United States Patent [19]

Laing

[11] **3,876,929**

[45] **Apr. 8, 1975**

[54] **TRANSFORMER CORE HAVING PLURALITY OF PORTIONS WITH DIFFERENT CROSS SECTIONS**

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[22] Filed: **July 30, 1973**

[21] Appl. No.: **383,499**

Related U.S. Application Data

[62] Division of Ser. No. 293,105, Sept. 28, 1972.

[30] **Foreign Application Priority Data**

Oct. 7, 1971 Austria 8688/71

[52] **U.S. Cl.** ..... **323/44 R;** 323/48; 336/5; 336/184; 336/215

[51] **Int. Cl.** **H01f 33/00**

[58] **Field of Search** ..... 336/5, 12, 172, 184, 212, 336/214, 215; 323/44 R, 48

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Primary Examiner—Gerald Goldberg

Attorney, Agent, or Firm—Pennie & Edmonds

[57] **ABSTRACT**

A transformer for use with an electric motor for a submersible pump the stator of which has a group of coils with each group of coils being subdivided into a plurality of coils of different widths arranged symmetrically with respect to the axis of each group of coils and where the transformer applies different voltages to each coil group. The transformer has a core made up of a plurality of portions having different cross sections and a plurality of secondary windings with a secondary winding surrounding each of the core portions and where each secondary winding is adapted to be connected at one of its ends to a common star point joining the plurality of coils of a single coil group and at its other end to an individual coil of the coil group.

1 Claim, 11 Drawing Figures

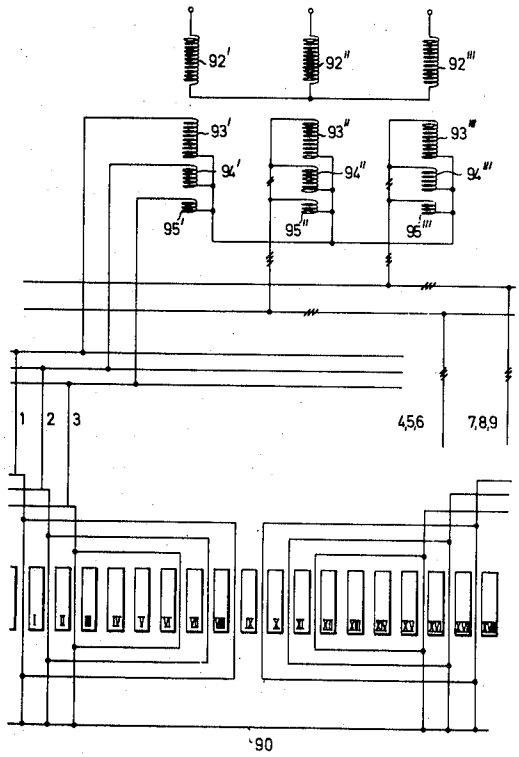


Fig.1

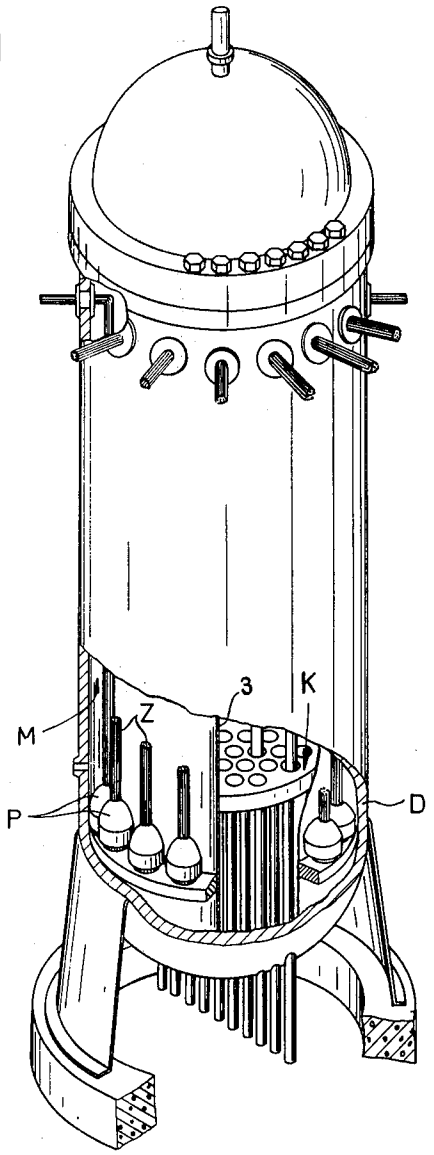
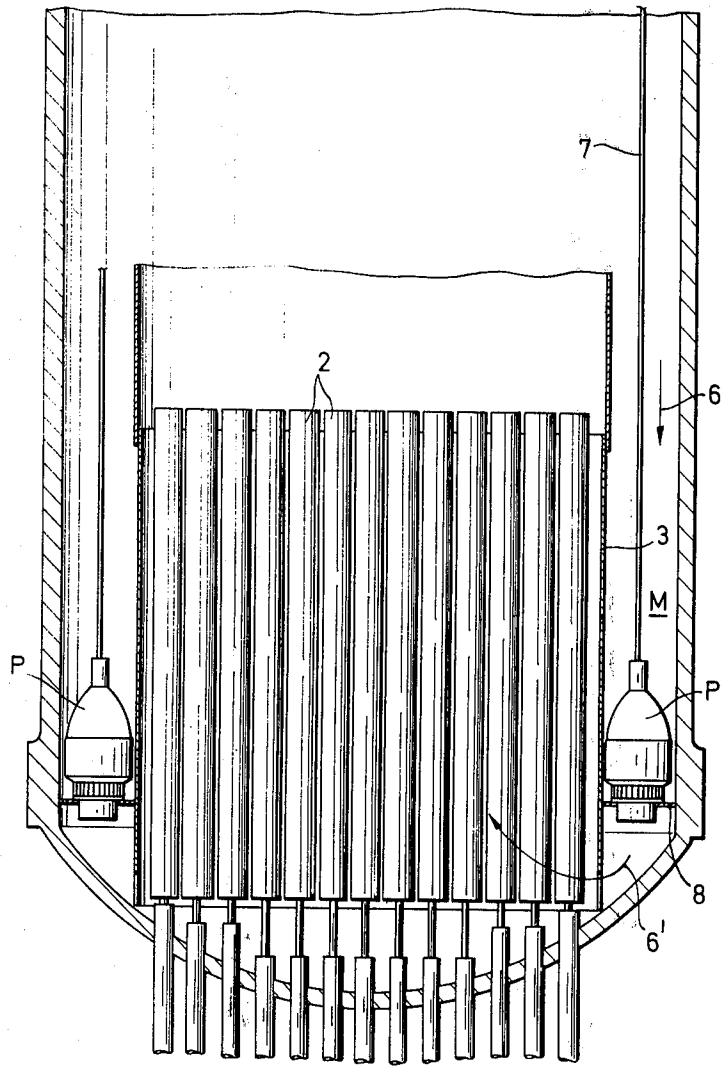


Fig. 2



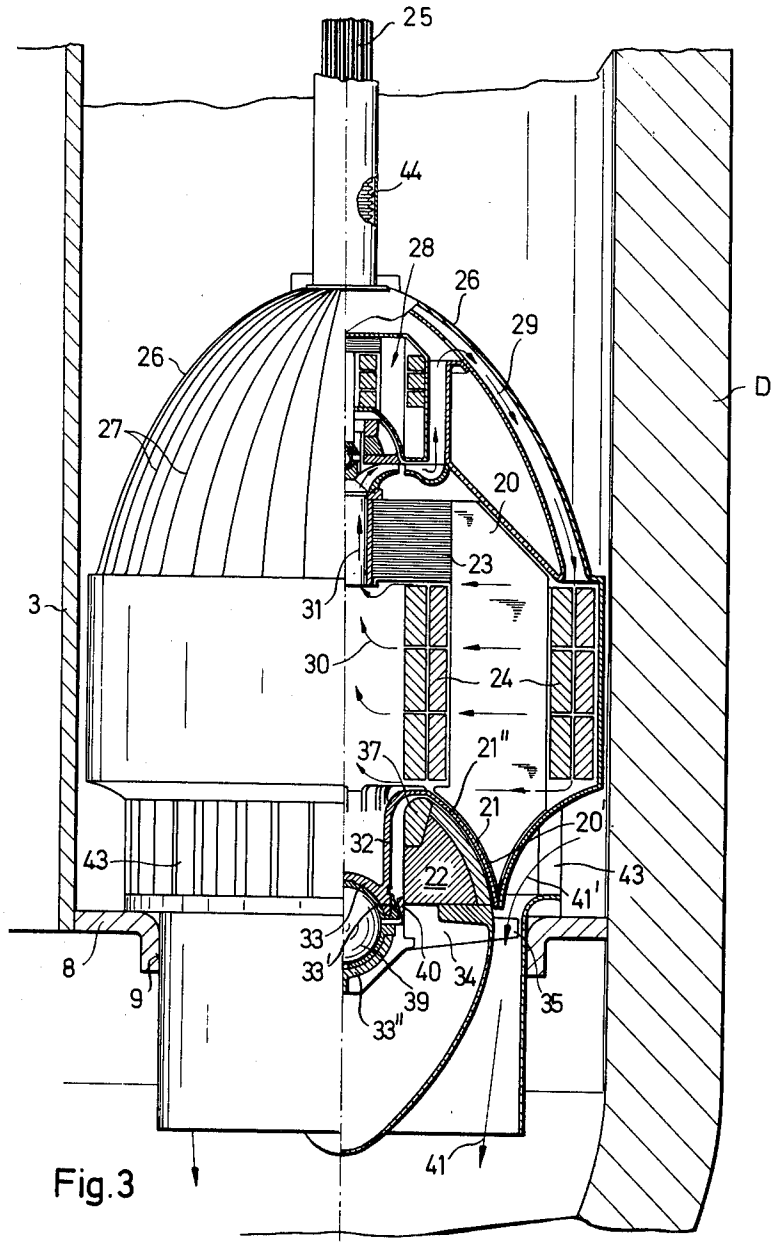

25
44
28
26
26
29
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24
37
21"
21
20'
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43
41'
33
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40
34
35
8
9
39
33"
41

Fig.3

Fig. 4

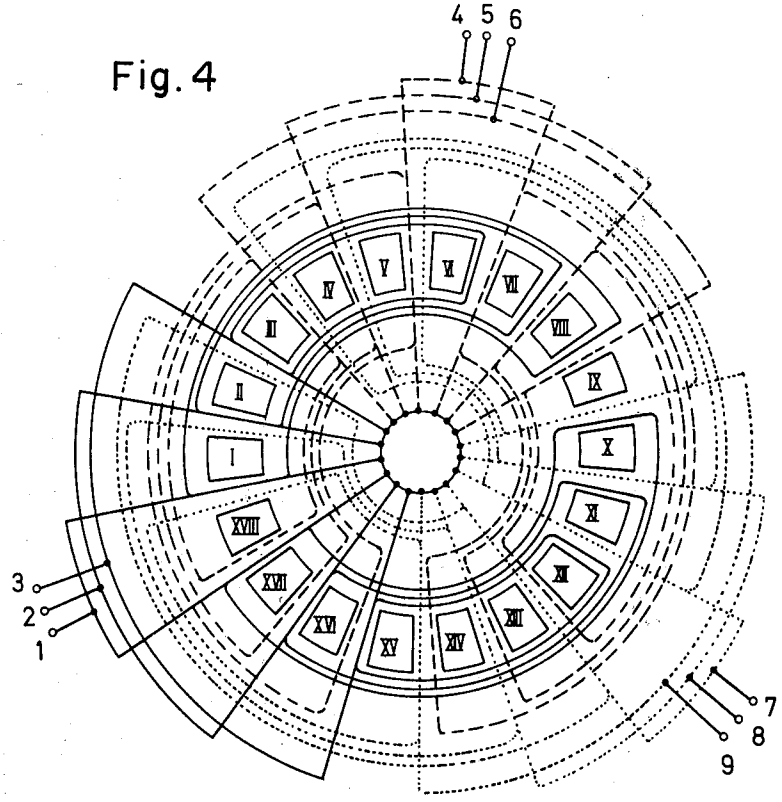

4
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6
7
8
9
3
2
1
I
II
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IX
X
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XII
XIII
XIV
XV
XVI
XVII
XVIII

Fig. 4a

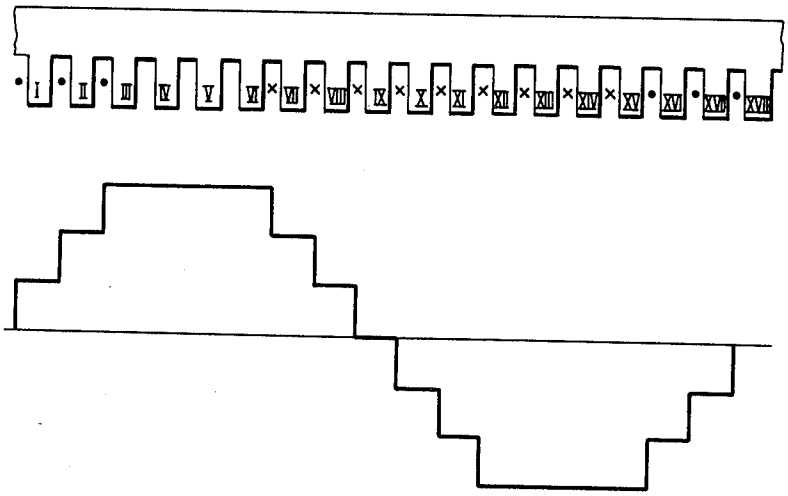

I
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Fig. 4b

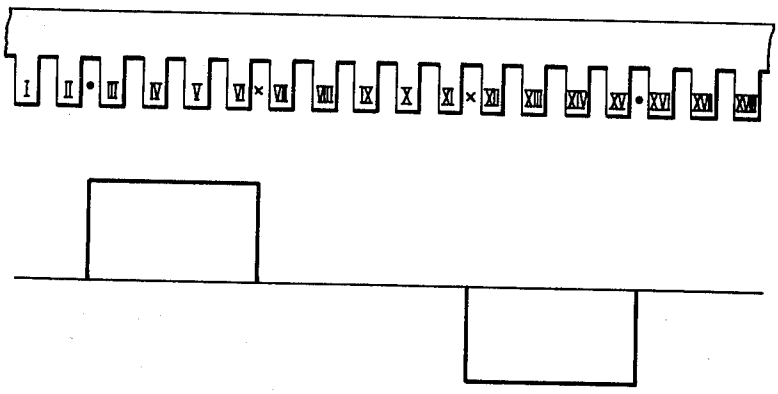

I
II
III
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V
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VII
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XI
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XIV
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XVI
XVII

Fig. 5

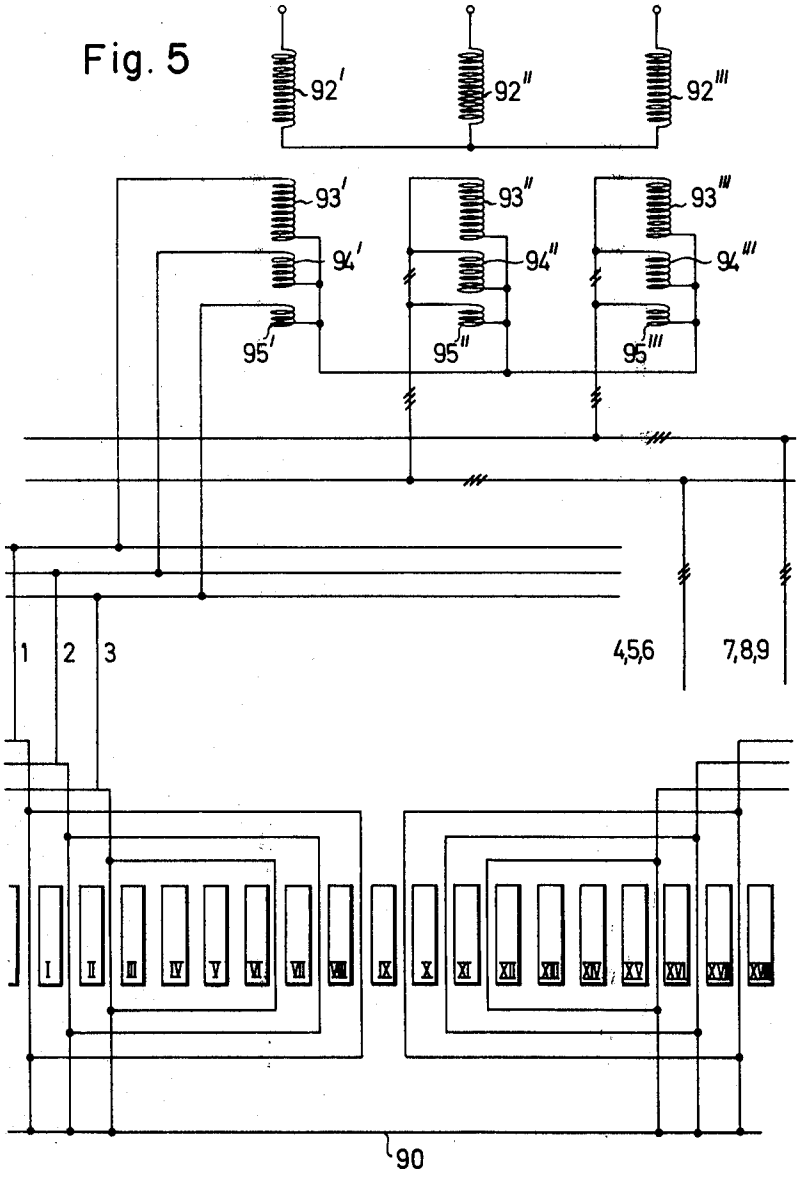
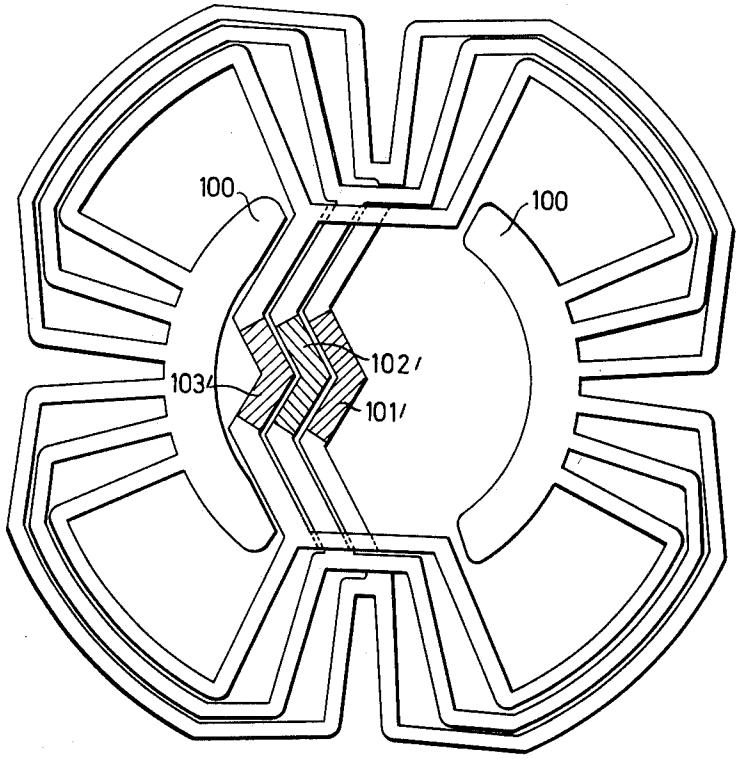

92'
92''
92'''
93'
93''
93'''
94'
94''
94'''
95'
95''
95'''
1
2
3
4,5,6
7,8,9
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
XIII
XIV
XV
XVI
XVII
XVIII
90

Fig. 6



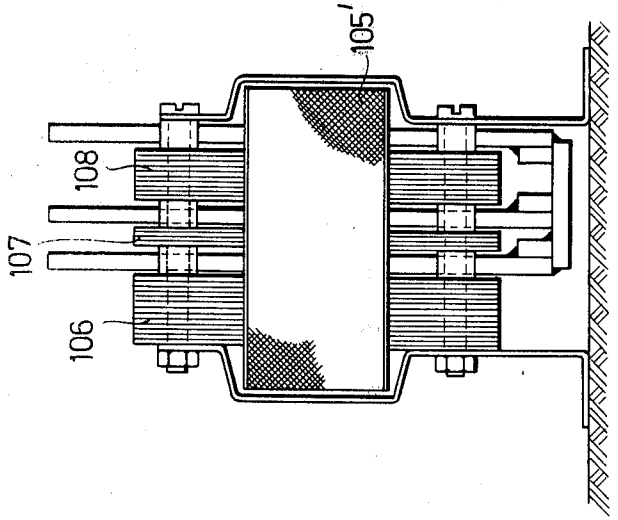


Fig. 7c

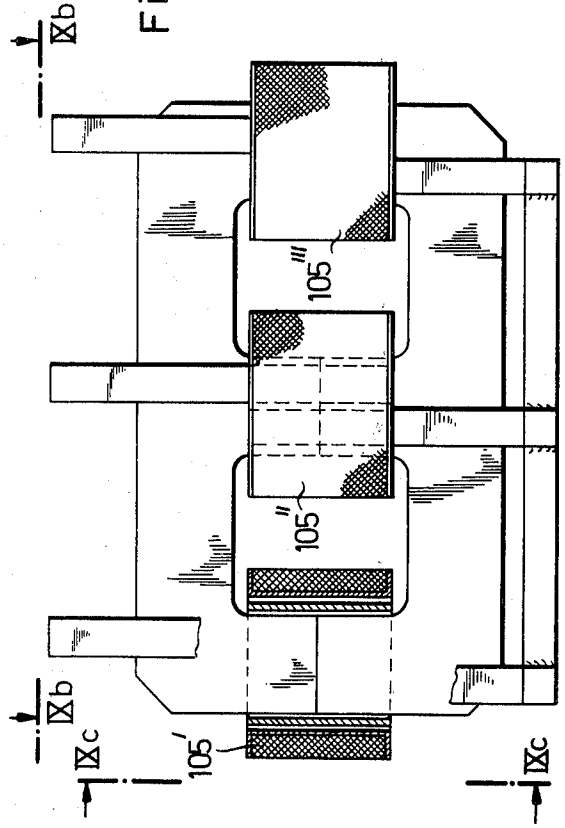


Fig. 7a

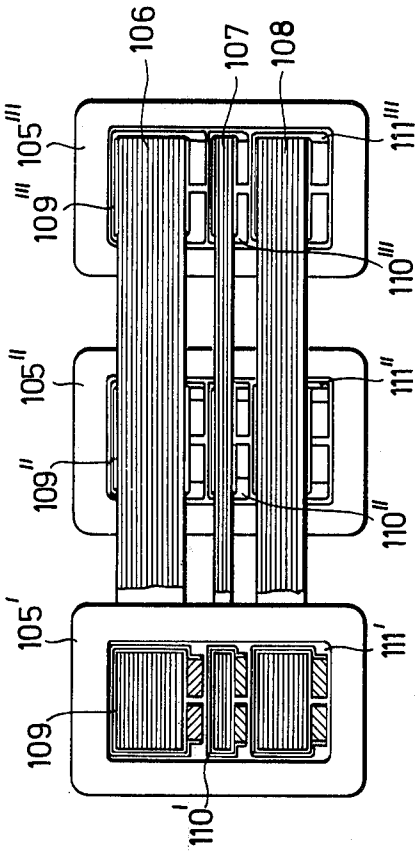


Fig. 7b

TRANSFORMER CORE HAVING PLURALITY OF PORTIONS WITH DIFFERENT CROSS SECTIONS

This is a division of application Ser. No. 293,105, filed Sept. 28, 1972.

THE PRIOR ART

Motors which are operated submerged in water and which drive pumps are known in relation to split tube pumps. A split tube pump consists of a stator carrying a winding and a short circuited rotor which is disposed in the water and which is separated from the stator by a non-magnetic split tube.

So-called submersible pumps have also become known, particularly for wells, in which not only the rotor but also the stator is disposed in the water. The windings are surrounded by a particularly strong and hermetically sealing insulating layer.

The disadvantage of split tube pumps consists in that the magnetic gap in which the split tube is located has to be large, which has an adverse effect on the weight per unit power of the motor and upon its efficiency. The disadvantage of the so-called submersible pumps consists in that the insulation has to consist of thick-walled organic absolutely waterproof insulating materials whose application is somewhat limited on account of their limited chemical stability and also on account of their limited thermal stability. Both systems have the disadvantage that they cannot be used under the conditions prevailing in a nuclear reactor at temperatures of 300°C and particularly in conditions of very high neutron flow, which leads to the destruction of all organic materials. Within a short space of time the insulation would no longer meet the requirements. Moreover the temperatures prevailing in the reactors are so high, that none of the known organic insulating materials is satisfactory. The problem of cooling motors, whose windings are insulated in known manner, by means of hot liquids is insoluble.

THE OBJECT OF THE INVENTION

An object of the invention is that of constructing a transformer for use with an electric motor for a pump in such a way that the motor can be operated in the liquid circuit of a reactor or generally in the circuit of a contaminated hot liquid.

DESCRIPTION OF THE INVENTION

The transformer of the invention solves the problem in that one side of each individual coil of each coil group is connected via a common star point at a further star point common to all coil groups and voltages are applied by means of the transformer to their other sides, which voltages increase from the coil having the smallest width to the coil having the largest width of each coil group by amounts which eliminate short circuiting of adjacent conductors in the medium being conveyed. By taking advantage of the fact that many media and particularly water have certain insulating properties, the transformer of the invention provides operating voltages between adjacent conductors which are so small that these insulating properties eliminate short circuiting between these adjacent conductors.

Having regard to the small voltages which are applied to the individual coils, the cross-section of these conductors, of which the coils are made up, have to be of appropriate size, so that the coils have adequate structural stability. By reason of this structural stability it is possible, by means of spacer members or spacing means to maintain the individual turns of the coils spaced from each other and from the pole teeth. If the medium being conveyed is hot water, the spacing means may take the form of coatings of glass- or mineral fibre fabrics which, whilst not being waterproof, nevertheless provide the spacing of the winding turns relative to each other and to the pole teeth, whilst the insulating function itself is performed by the medium being conveyed, namely the water. In this construction, voltages below 40 volt have been found to be adequate at spacings between the conductors of approximately 1mm.

In reactor vessels, glass fibre fabric wrappings are destroyed on account of the high neutron density and on account of the high temperatures. Preferably in this case voltages between adjacent conductors are chosen which are below 20 volt, so that metallic contaminants in the stream of the medium being conveyed cannot lead to short circuits between the conductors. Preferably when operating at voltages of this order of magnitude coils are used in the coil groups with only one turn per coil.

Fundamentally the transformer of the invention may be used with submersible pumps in all applications in which it was previously not possible to use a submersible motor, since the problem of insulation had not been capable of solution. Thus the pumps may for example also be used in conventional power station boilers for circulating the water or also for conveying the water; they may be used in pipe systems with extremely contaminated liquids; they may however also be used for conveying solvents or liquid substitutes for organic substances.

It is pointed out that the number of the supply leads to a stator of a motor adapted to be used with a transformer according to the invention equals $q\,m$, where q is the number of coils per coil group and m the number of phases. If, for example, in a practical embodiment, each coil group includes three coils and a three-phase supply is used, nine supply leads per pump motor are required. By making each supply lead of appropriate section, these supply leads may be combined into a bundle in which the individual elements are kept from each other at definite spacings by spacer means. Within the region of these spacer means, these bundles may for example be held by metal surrounds, which themselves are spaced from the conductors by spacer means, so that the supply lead bundles provide very stable suspension devices.

Use of the transformer according to the invention with the motor, according to which one end of each of the coils of a coil group of the motor has a voltage supplied to it by the transformer such that the voltages increase by definite amounts from the coil of the smallest width to the coil of largest width, has the effect that approximately the same current flows through each coil in each coil group. This result is surprising to the extent that it has been found that when all the coils of a coil group are connected in parallel practically only the coil of smallest width i.e. the innermost coil of a coil group, conducts current. This relationship will be explained in greater detail in the description of the drawings. Thus, in an arrangement in which all coils of a coil group are connected in parallel, given the same amount of winding material, the flux density which can be achieved in

the gap is considerably lower than with an arrangement in accordance with the invention.

The transformer according to the invention is adapted for use with a motor the stator of which has a secondary winding which is sub-divided into winding sections. When using a conventional transformer for supplying an electric motor of the type described above, in which the individual coils are connected to different tappings of the secondary winding, the current densities would, having regard to the high currents required, reach considerably higher values in some parts of the winding than in other parts, so that either the cross-sections of the winding would have to differ from each other considerably in different places or, if equal cross-sections are used, these would be substantially over-dimensioned in certain places.

The invention therefore provides a transformer for supplying a motor embodying the invention, in which different sections of the winding embrace different core cross-sections and these winding sections have one end connected to a common star point and the other end connected to the coils of the stator. Appropriately the numbers of the turns of the windings from which the individual voltages are tapped off are equal, the core cross-sections of the secondary portion of the transformer embraced by the individual windings having a particular relationship to the voltages tapped off the individual windings. The core sections which are embraced by the individual windings, are in this arrangement magnetically connected in parallel. In combination with the supply of the individual coils of the coil groups of a motor, according to the invention, which are supplied by the individual windings of the transformer according to the invention, the currents passing through these individual windings are approximately equal. By reason of the differential power outputs resulting from the different core cross-sections, the core of the secondary portion therefore has a magnetic flux passing through it homogeneously and maximum utilisation of the core iron is thereby achieved.

The invention will now be explained with reference to the drawings:

FIG. **1** shows a diagrammatic view and partly in section, a boiling water reactor having pumps with motors connected to transformers according to the invention;

FIG. **2** shows diagrammatically a section through the lower part of the boiling water reactor shown in FIG. **1**, with, however, only the most important elements shown;

FIG. **3** shows a pump in a reactor with a motor adapted to be connected to a transformer according to the invention, partly in section, and partly in elevation, the motor being located in a housing;

FIG. **4** shows diagrammatically a plan of a stator of a motor adapted to be connected to a transformer according to the invention with teeth designated by Roman numerals and the layout of the individual coils and coil groups which are inserted into the teeth;

FIG. *4a* shows the ideal spatial distribution of the magnetic flux density in the air gap produced by one phase of the winding when connected to a transformer according to the invention.

FIG. *4b* shows, by way of comparison to the arrangement shown in FIG. *4a* according to the invention, the spatial distribution of the magnetic flux density in the air gap produced by one phase of the winding when the coils of a coil group are connected in parallel;

FIG. **5** shows a circuit diagram for the two-pole stator with **18** pole teeth shown in FIG. **4** and the connection to a transformer according to the invention;

FIG. **6** shows in plan view one phase of the winding of a stator for a four-pole motor adapted to be connected to a transformer according to the invention with four coil groups, each of which has three coils of different width;

FIG. *7a* is a plane view of a transformer constructed according to the invention;

FIG. *7b* is a side view of the transformer of FIG. *7a;* and

FIG. *7c* is an end view of the transformer of FIG. *7a*.

The boiling water reactor shown in FIG. **1** has a pressure vessel D which encloses the core K and the envelope chamber M. In the envelope chamber M pumps P embodying the invention are located, in which the rotor, the stator and the pump impeller each constitute a unit which are suspended by the supply leads Z in the envelope chamber.

FIG. **2** shows again diagrammatically the lower portion of the reactor shown in FIG. **1.** The control rods **2** are surrounded by an envelope **3.** The pumps P are located in the envelope chamber M. The through-flow takes place in the direction of the arrows **6** and **6'** i.e., in a downward direction in the envelope chamber M and in an upward direction in the core chamber of the reactor. The pumps P are connected to the upper portion of the pressure vessel D by their connecting leads **7** and seated in a ring **8,** provided with an aperture for each pump.

FIG. **3** shows a pump of the kind used in the reactor shown in FIG. **2,** partly in elevation and partly in section. The pump is located between the envelope **3** and the reactor vessel D in an aperture **9** of the annular sheet metal member **8.** The stator of the motor has radially disposed sheet metal elements **20** which form the pole teeth and whose frontal sides **20'** together with the armature **22,** define the magnetic gap **21.** The magnetic return path is provided by a packet **23** of sheet metal discs. The coils **24** each have one or two turns only. The circuit of the conductors is completed inside the motor. The supply leads **25** which form the conductor bundle **7** in FIG. **2** lead to the upper region of the pressure vessel D and form the suspension of the pump. By this conductor bundle the pump can be withdrawn in a vertical upward direction. The pump stator **20, 23, 24** may be surrounded by a stator housing **26,** which has a corrugated rib profile **27.** A secondary motor **28,** which in principle is of the same construction as the pump motor, may provide circulation of the cooling water inside the stator. The cooling water flows through the stator in the direction of the arrows **29, 30,** 31. A bearing column **32** has a dish **33** with a concave region and an annular convex region **33'.** The pump impeller **34** with its axial blade ring **35** forms a unit with the armature **22** and the cage winding **37.** It is joined to a dish **33''.** A bearing sphere **39** is enclosed between the dishes **33** and **33''.** A collar **40** is provided as a back-up in the convex ring region **33',** so that the rotor cannot drop even when the pump is switched off. During start-up the rotor is, by reason of the magnetic forces and the thrust of the water being discharged and flowing in the direction of the arrow **41,** pressed against the sphere. The water enters through the radial blade ring **43** in the direction of the arrow **41'.** A bellows **44** provides pressure relieved volume equalization be-

tween the interior and the exterior of the motor housing. A separating wall **21''** of non-magnetic material may be provided in the gap **21.**

The pump shown is also suitable for conveying liquid metal, since the stator with its winding **24** is accommodated in a sealed housing **26.** The latter is also separated from the fluid being conveyed at the magnetic gap by the separating wall at **21''.** Inside the housing **26** a liquid is provided which has adequate insulating properties. The latter is caused to circulate by means of the cooling liquid circulating pump **28,** so that the heat representing the losses is circulated by means of the flow of the cooling medium **29,** which may for example be diphenyl or thiokol or some other thermally sable liquid, and given off through the wall **27** to the liquid metal.

FIG. **4** shows diagrammatically a stator of a motor adapted to be connected to a transformer according to the invention in plan view. The stator is intended for a two-pole machine and has **18** pole teeth I-XVIII. The broadest coil of a coil group embraces **8** pole teeth, the smallest coil of each coil group **4** pole teeth and the intermediate one **6** pole teeth each. Thus **3** coils per coil group and **2** coil groups per phase are provided in this two-pole machine. For connection to a three-phase supply **3** phases are required. Three different phases are indicated by continuous lines, interrupted lines and dotted lines. It can also be seen how each coil is connected at one end to the star point **90.** For the stator $q \times m$ (q = number of coils per coil group, in this case **3,** and m = number of phases in this case also **3**), i.e., 9 supply leads are required, which are designated 1 to 9.

As can be seen from FIGS. **4** and **5,** one end each of the coils of a coil group are subjected to a voltage which decreases from the coil of greatest width in each group to the coil of smallest width. The voltages in the **3** supply leads to each individual coil group are of the same phase. Again the coils of equal width in different coil groups and different phases are subjected to voltages of the same magnitude but of different phase. The magnitudes of the partial voltages required for supplying the individual coils of a coil group are, at a first approximation, related as the chord factors sin ($2p$ $90°Z_s/Z$) (p = number of pole pairs, Z_s = number of teeth embraced by one coil, Z = total number of teeth of the stator) of the coils concerned.

FIG. **4***a* shows a developed representation of the ideal spatial distribution of the magnetic flux density in the air gap produced by one phase of the winding when connected to a transformer in accordance with the invention. It is based on the winding embodying the invention in accordance with FIG. **4** or FIG. **5** with **3** coils per coil group and **2** poles.

By comparison, FIG. **4***b* shows in the same manner as FIG. **4***a* the spatial distribution of the magnetic flux density in the air gap in the case of all coils of a coil group being supplied with the same voltage, as becomes necessary when these coils are connected in parallel. It necessarily follows according to the law of induction in the case of parallel connection of the coils of a coil group and their supply with the same voltage that all coils of a coil group have the same magnetic flux. This however is possible only when only the innermost coil of a coil group conducts current, whilst all the coils of greater width remain substantially without current. This disadvantage is eliminated by the winding when connected to a transformer in accordance with the invention.

FIG. **5** shows diagrammatically the supply for a winding according to FIG. **6** embodying the invention, via a transformer, illustrated in greater detail in FIGS. **7***a*–**7***c* with the primary winding phases **92'**, **92''** **92'''**, and a secondary winding with the partial windings **93'**, **94'**, **95'** for the first phase, **93''**, **94''**, **95''**, for the second phase and **93'''**, **94'''**, **95'''** for the third phase. Of the winding of FIG. **4,** only the first phase with the teeth I-XVIII, the star point **90** and the supply leads **1, 2, 3,** are shown in developed representation. In the same way the second phase is connected by the supply leads **4,5,6** and the third phase by the supply leads **7,8,9.**

FIG. **6** shows one phase of a winding for a motor embodying the invention with **4** coil groups, each of which has **3** coils. This phase is intended for a **4**-pole machine having a stator with **36** pole teeth. One side of each coil group is connected to a star point **100** and its other side to a conductor **101'**, **102'** or **103'** respectively. These conductors are again supplied with voltages of different magnitude, namely the conductor **101'** with the greatest voltage and the conductor **103'** with the smallest voltage. In the case of a three-phase supply, **3** phases are required, as shown in FIG. **6,** which are relatively displaced by 60° in space and slid over the pole teeth.

FIGS. **7***a* to **7***c* show three views of a practical embodiment of a transformer according to the invention. The primary winding **105'**, **105''**, **105'''** surrounds the core consisting of three core portions **106, 107** and **108** having different cross-sections with portion **106** having the largest cross-section and portion **107** having the smallest cross-section, whilst the secondary windings made up of individual **109'**, **109''**, **109'''**; **110'**, **110''**, **110'''**; **111'**, **111''**, **111'''** each surround only one portion of the core, viz. **106, 107** and **108** respectively.

In this way different portions of the winding surround core portions of different cross-section. If the windings **109, 110** and **111** have the same number of turns, preferably **1** or **2,** then the voltages applied to these windings are proportional to the cross-sections of the portions to which the windings are applied.

I claim:

1. A multi-phase transformer for supplying a number of different voltages comprising a core having a plurality of core portions of different cross-sectional areas with the number of core portions equal to the number of different voltages required, a plurality of primary windings equal to the number of phases with each primary winding surrounding said core, and a plurality of secondary windings equal to the number of primary windings with each secondary winding comprising a plurality of individual windings of equal turns with the number of individual windings being equal to the number of voltages required and where each individual winding surrounds a core portion whereby when said primary windings are connected to a multi-phase current source, said individual core portions will impose a voltage on the individual windings proportional to the cross-sectional area of the core portions surrounded by the individual windings.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,876,929
DATED : April 8, 1975
INVENTOR(S) : NIKOLAUS LAING

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

Title Page, Item 56, change "3,232,318", the reference to the Kiltie Patent to --3,132,318--;

Col. 6, line 9, change "the partial" to --individual--;

Signed and Sealed this

second Day of *March 1976*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks

UNITED STATES PATENT OFFICE

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