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(54) **TRANSFORMER ARRANGEMENT HAVING AN AIR DUCT ELEMENT, AIR DUCT ELEMENT, AND COOLING SYSTEM FOR COOLING A TRANSFORMER**

(57) The invention relates to an air duct element which is configured to be attached to a fan air outlet of a fan for cooling a dry-type transformer. The air duct element is configured to divide an airflow generated by the fan and delivered through the fan air outlet into at least a first airflow portion and a second airflow portion. The air duct element is configured to direct the first airflow portion and the second airflow portion to different individual parts of the transformer. The air duct element comprises a first airflow portion opening for outlet of the first airflow portion. The first airflow portion opening has two opposing edge regions which are at least partially curved in an identical direction. The invention further relates to a cooling system comprising an air duct element, and to a dry-type transformer.

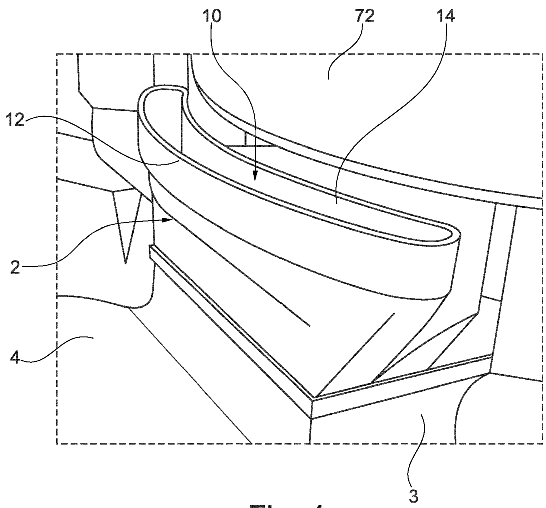

Fig. 4

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Description

BACKGROUND

[0001] The present disclosure relates to a transformer arrangement comprising an air duct element for cooling a coil assembly and/or a core of the transformer arrangement, a respective air duct element, and a cooling system comprising such an air duct element.

[0002] Transformers are used to convert electricity from a first voltage level to an electricity at a second voltage level which is either higher or a lower than the first voltage level. A typical transformer comprises two sets of insulated wire coils - herein also referred to as "windings" for short- around a ferromagnetic core of the transformer, namely a high voltage (HV) winding and low voltage (LV) winding. The LV winding often constitutes an inner winding, and the HV winding an outer winding. When electrical power is applied to one winding that draws power from a source of voltage, it is then magnetically transferred to another winding that delivers power to a load at a transformed voltage. The ratio of turns in one winding to the turns in another winding is the same as the ratio of the voltage of the source to the voltage of the load.

[0003] In a dry-type transformer, typically used for power distribution networks, no dielectric liquid is used for insulating the windings. A dry-type transformer performance is principally highly limited by temperature rise during operation due to losses and heat dissipation.

[0004] Presently, centrifugal fans with very high airflow rate are typically used for air-forced cooling of a dry-type transformer. Fig. 1 schematically shows a centrifugal fan 200 positioned in a lower region of a transformer. The transformer comprises a core 500, an inner winding 600, and an outer winding 700. Heat-producing parts of the transformer are primarily its windings and the core. The centrifugal fan 200 generates an airflow 800 directed at the windings 600, 700 and the core 500.

[0005] However, a problem here is that much of the air expelled by the centrifugal fan 200 does not specifically reach those parts of the transformer whose cooling is particularly important. This results in an airflow waste and a reduced cooling efficiency.

[0006] It is also known to use a fan and an air duct coupled to the fan to direct cooling air to a dry-type transformer. However, also here only limited efficiency can be achieved with the known solutions.

[0007] Therefore, there is a need for a technology providing improved cooling of a transformer, particularly a dry-type transformer.

SUMMARY

[0008] According to the present invention, a transformer arrangement is provided which comprises a transformer core, defining a longitudinal axis, a coil assembly wound around the core, the coil assembly comprising a winding, and an air duct element configured and arranged to direct an airflow portion to a bottom end of the winding and/or along an inner or outer surface area of the winding and/or to at least one cooling gap provided in the transformer arrangement for cooling the coil assembly and/or the core, wherein a distance between the air duct element and the bottom end of the winding is less than 50 mm.

[0009] The air duct element allows for directing the airflow portion in a particular effective way to the bottom end of the winding and/or along the inner or outer surface area of the winding and/or at least one cooling gap for cooling the coil assembly and/or the core, i.e. to parts of the transformer arrangement whose cooling during operation of the transformer is of particular importance. In this way, an airflow waste or loss can be significantly reduced. The air duct element is particularly suited to be adapted or configured to deliver the airflow portion in a particularly precise manner to respective areas or parts of the transformer arrangement. Air can be substantially prevented from flowing to regions where it is not needed for the desired cooling effect. Moreover, the air duct element can be easily configured such that generation of turbulences is significantly reduced.

[0010] Various embodiments may implement one or more of the following features:

[0011] The transformer arrangement may comprise a dry-type transformer. The coil assembly may comprise two or more windings. The windings may comprise at least one low-voltage winding and at least one high-voltage winding. The low-voltage winding may be an inner winding and the high-voltage winding may be an outer winding.

[0012] The bottom end of the winding may be the downward facing end of the winding when the transformer is set up in an operating position.

[0013] The distance is the smallest distance between two parts, e.g., the air duct element and the bottom end of the winding.

[0014] The distance may be less than 40 mm, less than 30 mm, less than 20 mm, less than 10 mm, or less than 5 mm. Generally, the smaller the distance, the better the guidance of the airflow. However, a minimum distance is necessary in order not to generate electrical problems between a fan, which may be provided for generating and delivering an airflow into the airduct element, and the winding of the transformer arrangement. This is naturally even more critical in the case of a high-voltage winding than in the case of a low-voltage winding. Thus, minimum distances may differ for high-voltage and low-voltage windings. The minimum distance is also dependent on the power of the transformer arrangement.

[0015] The airduct element may be made from a dielectrical material and/or a nonconductive material. This is advantageous because it reduces the risk of undesirable electrical effects being triggered by the airduct element. The airduct element may thus serve as an electric isolation between the transformer and its windings and the fan or other air guiding parts.

[0016] The air duct element may be manufactured by additive manufacturing. This particularly allows for a cheap, easy and fast manufacturing option of the airduct element and its particularly suitable geometries.

[0017] The air duct element may comprise an airflow portion opening as an outlet of an airflow portion, wherein the shape of the airflow portion opening matches the shape of an outer or inner edge of the bottom end of the winding and/or the inner or outer surface area of the winding, and/or at least one cooling gap provided in the transformer arrangement. In this way, a particularly precise guidance of the airflow portion is further supported. High losses of airflow may further be avoided by such matching shape. Reference to matching shape may be understood as referring to shapes which are aligned to a high degree as regards their geometry, extension and position. For example, the shape of the airflow portion opening may, at the side adjacent the outside or inside of a winding, correspond to the or part of the winding's bottom end's outside or inside geometry. This may, for example, refer to the two-dimensional shape of said winding, e.g., when seen at its footprint.

[0018] The airflow portion opening may just cover or be aligned with a segment of the bottom end of the winding and/or along an inner or outer surface area of the winding and/or to at least one cooling gap provided in the transformer arrangement for cooling the coil assembly and/or the core. It may thus extend within a spatial area defined or limited by two angular legs of an angle α whose angular vertex coincides with the longitudinal axis, wherein α is between 5° and 350°, preferably between 10° and 270°, preferably between 20° and 180°, preferably between 25° and 100°. Preferably, the angle α lies in a plane perpendicular to the longitudinal axis. For example, the edge of the airflow portion opening may extend in a plane perpendicular to the longitudinal axis, wherein the angle α lies the same plane as the edge of the airflow portion opening.

[0019] The airflow portion opening may match the shape of the inner or outer edge of the bottom end of the winding and/or the inner or outer surface area of the winding to such a degree that at least 80% of the airflow exiting the airflow portion opening, preferably at least 90% of the airflow, preferably at least 95% of the airflow, even more preferably at least 98% of the airflow reaches and flows along the inner or outer surface area of the winding and/or at least one cooling gap provided in the transformer arrangement.

[0020] The transformer arrangement may further comprise a fan having a fan air outlet, wherein the fan is configured and arranged to generate an airflow and to deliver the airflow through the fan air outlet to an air inlet opening of the air duct element. Inner surfaces of the air duct element for guiding the airflow from the air inlet opening to the airflow portion opening are preferably smooth and without steps or sharp edges. This further reduces generation of turbulences in the airflow and contributes to an efficient cooling.

[0021] According to a further aspect of the invention, an air duct element is provided which is configured to direct an airflow portion to an outer or inner edge of a bottom end of a winding of a coil assembly of a transformer and/or along an inner or outer surface area of a winding of a coil assembly of a transformer and/or to at least one cooling gap provided in the transformer arrangement. The air duct element comprises an airflow portion opening for outlet of the airflow portion. Preferably, the shape of the airflow portion opening matches the shape of an outer or inner edge of the bottom end of the winding and/or the inner or outer surface area of the winding, and/or at least one cooling gap provided in the transformer arrangement.

[0022] The airflow portion opening may have a circumferentially closed form extending around the longitudinal axis. This allows for a particular effective cooling.

[0023] According to a further aspect of the present disclosure an air duct element is provided which is configured to be attached to a fan air outlet of a fan for cooling a dry-type transformer, for example an air duct element as described above. The air duct element is configured to divide an airflow generated by the fan and delivered through the fan air outlet into at least a first airflow portion and a second airflow portion. The air duct element is configured to direct the first airflow portion and the second airflow portion to different individual parts of the transformer. Preferably, the air duct element comprises a first airflow portion opening for outlet of the first airflow portion. The first airflow portion opening has two opposing edge regions which are at least partially curved in an identical direction. Preferably, the air duct element is configured to divide the airflow generated by the fan and delivered through the fan air outlet in a controlled manner into at least a first airflow portion and a second airflow portion.

[0024] By dividing the airflow in a first airflow portion and a second airflow portion, it is possible to guide cooling air to different specific or individual parts or portions of the transformer. Since the parts of the transformer that generate particularly much heat during operation of the transformer, such as the windings and the core, typically have curved or substantially curved surface areas, the curved opposing edge regions of the first airflow portion opening allow the cooling air to be directed in a particularly targeted manner to the areas to be cooled. In this way, a significantly increased cooling efficiency can be achieved. Moreover, providing the first airflow portion opening with two opposing edge regions which are at least partially curved in an identical direction makes it possible to adapt the first airflow portion opening particularly well to the shape of an area to be cooled, which particularly reduces formation of turbulences in the airflow within the air duct element. This also contributes to the increase in efficiency.

[0025] The achievable increase in cooling efficiency allows an increase in transformer power performance to be achieved. For example, a performance increase of about 10 % can be achieved.

[0026] Further, the increase in cooling efficiency may allow to reduce the number of airgaps in a winding, e. g. in an LV winding, and/or to reduce the size of such airgaps.

[0027] Accordingly, also a reduction of the transformer size and weight can be achieved.

[0028] The air duct element is particularly suited for applications where a maximum airflow is set, such as for example in case of wind turbines.

[0029] The individual parts of the transformer may be selected from a winding of the transformer, an outer surface area of a winding of the transformer, an inner surface area of a winding of the transformer, a gap area between two windings or within a winding of the transformer, and an outer surface area of a core of the transformer. The winding may be a high voltage winding or a low voltage winding. The low voltage winding may be an inner winding and the high voltage winding may be an outer winding.

[0030] For example, the air duct element may be configured to direct the first airflow portion to an outer surface area of an outer winding, and to direct the second airflow portion to an inner surface area of the outer winding or to a gap area between the outer winding an inner winding.

[0031] The transformer may have a rated power of for example between 0.5 MVA and 40 MVA.

[0032] The air duct element may be made from a dielectrical material and/or a nonconductive material. In this way, unwanted electrical interference of the air duct element with the electrical function of the transformer can be prevented.

[0033] The air duct element may be manufactured by additive manufacturing, for example by 3D-printing. This enables particularly cost-effective production of the air duct element. Particularly, in this way, the air duct element can be produced quickly and easily at low cost.

[0034] The air duct element may be configured to be reversibly connectable to the fan air outlet.

[0035] The first airflow portion opening may comprise an edge extending in a first airflow portion opening plane.

[0036] The air duct element may comprise an air inlet opening for receiving the airflow generated by the fan. The air inlet opening may comprise an edge extending in an air inlet opening plane. The edge of the first airflow portion opening may have a length that is greater than the distance between the air inlet opening and the first airflow portion opening. In this way, the distance that the air travels between the air inlet opening and the first airflow portion opening can be kept comparatively short. In this way flow losses within the air duct element can be kept particularly low.

[0037] The first airflow portion opening plane and the air inlet opening plane may be parallel. The edge of the first airflow portion opening may have a length that is greater than the distance between the first airflow portion opening plane and the air inlet opening plane.

[0038] Alternatively, the first airflow portion opening plane and the air inlet opening plane may include an angle which is greater than 0°. This is generally advantageous with regard to an effective and space-saving arrangement of the fan. The angle may be less than 25°, preferably less than 20°.

[0039] At least a segment of the first airflow portion opening may extend along an arc of a first circle. This is a particularly advantageous design because the above-mentioned individual parts of the transformer are typically shaped at least partially circular-cylindrical. However, this is as well advantageous, for example, if a winding to be cooled is shaped so that it has a normal cross-section that is in the form of a square with "rounded corner areas", since the configuration of the first airflow portion opening may be such that the first circle matches the shape of one of the corner areas.

[0040] The arc of the first circle may be defined by an angle α of at least 30°, preferably at least 60°, preferably at least 90°. The first airflow portion opening may have a circumferential closed form. For example, the angle α may be 360°.

[0041] The first airflow portion opening may have an arcual length S measured along the first circle and a radial thickness Δr measured perpendicular to the first circle, wherein the relation $S/\Delta r$ fulfills 1.2 <_ $S/\Delta r$ <_ 200, preferably 1.5 <_ $S/\Delta r$ <_ 150, preferably 2 <_ $S/\Delta r$ <_ 100, preferably $2 \leq S/\Delta r \leq 50$.

[0042] In principle, it is not mandatory that the first airflow portion opening is shaped so that it extends along an arc. In such a case, the first airflow portion opening may extend along a line which is at least partially curved and/or at least partially straight. In this case, the above relations may apply analogously, wherein the "arcual length S" is replaced by the "extension of the first airflow portion opening measured along the line" and the radial thickness Δr is replaced by a thickness perpendicular to the line. This length may also be briefly referred to as the "edge length" of the first airflow portion opening.

[0043] The arcual length S or the edge length of the first airflow portion opening may be larger than the distance between the air inlet opening and the first airflow portion opening.

[0044] Inner walls of the air duct element for guiding the first airflow portion and the second airflow portion may be shaped stepless. This substantially contributes to reducing formation of turbulences.

[0045] The air duct element may further comprise a second airflow portion opening for outlet of the second airflow portion.

[0046] The first airflow portion opening and the second airflow portion opening may extend in one plane. Specifically, the edge of the first airflow portion opening and the edge of the second airflow portion opening may extend in one plane. This allows for example the two openings to be positioned particularly close to an outer surface area and an inner surface area of a winding.

[0047] The second airflow portion opening may have two opposing edge regions being at least partially curved in an identical direction.

[0048] The two opposing edge regions of the first flow portion opening and the two opposing edge regions of the second airflow portion opening may be curved in the identical direction. This allows to fit particularly well to corresponding parts pf the transformer.

[0049] At least a segment of the second airflow portion opening may extend along a second circle. The second circle may have a smaller radius than the first circle. The first circle and the second circle may be formed so that they share a same center point.

[0050] The second airflow portion opening may be configured analogous to the first airflow portion opening.

[0051] The second airflow portion opening may have a circumferential closed form.

[0052] The arc of the second circle may be defined by an angle $\alpha 2$ of at least 30°, preferably at least 60°, preferably at least 90°.

[0053] The second airflow portion opening may have an arcual length S2 measured along the second circle and a radial thickness $\Delta r2$ measured perpendicular to the second circle, wherein the relation $S2/\Delta r2$ fulfills $1.2 \leq S2/\Delta r2 \leq 200$, preferably $1.5 \leq S2/\Delta r2 \leq 150$, preferably $2 \leq S2/\Delta r2 \leq 100$, preferably $2 \leq S2/\Delta r2 \leq 50$. In the case of a non-circular extension of the second airflow portion opening, the above relationships apply again analogously.

[0054] The shape of the first airflow portion opening may be a transformation of the shape of the second airflow portion opening in form of a centric stretching with respect to a center.

[0055] The air duct element may be further configured to divide the airflow into a third airflow portion, wherein the air duct element further comprises a third airflow portion opening for outlet of the third airflow portion.

[0056] The air duct element may be further configured to divide the airflow into a fourth airflow portion, wherein the air duct element further comprises a fourth airflow portion opening for outlet of the fourth airflow portion. A fifth, sixth, seventh, etc. airflow portion opening may be provided in a corresponding manner.

[0057] The first airflow portion opening and the third airflow portion opening may extend in different planes. Specifically, the edge of the first airflow portion opening may extend in a first plane and the edge of the third airflow portion opening may extend in a second plane, wherein the second plane differs from the first plane. The first and the second plane may be parallel. In this way, the first airflow portion opening can be positioned particularly suitably close to a first winding of the transformer and the third airflow portion opening particularly close to a second winding of the transformer extending further down than the first winding. For example, the first airflow portion opening can be positioned particularly suitably close to an outer surface of an outer winding of the transformer and the third airflow portion opening particularly close to, for example below an inner winding of the transformer. The outer winding may be a high voltage winding, and the inner winding may be a low voltage winding. The inner winding may have at least one internal gap. Alternatively, the inner winding may have no internal gap.

[0058] The third airflow portion opening may have two opposing edge regions being at least partially curved in an identical direction.

[0059] The two opposing edge regions of the first airflow portion opening and the two opposing edge regions of the third airflow portion opening may be curved in the identical direction.

[0060] At least a segment of the third airflow portion opening may extend along a third circle. The third circle may have a smaller radius than the second circle. The third circle and the first circle may be formed so that they share a same center point. The arc of the third circle may be defined by an angle $\alpha 3$ of at least 30°, preferably at least 60°, preferably at least 90°.

[0061] The third airflow portion opening may be configured analogous to the first airflow portion opening.

[0062] The third airflow portion opening may have a circumferential closed form.

[0063] The third airflow portion opening may have an arcual length S3 measured along the third circle and a radial thickness $\Delta r3$ measured perpendicular to the third circle, wherein the relation $S3/\Delta r3$ fulfills $1.2 \leq S3/\Delta r3 \leq 200$, preferably $1.5 \leq S3/\Delta r3 \leq 150$, preferably $2 \leq S3/\Delta r3 \leq 100$, preferably $2 \leq S3/\Delta r3 \leq 50$. In the case of a non-circular extension of the third airflow portion opening, the above relationships apply again analogously.

[0064] According to a further aspect of the invention, a cooling system for cooling a dry-type transformer is provided which comprises a fan and an air duct element according to the present disclosure. The fan has a fan air outlet and is configured to generate an airflow and to deliver the airflow through the fan air outlet. The air duct element is attached to the fan air outlet.

[0065] The air duct element may be directly attached to the fan. The air duct element may comprise an air inlet opening for receiving the airflow generated by the fan. The air inlet opening may be attached particularly in an air-tight manner to the fan air outlet.

[0066] The cooling system may comprise an intermediate piece disposed between the fan and the air duct element. The intermediate piece may be coupled directly, particularly in an air-tight mannerto the fan air outlet and to the air inlet opening.

[0067] According to a further aspect of the invention, a dry-type transformer is provided which comprises a core, a coil assembly wound around the core, and a cooling system according to the present disclosure or an air duct element according to the present disclosure. The coil assembly comprises an outermost winding and an innermost winding.

[0068] The outermost winding may be a high-voltage winding. The innermost winding may be a low-voltage winding.

[0069] The core may comprise a linear core segment, where the outermost winding and the innermost winding are wound around the linear core segment. The linear core segment may be oriented vertically.

[0070] The first airflow portion opening of the air duct element may be configured and arranged to direct the first airflow portion along an outer surface area of the outermost winding.

[0071] The second airflow portion opening of the air duct element may be configured and arranged to direct the second airflow portion into a gap area formed by the coil assembly between the outermost winding and the innermost winding or to an inner surface area of the outermost winding.

[0072] The third airflow portion opening of the air duct element may be configured and arranged to direct the third airflow portion partially along an outer surface area of the innermost winding and/or partially along an inner surface area of the innermost coil.

[0073] The distance between the coil assembly and the air duct element may be less than 10 cm, preferably less than 5 cm.

[0074] In particular, the present disclosure comprises the following aspects:

1. A transformer arrangement, comprising

   a transformer core (50), defining a longitudinal axis (L),
   a coil assembly wound around the core (50), the coil assembly comprising a winding (60, 70), and
   an air duct element (2) configured and arranged to direct an airflow portion (62, 64, 66) to a bottom end (69, 79) of the winding (60, 70) and/or along an inner or outer surface area (72, 74; 65, 67) of the winding (60, 70) for cooling the coil assembly and/or the core (50),
   wherein a distance (δ) between the air duct element (2) and the bottom end (69, 79) of the winding (60, 70) is less than 50 mm.

2. The arrangement of aspect 1, wherein the distance (δ) is less than 40 mm, preferably less than 30 mm, preferably less than 20 mm, preferably less than 10 mm.

3. The arrangement of aspect 1 or 2,

   wherein the airduct element (2) is made from a dielectrical material and/or a nonconductive material; and/or
   wherein the air duct element (2) is manufactured by additive manufacturing.

4. The arrangement of any of the preceding aspects, wherein the air duct element (2) comprises an airflow portion opening (10, 20, 30) for outlet of the airflow portion,
wherein the shape of the airflow portion opening (10, 20, 30) matches the shape of an outer or inner edge of the bottom end (69, 79) of the winding (60, 70) and/or the inner or outer surface area (72, 74, 65, 67) of the winding, and/or at least one cooling gap provided in the transformer arrangement.

5. The arrangement of aspect 4, wherein the airflow portion opening (10, 20, 30) extends within a spatial area defined by two angular legs of an angle α whose angular vertex coincides with the longitudinal axis (L), wherein α is between 5° and 350°, preferably between 10° and 270°, preferably between 20° and 180°, preferably between 25° and 100°.

6. The arrangement of any of aspect 4 or 5, wherein the airflow portion opening (10, 20, 30) matches the shape of the inner or outer edge of the bottom end (69, 79) of the winding (60, 70) and/or the inner or outer surface area (72, 74, 65, 67) of the winding to such a degree that at least 80% of the airflow exiting the airflow portion opening (10, 20, 30), preferably at least 90% of the airflow, preferably at least 95% of the airflow, even more preferably at least 98% of the airflow reaches and flows along the inner or outer surface area (72, 74, 65, 67) of the winding and/or at least one cooling gap provided in the transformer arrangement.

7. The arrangement of any of the preceding aspects,

   further comprising a fan (4) having a fan air outlet (42), the fan (4) being configured and arranged to generate an airflow (6) and to deliver the airflow (6) through the fan air outlet (42) to an air inlet opening (22) of the air duct element (2), preferably wherein inner surfaces of the air duct element (2) for guiding the airflow (6) from the air inlet opening (22) to the airflow portion opening (10, 20, 30) are smooth and without steps or sharp edges.

8. An air duct element (2), configured to direct an airflow portion (62, 64, 66) to an outer or inner edge of a bottom end (69, 79) of a winding (60, 70) of a coil assembly of a transformer and/or along an inner or outer surface area (72, 74, 65, 67) of a winding (60, 70) of a coil assembly of a transformer and/or to at least one cooling gap provided in the transformer arrangement,

   the air duct element (2) comprising an airflow portion opening (10, 20, 30) for outlet of the airflow portion (62, 64, 66),
   wherein the shape of the airflow portion opening (10, 20, 30) matches the shape of an outer or inner edge of the bottom end (69, 79) of the winding (60, 70) and/or the inner or outer surface area (72, 74, 65, 67) of the winding, and/or at least one cooling gap provided in the transfor-

mer arrangement; and/or
wherein the airflow portion opening (10, 20, 30) has a circumferentially closed form extending around the longitudinal axis (L).

9. An air duct element (2) configured to be attached to a fan air outlet (42) of a fan (4) for cooling a dry-type transformer, preferably the air duct element of aspect 8,

wherein the air duct element (2) is configured to divide an airflow (6) generated by the fan (4) and delivered through the fan air outlet (42) into at least a first airflow portion (62) and a second airflow portion (64),
wherein the air duct element (2) is configured to direct the first airflow portion (62) and the second airflow portion (64) to different individual parts of the transformer.

10. The air duct element (2) of aspect 9,
wherein the air duct element (2) comprises a first airflow portion opening (10) for outlet of the first airflow portion (62), the first airflow portion opening (10) having two opposing edge regions (12, 14) being at least partially curved in an identical direction.

11. The air duct element of aspect 9 or 10, wherein the individual parts of the transformer are selected from a winding (60, 70) of the transformer, an outer surface area (72) of a winding (70) of the transformer, an inner surface area (74) of a winding of the transformer, a gap area (80) between two windings (60, 70) or within a winding of the transformer, and an outer surface area (52) of a core (50) of the transformer.

12. The air duct element of any of aspects 9 to 11, wherein the air duct element (2) comprises an air inlet opening (22) for receiving the airflow (6) generated by the fan (4),
wherein the edge of the first airflow portion opening (10) has a length that is greater than the distance between the air inlet opening (22) and the first airflow portion opening (10).

13. The air duct element of any of aspects 9 to 12, wherein at least a segment of the first airflow portion opening (10) extends along an arc of a first circle.

14. The air duct element of aspect 13, wherein the arc of the first circle is defined by an angle α of at least 30°, preferably at least 60°, preferably at least 90°.

15. The air duct element of any of aspects 9 to 14, wherein the first airflow portion opening (10) has a circumferential closed form.

16. The air duct element of any of the preceding aspects, comprising the features of aspect 13, wherein the first airflow portion opening (10) has an arcual length S measured along the first circle and a radial thickness Δr measured perpendicular to the first circle, wherein the relation $S/\Delta r$ fulfills $1.2 \leq S/\Delta r \leq 200$, preferably $1.5 \leq S/\Delta r \leq 150$, preferably $2 \leq S/\Delta r \leq 100$, preferably $2 \leq S/\Delta r \leq 50$.

17. The air duct element of aspect 16, comprising the features of aspect 10,
wherein the arcual length S of the first airflow portion opening (10) is larger than the distance between the air inlet opening (22) and the first airflow portion opening (10).

18. The air duct element of any of aspects 9 to 17, wherein inner walls of the air duct element (2) for guiding the first airflow portion (62) and the second airflow portion (64) are shaped stepless.

19. The air duct element of any of the preceding aspects,
wherein the air duct element (2) further comprises a second airflow portion opening (20) for outlet of the second airflow portion (64).

20. The air duct element of aspect 19, wherein the first airflow portion opening (10) and the second airflow portion opening (20) extend in one plane.

21. The air duct element of aspect 19 or 20, wherein the second airflow portion opening (20) has two opposing edge regions (22, 24) being at least partially curved in an identical direction.

22. The air duct element of aspect 21, wherein the two opposing edge regions (12, 14) of the first flow portion opening (10) and the two opposing edge regions (22, 24) of the second airflow portion opening (20) are curved in the identical direction.

23. The air duct element of any of aspects 19 to 22, wherein at least a segment of the second airflow portion opening (20) extends along an arc of a second circle.

24. The air duct element of any of aspect 23, wherein the first circle and the second circle are formed so that they share a same center point (M).

25. The air duct element of any of aspects 9 to 24, wherein the air duct element (2) is further configured to divide the airflow (6) into a third airflow portion (66), wherein the air duct element (2) further comprises a third airflow portion opening (30) for outlet of the third airflow portion (66).

26. The air duct element of aspect 25, wherein the first airflow portion opening (10) and the third airflow portion opening (30) extend in different planes.

27. The air duct element of aspect 25 or 26, wherein the third airflow portion opening (30) has two opposing edge regions (32, 34) being at least partially curved in an identical direction.

28. The air duct element of aspect 27, wherein the two opposing edge regions (12, 14) of the first airflow portion opening (10) and the two opposing edge regions (32, 34) of the third airflow portion opening (30) are curved in the identical direction.

29. The air duct element of any of aspect 25 to 28, wherein at least a segment of the third airflow portion opening (30) extends along a third circle.

30. A cooling system for cooling a dry-type transformer, comprising

a fan (4) having a fan air outlet (42), and being configured to generate an airflow (6) and to deliver the airflow (6) through the fan air outlet (42), and
at least one air duct element (2) according to any of aspects 9 to 29, attached to the fan air outlet (42).

31. A dry-type transformer, comprising

a core (50),
a coil assembly wound around the core (50), the coil assembly comprising at least one winding, for example an outermost winding (70) and an innermost winding (60), and
a cooling system according to aspect 30 or an air duct element (2) according to any of aspects 9 to 29 for cooling the coil assembly and/or the core (50).

32. The dry-type transformer of aspect 31,
wherein the first airflow portion opening (10) of the air duct element (2) is configured and arranged to direct the first airflow portion (62) along an outer surface area (72) of the outermost winding (70).

33. The dry-type transformer of aspect 31 or 32,
wherein the second airflow portion opening (20) of the air duct element (2) is configured and arranged to direct the second airflow portion (64) into a gap area (80) formed by the coil assembly between the outermost winding (70) and the innermost winding (60).

34. The dry-type transformer of any of aspects 31 to 33,
wherein the third airflow portion opening (30) of the air duct element (2) is configured and arranged to direct the third airflow portion (66) partially along an outer surface area of the innermost winding (60) and/or partially along an inner surface of the innermost winding (60).

35. The dry-type transformer of any of aspects 31 to 34,
wherein the distance δ between the coil assembly and the air duct element (2) is less than 10 cm, preferably less than 5 cm.

SHORT DESCRIPTION OF THE DRAWINGS

[0075] The subject-matter of the disclosure will be explained in more detail with reference to preferred exemplary embodiments which are illustrated in the attached drawings.

Fig. 1 is a schematic view of lower region of a transformer and a fan for cooling the transformer according to prior art.

Fig. 2 is a view of a lower region of a transformer comprising three coil assemblies, each coil assembly provided with a cooling system according to the present disclosure.

Fig. 3 is a perspective view of a first one of the cooling systems.

Fig. 4 is an enlarged section of Fig. 3.

Fig. 5 is a schematic cross-sectional view of an air duct element according to the present disclosure and adjacent portions of a fan and a transformer.

Fig. 6 is a perspective view of a separated air duct element according to the present disclosure.

Fig. 7 is a rear view of the lower region of the transformer shown in Fig. 2.

Fig. 8a is a schematic sectional view of a core, an inner winding, and outer winding and an air duct element.

Fig. 8b is a schematic sectional view of a core, an inner winding, and outer winding and an alternatively shaped air duct element.

Fig. 9 is a schematic cross-sectional view of a lower portion of a transformer arrangement according to the present invention.

DETAILED DESCRIPTION

[0076] Fig. 2 is a view of a lower region of a dry-type transformer comprising three coil assemblies 7, 7', 7", each coil assembly provided with a corresponding cooling system 5, 5', 5" according to the present disclosure.

[0077] The transformer comprises a core having three linear core segments, wherein each coil assembly 7, 7', 7" is wound around a respective linear core segment.

[0078] The cooling systems 5, 5', 5" may be of the same configuration. Therefore, only one cooling system 5 is described in more detail below. The corresponding linear core segment is also referred to as "core" in the following for the sake of brevity.

[0079] Fig. 3 is a perspective view of the cooling system 5. The cooling system 5 comprises a fan 4 and an air duct element 2 attached to the fan 4. Fig. 4 is an enlarged section of Fig. 3. Fig. 5 shows a corresponding cross-sectional view. The air duct element 2 is preferably made from a dielectric material and may be manufactured by additive manufacturing, e. g. by 3D printing.

[0080] The fan 4 is configured to generate an airflow 6 and to deliver the airflow 6 through a fan air outlet 42. The air duct element 2 has an air inlet opening 22 for receiving the airflow 6 generated by the fan 4. The air duct element 2 may be attached directly to the fan air outlet 42, as sketched in Fig. 5. This is particularly advantageous if the edge of the fan air outlet 42 and the edge of the inlet opening 22 of the air duct element 2 extend at least approximately in the same plane.

[0081] Alternatively, as shown in Fig. 4, the cooling system may further comprise an intermediate piece or adapter 3 which connects the air duct element 2 to the fan 4. This is for example advantageous, if the edge of the fan air outlet 42 and the edge of the inlet opening 22 extend in two different planes which include an angle greater than 0°, since the intermediate piece 3 may be configured in such a case to connect the fan air outlet 42 and the air inlet opening 22 of the airduct element 2 by bridging the corresponding space in between, particularly in an air-tight manner.

[0082] The air duct element 2 is configured to divide the airflow 6 generated by the fan 4 and delivered through the fan air outlet 42 into at least a first airflow portion 62 and a second airflow portion 64. The air duct element 2 is configured to direct the first airflow portion 62 and the second airflow portion 64 to different individual parts of the transformer.

[0083] In the example illustrated in Fig. 5, an innermost winding 60 and an outermost winding 70 are wound around a linear core segment or core 50 for short.

[0084] Generally, more than two windings can be provided around each linear core section. In the example of Fig. 5, the number of windings wound around the core 50, is two so that here the outermost winding is an outer winding 70 and the innermost winding is an inner winding 60. The outer winding 70 comprises a bottom end 79 and the inner winding 60 comprises a bottom end 69.

[0085] Barrier elements 90 may be provided in a gap area 80 formed between the inner winding 60 and the outer winding 70. Typically, such barrier elements show practically no or at best little relevance with respect to heat generation by the transformer. Accordingly, the air duct element 2 may be configured not - or at least not specifically - to guide air to the barrier elements 90.

[0086] The core 50 extends along a longitudinal axis L which is typically oriented vertically. Fig. 8a shows a schematic cross-sectional view normal to the longitudinal axis L (not to scale). The windings 60, 70 are wound around the core 50 so that, when viewed in the normal cross-section, the core 50, the inner winding 60, and the outer winding 70 may share a common center point M.

[0087] In the example illustrated in Fig. 5, the air duct element 2 is configured to direct the first airflow portion 62 to an outer surface area 72 of the outer winding 70 and the second airflow portion 64 to an inner surface area 74 of the outer winding 70.

[0088] Fig. 6 shows a perspective view of the separated air duct element 2. The air duct element 2 comprises a first airflow portion opening 10 for outlet of the first airflow portion 62. The first airflow portion opening 10 has two opposing edge regions 12, 14 being at least partially curved in an identical direction. In this way, the shape of the first airflow portion opening 10 can be particularly well adapted to the outer surface area 72 of the outer winding 70 to be cooled.

[0089] In the example illustrated in Fig. 6, the first airflow portion opening 10 extends along an arc of a first circle - here having a first radius R1 - defined by an angle α. Preferably, the angle α is at least 30°. The first airflow portion opening 10 may have an arcual length S measured along the first circle and a radial thickness Δr measured perpendicular to the first circle, wherein the relation $2 \leq S/\Delta r \leq 50$ is fulfilled.

[0090] Generally, as sketched exemplarily in Fig. 8a, the angle α may be 360° so that the first airflow portion opening 10 has a circumferential closed form. In this way a particularly effective cooling of the respective part of the transformer, for example the outer surface area 72 of the outer winding70 can be achieved.

[0091] Alternatively, as sketched more simplified in a cross-sectional view in Fig. 8b, only a (true) first segment $\sigma 1$ the first airflow portion opening 10 may extend along an arc of a first circle. A second segment $\sigma 2$ may extend for example straight. Also in such a case, the first airflow portion opening 10 may have a circumferential closed form as sketched exemplarily in Fig. 8b.

[0092] This may be advantageous for example in a case where a corresponding winding shows a normal cross-section having a shape of a rectangle with "rounded edges", as sketched in Fig. 8b. In this case, the first circle may match advantageously a corresponding rounded edge region of the corresponding winding 70. In the example shown in Fig. 8b, the first segment $\sigma 1$ of the first airflow portion opening 10 is shaped so that the first circle has a center point M1. A third segment $\sigma 3$ of the first airflow portion opening 10 may be shaped so that a corresponding further circle has a further center point M2, and so on. Thus, in the example shown in Fig. 8b, the first airflow portion opening 10 has circumferential closed form, however it is not shaped circular.

[0093] However, alternatively and more generally, the first airflow portion opening 10 may be shaped exclusively straight, for example, it may merely extend along the segment indicated by reference sign $\sigma 2$.

[0094] In the example shown in Figures 5 and 6, the edge of the air inlet opening 22 and the edge of the first airflow portion opening 10 extend in parallel planes.

[0095] It is generally advantageous if the path of the airflow within the air duct element 2 is kept comparatively short. To this end, it is advantageous if the length of the edge of the first airflow portion opening 10 is larger than the distance D, see Fig. 5, between the air inlet opening plane and the first airflow portion opening plane. Preferably, the arcual length S of the first airflow portion opening 10 is larger than the distance D.

[0096] In the example shown in Fig. 6, the air duct element 2 further comprises a second airflow portion opening 20 for outlet of the second airflow portion 64. The configuration may be so that the second airflow portion 64 is directed by the air duct element 2 to an inner surface area 74 of the outer winding 70. Advantageously, the first airflow portion opening 10 and the second airflow portion opening 20 extend in one plane. The second airflow portion opening 30 may extend along an arc of a second circle, having a radius R2 which is smaller than the radius R1 of the first circle. The first and the second circle may share a same center point M.

[0097] The air duct element 2 may comprise wall portions 29 separating the first airflow portion 62 and the second airflow portion 64. These wall portions 29 may extend to the plane of the air inlet opening 22. In other words, the air inlet opening 22 may comprise a first part and a second part (or more parts), the first part being designed to receive a first portion of the airflow 6 which forms the first airflow portion 62 after entry into the air duct element 2, and the second part being designed to receive a second portion of the airflow 6 which forms the second airflow portion 64 after entry into the air duct element 2.

[0098] The air duct element 2 may be further configured to divide the airflow 6 into a third airflow portion 66, wherein the air duct element 2 further comprises a third airflow portion opening 30 for outlet of the third airflow portion 66. In the example illustrated in Fig. 5, the third airflow portion opening 30 faces the bottom end 69 of the inner winding 60. In the normal cross-section, as exemplarily shown in Fig. 8a, the projection of the third airflow portion opening 30 may include the inner winding 60, specifically, the bottom end 69 of the inner winding.

[0099] The configuration may be so that the third airflow portion 66 is directed by the air duct element 2 partially to an outer surface area 65 of the inner winding 60 and partially to an inner surface area 67 of the inner winding 60. Further, the third airflow portion opening 30 may be configured to match the shape of the bottom end 69 of the inner winding 60.

[0100] Moreover, the inner winding 60 may comprise at least one internal gap extending parallel to the longitudinal axis L throughout the vertical length of the inner winding 60, where the third airflow portion 66 may be directed further through a gap area of the at least one gap of the internal winding 60.

[0101] As shown for example in Figures 5 and 6, the first airflow portion opening 10 and the third airflow portion opening 30 may extend in different planes. This is for example particularly advantageous if the inner winding 60 extends further down than the outer winding 70, as exemplarily illustrated in Fig. 5. The air duct element 2 may further comprise wall portions 39 separating the second airflow portion 64 and the third airflow portion 66. These wall portions 39 may extend - as the wall portions 29 - to the plane of the air inlet opening 22.

[0102] Fig. 7 shows a variation of an air duct element 2' in which the first airflow portion opening 10' is formed having a shorter length than in the above example. Furthermore, this variation differs in that the air duct element 2' further comprises a "further" first airflow portion opening 10", which is directed towards a further outer surface area of the outer winding 70. These first airflow portion openings 10', 10" may extend along two distinct segments of a common circle. These segments may each be defined by a corresponding angle α as described above. Generally, a plurality of corresponding segments may be provided.

[0103] This design can be advantageous, for example, if the outer surface of the outer winding 70 has a radially outwardly projecting region, such as for example a dome region 92. Here, the two first airflow portion openings 10', 10" can advantageously be arranged on both sides of the radially outwardly projecting region or dome region 92.

[0104] Fig. 9 is a schematic cross-sectional view of a lower portion of a transformer arrangement, for example the transformer, the front of which is shown exemplarily in Fig. 2 and the rear of which is shown in Fig. 7. The air duct element 2 may be disposed in the front as illustrated in Figures 5 and 9, and a further air duct element 2' according to the above-described variation together with a respective further fan 4' is disposed in the rear, where the outer winding 70 shows the dome region 92.

[0105] As already described above, an air duct element according to the present disclosure is particularly advantageous, since it enables guiding cooled air in a very specific manner to parts of the transformer which need cooling during operation. More specifically, as shown in Fig. 5, the configuration may be such that a distance δ between the coil assembly, for example a lower edge or bottom end 79 of the outer winding 70, and the air duct element 2, for example the edge of the first airflow portion opening 10, is less than 10 cm, preferably less than 5 cm, even more preferably less than 3 cm, for example less than 2 cm. In this way a particularly high cooling efficiency can be achieved.

[0106] Some of the advantages achievable with the invention are listed in the following:

- Cooling air can be guided very precisely and specifically to parts of the transformer which need to be cooled during operation, such as the windings and the core.
- Cooling air can also be supplied to locations that cannot or cannot suitably be supplied with cooling air according to the state of the art.
- It can be achieved that the cooling air is practically not lost before it reaches the parts to be cooled, for example the windings.
- The air can be guided through a confined space up to the very edge of the windings.
- The technology makes it possible, with comparable performance, to reduce the size, the weight, and the required material of the transformer.
- The disclosed technology is of particular benefit for applications where there are restrictions in the maximum airflow permitted to cool the transformer, such as for example in case of wind turbines.
- The transformer according to the present disclosure allows for a significant increase in the power of the transformer, for example by as much as about 10%.
- The air duct element according to the present disclosure can be easily adapted to requirements of different transformers.
- A cooling system according to the present disclosure is suited to be implemented in a large variety of transformers, regardless of whether they have an enclosure or not.

Claims

1. A transformer arrangement, comprising

a transformer core (50), defining a longitudinal axis (L),
a coil assembly wound around the core (50), the coil assembly comprising a winding (60, 70), and
an air duct element (2) configured and arranged to direct an airflow portion (62, 64, 66) to a bottom end of the winding (60, 70) and/or along an inner or outer surface area (72, 74; 65, 67) of the winding (60, 70) for cooling the coil assembly and/or the core (50),
wherein a distance (δ) between the air duct element (2) and the bottom end of the winding (60, 70) is less than 50 mm.

2. The arrangement of claim 1, wherein the distance (δ) is less than 40 mm, preferably less than 30 mm, preferably less than 20 mm, preferably less than 10 mm.

3. The arrangement of claim 1 or 2,

wherein the airduct element (2) is made from a dielectrical material and/or a nonconductive material; and/or
wherein the air duct element (2) is manufactured by additive manufacturing.

4. The arrangement of any of the preceding claims, wherein the air duct element (2) comprises an air flow portion opening (10, 20, 30) for outlet of the airflow portion,
wherein the shape of the air flow portion opening (10, 20, 30) matches the shape of an outer or inner edge of the bottom end of the winding (60, 70) and/or the inner or outer surface area (72, 74, 65, 67) of the winding, and/or at least one cooling gap provided in the transformer arrangement.

5. The arrangement of any of claim 4, wherein the airflow portion opening (10, 20, 30) matches the shape of the inner or outer edge of the bottom end of the winding (60, 70) and/or the inner or outer surface area (72, 74, 65, 67) of the winding to such a degree that at least 80% of the airflow exiting the airflow portion opening (10, 20, 30), preferably at least 90% of the airflow, preferably at least 95% of the airflow, even more preferably at least 98% of the airflow reaches and flows along the inner or outer surface area (72, 74, 65, 67) of the winding and/or at least one cooling gap provided in the transformer arrangement.

6. The arrangement of any of the preceding claims,

further comprising a fan (4) having a fan air outlet (42), the fan (4) being configured and arranged to generate an airflow (6) and to deliver the airflow (6) through the fan air outlet (42) to an air inlet opening (22) of the air duct element (2), preferably wherein inner surfaces of the air duct element (2) for guiding the airflow (6) from the air inlet opening (22) to the airflow portion opening (10, 20, 30) are smooth and without steps or sharp edges.

7. An air duct element (2), configured to direct an airflow portion (62, 64, 66) to an outer or inner edge of a bottom end of a winding (60, 70) of a coil assembly of a transformer and/or along an inner or outer surface area (72, 74, 65, 67) of a winding (60, 70) of a coil assembly of a transformer and/or to at least one cooling gap provided in the transformer arrangement,
the air duct element (2) comprising an airflow portion opening (10, 20, 30) for outlet of the airflow portion (62, 64, 66),

wherein the shape of the air flow portion opening (10, 20, 30) matches the shape of an outer or inner edge of the bottom end of the winding (60, 70) and/or the inner or outer surface area (72,

74, 65, 67) of the winding, and/or at least one cooling gap provided in the transformer arrangement; and/or
wherein the air flow portion opening (10, 20, 30) has a circumferentially closed form extending around the longitudinal axis (L).

8. An air duct element (2) configured to be attached to a fan air outlet (42) of a fan (4) for cooling a dry-type transformer, preferably the air duct element of claim 7,

wherein the air duct element (2) is configured to divide an airflow (6) generated by the fan (4) and delivered through the fan air outlet (42) into at least a first airflow portion (62) and a second airflow portion (64),
wherein the air duct element (2) is configured to direct the first airflow portion (62) and the second airflow portion (64) to different individual parts of the transformer.

9. The air duct element of claim 8,
wherein the air duct element (2) comprises a first airflow portion opening (10) for outlet of the first airflow portion (62), the first airflow portion opening (10) having two opposing edge regions (12, 14) being at least partially curved in an identical direction.

10. The air duct element of claim 9, wherein at least a segment of the first airflow portion opening (10) extends along an arc of a first circle.

11. The air duct element of claim 10, wherein the arc of the first circle is defined by an angle α of at least 30°, preferably at least 60°, preferably at least 90°.

12. The air duct element of any of claims 9 to 11, wherein the first airflow portion opening (10) has an arcual length S measured along the first circle and a radial thickness Δr measured perpendicular to the first circle, wherein the relation $S/\Delta r$ fulfills $1.2 \leq S/\Delta r \leq 200$, preferably $1.5 \leq S/\Delta r \leq 150$, preferably $2 \leq S/\Delta r \leq 100$, preferably $2 \leq S/\Delta r \leq 50$.

13. The air duct element of any of claims 9 to 12, wherein the air duct element (2) further comprises a second airflow portion opening (20) for outlet of the second airflow portion (64), preferably
wherein the first airflow portion opening (10) and the second airflow portion opening (20) extend in one plane.

14. The air duct element of any of claims 9 to 13, wherein the air duct element (2) is further configured to divide the airflow (6) into a third airflow portion (66), wherein the air duct element (2) further comprises a third airflow portion opening (30) for outlet of the third airflow portion (66).

15. The air duct element of claim 14, wherein the first airflow portion opening (10) and the third airflow portion opening (30) extend in different planes.

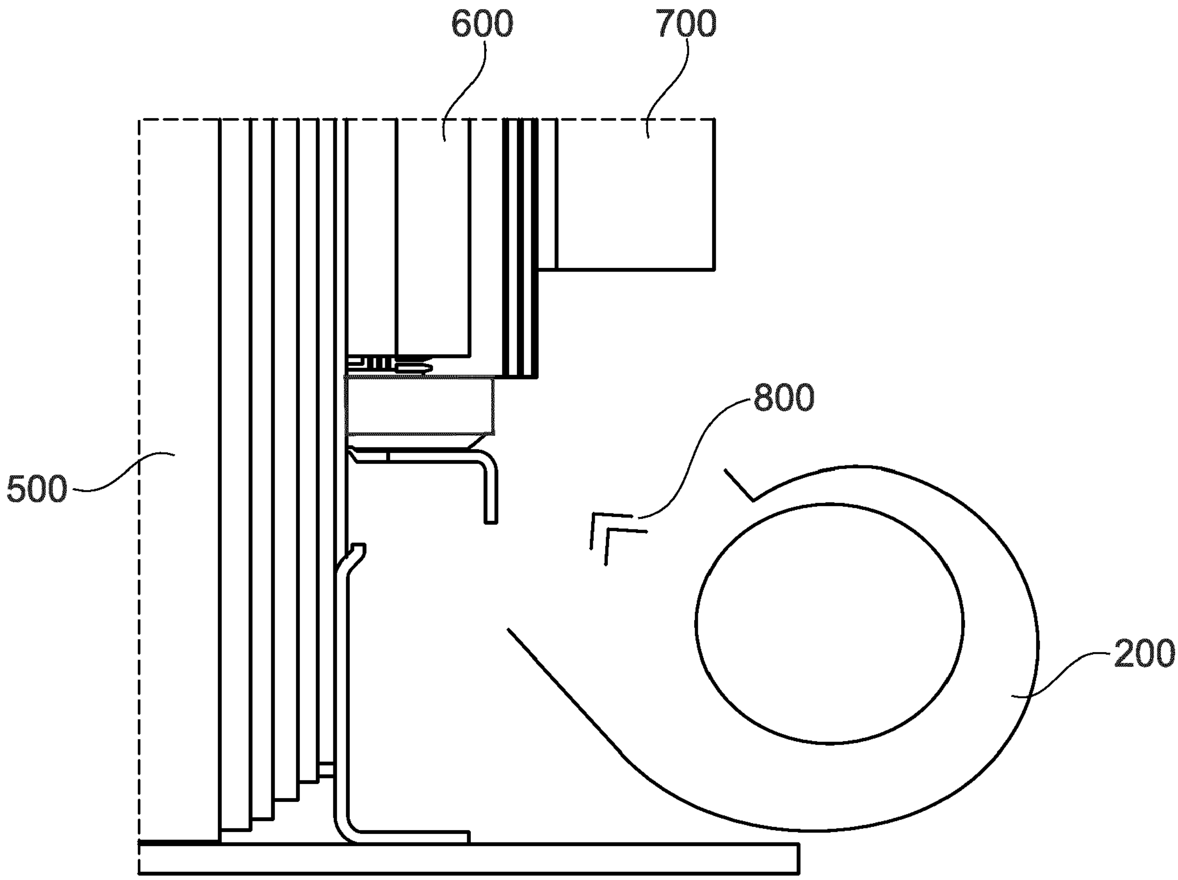

Fig. 1

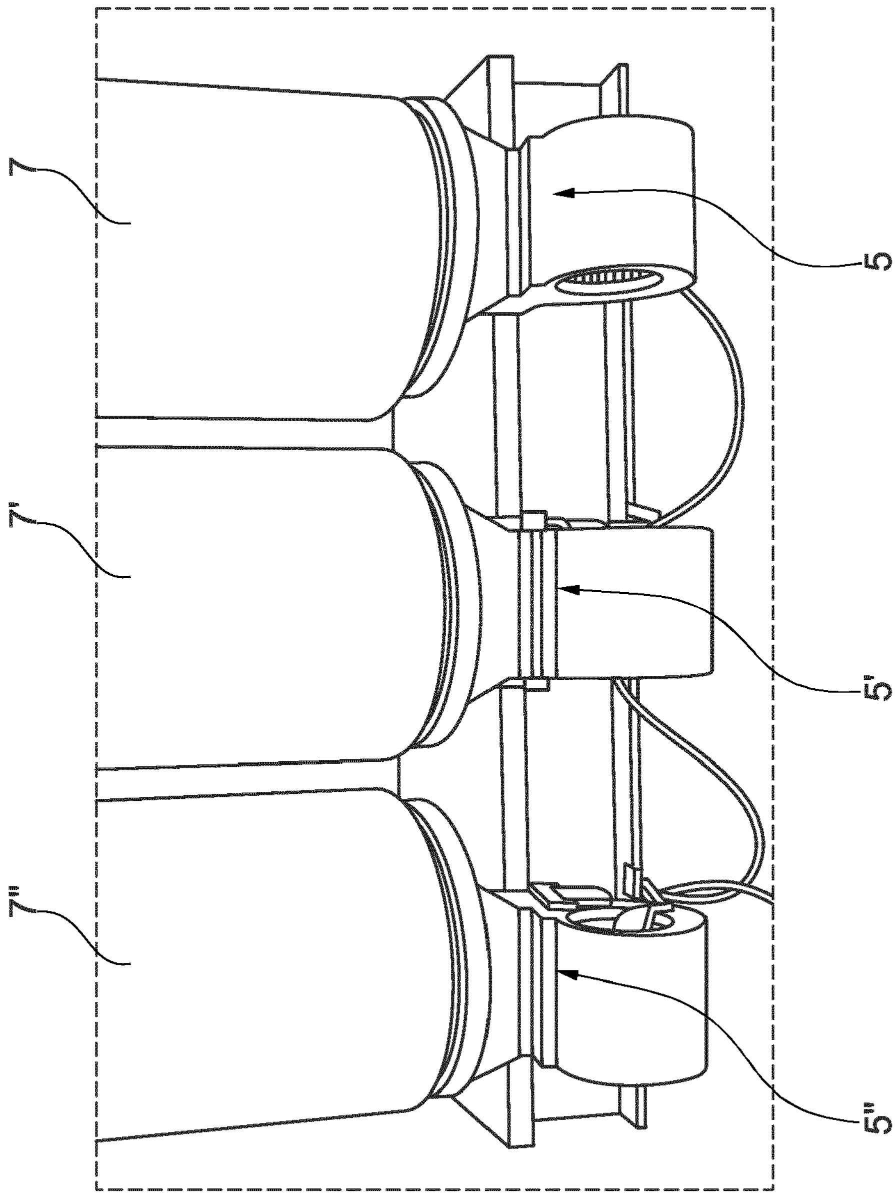

Fig. 2

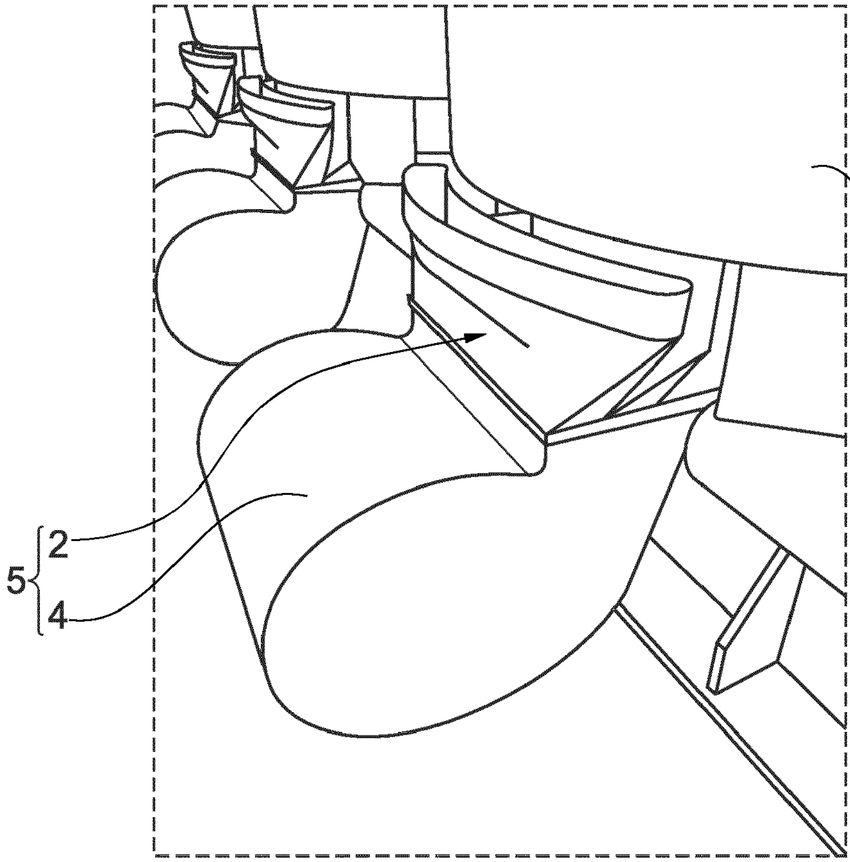

Fig. 3

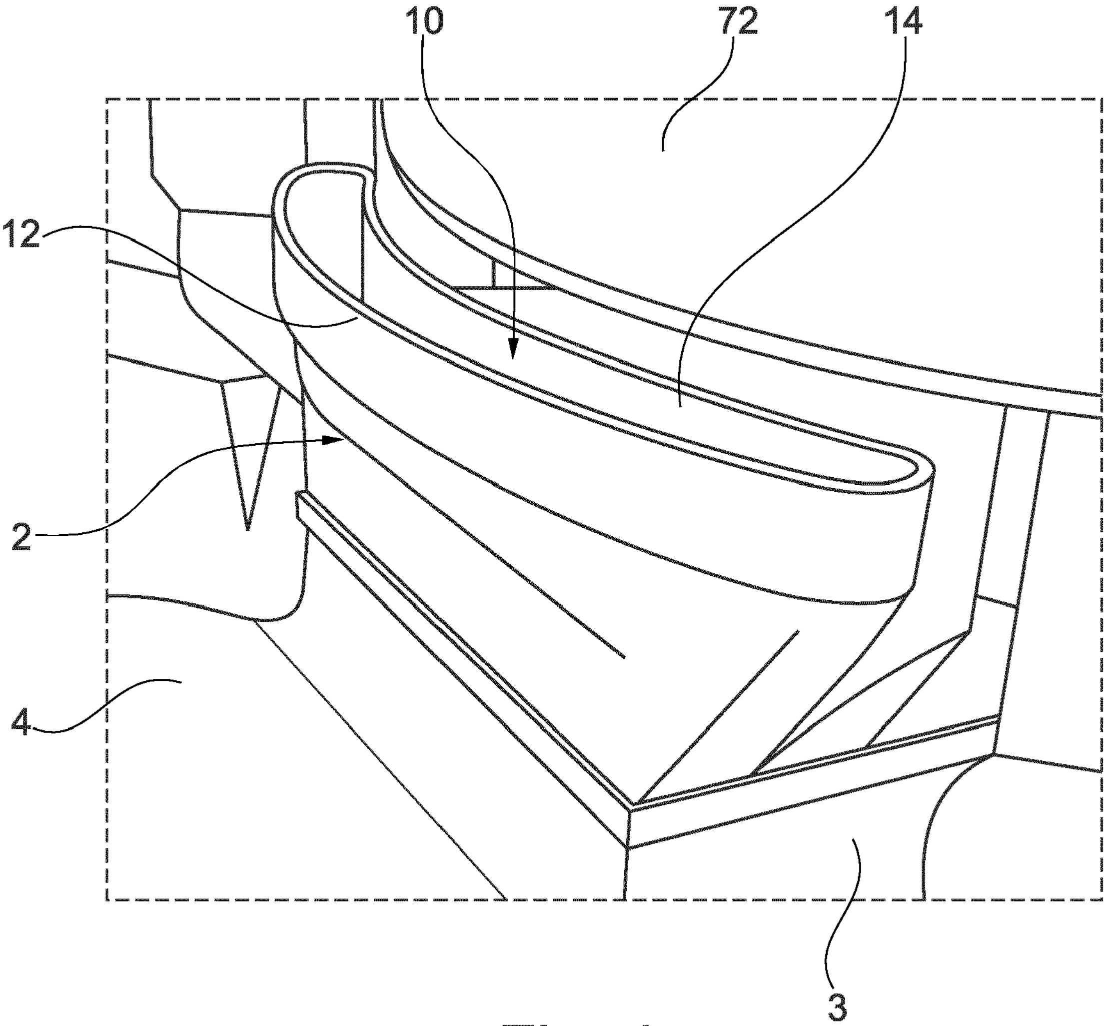

Fig. 4

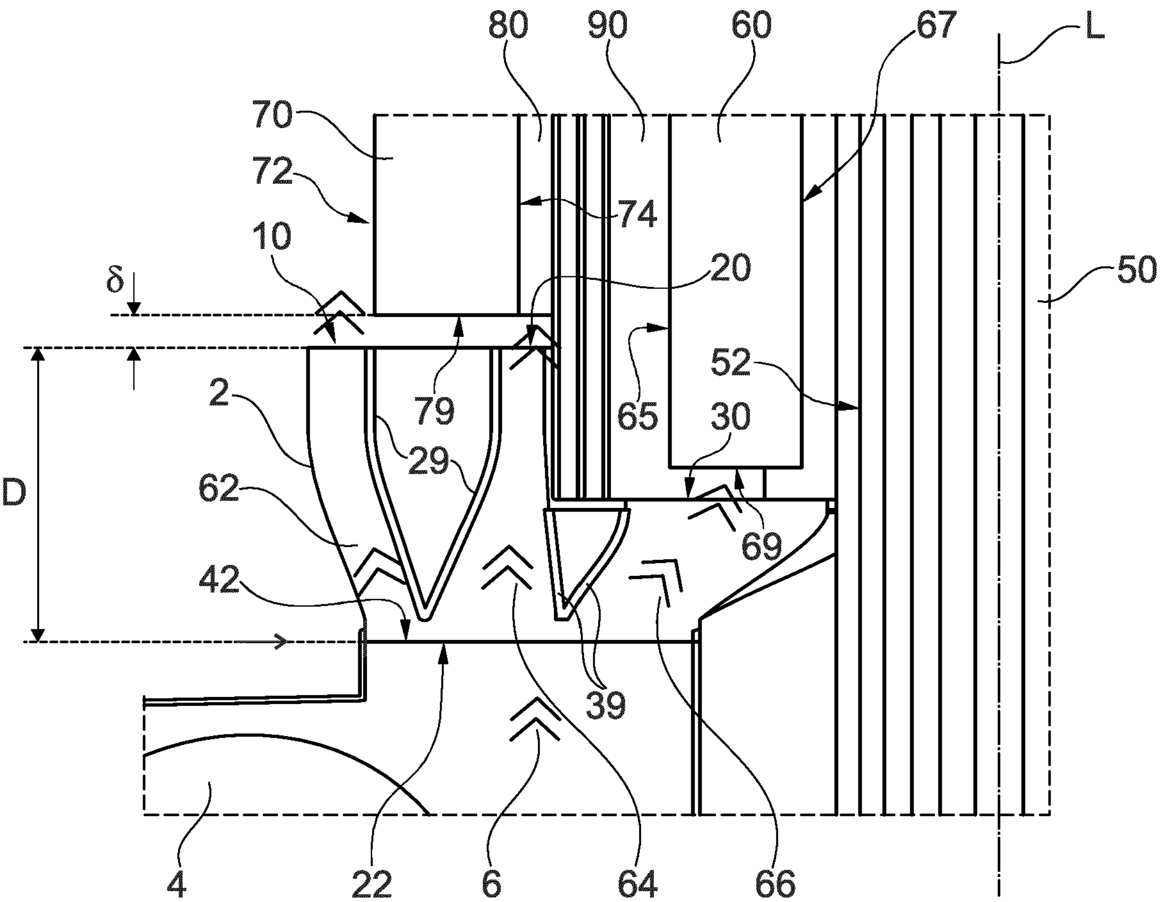
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Fig. 5

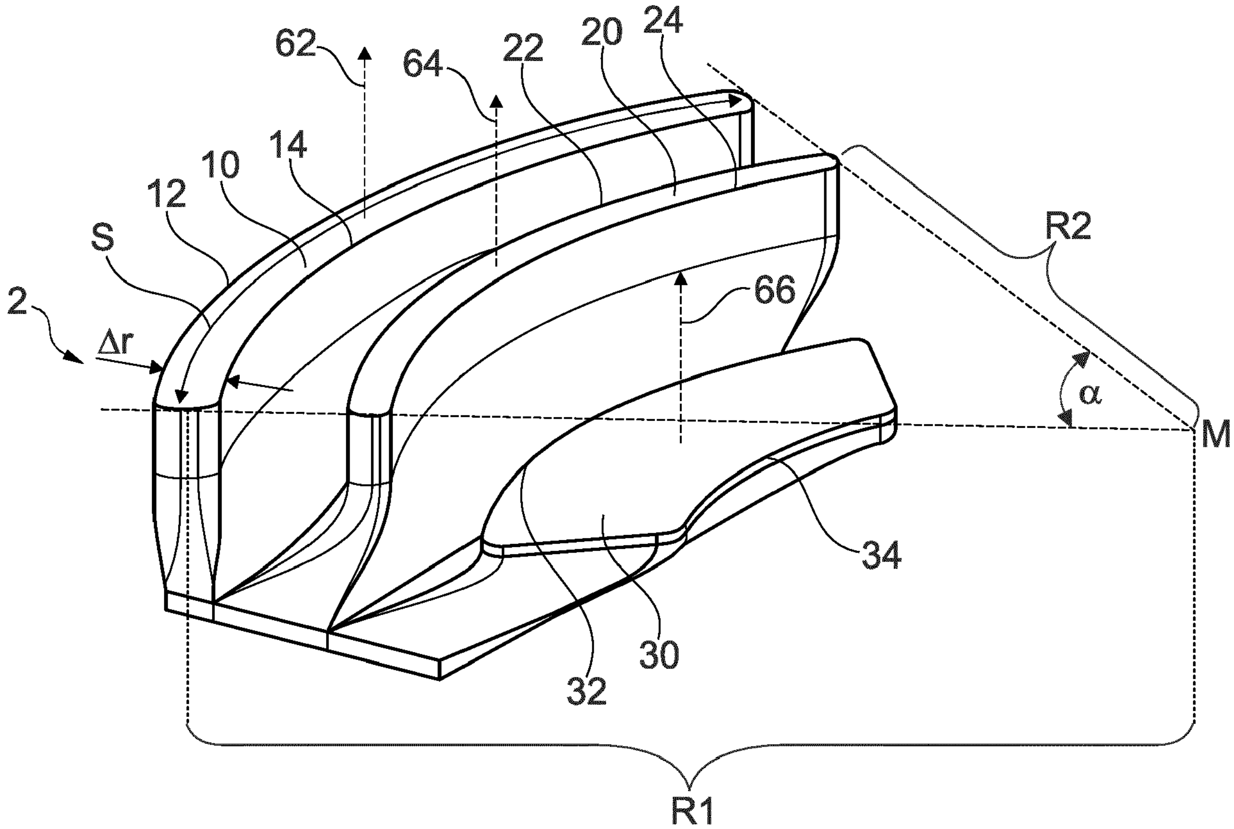

Fig. 6

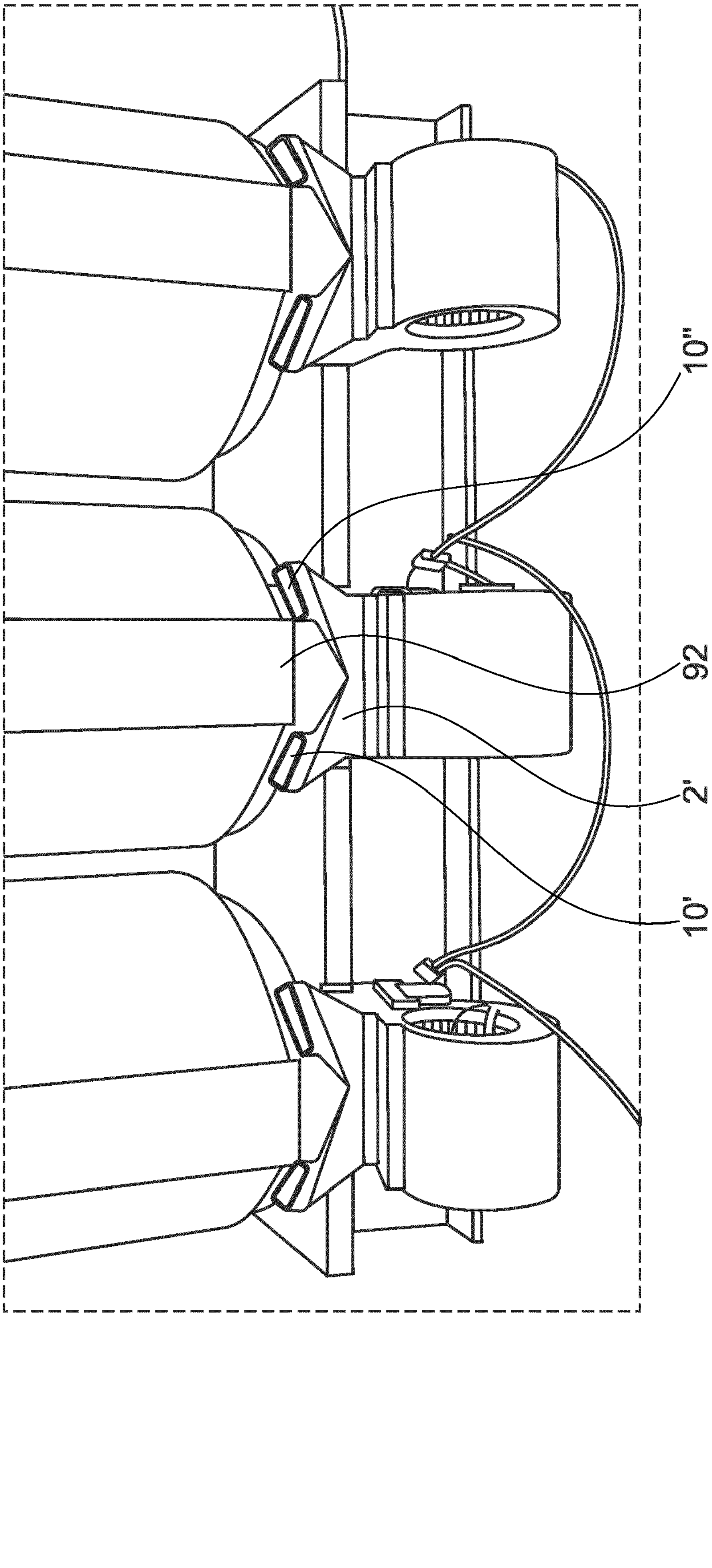

Fig. 7

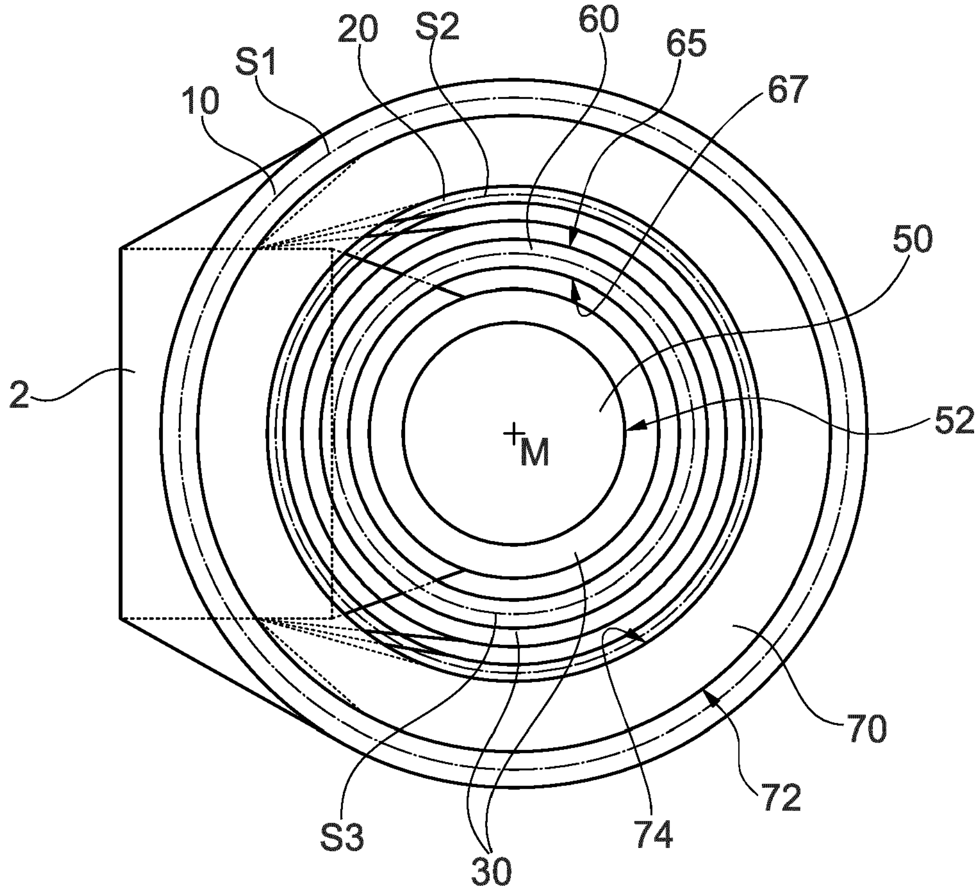

Fig. 8a

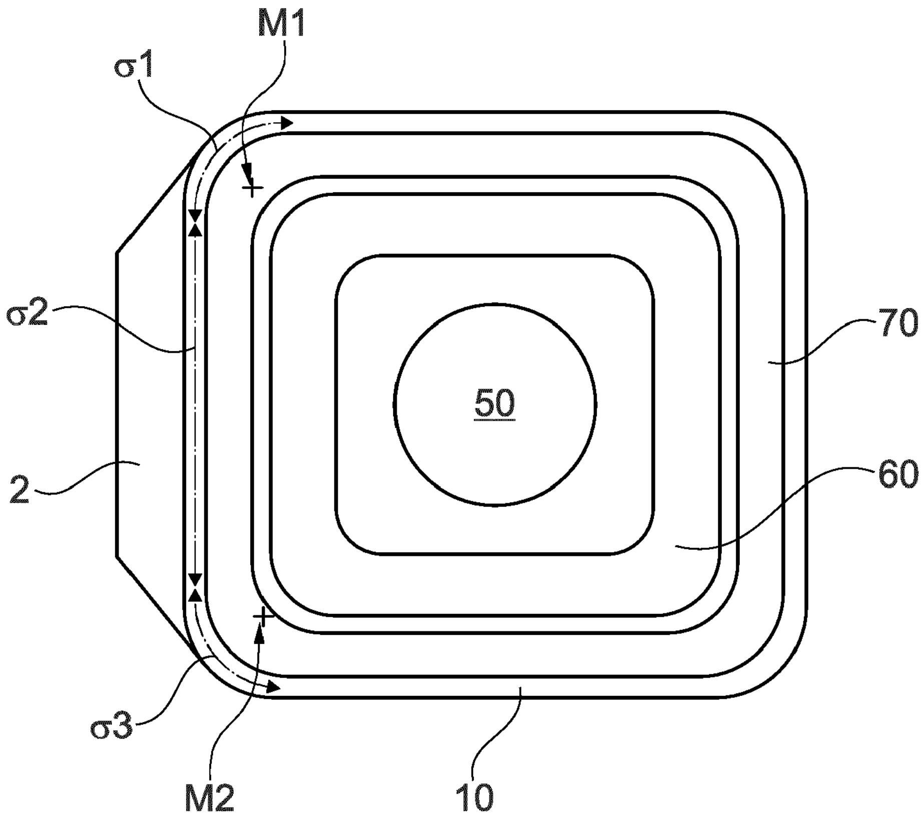

Fig. 8b

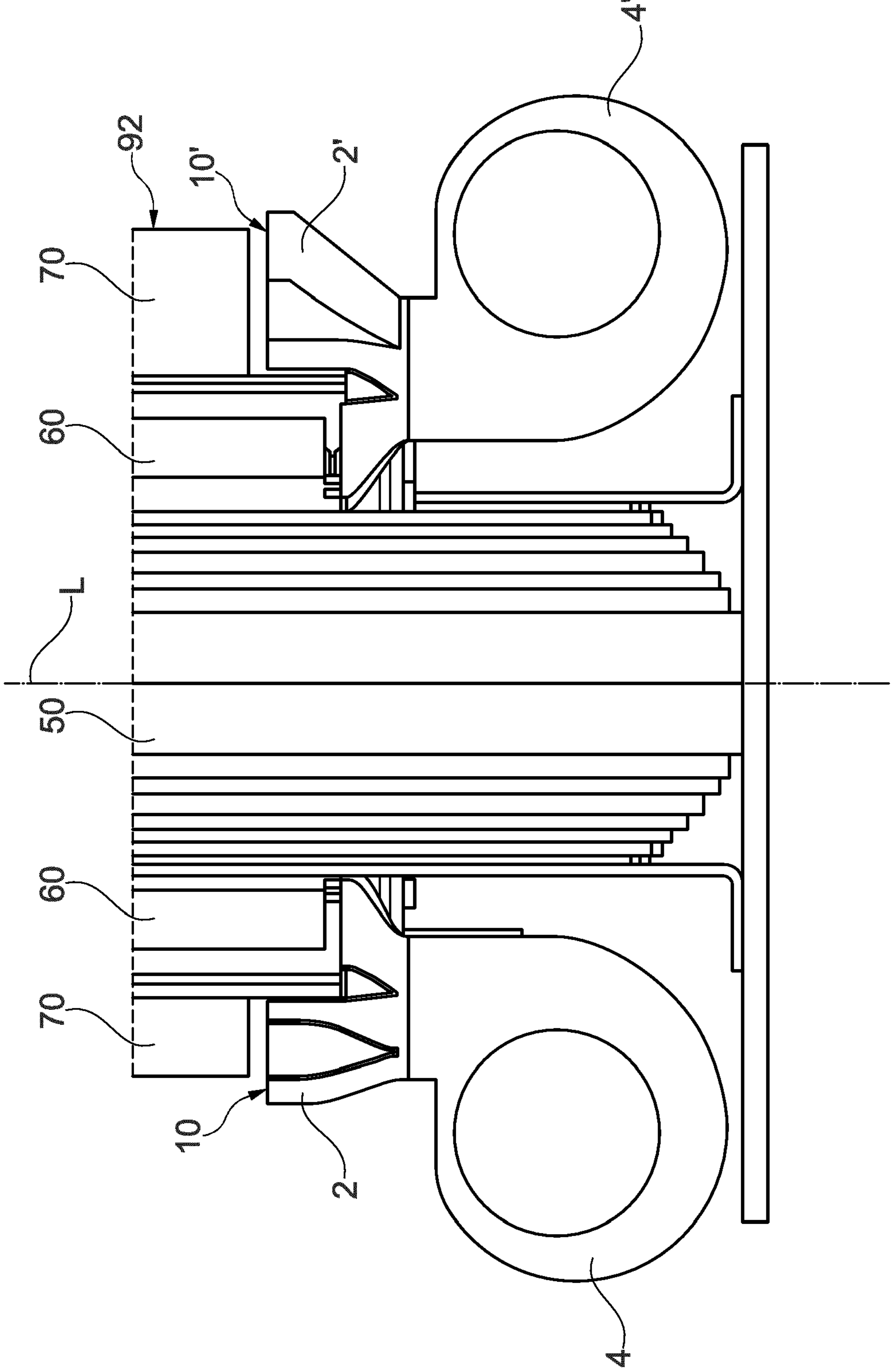

Fig. 9

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EUROPEAN SEARCH REPORT

Application Number
EP 23 38 2690

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	EP 3 312 856 A1 (STARKSTROM GERAETEBAU GMBH [DE]) 25 April 2018 (2018-04-25) * abstract * * column 1, paragraph 1 - column 10, paragraph 83; figures 1-15 * * column 11, paragraph 94-102; figures 18,19 * * claims 1-14 * -----	1-8 15	INV. H01F27/08 H01F27/28 ADD. H01F27/32
X	CN 116 168 935 A (TIANSHUI CHANGCHENG SWITCHGEAR GROUP CO LTD) 26 May 2023 (2023-05-26) * the whole document * * figures 1,5-8 * -----	1-7	
X Y	JP S60 81615 U (FUJI ELECTRIC CO.) 6 June 1985 (1985-06-06) * the whole document * * figures 4,5 * -----	1-14 15	
X	JP S62 49216 U (HITACHI LTD.) 26 March 1987 (1987-03-26) * the whole document * * figures 3,4 * -----	1-8	TECHNICAL FIELDS SEARCHED (IPC) H01F
X	EP 3 580 770 B1 (HITACHI ENERGY SWITZERLAND AG [CH]) 12 April 2023 (2023-04-12) * abstract * * claims 1-7 * * figures 1-7 * * column 1, paragraph 2 - column 6, paragraph 27 * -----	7-13	
X Y	CN 211 404 242 U (MAANSHAN DANGTU POWER GENERATION CO LTD) 1 September 2020 (2020-09-01) * the whole document * * figures 1-7 * -----	7-14 15	

2

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	8 December 2023	Kardinal, Ingrid

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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Application Number
EP 23 38 2690

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

- [ ] Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

- [ ] No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

- [ ] All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

- [x] As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

- [ ] Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

- [ ] None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

- [ ] The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

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LACK OF UNITY OF INVENTION SHEET B

Application Number
EP 23 38 2690

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-15

Air duct element for transformer arrangement cooled by forced air convection

1.1. claims: 1-6

Transformer arrangement with air duct element arranged at a specific distance from the winding

1.2. claim: 7

Air duct element with specifically shaped air portion openings

1.3. claims: 8-15

Air duct element with division of air flow to different parts of transformer

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Please note that all inventions mentioned under item 1, although not necessarily linked by a common inventive concept, could be searched without effort justifying an additional fee.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 23 38 2690

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

08-12-2023

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82