a dielectric layer.

Connection of the transformer to the primary supply may preferably be effected in such a way that the primary winding is, for instance, electrically connected with the cap 39 and that a suitable terminal is mounted on this cap. The shell portions 38 may be electrically connected to the cap 39 across resistances, so dimensioned that substantial eddy currents are unable to develop. In the same manner the shell portions 40 of the socket or base may be connected to the bottom of the socket 41 across resistances. The secondary winding is passed outward in the usual manner through insulated bushings in the bottom 41 of the transformer.

The interior of the insulating tank or case 37 and the case consisting of the parts 38 and 39, or 40 and 41 respectively, is preferably filled with oil. In addition to the substantial advantage that the insulating tanks or cases 37 are greatly reduced in diameter in comparison with a single case or tank enclosing both legs of the transformer, the further advantage is obtained that the quantity of oil for filling is considerably smaller than in the case of a tank common to both transformer legs. It is absolutely necessary to accommodate the entire transformer in an oil tank or case.

Referring to Fig. 8, 1 is again the iron core built up of laminations and preferably of cross-shape approximating a circular cross-section, to facilitate the mounting of the insulating envelope. Around this iron core is wound the secondary winding 2, a dielectric shield or layer being placed between the two parts. Then the iron core together with the secondary winding is en-

closed by a longitudinally slit conducting metal layer 18.

To the sheet metal envelope 18 is applied an insulating envelope 3, preferably consisting of paper tape. 61 are tubes of insulating material, which traverse the sheet metal envelope 18 and the insulating envelope 3, and which put the channels formed along the core in consequence of the cross-shape of the core, in communication with the outer air. Their object is (when the transformer has an oil filling) to bring about a circulation of the oil along the core favorable for the discharge of heat. The primary winding is subdivided into a plurality of disc coils. For the sake of clearness only six such disc coils are shown in the drawings. In actual use this number will be greatly exceeded. The manufacture takes place in such a way that the disc coil 62, which carries the high-tension terminal 63 and contains substantially the safety windings of stout wire, is first enclosed by two insulating envelopes 64 and 65. Both insulating envelopes also extend to the high-tension leading-out wire 63. Then the adjacent coil 66 is first by itself enclosed by an insulating envelope and then together with the coil 62 by an insulating envelope 67, which likewise extends to the high-tension leading out wire. In the same manner all the subsequent coils are first insulated individually and then together with the preceding ones enclosed by an insulating envelope, the latter envelopes all extending to the high-tension leading out wire. The connecting lead 68 from the lowest coil is grounded.

The individual insulating envelopes are preferably constructed of insulating material in the form of strips or tape, more particularly paper strip or tape, because it is thus possible to follow most closely the shape of the coils to be enveloped.

The connection of the individual coils amongst themselves is illustrated in Fig. 11. Referring to this figure 69 and 70 are insulating envelopes enclosing two adjacent disc coils. 71 and 72 are the wire ends leading out of these disc coils. These ends are passed through paper tubes 73 and 74 traversing the insulating envelopes. They are connected with each other at the points 75, and around this place 75 is rolled a further paper tube 76 which also encloses the ends of the paper tubes 73 and 74 projecting from the insulating envelopes 69 and 70. After the tube 76 has been applied, the coils can be firmly pressed together. Preferably an adequate space for the reception of the connecting lead located between the coils is left between the coils, for instance by inserting intermediate discs of fibre provided with recesses for containing the connecting lead.

In Fig. 9 of the drawings a complete transformer is shown, with its casing in vertical

section. The core 1 of the transformer is by means of its lower transverse yoke mounted on a base plate 77, preferably constructed of sheet iron, and reinforced by an U-shaped ring 78. Over the transformer is placed an insulator 79 of the pedestal type which is sealed against the bottom plate 77 by holding down screws 81, a packing ring 80 being interposed between insulator and base plate.

Through the bottom plate 77 are in an oil-tight manner passed the leading-in leads of the secondary (low-tension) winding and the ground wire of the primary high-tension winding. At the top the insulator 77 is closed by a cap 82 which carries the high-tension terminal 83 and at the same time serves as an oil conservator or expansion chamber for the oil filling of the transformer. The insulation of the conducting parts of the transformer according to our invention permits of accommodating the transformer in a container which only has a height just sufficient for the service voltage. The transformer thus becomes not only very cheap, but it can also easily be shipped in the assembled state and installed in existing plants without changing the direction of the line because such transformer may simply take the place of a standard pedestal-type or bushing-type insulator, which in its turn can take the place of a removed transformer.

The embodiments described above start with an iron core at ground potential, i. e. an iron core whose potential corresponds with that of one of the wires leading out from the primary winding. Our invention may, however, also be used to advantage in such cases in which the core is given a potential which approximately corresponds with the medium potential of the primary winding, in order to save in insulation. An embodiment of this nature is shown in Fig. 10. Here the transformer consists of two U-shaped iron cores which to start with are each separately provided with an insulating envelope and a primary winding, and which are only subsequently combined in the manner shown, the connecting lead of the two primary windings being also brought into electric connection with the iron core. Both high-tension (primary) windings are constructed in such a manner that their portions nearest the core yokes will have the thickest insulation, while the portions nearest the center will have the thinnest insulation. Furthermore the low-tension (secondary) winding is insulated relatively to the core sufficiently to take care of a voltage equal to one-half of the primary (high-tension) voltage. For this purpose, we prefer to employ a wrapping corresponding to the one described in connection with the high-tension insulation, with this difference, however, that a subdivision of the low-tension winding into several coils is not necessary. All connections or leads of the coils

are constructed in the same manner as shown in Fig. 3 with reference to the line supplying the high-tension voltage. There would thus be provided one coil lead for supplying the high-tension, and three outgoing leads, of which one serves for grounding the high-tension winding, while the other two belong to the low-tension winding.

The construction of the transformer will be readily understood on referring to Fig. 10. The active parts are carried by a metal plate 84 which must be so designed that it does not form a short-circuit winding for the core. It is sufficient for this purpose if a recess is provided in the plate between the two legs of the transformer. This plate is supported by a tubular insulator 85, which may be mounted on a baseplate in the manner shown in Fig. 9. Over the upper half of the transformer is again placed an insulator 79 like an ordinary line supporting insulator, which is closed at the top by a cap 82 with terminal 83 and leading-in wire for the primary voltage.

Any suitable means may be employed for bracing the two insulating members relatively to the plate 84. This transformer is preferably again filled with oil.

An advantage of the embodiment of our invention illustrated in Fig. 10 resides in the fact that the potential along the insulating body is controlled by the plate 84 maintained at a medium potential and preferably electrically connected to the preferably annular parts holding the insulating members together. Above all it is easily possible to use the transformer for two voltage ranges, by leading lower voltages directly across the plate 84 only to one half of the primary winding.

We claim as our invention:

1. An iron core with completely closed magnetic circuit, said core having a plurality of legs and two yokes connecting them, an insulating envelope enclosing all of said legs and one of said yokes, and a voltage winding located upon said insulating envelope and having a potential which drops toward that yoke which is clear of said insulating envelope.

2. An iron core with completely closed magnetic circuit, said core including two legs and two yokes connecting them, a low-tension winding on said core, an insulating envelope enclosing said winding and said core with the exception of one of said yokes, and a high-tension winding located upon said insulating envelope and having a potential which drops toward the yoke which is clear of said insulating envelope.

3. An iron core with completely closed magnetic circuit, said core having a plurality of legs and two yokes connecting them, an insulating envelope enclosing all of said legs and one of said yokes, a longitudinally-interrupted conducting bushing forming an

interior lining for said insulating envelope, and a voltage winding located upon said insulating envelope and having a potential which drops toward that yoke which is clear of said insulating envelope.

4. An iron core with completely closed magnetic circuit, said core including a yoke, a low-tension winding on said core, an insulating envelope enclosing said winding and said core with the exception of said yoke, a longitudinally-interrupted conducting bushing forming an interior lining for said insulating envelope, and a high-tension winding located upon said insulating envelope and having a potential which drops toward the yoke which is clear of said insulating envelope.

5. An iron core with completely closed magnetic circuit, said core having a plurality of legs and yokes connecting them, an insulating envelope enclosing said legs and one of said yokes, said envelope having open ends and diminishing in thickness toward such open ends, a longitudinally-interrupted conducting bushing forming an interior lining for said insulating envelope, and a voltage winding located upon said insulating envelope and having a potential which drops toward the open ends of said envelope.

6. An iron core with completely closed magnetic circuit, said core including a yoke, a low-tension winding on said core, an insulating envelope enclosing said winding and said core with the exception of said yoke, said envelope having open ends and diminishing in thickness toward such open ends, a longitudinally-interrupted conducting bushing forming an interior lining for said insulating envelope, and a high-tension winding located upon said insulating envelope and having a potential which drops toward the yoke which is clear of the insulating envelope.

7. An iron core with completely closed magnetic circuit, said core having a plurality of legs and yokes connecting them, an insulating envelope enclosing said legs and one of said yokes, said envelope having open ends and being spaced from said iron core so as to provide a passage for a stream of a cooling medium, and a voltage winding located upon said insulating envelope and having a potential which drops toward the open ends of said envelope.

8. An iron core with completely closed magnetic circuit, said core including a yoke, a low-tension winding on said core, an insulating envelope enclosing said winding and said core with the exception of said yoke, said envelope having open ends and being spaced from said iron core so as to provide a passage for a stream of a cooling medium, and a high-tension winding located upon said insulating envelope and having a potential

which drops toward the open ends of said envelope.

9. An iron core with completely closed magnetic circuit, said core having a plurality of legs and yokes connecting them, a longitudinally-interrupted metallic envelope enclosing the legs and one yoke of said iron core, an envelope of insulating material enclosing said metallic envelope and having open ends, and a voltage winding located upon said insulating envelope and having a potential which drops toward the open ends of said envelope.

10. An iron core with completely closed magnetic circuit, said core including a yoke, a low-tension winding located on said iron core, an envelope of insulating material enclosing said low-tension winding and said core with the exception of said yoke, said envelope having open ends, and a high-tension winding located upon said insulating envelope and having a potential which drops toward the open ends of said envelope.

11. An iron core with completely closed magnetic circuit, said core having a plurality of legs and yokes connecting them, a longitudinally-interrupted metallic envelope enclosing the legs and one yoke of said iron core, an envelope of insulating material enclosing said metallic envelope and having open ends, a voltage winding located upon said insulating envelope and having a potential which drops toward the open ends of said envelope, an insulating casing enclosing all of the above-mentioned parts, and open at the top and at the bottom, and members for closing the open upper and lower ends of said casing.

12. An iron core with completely closed magnetic circuit, said core including a yoke, a low-tension winding located on said iron core, an envelope of insulating material enclosing said low-tension winding and said core with the exception of said yoke, said envelope having open ends, a high-tension winding located upon said insulating envelope and having a potential which drops toward the open ends of said envelope, an insulating casing enclosing all of the above-mentioned parts and open at the top and at the bottom, and members for closing the open upper and lower ends of said casing.

13. An iron core with completely closed magnetic circuit, said core having a plurality of legs and yokes connecting them, a metallic envelope enclosing said legs and one of said yokes, an envelope of insulating material enclosing said metallic envelope and having open ends, a voltage winding located upon said insulating envelope and having a potential which drops toward said open ends, an insulating casing enclosing all of the above-mentioned parts and open at the top and at the bottom, members for closing the open

upper and lower ends of said casing, and a filling of insulating liquid in said casing.

14. An iron core with completely closed magnetic circuit, said core including a yoke, a low-tension winding on said core, a U-shaped metallic envelope enclosing said low-tension winding and said core with the exception of said yoke, an envelope of insulating material enclosing said metallic envelope and having open ends, a high-tension winding located upon said insulating envelope and having a potential which drops toward said open ends, an insulating casing enclosing all of the above-mentioned parts and open at the top and at the bottom, members for closing the open upper and lower ends of said casing, and a filling of insulating liquid in said casing.

15. An iron core with completely closed magnetic circuit, a voltage winding surrounding said core and subdivided into a plurality of disc coils in axial sequence, and a plurality of insulating envelopes completely enclosing each other and said coils and graded stepwise in such a manner that, with respect to the individual disc coils, the number of insulating envelopes enclosing such coils will increase as the potential relatively to the iron core increases.

16. An iron core with completely closed magnetic circuit, said core having a plurality of legs and yokes connecting them, an insulating envelope enclosing said legs and one of said yokes, a voltage winding surrounding said insulating envelope and subdivided into a plurality of disc coils in axial sequence, and a plurality of insulating envelopes completely enclosing each other and said coils and graded stepwise in such a manner that, with respect to the individual disc coils, the number of insulating envelopes enclosing such coils will increase as the potential relatively to the iron core increases.

17. An iron core with completely closed magnetic circuit, a low-tension winding surrounding said core, a high-tension winding surrounding said low-tension winding and said core, and subdivided into a plurality of disc coils in axial sequence, and a plurality of insulating envelopes completely enclosing each other and said coils and graded stepwise in such a manner that, with respect to the individual disc coils, the number of insulating envelopes enclosing such coils will increase as the potential relatively to the iron core increases.

18. An iron core with completely closed magnetic circuit, said core including a yoke, a low-tension winding located on said core, an insulating envelope enclosing said low-tension winding and said core with the exception of said yoke, a high-tension winding located upon said insulating envelope and subdivided into a plurality of disc coils in axial sequence, and a plurality of insulating

envelopes completely enclosing each other and said coils and graded stepwise in such a manner that, with respect to the individual disc coils, the number of insulating envelopes enclosing such coils will increase as the potential relatively to the iron core increases.

19. An iron core with completely closed magnetic circuit, a voltage winding surrounding said core and subdivided into a plurality of disc coils in axial sequence, and a plurality of insulating envelopes completely enclosing each other and said coils and graded stepwise in such a manner that, with respect to the individual disc coils, the number of insulating envelopes enclosing such coils will increase as the potential relatively to the iron core increases, and current leads for said voltage winding, the said insulating envelopes having extensions to cover those current leads which have a potential different from that of the iron core.

20. An iron core with completely closed magnetic circuit, said core having a plurality of legs and yokes connecting them, an insulating envelope enclosing said legs and one of said yokes, a voltage winding surrounding said insulating envelope and subdivided into a plurality of disc coils in axial sequence, and a plurality of insulating envelopes completely enclosing each other and said coils and graded stepwise in such a manner that, with respect to the individual disc coils, the number of insulating envelopes enclosing such coils will increase as the potential relatively to the iron core increases, and current leads for said voltage winding, the said insulating envelopes having extensions to cover those current leads which have a potential different from that of the iron core.

21. An iron core with completely closed magnetic circuit, a voltage winding surrounding said core and subdivided into a plurality of disc coils in axial sequence, and a plurality of insulating envelopes completely enclosing each other and said coils, said envelopes consisting substantially of paper strips wound in a number of turns and graded stepwise in such a manner that, with respect to the individual disc coils, the number of insulating envelopes enclosing such coils will increase as the potential relatively to the iron core increases, and current leads for said voltage winding, the said insulating envelopes having extensions to cover those current leads which have a potential different from that of the iron core.

22. An iron core with completely closed magnetic circuit, said core having a plurality of legs and yokes connecting them, an insulating envelope enclosing said legs and one of said yokes, a voltage winding surrounding said core and subdivided into a plurality of disc coils in axial sequence, and a plurality of insulating envelopes complete-

ly enclosing each other and said coils, said envelopes consisting substantially of paper strips wound in a number of turns and graded stepwise in such a manner that, with respect to the individual disc coils, the number of insulating envelopes enclosing such coils will increase as the potential relatively to the iron core increases, and current leads for said voltage winding, the said insulating envelopes having extensions to cover those current leads which have a potential different from that of the iron core.

23. An iron core with completely closed magnetic circuit, a low-tension winding surrounding said core, a high-tension winding surrounding said low-tension winding and said core and subdivided into a plurality of disc coils in axial sequence, and a plurality of insulating envelopes completely enclosing each other and said coils and graded stepwise in such a manner that, with respect to the individual disc coils, the number of insulating envelopes enclosing such coils will increase as the potential relatively to the iron core increases, and current leads for said high-tension winding, the said insulating envelopes having extensions to cover those current leads which have a potential different from that of the iron core.

24. An iron core with completely closed magnetic circuit, said core including a yoke, a low-tension winding located on said core, an insulating envelope enclosing said low-tension winding and said core with the exception of said yoke, a high-tension winding located upon said insulating envelope and subdivided into a plurality of disc coils in axial sequence, and a plurality of insulating envelopes completely enclosing each other and said coils and graded stepwise in such a manner that, with respect to the individual disc coils, the number of insulating envelopes enclosing such coils will increase as the potential relatively to the iron core increases, and current leads for said high-tension winding, the said insulating envelopes having extensions to cover those current leads which have a potential different from that of the iron core.

25. An iron core with completely closed magnetic circuit, a low-tension winding surrounding said core, a high-tension winding surrounding said low-tension winding and said core and subdivided into a plurality of disc coils in axial sequence, and a plurality of insulating envelopes completely enclosing each other and said coils, said envelopes consisting substantially of paper strips wound in a number of turns and graded stepwise in such a manner that, with respect to the individual disc coils, the number of insulating envelopes enclosing such coils will increase as the potential relatively to the iron core increases, and current leads for said high-tension winding, the said insulating en-

velopes having extensions to cover those current leads which have a potential different from that of the iron core.

26. An iron core with completely closed magnetic circuit, said core including a yoke, a low-tension winding located on said core, an insulating envelope enclosing said low-tension winding and said core with the exception of said yoke, a high-tension winding located upon said insulating envelope and subdivided into a plurality of disc coils in axial sequence, and a plurality of insulating envelopes completely enclosing each other and said coils, said envelopes consisting substantially of paper strips wound in a number of turns and graded stepwise in such a manner that, with respect to the individual disc coils, the number of insulating envelopes enclosing such coils will increase as the potential relatively to the iron core increases, and current leads for said high-tension winding, the said insulating envelopes having extensions to cover those current leads which have a potential different from that of the iron core.

27. An iron core with completely closed magnetic circuit, said core having a plurality of legs and yokes connecting them, an insulating envelope enclosing said legs and one of said yokes, and having open ends, a voltage winding located upon said insulating envelope and subdivided into a plurality of disc coils in axial sequence, and a plurality of insulating envelopes completely enclosing each other and said coils and graded stepwise in such a manner that, with respect to the individual disc coils, the number of insulating envelopes enclosing such coils will increase as the potential relatively to the iron core increases, and current leads for said voltage winding, the said insulating envelopes having extensions to cover those current leads which have a potential different from that of the iron core, an insulating casing enclosing all of the above-mentioned parts and open at the top and at the bottom, members for closing the open upper and lower ends of said casing, and a filling of insulating liquid in said casing.

28. An iron core with completely closed magnetic circuit, said core including a yoke, a low-tension winding located on said core, an insulating envelope enclosing said low-tension winding and said core with the exception of said yoke and having open ends, a high-tension winding located upon said insulating envelope and having a potential which drops toward said open ends, said high-tension winding being subdivided into a plurality of disc coils in axial sequence, and a plurality of insulating envelopes completely enclosing each other and said coils and graded stepwise in such a manner that, with respect to the individual disc coils, the number of insulating envelopes enclosing

such coils will increase as the potential relatively to the iron core increases, current leads for said high-tension winding, the said insulating envelopes of the high-tension winding having extensions to cover those current leads which have a potential different from that of the iron core, an insulating casing enclosing all of the above-mentioned parts and open at the top and at the bottom, members for closing the open upper and lower ends of said casing, and a filling of insulating liquid in said casing.

29. An iron core with completely closed magnetic circuit, said core having a plurality of legs and yokes connecting them, an insulating envelope enclosing said legs and one of said yokes, and having open ends, a voltage winding located upon said insulating envelope and subdivided into a plurality of disc coils in axial sequence, and a plurality of insulating envelopes completely enclosing each other and said coils, said envelopes consisting substantially of paper strips wound in a number of turns and graded stepwise in such a manner that, with respect to the individual disc coils, the number of insulating envelopes enclosing such coils will increase as the potential relatively to the iron core increases, and current leads for said voltage winding, the said insulating envelopes having extensions to cover those current leads which have a potential different from that of the iron core, leads connecting said disc coils, open-end insulating tubes surrounding said connecting leads and extending through, and projecting from, the insulating envelopes separating said coils, insulating strips wrapped on the portions between the open ends of said tubes, an insulating casing enclosing all of the above-mentioned parts and open at the top and at the bottom, members for closing the open upper and lower ends of said casing, and a filling of insulating liquid in said casing.

30. An iron core with completely closed magnetic circuit, said core including a yoke, a low-tension winding located on said core, an insulating envelope enclosing said low-tension winding and said core with the exception of said yoke and having open ends, a high-tension winding located upon said insulating envelope and having a potential which drops toward said open ends, said high-tension winding being subdivided into a plurality of disc coils in axial sequence, and a plurality of insulating envelopes completely enclosing each other and said coils, said envelopes consisting substantially of paper strips wound in a number of turns and graded stepwise in such a manner that, with respect to the individual disc coils, the number of insulating envelopes enclosing such coils will increase as the potential relatively to the iron core increases, and current leads for said high-tension winding, the said insu-

lating envelopes having extensions to cover those current leads which have a potential different from that of the iron core, leads connecting said disc coils, open-end insulating tubes surrounding said connecting leads and extending through, and projecting beyond, the insulating envelopes separating said coils, and insulating strips wrapped on the portions between the open ends of said tubes.

31. An iron core with completely closed magnetic circuit, a high-tension winding located upon said core and subdivided into a plurality of disc coils in axial sequence, and a plurality of insulating envelopes completely enclosing each other and said coils and graded stepwise in such a manner that, with respect to the individual disc coils, the number of insulating envelopes enclosing such coils will increase as the potential relatively to the iron core increases, a low-tension winding on said iron core, insulating material completely enveloping said low-tension winding, current leads for said windings, the insulating envelopes of the high-tension winding having extensions to cover those current leads which have a potential different from that of the iron core, an insulating casing enclosing all of the above-mentioned parts and open at the top and at the bottom, members for closing the open upper and lower ends of said casing, and a filling of insulating liquid in said casing.

32. An iron core with completely closed magnetic circuit, said core having a plurality of legs and yokes connecting them, a slit conducting envelope enclosing the said legs and one of said yokes, an insulating envelope surrounding said conducting envelope, a high-tension winding located upon said insulating envelope and subdivided into a plurality of disc coils in axial sequence, and a

plurality of insulating envelopes completely enclosing each other and said coils and graded stepwise in such a manner that, with respect to the individual disc coils, the number of insulating envelopes enclosing such coils will increase as the potential relatively to the iron core increases, a low-tension winding located on the insulating envelope which surrounds said conducting envelope, insulating material completely enveloping said low-tension winding, current leads for said windings, the insulating envelopes of the high-tension winding having extensions to cover those current leads which have a potential different from that of the iron core, an insulating casing enclosing all of the above-mentioned parts and open at the top and at the bottom, members for closing the open upper and lower ends of said casing, and a filling of insulating liquid in said casing.

33. An iron core with completely closed magnetic circuit, said core having two legs and two yokes connecting them, an insulating envelope enclosing the entire core with the exception of a portion serving to support the core, and voltage windings located in contact with said insulating envelope.

34. An iron core with completely closed magnetic circuit, said core having two legs and two yokes connecting them, an insulating envelope enclosing the entire core with the exception of one of said yokes, and voltage windings in contact with said insulating envelope.

In testimony whereof we affix our signatures.

CARL SCHRADER.
GEORG KEINATH.
FRANZ POLIN.
HANS RITZ.

45 110
50 115
55 120
60 125
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