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(54) **High power helical filter with fourfold-tuned circuit**

(57) The invention refers to the high power helical filter with fourfold-tuned circuit for VHF band. The filter consist of a metal housing (2) with at least two resonant cavities (14), helical coils (3) connected at one end to the metal housing of the filter (2), piston rods (4) located in the interior of the helical coils (3) and movable along X, X' axis by the tuning screws (7), input and output connectors (5), partition wall (6) made of the upper and the bottom part and connected to the partition wall lath (12) and movable by the partition wall lath screw (19), radiator (10) and coupling loops (17) movable along X, X' axis with the mechanisms (13) for positioning coupling loops (17) and rotatable around Y, Y' axis.

The tuning assembly of the filter has been constructed in such a way that the filter can be tuned with the changing work bandwidth and changing insertion loss and to enable the change of the working frequency within the given band. For the heat transfer from the inside of the filter the heat pipe (9) has been provided together with the set of radiators (10) on the housing (2) of the filter. Ventilation holes (11) at the bottom and on the top of the filter housing (2) are provided which enable the gravitational ventilation and consequently cooling the helical coils (3). The electrical parameters of the filter are not worse than of the typical coaxial filter produced to transfer high transmission powers but is much smaller.

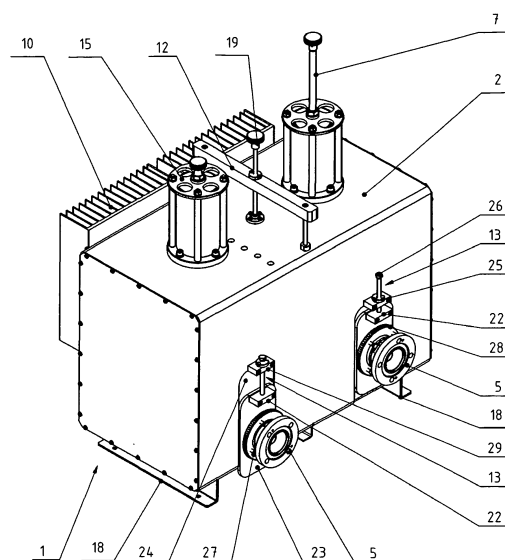


Fig. 1

Description

Field of the Invention

[0001] The high power helical filter with fourfold-tuned circuit refers to a filter, which is tuned in the VHF band with any given width of the working channel and has a high transmission power range. It corresponds to the helical resonator placed in the metal housing.

Background of the Invention

[0002] Typical high power filters used on the radio transmitting sites for separating the radio signals before sending them into the ether are manufactured with technology of coaxial filter. They are a multiplication of the λ wavelength corresponding to the operating frequency of the filter. Commonly applied coaxial filters are of the resonator length of $\lambda/4$ and for this reason they are also known as quarter-wave resonator coaxial line filters. Typical filter for a radio VHF band in case of FM sub-band manufactured with this technology is over 0.8 meters long. Because the length of the filter is defined by the wavelength, this is why physical restraint appears while attempting to minimize devices of this kind, especially the biggest one of having dimensions or the length of a filter. One solution is the use of the cavity filter of helical type. The filters of this type are commonly used, however not to transmit high transmission powers, i.e. in the range of kilowatts.

[0003] Basic concepts for helical filters are known from patents US3820045, US3836881 and US4374370. Patent US3820045 describes a double-tuned circuit device having a rod for adjusting the resonant frequency and electromagnetic coupling of the device. US3836881 describes a double-tuned circuit device with several solutions for adjusting electromagnetic coupling coefficients between the resonator units. US4374370 describes a helical resonator filter with the coupling element for modifying the filter bandwidth.

[0004] Typical helical filters are not used for high transmission powers because of the significant warming of the helical coil and the inability of efficient reduction of the heat accumulated inside the filter. Due to the warming, the change in length of the metal elements of the filter, and consequently retuning of the filter, are needed. The key parameter of the filter is the transmission loss which directly influences the release of the heat in the filter and intensification of the process described above. Helical cavity filter is of mutually dependent dimensions which are calculated for the frequency of the filter's work. Parameter Q, which is related to the transmission loss of the filter, depends to a large extent on the overall dimensions of the device. Another problem of helical filters is their continuous regulation of frequency for the operation of the filter with simultaneous adjustment of bandwidth ranges with the least possible transmission loss. Present solution is fourfold-tuned circuit filter which rep-

resents improved helical filter regarding tuning possibilities and especially to enable work at high transmission powers. The main objective of said invention is to make a helical filter which would work at high transmission power in the radio VHF band with parameters of the filter that would not be worse than ones in commonly used high power coaxial filters.

[0005] With the high power helical filter with fourfold-tuned circuit according to the present invention more tuning possibilities for optimal performance of the device are provided. The dimensions of the helical filter according to the present invention are at least two times smaller comparing to the coaxial filter of the same power which leads to reduction of the production costs.

Summary of the Invention

[0006] The present invention refers to a construction of a cavity helical filter for the transmission of high power RF signals in the VHF band. It consists of at least two resonant cavities within the metal housing. The cavity's dimensions are calculated in such a way that they fulfill the resonant estimations for this type of the filter and that they work when loaded with high power RF signals. Helical filter cavity is at least two times shorter comparing to the equivalent coaxial filter with similar parameters. The helical coil in the resonant cavity is connected at one end to the metal housing of the filter while the other end is not fixed. The helical coil is positioned in the cavity in such a way that the axis along which it is wrapped coincide with the axis of the cavity passing through the middle of the bottom and the upper wall of the cavity, i.e. along the X, X' axis. The diameter of the rod or the pipe of which the helical coil is made is selected to be the largest possible for given dimensions of the cavity and conditions of staying resonant.

[0007] In order to ensure the functionality of the filter in a given RF band, tuning elements were used, allowing adjusting the filter to the given bandwidth, frequency and insertion loss. The tuning circuit comprises the piston rod, input/output coupling loop and a partition wall separating resonant cavities.

[0008] The piston rods are made of closed pipes produced of silvered brass of a diameter respectively smaller than a wrapping diameter of the helical coil thus maintaining the safety margin for the breakdown voltage. The length of the piston rods is selected in such a way to enable the change of the frequency of a given working band for example FM sub-band in VHF range. The depth of placing the piston rods into the resonant cavities and into the interior of the helical coil is regulated with the tuning screws which are placed on the outside of the filter, i.e. on the metal housing of the filter and are in contact with the piston rods and with the metal housing of the filter. By screwing and unscrewing them the piston rods are pulled in or out. The piston rod is in contact with the metal housing of a cavity with the silvered springy brass ring that is affixed directly to the upper part of the

resonant compartment cavity frame structure.

[0009] Input/output coupling loops are connecting input and output of the filter with the resonant circuit through the electromagnetic coupling. Overall dimensions of the loop are chosen in such a way, to enable the transfer of a given power and expected bandwidth to the filter. Diameter of the rod of which the coupling loop is made is the same as the diameter of the internal conductor of the input connector. The diameter of the loop is selected in such a way to guarantee estimated bandwidth. Input/output coupling loop is fixed with one end to the metal housing of the resonant cavity with the contact flange and with the other end to the entry of the connector. Input and output coupling loop is moving along the X, X' axis and rotates around Y, Y' axis as well. The shape of the coupling loop and its freedom of movement along said axis are defined in such a way that the coupling loop is moving without collision with the helical coil and the metal housing of the resonant cavity. The preferred shape of the coupling loop is at the end, where it is connected to the internal conductor of the input connector, in the shape of a strait rod which continues into a semi-circular shape, in a way that the top of the semi-circular shape is positioned exactly below the center of the helical coil, and further continues in the shape of a strait rod to be connected to a flange. The loop is made of the brass silvered rod.

[0010] Partition wall is separating resonant cavities. Between each adjacent resonant cavity partially regulated wall is situated. The partition wall is made of upper and bottom part. The bottom and the upper part of the partition wall are located at equal distances from the X, X' axis of the helical coils. The partition wall is made in such a way that in a given frequency band, the change of the bandwidth and the insertion loss in accordance with the assumptions estimated for selected type of VHF sub-range is possible. The upper part of the partition wall can be shifted up and down in the vertical direction thanks to the partition lath screw connected to the partition lath that has two guide pillars. Guide pillars are passing through the filter body and are directly connected to the upper edge of the partition wall. By screwing and unscrewing the partition lath screw the position of the upper part of the partition wall can be regulated. The bottom part of the partition wall is made in such a way that it can range partially from the metal housing on its bottom side. The upper and the bottom part of the partition wall are connected with contacting trucks which serve at same time as an electric junction between the partition wall and the metal housing of the resonant cavities.

[0011] The operation of the high power helical filter involves emission of large amounts of heat on the helical coil of the resonant circuit. Point of contact of the helical coil with the metal housing itself is too small to remove such big amount of heat accumulated in the resonant cavity. For this purpose two independent solutions are used to transport the heat to the outside. According to the first solution one side of the heat pipe is installed into

the center of the helical coil. The diameter of the heat pipe with the additional heat conducting element is slightly smaller than the internal diameter of the pipe of which the helical coils of the resonant circuits is made. The opposite side of the heat pipe leads out of the filter and is incased in the radiator. Radiator is affixed to the housing of the filter.

[0012] According to the second solution gravity cooling by ventilation holes is made in the bottom and the upper part of the resonant cavities. The ventilation holes are made in the metal housing and they are positioned around X, X' axis on the bottom and the upper part of the filter's resonant cavities with diameter that is smaller than 0.01λ . Thanks to this solution the heated air may escape from the interior of the filter through the upper ventilation holes. Additional bottom ventilation holes are increasing the free movement and the air circulation. Optionally an additional air fan can be used on ventilation holes to accelerate the air movement in the resonant cavities. If required an additional air fan attached on the radiator can be used to minimize the size of a radiator.

Brief Description of the Drawings

[0013] The present invention will now be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 shows perspective view of a high power helical filter with fourfold-tuned circuit according to the present invention;

Figure 2 shows a cut away perspective view of a high power helical filter with fourfold-tuned circuit according to the present invention;

Figure 3 shows a cut away front side view of a high power helical filter with possible movements of tuning components according to the present invention

A, A' - changing position of the piston rod,

B - changing position of the partition wall separating cavity resonant circuit,

C, C' - changing position of coupling loop along the X, X' axis,

D, D' - rotation around the Y, Y' axis (360°) of coupling loop;

Figure 4 shows a cut away side view of a high power helical filter with radiator and cooling system according to the present invention.

Detailed Description of the Invention

[0014] A high power helical filter with fourfold-tuned

circuit is solving a problem of helical filter working at high transmission powers, cooling of the filter and tuning possibilities. A high power helical filter with fourfold-tuned circuit 1 consists of a metal housing 2, helical coils 3, piston rods 4, input and output connectors 5, partition wall 6, tuning screws 7, radiator 10, partition wall lath 12, coupling loops 17 and mechanism 13 for positioning coupling loops 17.

[0015] The housing 2 is made of metal aluminum plates or material with similar mechanical and radiofrequency characteristics, screwed together on their edges if plates are sufficiently thick, otherwise they are installed on the outer frame structure. Two symmetrical electromagnetically coupled resonant circuits, located in the resonant cavities 14, consist of helical coils 3 and piston rods 4. To minimize the weight helical coils 3 are made of pipe for high transmission powers or of thin rod for lower transmission powers. For high transmission powers helical coils 3 are made of large-size diameter copper pipes or material with similar mechanical and radiofrequency characteristics. The length of the helical coils 3 depends on the size of the resonant cavity 14. The dimensions of the cavity and the diameter do of the pipe of which the helical coils are made are defined by estimated transmitted filter power.

[0016] Piston rods 4 are closed pipes made of brass or material with similar mechanical and radiofrequency characteristics, plated with silver. Piston rods 4 are located in the housing 2 in the interior of the helical coils 3. To enable changing resonant frequency of the filter, piston rods 4 are movable along X, X' axis following the movements A, A'. Movement A, A' is performed by the tuning screw 7 which is connected to the piston rod 4 and to the outside mechanism 15 for positioning piston rod 4. By rotating the tuning screw 7 the depth of penetration of the piston rod 4 in the resonant cavity 14 can be changed. Piston rod 4 is in contact with the metal housing 2 by the silvered springy brass ring 16 which is attached directly to the metal plates of the housing 2. Housing cylinder 21 is one of the parts of the mechanism 15 for positioning piston rod 4 and at same time it covers the piston rod 4.

[0017] Two coupling loops 17 maintain electromagnetic coupling connection between input/output connectors 5 with resonant circuit. Changing of the position of the coupling loop 17 along the X, X' axis is done with the mechanism 13 for positioning the coupling loop 17 and is marked as the movement in direction C, C' in figure 3. The coupling loop 17 is fully rotatable around Y, Y' axis as shown in figure 3 with the movement marked as D, D'. The mechanism 13 consists of a plate 23, a screw 26, a nut 25, an upper fixing plate 29 and a lower fixing plate 22. The upper fixing plate 29 is attached to the metal housing 2 and the lower fixing plate 22 is attached to the upper part of the plate 23 of the connector 5. The plate 23 is positioned in the groove 24 in the housing 2. By turning the screw 26 the lower fixing plate 22 and at the same time the plate 23 of the connector 5 as well as the

coupling loop 17 is moving along X, X' axis within the groove 24. When the right position is set the movement of the screw 26 is disabled by additional fixing with the nut 25. To enable the rotation around Y, Y' axis, the screws 27 which affix the connector 5 to the plate 23 are released, with the knurled nut 28 the rotation is enabled and after the right position is set, the screws 27 are tightened. Adjustment of the position in direction C, C' and rotation around Y, Y' axis of the coupling loop 17 enables adjusting of the resonant circuit frequency and bandwidth. Movements C, C' and D, D' are possible due to the defined dimension of the groove 24 in the device housing 2 and the assembly of the contact flange 8. The minimum width of the groove 24 is defined with the diameter of the connector 5 and the height of the groove 24 is defined with the dimension of the coupling loop 17, i.e. with the freedom of its movement. Contact flange 8 enables proper setting of the entry circuit and subsequently its fixation. The freedom of movement of loop 17 along X, X' and Y, Y' axis is defined in such a way that the collision with the helical coil 3 and the metal housing 2 of the resonant cavity 14 is prevented. The dimensions of the coupling loop 17 are determined by the transmitted power and expected transmission band. The coupling loop 17 is made from the brass silvered rod or material with similar mechanical and radiofrequency characteristics.

[0018] Two resonant cavities 14 with the partition wall 6 define the coupling between the circuits and hence the bandwidth. The partition wall 6 is made in such a way that the space between resonant cavities 14 is partially permanently open and partially permanently separated. To additionally increase the bandwidth tuning range and at same time to minimize the weight of the metal housing 2, the partition wall 6 is made of the upper and the bottom part. Connection of the upper and the bottom part of the partition wall 6 and the metal housing 2 is done in such a way that the bottom part can range partially from the housing 2. Because the bottom part of the partition wall 6 and input/output connectors 5 are located in the bottom part of the metal housing 2 and their position can range partially from the metal housing 2, additional housing distance holders 18 are provided. The partition wall 6 can be shifted up and down in the vertical direction with the movement marked as B as shown in figure 3. The partition wall 6 is connected to the partition wall lath 12 in such way, that by rotating the partition wall lath screw 19, the movement B of the partition wall 6 is done. The partition wall lath screw 19 is on one side fixed on the metal housing 2 and on other side to the thread in the partition wall lath 12.

[0019] Into the interior of the helical coil 3, at the side that is connected to the metal housing 2, a heat pipe 9 is installed to transfer the heat from the helical coil 3 to the radiator 10. In cases where the helical coil 3 is made of a pipe additional heat conduction element 20 can be used between the inner wall of the helical coil 3 and the outer wall of the heat pipe 9 to enable heat transfer and

at same time minimizing the diameter size of the heat pipe 9. If the helical coil 3 is made of thin rod, connection to the heat pipe 9 is done by making a hole in the helical coil 3. The heat pipe 9 and the heat conduction element 20 are made of copper or any other material with good heat conductivity. The radiator 10 is made of aluminum or any other material with similar characteristics. The surface of the radiator 10 is dimensioned to the amount of the heat which can be emitted per maximal power of the filter. The radiator 10 is placed on the outside wall of the metal housing 2. In order to improve the cooling process the air ventilation holes 11 are made in the bottom and the upper wall of the metal housing 2. Air ventilation holes 11 are made symmetrically around the X, X' axis and their diameter is at least hundred times smaller than the wavelength of VHF band frequencies to minimize the influence on electromagnetic coupling.

Claims

1. A high power helical filter with fourfold-tuned circuit for working at high transmission powers consists of a metal housing (2) with at least two resonant cavities (14), helical coils (3) connected at one end to the metal housing (2) of the filter (1), piston rods (4) located in the interior of the helical coils (3) and movable along X, X' axis by the tuning screws (7), input and output connectors (5), partition wall (6) made of the upper and the bottom part and connected to the partition wall lath (12) and movable up and down in the vertical direction by the partition wall lath screw (19), radiator (10) and coupling loops (17) movable along X, X' axis with the mechanisms (13) for positioning coupling loops (17) and rotatable around Y, Y' axis with the knurled nut (28).
2. A device according to claim 1, **characterized in that** the helical coil (3) is a pipe for high transmission powers or a thin rod for lower transmission powers.
3. A device according to claim 1, **characterized in that** the diameter of the piston rod (4) is smaller than a wrapping diameter of the helical coil (3) and is in contact with the metal housing (2) by the silvered springy brass ring (16).
4. A device according to claim 1, **characterized in that** the mechanism (13) consists of a plate (23), a screw (26), a nut (25), an upper fixing plate (29) and a lower fixing plate (22), whereby the plate (23) is positioned in the groove (24) in the housing (2).
5. A device according to claim 1, **characterized in that** the partition wall lath screw (19) is on one side fixed on the metal housing (2) and on other side to the thread in the partition wall lath (12).

6. A device according to claim 1, **characterized in that** the coupling loop (17) is fixed with one end to the metal housing (2) with the contact flange (8) and with the other end to the entry of the connector (5); the shape of the coupling loop (17) and its freedom of movement along X, X' and Y, Y' axis are defined in such a way that the coupling loop (17) is moving without collision with the helical coil (3) and the metal housing (2).
7. A device according to claim 1, **characterized in that** into the interior of the helical coil (3) at the side that is connected to the metal housing (2) a heat pipe (9) is installed whereby the opposite side of the heat pipe (9) leads out of the filter (1) and is incased in the radiator (10) to transfer the heat from the helical coil (3) to the radiator (10) with or without additional heat conduction element (20).
8. A device according to claim 1, **characterized in that** the ventilation holes (11) are made in the housing (2) and are positioned around X, X' axis on the bottom and the upper part of the housing (2) with diameter that is smaller than 0.01λ .
9. A device according to claim 6 or 7, **characterized in that** a radiator (10) and ventilation holes (11) are with or without additionally attached fans for forced airflow.
10. Process for tuning a high power helical filter with fourfold-tuned circuit for working at high transmission powers, **characterized in that** the adjustment of the resonant circuit frequency and bandwidth is achieved with the positioning of the coupling loop (17) by moving it along X, X' axis with the mechanisms (13) and rotating it around Y, Y' axis, whereby by turning the screw (26) the lower fixing plate (22) and at the same time the plate (23) of the connector (5) as well as the coupling loop (17) is moving along X, X' axis within the groove (24) and by releasing the screws (27) which affix the connector (5) to the plate (23) the rotation around Y, Y' axis with the knurled nut (28) is enabled; the change of the resonant frequency of the filter is achieved with the depth of placing the piston rod (4) into the resonant cavity (14) and into the interior of the helical coil (3) by moving it along X, X' axis by the tuning screws (7); the change of the bandwidth and the insertion loss for selected type of VHF sub-range is achieved with shifting the partition wall (6) up and down in the vertical direction by rotating the partition wall lath screw (19).

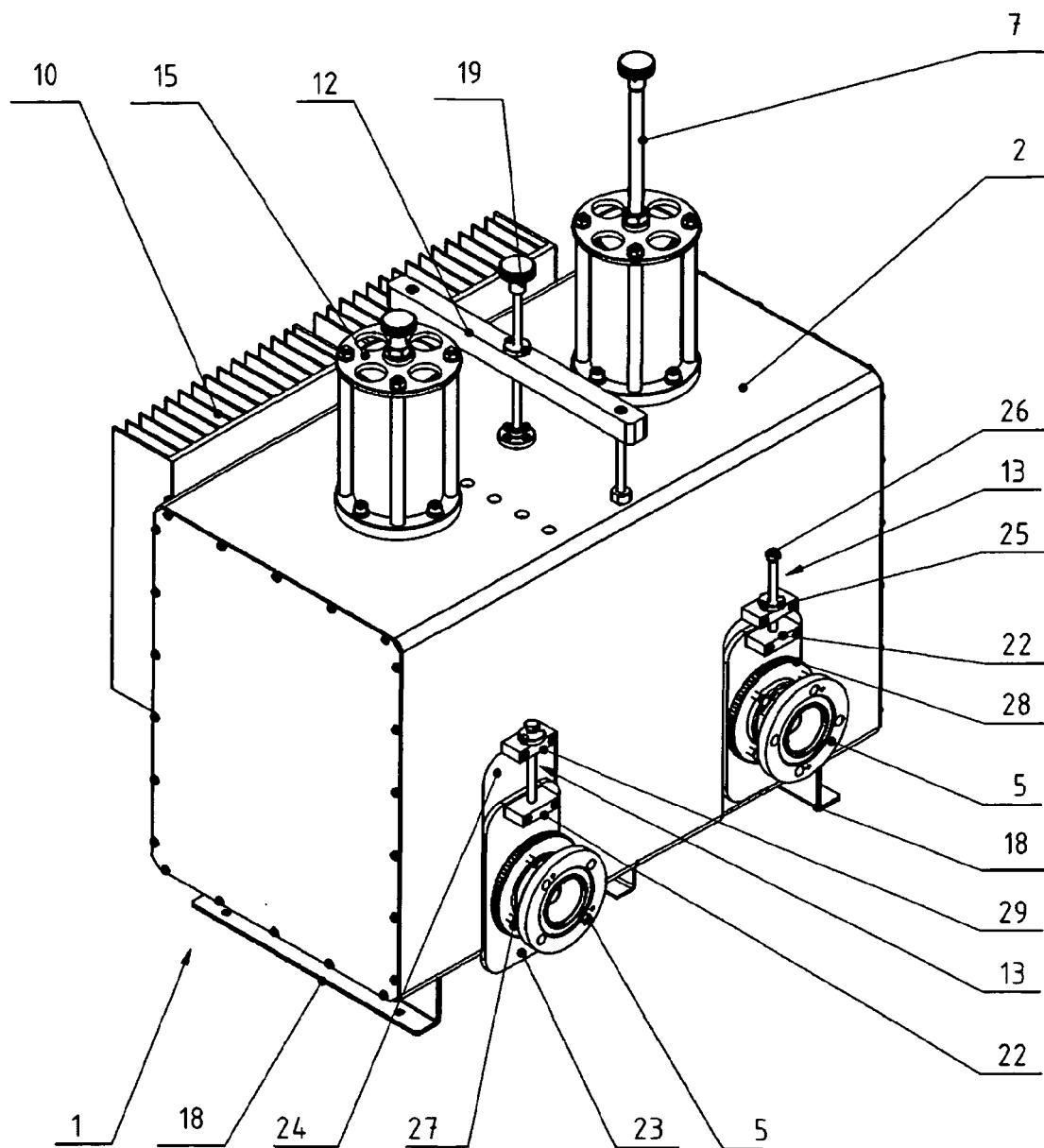


Fig. 1

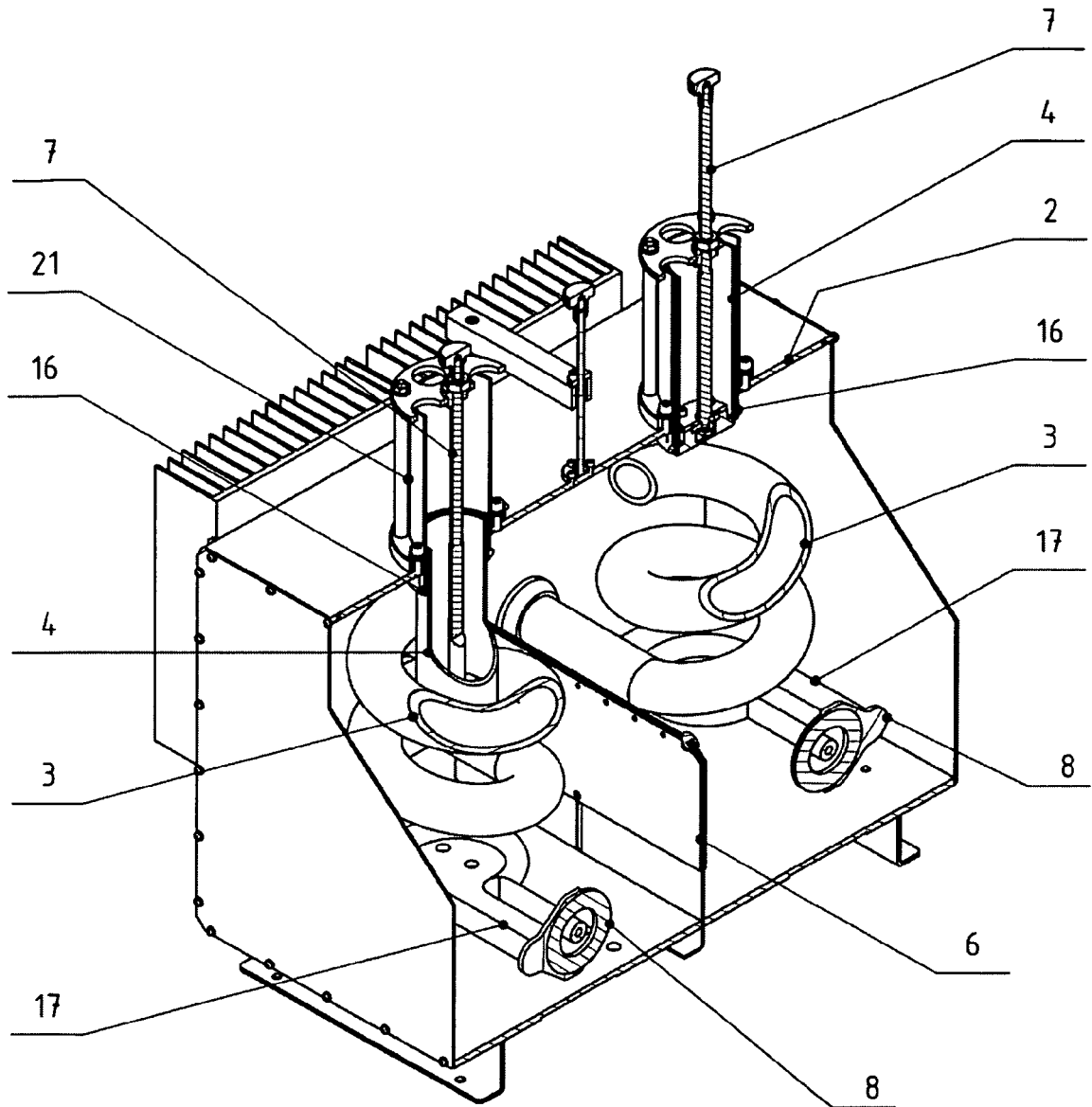


Fig. 2

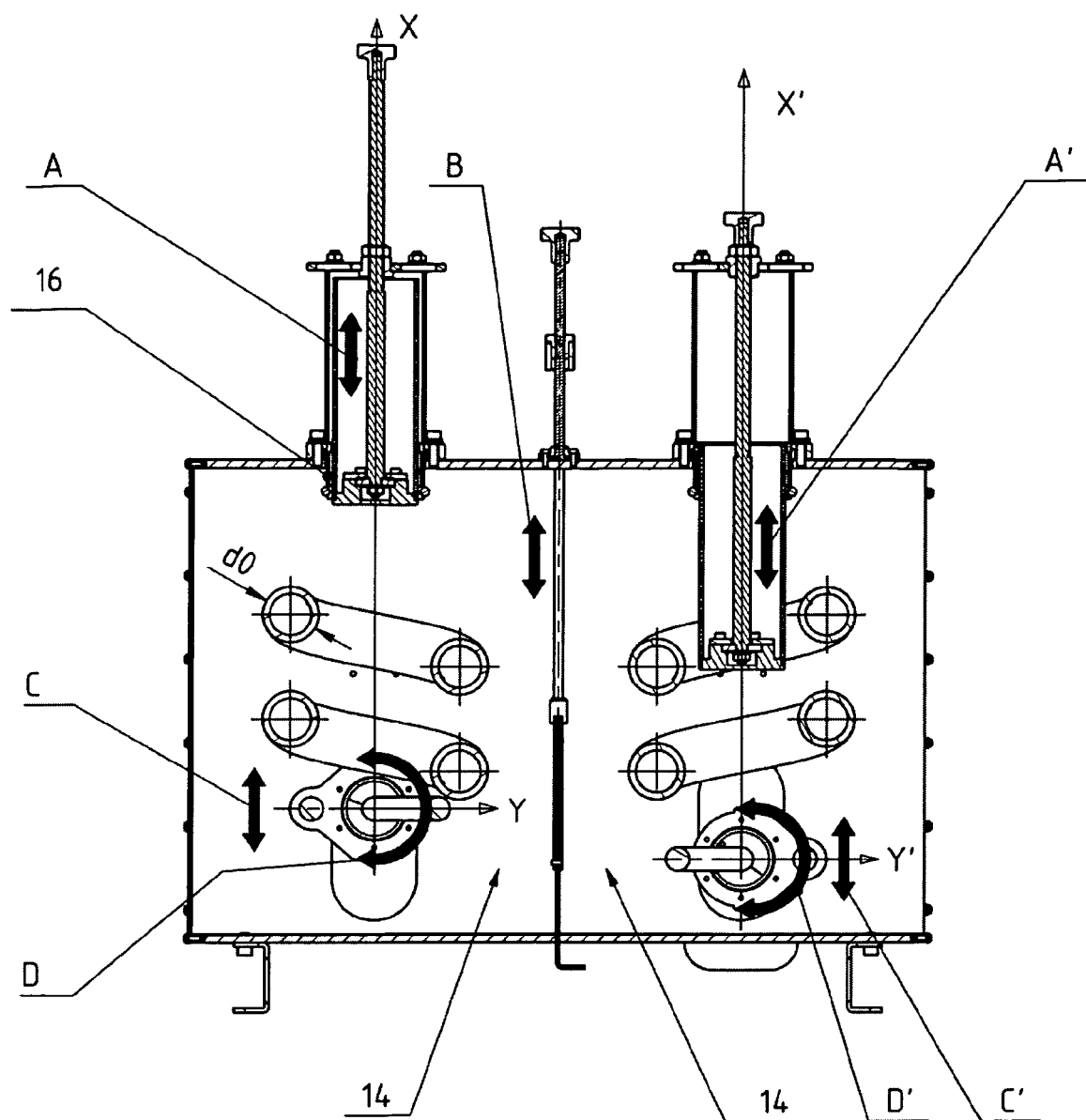


Fig. 3

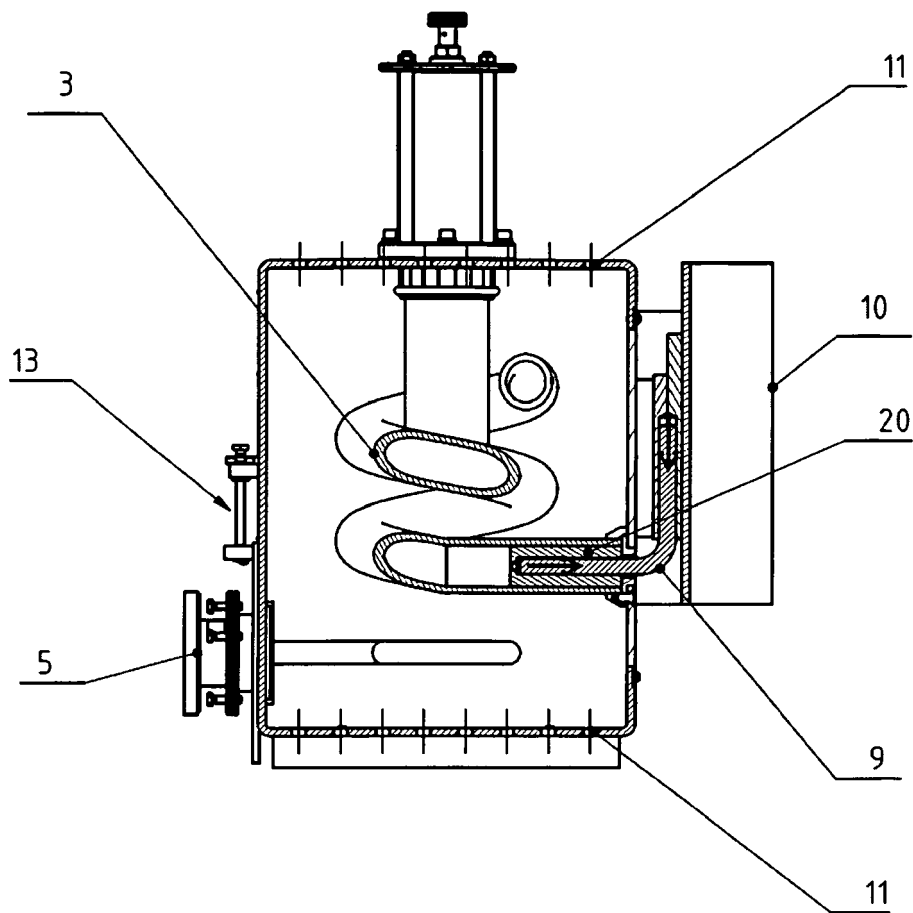


Fig. 4



EUROPEAN SEARCH REPORT

Application Number
EP 14 00 2266

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DOCUMENTS CONSIDERED TO BE RELEVANT			
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			TECHNICAL FIELDS SEARCHED (IPC)
			H01P
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 5 December 2014	Examiner Ribbe, Jonas
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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ANNEX TO THE EUROPEAN SEARCH REPORT
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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
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