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(71) Applicant *(for all designated States except US)*: ASEA BROWN BOVERI AB [SE/SE]; S-721 83 Västerås (SE).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: FROMM, Udo [SE/SE]; Liegatan 33, S-724 67 Västerås (SE). HÖRNFELDT, Sven [SE/SE]; Götgatan 4 A, S-724 62 Västerås (SE). HOLMBERG, Pär [SE/SE]; Haga Parkgata 6 C, S-721 78 Västerås (SE). KYLANDER, Gunnar [SE/SE]; Stentorpsgatan 16 A, S-723 43 Västerås (SE). MING, Li [CN/SE]; Högbyskogsväg 1, S-723 41 Västerås (SE). LEIJON, Mats [SE/SE]; Hyvlargatan 5, S-723 35 Västerås (SE).

(74) Agent: ASKERBERG, Fredrik; L.A. Groth & Co. KB, P.O. Box 6107, S-102 32 Stockholm (SE).

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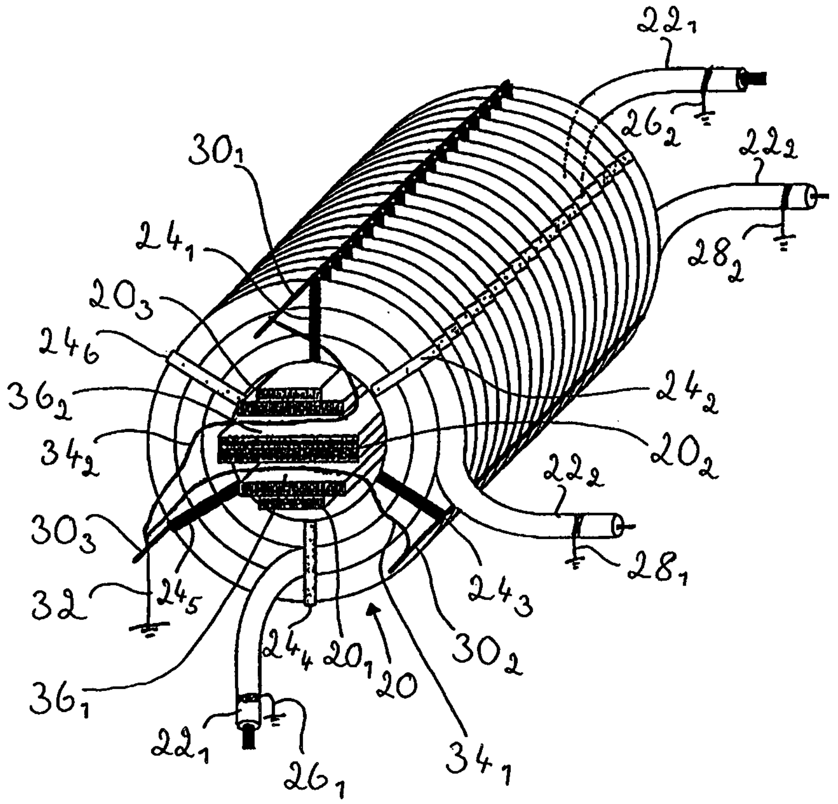
(54) Title: POWER TRANSFORMER/INDUCTOR

(57) Abstract

The present invention relates to a power transformer/inductor comprising at least one winding. The windings are designed by means of a high-voltage cable, comprising an electric conductor, and around the conductor there is arranged a first semiconducting layer, around the first semiconducting layer there is arranged an insulating layer and around the insulating layer there is arranged a second semiconducting layer. The second semiconducting layer is earthed at or in the vicinity of both ends ($26_1$, $26_2$; $28_1$, $28_2$) of each winding and furthermore one point between both ends ($26_1$, $26_2$; $28_1$, $28_2$) is directly earthed.



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# POWER TRANSFORMER/INDUCTOR

## Technical field

The present invention relates to a power transformer/inductor. In all transmission and distribution of electric energy transformers are used for enabling exchange between two or more electric systems normally having different voltage levels. Transformers are available for powers from the VA region to the 1000 MVA region. The voltage range has a spectrum of up to the highest transmission voltages used today. Electro-magnetic induction is used for energy transmission between electric systems.

Inductors are also an essential component in the transmission of electric energy in for example phase compensation and filtering.

The transformer/inductor related to the present invention belongs to the so-called power transformers/inductors having rated outputs from several hundred kVA to in excess of 1000 MVA and rated voltages of from 3-4 kV to very high transmission voltages

## Background art

In general the main task of a power transformer is to enable the exchange of electric energy, between two or more electric systems of mostly differing voltages with the same frequency.

Conventional power transformers/inductors are e.g. described in the book "Elektriska Maskiner" by Fredrik Gustavson, page 3-6 - 3-12, published by The Royal Institute of Technology, Sweden, 1996.

A conventional power transformer/inductor comprises a transformer core, referred to below as core, formed of laminated commonly oriented sheet, normally of silicon iron. The core is composed of a number of core legs connected by yokes. A number of windings are provided around the core legs normally referred to as primary, secondary and regulating winding. In power transformers these windings are practically always arranged in concentric configuration and distributed along the length of the core leg.

Other types of core structures occasionally occur in e.g. so-called shell transformers or in ring - core transformers. Examples related to core transformers are discussed in DE 40414. The core may consist of conventional magnetizable materials such as said oriented sheet and other magnetizable materials such as ferrites, amorphous material, wire strands or metal tape. The magnetizable core is, as known, not necessary in inductors

The above-mentioned windings constitute one or several coils connected in series, the coils of which having a number of turns connected in series. The turns of a single coil normally make up a geometric, continuous unit which is physically separated from the remaining coils

A conductor is known through US 5 036 165, in which the insulation is provided with an inner and an outer layer of semiconducting pyrolized glassfiber. It is also known to provide conductors in a dynamo-electric machine with such an insulation, as described in US 5 066 881 for instance, where a semiconducting pyrolized glassfiber layer is in contact with the two parallel rods forming the conductor, and the insulation in the stator slots is surrounded by an outer layer of semiconducting pyrolized glassfiber. The pyrolized glassfiber material is described as suitable since it retains its resistivity even after the impregnation treatment.

The insulation system on the inside of a coil/winding and between coils/windings and remaining metal parts, is normally in the form of a solid- or varnish based insulation closest to the conducting element and on the outside thereof the insulation system is in the form of a solid cellulose insulation, a fluid insulation, and possibly also an insulation in the form of gas. Windings with insulation and possible bulky parts represent in this way large volumes that will be subjected to high electric field strengths occurring in and around the active electric magnetic parts belonging to transformers. A detailed knowledge of the properties of insulation material is required in order to predetermine the dielectric field strengths which arise and to attain a dimensioning such that there is a minimal risk of electrical discharge. It is important to achieve a surrounding environment which does not change or reduce the insulation properties.

Today's predominant outer insulation system for conventional high voltage power transformers/inductors consists of cellulose material as the solid insulation and transformer oil as the fluid insulation. Transformer oil is based on so-called mineral oil.

Conventional insulation systems are e.g. described in the book "Elektriska Maskiner" by Fredrik Gustavson, page 3-9 - 3-11, published by The Royal Institute of Technology, Sweden, 1996.

Conventional insulation systems are relatively complicated to construct and additionally, special measures need to be taken during manufacture in order to utilise good insulation properties of the insulation system. The system must have a low moisture content and the solid phase in the insulation system needs to be well impregnated with the surrounding oil so that there is minimal risk of gas pockets. During manufacture a special drying process is carried out on the complete core with windings before it is lowered into the tank. After lowering the core and sealing the tank, the tank is emptied of all air by a special vacuum treatment before being filled with oil. This process is relatively time-consuming seen from the entire manufacturing process in addition to the extensive utilisation of resources in the workshop.

The tank surrounding the transformer must be constructed in such a way that it is able to withstand full vacuum since the process requires that all the gas be pumped out to almost absolute vacuum which involves extra material consumption and manufacturing time.

Furthermore the installation requires vacuum treatment to be repeated each time the transformer is opened for inspection.

## Summary of the invention

According to the present invention the power transformer/ inductor comprises at least one winding in most cases arranged around a magnetizable core which may be of different geometries. The term "windings" will be referred to below in order to simplify the following specification. The windings are composed of a high voltage cable with solid insulation. The cables have at least one centrally situated electric conductor. Around the conductor there is arranged a first semi-conducting layer, around the semi-conducting layer there is arranged a solid insulating layer and around the solid insulating layer there is arranged a second external semi-conducting layer.

The use of such a cable implies that those regions of a transformer/inductor which are subjected to high electric stress are confined to the solid insulation of the cable. Remaining parts of the transformer/inductor, with respect to high voltage, are only subjected to very moderate electric field strengths. Furthermore, the use of such a cable eliminates several problem areas described under the background of the invention. Consequently a tank is not needed for insulation means and coolant. The insulation as a whole also becomes substantially simple. The time of construction is considerably shorter compared to that of a conventional power transformer/inductor. The windings may be manufactured separately and the power transformer/inductor may be assembled on site.

However, the use of such a cable presents new problems which must be solved. The second semi-conducting layer must be directly earthed in or in the vicinity of both ends of the cable so that the electric stress which arises, both during normal operating voltage and during transient progress, will primarily load only the solid insulation of the cable. The semi-conducting layer and these direct earthings form together a closed circuit in which a current is induced during operation. The resistivity of the layer must be high enough so that resistive losses arising in the layer are negligible.

Besides this magnetic induced current a capacitive current is to flow into the layer through both directly earthed ends of the cable. If the resistivity of the layer is too great, the capacitive current will become so limited that the potential in parts of the layer, during a period of alternating stress, may differ to such an extent from earth potential that regions of the power transformer/inductor other than the solid insulation of the windings will be subjected to electric stress. By directly earthing several points of the semiconducting layer, preferably one point per turn of the winding, the whole outer layer resting at earth potential and the elimination of the above-mentioned problems is ensured if the conductivity of the layer is high enough.

This one point earthing per turn of the outer layer is performed in such a way that the earth points rest on a generatrix to a winding and that points along the axial length of the winding are electrically directly connected to a conducting earth track which is connected thereafter to the common earth potential.

In order to keep the losses in the outer layer as low as possible, it may be desirable to have such a high resistivity in the outer layer that several earth points per turn are required. This is possible according to a special earthing process in accordance with the invention.

Thus, in a power transformer/inductor according to the invention the second semiconducting layer is earthed at or in the vicinity of both ends of each winding and furthermore one point between both ends is directly earthed.

In a power transformer/inductor according to the invention the windings are preferably composed of cables having solid, extruded insulation, of a type now used for power distribution, such as XLPE-cables or cables with EPR-insulation. Such cables are flexible, which is an important property in this context since the technology for the device according to the invention is based primarily on winding systems in which the winding is formed from cable which is bent during assembly. The flexibility of a XLPE-cable normally corresponds to a radius of curvature of approximately 20 cm for a cable 30 mm in diameter, and a radius of curvature of approximately 65 cm for a cable 80 mm in diameter. In the present application the term "flexible" is used to indicate that the winding is flexible down to a radius of curvature in the order of four times the cable diameter, preferably eight to twelve times the cable diameter.

Windings in the present invention are constructed to retain their properties even when they are bent and when they are subjected to thermal stress during operation. It is vital that the layers of the cable retain their adhesion to each other in this context. The material properties of the layers are decisive here, particularly their elasticity and relative coefficients of thermal expansion. In a XLPE-cable, for instance, the insulating layer consists of cross-linked, low-density polyethylene, and the semiconducting layers consist of polyethylene with soot and metal particles mixed in. Changes in volume as a result of temperature fluctuations are completely absorbed as changes in radius in the cable and, thanks to the comparatively slight difference between the coefficients of thermal expansion in the layers in relation to the elasticity of these materials, the radial expansion can take place without the adhesion between the layers being lost.

The material combinations stated above should be considered only as examples. Other combinations fulfilling the conditions specified and also the condition of being semiconducting, i.e. having resistivity within the range of $10^{-1}$-$10^{6}$

ohm-cm, e.g. 1-500 ohm-cm, or 10-200 ohm-cm, naturally also fall within the scope of the invention.

The insulating layer may consist, for example, of a solid thermoplastic material such as low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), polybutylene (PB), polymethyl pentene (PMP), cross-linked materials such as cross-linked polyethylene (XLPE), or rubber such as ethylene propylene rubber (EPR) or silicon rubber.

The inner and outer semiconducting layers may be of the same basic material but with particles of conducting material such as soot or metal powder mixed in.

The mechanical properties of these materials, particularly their coefficients of thermal expansion, are affected relatively little by whether soot or metal powder is mixed in or not - at least in the proportions required to achieve the conductivity necessary according to the invention. The insulating layer and the semiconducting layers thus have substantially the same coefficients of thermal expansion.

Ethylene-vinyl-acetate copolymers/nitrile rubber, butyl graft polyethylene, ethylene-butyl-acrylate-copolymers and ethylene-ethyl-acrylate copolymers may also constitute suitable polymers for the semiconducting layers.

Even when different types of material are used as base in the various layers, it is desirable for their coefficients of thermal expansion to be substantially the same. This is the case with combination of the materials listed above.

The materials listed above have relatively good elasticity, with an E-modulus of $E < 500$ MPa, preferably $< 200$ MPa. The elasticity is sufficient for any minor differences between the coefficients of thermal expansion for the materials in the layers to be absorbed in the radial direction of the elasticity so that no cracks or other damage appear and so that the layers are not released from each other. The material in the layers is elastic, and the adhesion between the layers is at least of the same magnitude as the weakest of the materials.

The conductivity of the two semiconducting layers is sufficient to substantially equalize the potential along each layer. The conductivity of the outer semiconducting layer is sufficiently large to contain the electrical field in the cable, but sufficiently small not to give rise to significant losses due to currents induced in the longitudinal direction of the layer.

Thus, each of the two semiconducting layers essentially constitutes one equipotential surface, and these layers will substantially enclose the electrical field between them.

There is, of course, nothing to prevent one or more additional semiconducting layers being arranged in the insulating layer.

The above indicated and other advantageous embodiments of the present invention are stated in the dependent claims.

The invention will now be described in more detail in the following description of preferred embodiments with reference to the accompanying drawings.

Brief description of the drawings

Figure 1 shows a cross-sectional view of a high-voltage cable;

Figure 2 shows a perspective view of windings with one earthing point per winding turn;

Figure 3 shows a perspective view of windings with two earthing points per winding turn according to a first embodiment of the present invention;

Figure 4 shows a perspective view of windings with three earthing points per winding turn according to a second embodiment of the present invention;

Figures 5a and 5b respectively, show a perspective view and a side view respectively of a winding, on an outer leg of a three phase transformer with three legs, with three earthing points per winding turn according to a third embodiment of the present invention;

Figures 6a and 6b respectively, show a perspective view and a side view respectively of a winding, on a central leg of a three phase transformer with three or more legs, with three earthing points per winding turn according to a fourth embodiment of the present invention.

Detailed description of the embodiments of the present invention

Figure 1 shows a cross-sectional view of a high voltage cable 10 which is used traditionally for the transmission of electric energy. The shown high voltage cable may for example be a standard XLPE cable 145 kV but without mantle and screen. The high voltage cable 10 comprises an electric conductor, which may comprise one or several strands 12 with circular cross-section of for example copper (Cu). These strands 12 are arranged in the centre of the high voltage cable 10. Around the strands 12 there is arranged a first semi conducting layer 14. Around the first semi conducting layer 14 there is arranged a first insulating layer 16, for example XLPE insulation. Around the first insulating 16 there is arranged a second semi conducting layer 18. The high voltage cable 10, shown in Figure 1, is built with a conductor area of between 80 and 3000 $mm^2$ and an outer cable diameter of between 20 and 250 mm.

Figure 2 shows a perspective view of windings with one earthing point per winding turn. Figure 2 shows a core leg designated by the numeral 20 within a power transformer or inductor. Two windings $22_1$ and $22_2$ are arranged around the core leg 20 which are formed from the high-voltage cable (10) shown in figure 1. With the aim of fixing windings $22_1$ and $22_2$ there are, in this case, four radially arranged spacer members $24_1$, $24_2$, $24_3$, $24_4$ per winding turn. As shown in figure 2 the outer semi conducting layer is earthed at both ends $26_1$, $26_2$, $28_1$, $28_2$ of each winding $22_1$, $22_2$. Spacer member $24_1$, which is emphasised in black, is utilized to achieve one earthing point per winding turn. The spacer member $24_1$ is directly connected to one earthing element $30_1$, i.e. in the form of an earthing track $30_1$, which is connected 32 to the common earth potential at the periphery of the winding $22_2$ and along the axial length of the winding $22_2$. As shown in Figure 2 the earthing points rest (one point per winding turn) on a generatrix to a winding.

Figure 3 shows a perspective view of windings with two earthing points per winding turn according to a first embodiment of the present invention. In Figures 2 and 3 the same parts are designated by the same numerals in order to make the Figures more clear. Also in this case the two windings $22_1$ and $22_2$, formed from the high-voltage cable 10 shown in Figure 1, are arranged around the core leg 20. Spacer members $24_1$, $24_2$, $24_3$, $24_4$ are also in this case radially arranged with the aim of fixing the windings $22_1$ and $22_2$. At both ends $26_1$, $26_2$, $28_1$, $28_2$ of each winding $22_1$ and $22_2$ the second semiconducting layer (compare with Figure 1) is earthed in accordance with Figure 2. Spacer members $24_1$, $24_3$ , which are marked in black, are used in order to achieve two earthing points per winding turn. Spacer member $24_1$ is directly connected to a first earthing element $30_1$ and spacer member $24_3$ is directly connected to a second earthing element $30_2$ at the periphery of the winding $22_2$ and along the axial length of the winding $22_2$. Earthing elements $30_1$ and $30_2$ may be in the form of earthing tracks $30_1$ and $30_2$ which are connected to the common earth potential 32. Both earthing elements $30_1$, $30_2$ are coupled by means of an electric connection $34_1$ (cable). The electric connection $34_1$ is drawn into one slot $36_1$ arranged in the core leg 20. The slot $36_1$ is arranged such that the cross-section area $A_1$ of the core leg 20 (and thereby the magnetic flow $\Phi$) is divided into two partial areas $A_1$, $A_2$. Accordingly, the slot $36_1$ divides the core leg 20 into two parts, $20_1$, $20_2$. This entails that currents are not magnetically induced in connection with earthing tracks. By earthing in the above-mentioned way the losses in the second semiconducting layer are kept to a minimum.

Figure 4 shows a perspective view of windings with three earthing points per winding turn according to a second embodiment of the present invention. In Figures 2-4 the same parts are designated by the same numerals in order to make the Figures more clear. Also here two windings $22_1$ and $22_2$, formed from the high-voltage cable 10 shown in Figure 1, are arranged around the core leg 20. Spacer members $24_1$, $24_2$, $24_3$, $24_4$, $24_5$, $24_6$, are also radially arranged with the aim of fixing windings $22_1$ and $22_2$ . As shown in Figure 4 there are 6 spacer members per winding turn. At both ends $26_1$, $26_2$; $28_1$, $28_2$ of each winding $22_1$, $22_2$ the outer semiconducting layer (compare with Figure 1) is earthed as in accordance with Figures 2 and 3. Spacer members $24_1$, $24_3$, $24_5$ which are marked in black are used to achieve three earthing points per winding turn. These spacer members $24_1$, $24_3$, $24_5$ are accordingly connected to the second semiconducting layer of the high power cable 10. Spacer member $24_1$is directly connected to a first earthing element $30_1$ and spacer member $24_3$ is directly connected to a second earthing element $30_2$ and spacer member $24_5$ is directly connected to a third earthing element $30_3$ at the periphery of the winding $22_2$and along the axial length of the winding $22_2$. Earthing elements $30_1$, $30_2$, $30_3$, may be in the form of earthing tracks $30_1$, $30_2$, $30_3$ which are connected to the common earth potential 32. All three earthing elements $30_1$, $30_2$, $30_3$ are joined by means of two electric connections $34_1$, $34_2$ (cables). The electric connection $34_1$ is drawn into a first slot $36_1$ arranged in the core leg 20 and is connected to earthing elements $30_2$ and $30_3$. The electric connection $34_2$ is drawn into second slot $36_2$ arranged in the core leg 20. Slots $36_1$, $36_2$ are arranged such that the cross-section area A, of the core leg 20 (and thereby the magnetic flow $\Phi$) are divided into three partial areas $A_1$, $A_2$, $A_3$. Accordingly slots $36_1$, $36_2$ divide the core leg 20 into three parts $20_1$, $20_2$, $20_3$. This entails that currents are not magnetically induced in connection with earthing tracks. By earthing in the above-mentioned way losses in the second semiconducting layer are kept to a minimum.

Figures 5a and 5b respectively, show a perspective view respectively a sectional view of a winding on an outer leg of a three phase transformer with three legs with three earthing points per winding turn according to a third embodiment of the present invention. In Figures 2 - 5 the same parts are designated the same numerals in order to make the Figures more clear. A winding $22_1$, formed from the high-voltage cable 10 shown in Figure 1, is arranged around the outer leg 20 of the transformer. Additionally in this case spacer members $24_1$, $24_2$, $24_3$, $24_4$, $24_5$, $25_6$ are arranged radially with the aim of fixing the winding $22_1$. At both ends of the winding $22_2$ the second semiconducting layer(compare with Figure 1) is earthed (not shown in Figures 5a and 5b respectively). Spacer members $24_1$, $24_3$, $24_5$, which are marked in black, are used to achieve three earthing points per winding turn. Spacer member $24_1$ is directly connected to a first earthing element $30_1$, spacer member $24_3$ is directly connected to a second earthing element (not shown) and spacer member $24_5$ is directly connected to a third earthing element $30_3$ at the periphery of the winding $22_1$ and along the axial length of the winding $22_1$. Earthing elements $30_1$ - $30_3$ may be in the form of earthing tracks which are connected to the common earth potential (not shown). The three earthing elements $30_1$ - $30_3$ are joined by means of two electric connections $34_1$, $34_2$ (cables). The two electric connections $34_1$, $34_2$ are drawn in two slots $36_1$, $36_2$, arranged in a yoke 38 connecting the three earthing elements $30_1$ - $30_3$ to each other. The two slots $36_1$, $36_2$ are arranged such that the cross-section area A of the yoke 38, (and thereby the magnetic flux $\Phi$) is divided into three partial areas $A_1$, $A_2$, $A_3$. The electric connections $34_1$, $34_2$ are threaded through the two slots $36_1$, $36_2$ and over the front and back side of the yoke 38. By earthing in the above-mentioned way the losses are kept to a minimum.

Figure 6a and 6b respectively, show a perspective view respectively a sectional view of a winding, on a central leg of a three phase transformer with three or more legs, with three earthing points per winding turn according to a fourth embodiment of the present invention. In Figures 2 - 6 the same parts are designated the same numerals in order to make the Figures more clear. A winding $22_1$, formed from the high-voltage cable 10 shown in Figure 1 is arranged around the central leg 20 of the transformer. Additionally in this case spacer members $24_1$ - $24_6$ are arranged radially, three of which $24_1$, $24_3$, $24_5$ are used to achieve three earthing points per winding turn. The spacer members $24_1$, $24_3$, $24_5$ are directly connected to the earthing elements $30_1$ - $30_3$, of which only two are shown, in the same way as described above in connection with Figures 5a, and 5b. The three earthing elements $30_1$ - $30_3$ are connected by means of two electric connections $34_1$, $34_2$ (cables). The two electric connections $34_1$, $34_2$ are drawn into two slots $36_1$, $36_2$ arranged in a yoke 38. The two slots $36_1$, $36_2$ are arranged such that the cross-section area A of the yoke 38 (and thereby the magnetic flux $\Phi$) is divided into three partial areas $A_1$, $A_2$, $A_3$. The two electric connections $34_1$, $34_2$ are threaded through slots $36_1$, $36_2$ on both sides of the central leg 20 relative to the yoke 38. By earthing in the above-mentioned way the losses in the second semiconducting layer are kept to a minimum.

The principles used above may be used for several earthing points per winding turn. The magnetic flux, $\Phi$, is located in the core with a cross-section area A. This cross-section area A can be divided into a number of partial areas $A_1$, $A_2$, ... , An so that;

$$A = \sum_{i=1}^{n} A_i$$

The circumference of a winding turn with length l can be divided into a number of parts $l_1$, $l_2$, ... , $l_n$ so that;

$$l = \sum_{i=1}^{n} l_i$$

No extra losses due to earthing are introduced if the electric connections are made in such a way that the ends of every part $l_i$ are electrically connected so that only the partial area $A_i$ is encompassed by a coil consisting of an electric connection $66_i$ and the segment $l_i$ and the condition,

$$\frac{\Phi_i}{\Phi} = \frac{l_i}{l}$$

is fulfilled, whereby $\Phi$ is the magnetic flux in the core and $\Phi_i$ is the magnetic flux through the partial area $A_i$.

If the magnetic flux density is constant throughout the entire cross-section of the core, then $\Phi = B*A$ leads to the ratio;

$$\frac{A_i}{A} = \frac{l_i}{l}$$

The power transformer/inductor in the above shown figures comprises an iron core consisting of a core leg and a yoke. It should however be understood that a power transformer/ inductor may also be designed without an iron core (air-cored transformer).

The invention is not limited to the shown embodiments since several variations are possible within the frame of the attached patent claims.

CLAIMS

1. A power transformer/inductor comprising at least one winding, **characterized** in that the winding/windings are composed of a high-voltage cable (10), comprising an electric conductor, and around the conductor there is arranged a first semiconducting layer (14), around the first semiconducting layer (14) there is arranged an insulating layer (16) and around the insulating layer (16) there is arranged a second semiconducting layer (18), whereby the second semiconducting layer (18) is earthed at or in the vicinity of both ends ($26_1$, $26_2$; $28_1$, $28_2$) of each winding ($22_1$, $22_2$) and that furthermore one point between both ends ($26_1$, $26_2$; $28_1$, $28_2$) is directly earthed.

2. A power transformer/inductor according to claim 1, **characterized** in that n points ($n \geq 2$) per at least one turn of at least one winding are directly earthed in such a way that the electric connections ($34_1$, $34_2$ ..., $34_{n-1}$) between the n earthing points divide the magnetic flux into n parts to limit the losses produced by earthing.

3. A power transformer/inductor according to claim 2, **characterized** in that the high-voltage cable (10) is manufactured with a conductor area of between 80 and 3000 $mm^2$ and with an outer cable diameter of between 20 and 250 mm.

4. A power transformer/inductor according to claim 3, where the windings surround a cross-section area A and the circumference of each winding turn has a length l, whereby the electric connections ($34_1$, $34_2$, ..., $34_{n-1}$) between the n earthing points divide the said cross-section area into n partial areas $A_1$, $A_2$, .... An so that,

$$A = \sum_{i=1}^{n} A_i$$

and divides said length l into n parts $l_1$, $l_2$,....$l_n$, so that,

$$l = \sum_{i=1}^{n} l_i$$

**characterized** in that the electric connections ($34_1$,$34_2$, ..., $34_{n-1}$) between the n earthing points are performed in such a way that the ends of every segment $l_i$ are electrically connected so that only the partial area $A_i$ is encompassed by a coil consisting of the electric connection ($34_{i-1}$ )and the segment $l_i$ and the condition,

$$\frac{\Phi_i}{\Phi} = \frac{l_i}{l}$$

is fulfilled, whereby $\Phi_i$ is the magnetic flux through the partial area $A_i$.

5. A power transformer/inductor according to claim 4, whereby the magnetic flux density B is constant throughout the cross-section of the core, **characterized** in that the electric connections ($34_1$, $34_2$, ..., $34_{n-1}$) between the n earthing points are performed in such a way that the condition,

$$\frac{A_i}{A} = \frac{l_i}{l}$$

is fulfilled.

6. A power transformer/inductor according to any one of claims 1-5, **characterized** in that the power transformer/inductor comprises a magnetizable core.

7. A power transformer/inductor according to any one of claims 1-5, **characterized** in that the power transformer/inductor is built without a magnetizable core.

8. A power transformer/inductor according to claim 1, **characterized** in that the winding/windings are flexible (a) and in that said layers adhere to each other.

9. A power transformer/inductor according to claim 8, **characterized** in that said layers are of a material with such an elasticity and with such a relation between the coefficients of thermal expansion of the material that during operation changes in volume, due to temperature variations, are able to be absorbed by the elasticity of the material such that the layers retain their adherence to each other during the temperature variations that appear during operation.

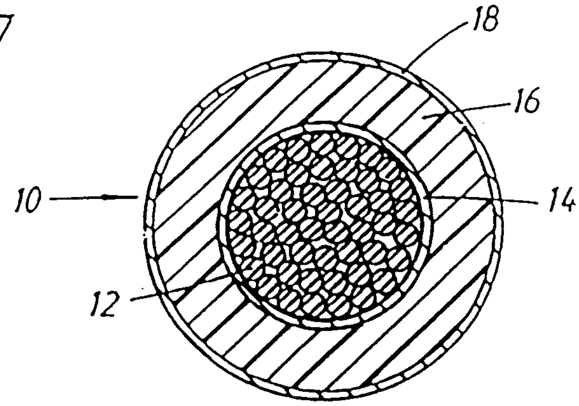
10. A power transformer/inductor according to claim 9, **characterized** in that the materials in the said layers have a high elasticity, preferably with an E-module less than 500 MPa and most preferably less than 200 MPa.

11. A power transformer/inductor according to claim 9, **characterized** in that the coefficients of thermal expansion in the materials of the said layers are substantially equal.

12. A power transformer/inductor according to claim 9, **characterized** in that the adherence between layers is at least of the same rating as in the weakest of the materials.

13. A power transformer/inductor according to claim 8, or 9, **characterized** in that each semiconducting layer constitutes substantially an equipotential surface.

Fig. 1



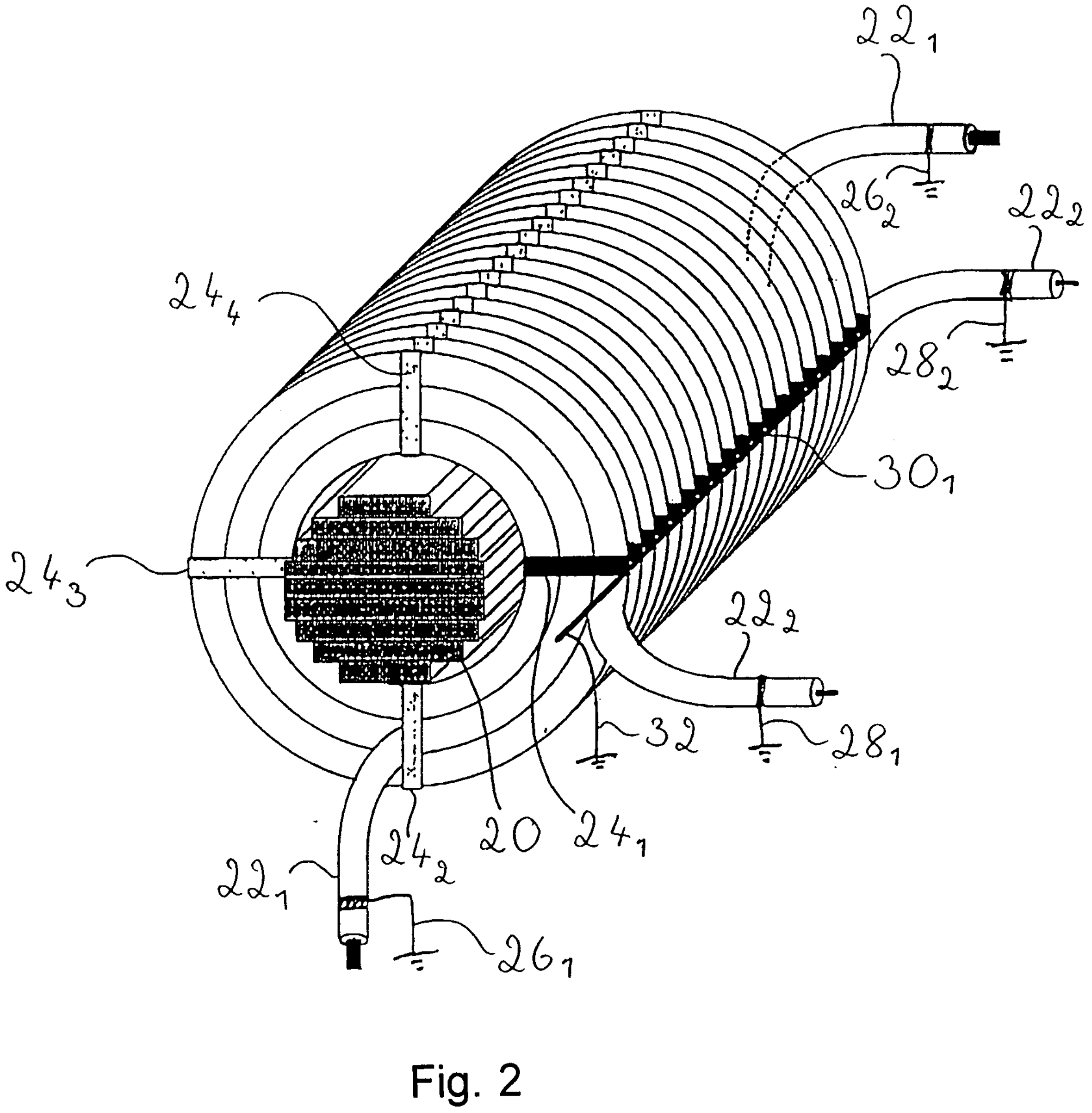
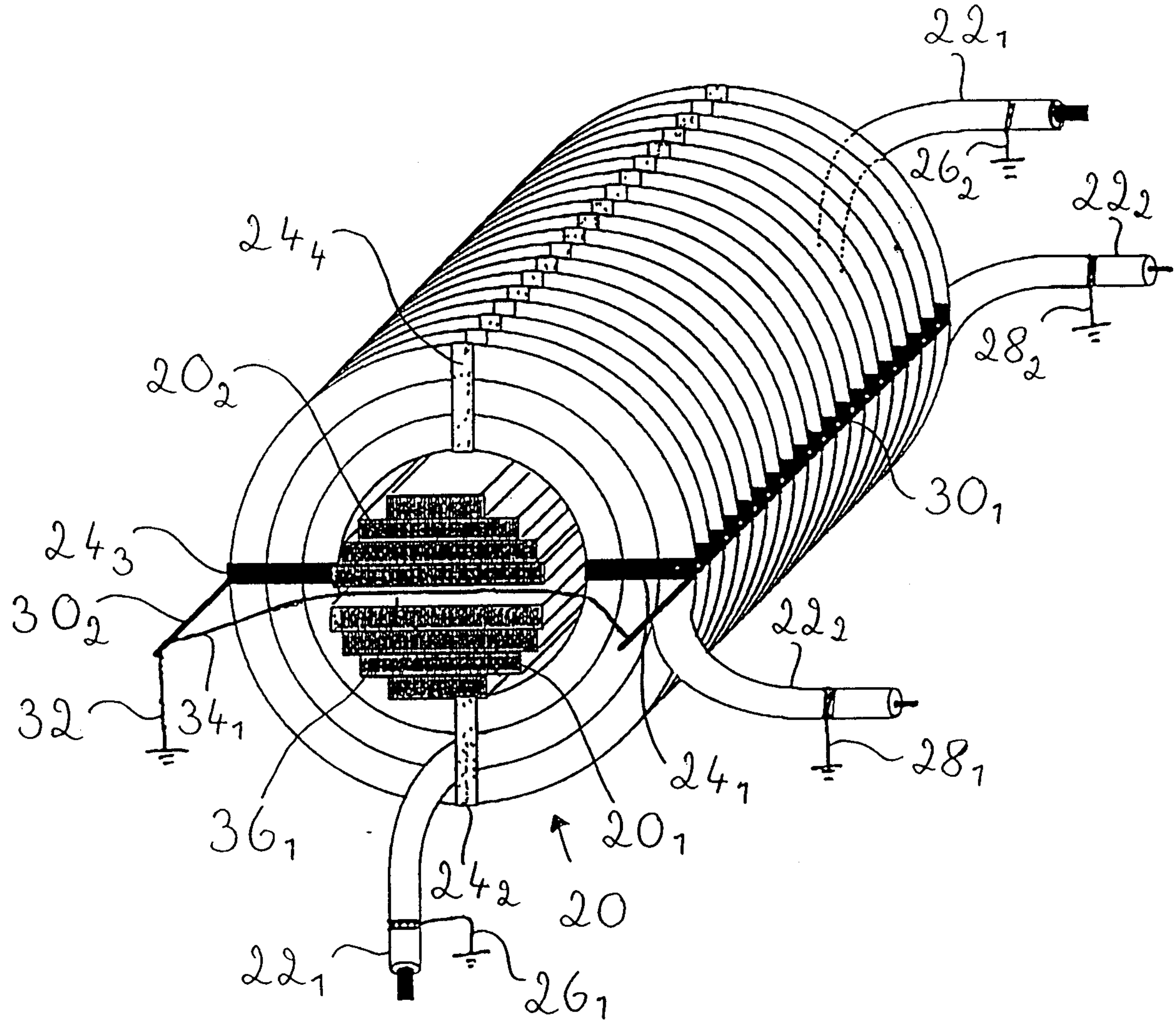



Fig. 2



$22_1$
$26_2$
$22_2$
$24_4$
$28_2$
$20_2$
$30_1$
$24_3$
$30_2$
$22_2$
$32$
$34_1$
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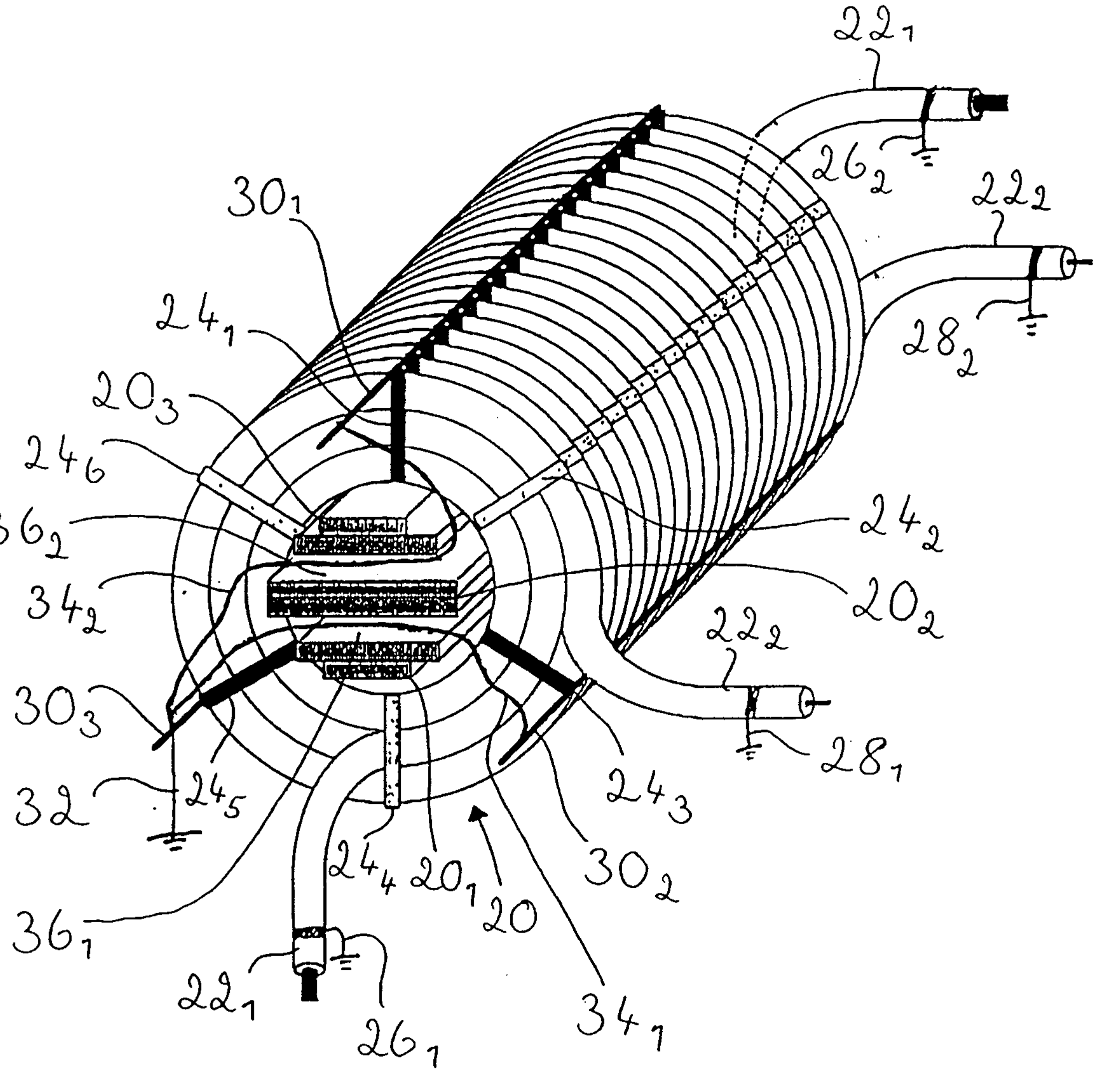
$36_1$
$20_1$
$24_2$
$20$
$22_1$
$26_1$


Fig. 3


22₁
26₂
22₂
30₁
28₂
24₁
20₃
24₆
24₂
36₂
20₂
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30₃
28₁
24₃
32
24₅
24₄
20₁
30₂
20
36₁
22₁
34₁
26₁

Fig. 4

Fig. 5 a

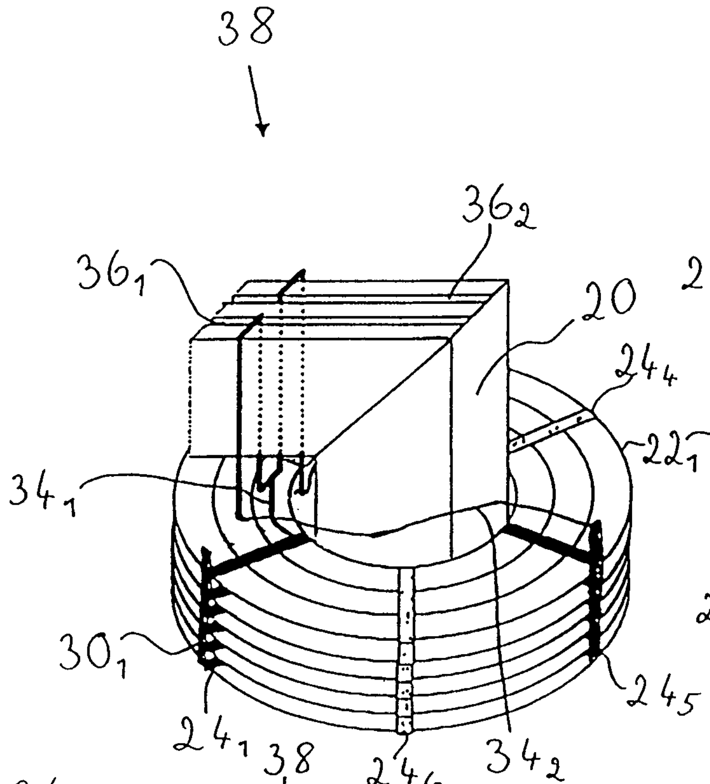
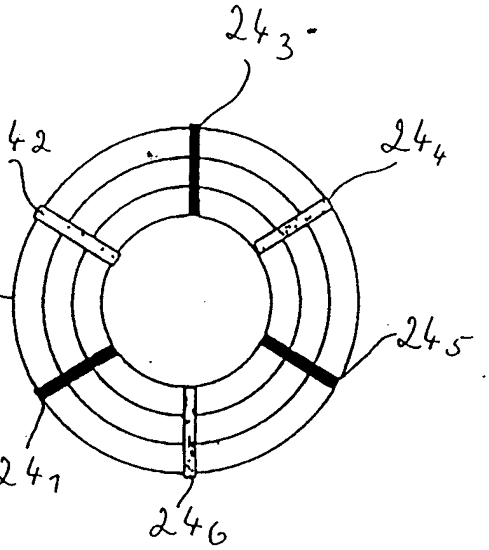
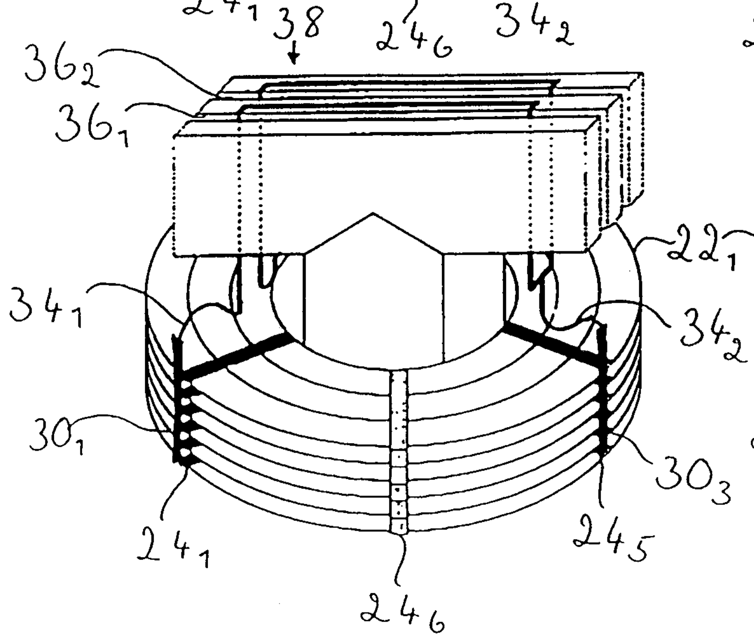



Fig. 5 b



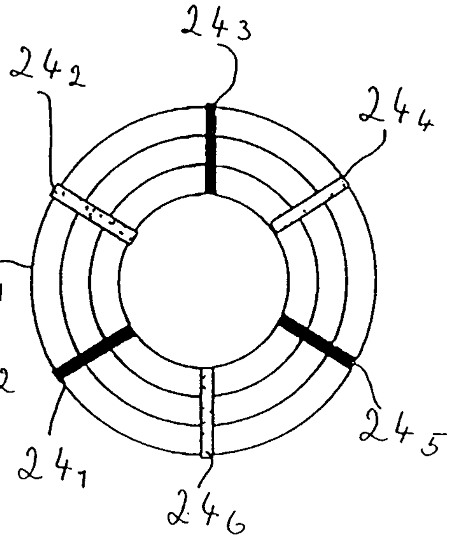




Fig. 6 b

Fig. 6 a

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/00153

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC6: H01F 27/34

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EDOC, WPIL, JAPIO

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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|---|---|---|
| A | US 5036165 A (RICHARD K. ELTON ET AL), 30 July 1991 (30.07.91), abstract<br>-- | 1 |
| A | US 4109098 A (MATS GUNNAR OLSSON ET AL), 22 August 1978 (22.08.78), abstract<br>--<br>-------- | 1 |

☐ Further documents are listed in the continuation of Box C.  ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" erlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 11 June 1998 | 17 -06- 1998 |
| Name and mailing address of the ISA/<br>Swedish Patent Office<br>Box 5055, S-102 42 STOCKHOLM<br>Facsimile No. +46 8 666 02 86 | Authorized officer<br><br>Magnus Westöö<br>Telephone No. +46 8 782 25 00 |

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Information on patent family members

09/06/98

International application No.
PCT/SE 98/00153

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