



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
06.04.2022 Bulletin 2022/14

(51) International Patent Classification (IPC):
H05G 1/02 ^(2006.01) **H05G 1/04** ^(2006.01)

(21) Application number: **20199885.3**

(52) Cooperative Patent Classification (CPC):
H05G 1/025; H05G 1/04

(22) Date of filing: **02.10.2020**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(72) Inventors:
• **BEHLING, Rolf Karl Otto**
5656 AE Eindhoven (NL)
• **HAENEL, Joern**
5656 AE Eindhoven (NL)

(74) Representative: **Philips Intellectual Property & Standards**
High Tech Campus 52
5656 AG Eindhoven (NL)

(71) Applicant: **Koninklijke Philips N.V.**
5656 AG Eindhoven (NL)

(54) **FLUID-COOLED X-RAY TUBES**

(57) In fluid-cooled X-ray tubes, exceeding certain temperatures may result in unwanted surface buildup of carbon following cracking of the coolant fluid, leading to delamination of the carbon and pollution of the fluid with carbon flakes. The invention provides a fluid-cooled X-ray tube, a fluid-facing surface of the X-ray tube having a hotspot formation portion (308) at which a hotspot is known to arise in use as a consequence of operation of the X-ray tube, the X-ray tube comprising a barrier structure (302) configured in use to encapsulate a sacrificial reservoir (304) of coolant fluid to form a shield thermally insulating a surrounding body (306) of the coolant fluid from the hotspot formation portion. Advantageously, cracking of the fluid thus occurs solely or mainly within the sacrificial reservoir to provide partial or complete containment of pollutants, while the sacrificial reservoir insulates the surrounding body of fluid from the hotspot.

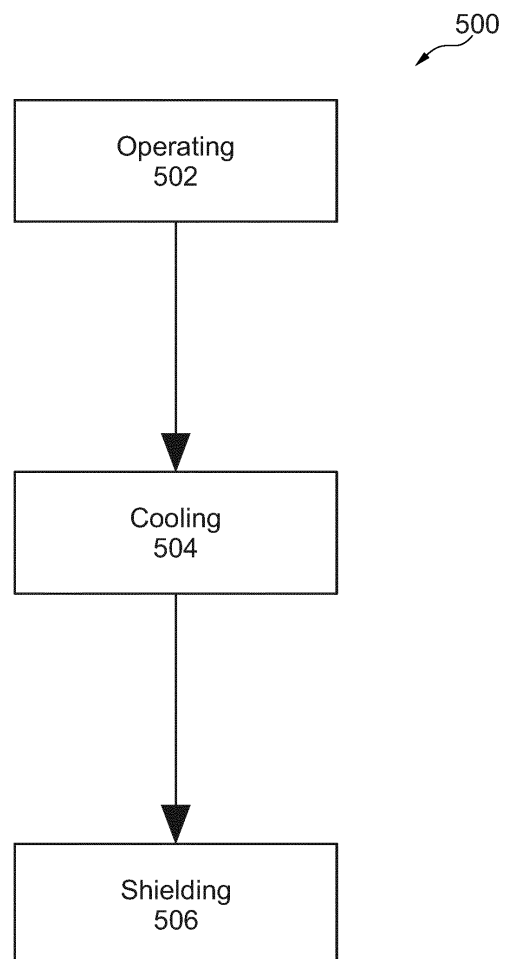


Fig. 5

Description

FIELD OF THE INVENTION

[0001] The invention relates to the field of X-ray tubes, and more specifically to fluid-cooled X-ray tubes.

BACKGROUND OF THE INVENTION

[0002] For reliable operation of X-ray sources, the temperature of interfaces between hot solids and cooling oil preferably should not exceed a characteristic maximum. This maximum temperature is defined by the time the temperature exists, the chemical composition and texture of the solid, and the hydrodynamic speed and composition of the oil. For example, a typical characteristic maximum of a copper interface with high voltage insulating oil in an X-ray tube assembly may be of the order of 180°C. Exceeding this maximum may result in cracking of the oil on the surface of the solid, along with unwanted surface buildup of carbon and other substances contained in the oil. Exceeding the maximum allowed temperature by far may result in boiling of the oil, delamination of the carbon layer and pollution of the oil with carbon flakes. This in turn may deteriorate the high voltage insulating capabilities. One way to improve on this issue is to enhance the oil speed by way of a pump. But this is an expensive solution, which may not be practical in many cases. Further solutions may entail applying conductive coatings to the fluid-facing surface of the X-ray tube to prevent hotspot formation.

SUMMARY OF THE INVENTION

[0003] In a first aspect, there is provided a fluid-cooled X-ray tube. A fluid-facing surface of the X-ray tube includes a hotspot formation portion at which a hotspot is known to arise in use as a consequence of operation of the X-ray tube. The X-ray tube comprises a barrier structure configured in use to encapsulate a sacrificial reservoir of coolant fluid to form a shield thermally insulating a surrounding body of the coolant fluid from the hotspot formation portion.

[0004] Advantageously, cracking of the coolant fluid thus occurs solely or mainly within the sacrificial reservoir, with the cracked fluid being segregated from the surrounding body of fluid by the barrier structure, so as to provide partial or complete containment of pollutants resulting from cracking, delamination, and blow-out, thereby mitigating or avoiding corruption of the surrounding body of coolant fluid. The claimed X-ray tube thus counterintuitively accepts oil cracking at hotspots but separates the cracked oil from the open oil. Moreover, the surrounding body of coolant fluid is thermally insulated from the hotspot by the sacrificial reservoir so as to avoid or mitigate cracking of the coolant fluid in the surrounding body. The claimed X-ray tube thus counterintuitively retains heat at the hotspot rather than using ther-

mally conductive elements in an attempt to prevent hotspot formation. In the claimed X-ray tube, tube life may be extended while enhancing power rating, and arcing through, and destruction of, the coolant fluid may be reduced or avoided.

[0005] The barrier structure may enclose one or more heat-retention elements to be immersed in use in the sacrificial reservoir of coolant fluid. The one or more heat-retention elements may comprise a solid thermally insulating material in granular form. The one or more heat-retention elements may comprise a plurality of hollow particles. The hollow particles may comprise hollow glass spheres. The hollow glass spheres may be gas-filled. The hollow glass spheres may be formed of an inorganic material. The heat retention elements may also be referred to as a filler material. Solid foam-like material may also serve as a heat retention element, such as metal foam, magma foam, and other kinds of inorganic foam. Other suitable forms of filler material or heat retention elements will be apparent to the skilled person. These features serve further to enhance the thermal insulation of the surrounding body of coolant fluid from the hotspot.

[0006] The barrier structure may comprise an ingress port or permeable structure configured to admit ingress of coolant fluid to form the sacrificial reservoir during a vacuum impregnation procedure and to inhibit egress of carbon flakes from the sacrificial reservoir during use. These features may facilitate formation and containment of the sacrificial reservoir and the containment of pollutants. The ingress port may comprise for example an inlet valve or inlet aperture, i.e. a small hole, while the permeable structure may comprise for example an oil-permeable structure such as a fine net structure, with these elements admitting fluid to the reservoir during the vacuum impregnation procedure, while nonetheless holding the filler material inside, and inhibiting or preventing egress of carbon flakes from the sacrificial reservoir. The skilled person will be able to determine suitable shapes and dimensions for the apertures of the ingress port or permeable structure for adequate containment of carbon flakes, with the permeable structure functioning in this case as a filter. It will be appreciated that the ingress of coolant fluid into the sacrificial reservoir will be facilitated by a pressure differential created during the vacuum impregnation procedure while there may be no such factor facilitating egress of the coolant fluid. Any filler material or heat retention elements present in the sacrificial reservoir will also serve to inhibit egress of the coolant fluid. In such ways, the ingress port or permeable structure is able to admit ingress of fluid while inhibiting its egress, to facilitate formation and containment of the sacrificial reservoir.

[0007] By "sacrificial reservoir" is meant a portion, pool or amount of the coolant fluid surrounding the hotspot which can be expended, ceded, forfeit, or surrendered, in the sense that cracking of the coolant fluid on the fluid-facing surface of the X-ray tube, growth of a layer of carbon, delamination of that carbon layer, and pollution of

the expendable portion of fluid by the resulting carbon flakes is accepted inside the sacrificial reservoir but contained therein so as to hinder or avoid contamination of the remainder of the coolant fluid. The carbon layer may be referred to herein as an "oil cake".

[0008] By "shield" is meant a guard, cover, screen, jacket, or protector safeguarding the surrounding body of coolant fluid from the hotspot. It will be apparent that the sacrificial reservoir serves not only as an expendable portion of fluid in which contamination is accepted and contained but also as a thermally insulating layer disposed between the hotspot and the surrounding fluid. The function of the shield is thus twofold.

[0009] The coolant fluid may comprise any suitable fluid such as a coolant oil, (high voltage) insulating oil, transformer oil. The surrounding body of the coolant fluid may refer the circulating portion of the coolant fluid flowing past and along the protective component.

[0010] The barrier structure may comprise any wall or wall structure, enclosure, partition, or segregation configured to prevent or at least inhibit mixing of the fluid in the sacrificial reservoir with that in the surrounding body. The barrier structure may comprise for example a frame or lid and may be formed entirely or partially of the permeable structure described above. The barrier structure may be formed at least partially of metal.

[0011] The term "hotspot" will be familiar to the person skilled in the art. For example, in an X-ray tube, hotspots are known to occur in an X-ray window for example as a result of insufficient heat transfer. The predetermined hotspot formation portion may therefore comprise all or a portion of the X-ray window. The location, dimensions, shape, periphery of the hotspot formation portion may be determined empirically. The size and shape of the shield may be determined based on the preference or requirement that the temperature of the heated surface, which is exposed to the coolant fluid, shall nowhere exceed the permitted temperature that the interface may reach without the coolant fluid being irreversibly altered, chemically cracked or otherwise modified in an undesired manner. If any portion of the shielded surface or its vicinity becomes too hot, notwithstanding the shielding, the shield may be extended or redesigned additionally to cover this portion. This measure may further reduce the total heat transfer but assists in preventing the coolant fluid from being damaged and for example the surface from being coated with residuals in an undesired manner.

[0012] Stated another way, according to the present disclosure, hotspots in an X-ray tube assembly are shielded against surrounding fluid by an encapsulated thermally insulating layer in the arrangements described herein. The disclosed arrangements accept oil cracking at hotspots but prevent the resulting 'cake' (of cracked oil and e.g. filler of hollow glass balls) from being released into the open oil.

[0013] In a second aspect, there is provided an X-ray tube assembly comprising a housing in which the fluid-cooled X-ray tube of any preceding claim is disposed.

The X-ray tube assembly may further comprise the coolant fluid contained in (e.g. a fluid chamber of) the housing.

[0014] In a third aspect, there is provided a method of preparing the X-ray tube assembly of the second aspect for operation. The method comprises filling (e.g. a fluid chamber of) the housing with the coolant fluid during a vacuum impregnation procedure, and during the vacuum impregnation procedure, encapsulating by the barrier structure the sacrificial reservoir of coolant fluid to form the shield thermally insulating the surrounding body of the coolant fluid from the hotspot formation portion. The method may further comprise, during the vacuum impregnation procedure, immersing the one or more heat-retention elements in the sacrificial reservoir of coolant fluid. The method may further comprise using an ingress port or permeable structure in the barrier structure to admit ingress of coolant fluid to form the sacrificial reservoir during the vacuum impregnation procedure and to inhibit egress of carbon flakes from the sacrificial reservoir during use.

[0015] In a fourth aspect, there is provided a method of operating the X-ray tube assembly of the second aspect. The method comprises operating the X-ray tube thereby causing the hotspot to arise at the hotspot formation portion on the fluid-facing surface of the X-ray tube; cooling the X-ray tube using the coolant fluid; and using the barrier structure encapsulating the sacrificial reservoir of coolant fluid to form the shield thermally insulating the surrounding body of the coolant fluid from the hotspot formation portion.

[0016] While the techniques disclosed herein concern X-ray tubes, it will be appreciated that the techniques are applicable to any fluid-cooled electrical equipment in which hotspots arise. For example, in place of an X-ray tube, the techniques may be applied to a fluid-cooled transformer.

[0017] These and other aspects of the invention will be apparent from and elucidated with reference to the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018]

Fig 1 illustrates an oil-cooled X-ray tube assembly. Fig. 2A illustrates unwanted surface buildup in the form of an oil cake on an X-ray window of the X-ray tube assembly of Fig. 1.

Fig. 2B illustrates carbon flakes contaminating the coolant oil of the X-ray tube assembly of Fig. 1 following delamination of the oil cake of Fig. 2A.

Fig. 3 illustrates improvements in the X-ray tube assembly of Fig. 1.

Fig. 4 is a flowchart illustrating a method of preparing the X-ray tube assembly of Figure 1 including the improvements of Fig. 3 for operation.

Fig. 5 is a flowchart illustrating a method of operating the X-ray tube assembly of Fig. 1 including the im-

provements of Fig. 3.

DETAILED DESCRIPTION

[0019] Fig. 1 illustrates an oil-cooled X-ray tube assembly 100 comprising a housing 102 containing a coolant oil 104. An X-ray tube 110 is immersed in the coolant oil 104 and supported for imaging the patient. Opposite to the X-ray tube 110 and supported with it on a gantry rotor rotates a detector system (not shown) which converts the attenuated X-rays into electrical signals. A computer system (not shown) reconstructs thereby an image of the patient's anatomy. The X-ray tube 110 is configured to generate a fan beam of X-rays 108 which exits the X-ray tube 110 through an X-ray window 106. The X-ray tube 110 has a tube envelope 112 housing a bearing system 114 between an anode support shaft 122 and a rotor body 116 with the rotor body 116 thereby positioned for rotation relative to a stator 124 mounted to the housing 102. Affixed to the opposite end of the bearing system 114 is a rotatable anode disc 126 which generates the X-rays 108 in response to a primary electron beam 130 emitted from the cathode 132. Electrons 134 backscattered from the anode disc 126 strike the X-ray window 106. As is known in the art, a hotspot may therefore arise at a hotspot formation portion on a fluid-facing surface of the X-ray window 106. A further hotspot may arise at a hotspot formation portion 118 on a fluid-facing surface of the anode support shaft 122, where the anode support shaft 122 is not protected by a plastics insulator 120, as heat flows from the hot anode into the coolant fluid when the target is subject to electron bombardment for X-ray production and the anode dissipates the generated heat into the coolant fluid. According to the present disclosure, a heat shield may be located at the anode shaft to reduce the heat flow through the anode shaft and enhance alternative heat flow through competing channels. For protection, a metal shield 128 is provided on ground potential.

[0020] As shown in Fig. 2A, it is known in the art that a layer 202 of cracked oil (colloquially referred to as an "oil cake" 202) forms at a hotspot formation portion 206 where the backscattered electrons 134 hit the X-ray window 106 of the X-ray tube 110. As shown in Fig. 2B, this results in carbon flakes 204 detaching from the delaminated oil cake 202 and polluting the coolant oil 104.

[0021] Fig. 3 illustrates improvements in the X-ray tube assembly of Fig. 1. At a hotspot formation portion 308 in the X-ray window 106 is provided a barrier structure 302 encapsulating a sacrificial reservoir 304 of coolant oil 204 to form a shield thermally insulating a surrounding body 306 of the coolant oil 104 from the hotspot formation portion 308.

[0022] The barrier structure 302 optionally encloses one or more heat-retention elements (not shown) to be immersed in use in the sacrificial reservoir of coolant fluid. In one non-limiting example, the one or more heat-retention elements comprise a solid thermally insulating ma-

terial in granular form. Additionally or alternatively, the one or more heat-retention elements may comprise a plurality of hollow particles such as hollow glass spheres, which may be gas-filled, and which may be formed of an inorganic material.

[0023] The barrier structure optionally comprises an ingress port or permeable structure (not shown) configured to admit ingress of coolant fluid to form the sacrificial reservoir during a vacuum impregnation procedure and to inhibit egress of carbon flakes from the sacrificial reservoir during use.

[0024] The coolant oil 104 itself is thus utilized additionally as a dielectric insulation material. The hotspot is typically located at or close to high voltage potentials. The coolant oil 104 inside the thermal barrier provided by the sacrificial reservoir 304 will first insulate and over time become carbonized, thus becoming conductive with correspondingly impaired ability for cooling or electrical insulation. This portion of the coolant oil 104 is thus 'sacrificed'. However, once carbonized, the oil 104 stays to a large extent inside the barrier structure 302, perhaps under high electric potential, but its escape from the barrier structure 304 is hindered at least partly because the ingress port or permeable structure is too small for carbon flakes. Inside the barrier structure 302, the carbon flakes can do little to no harm to the surrounding body 306 of oil 104. If a little oil 104 escapes the sacrificial reservoir 304, this does little to no harm, provided the carbon flakes are mostly or completely retained.

[0025] The barrier structure 302 is depicted as having a jagged surface to indicate that it is optionally sufficiently flexible to compensate for thermomechanical motion, caused for example by using materials of different thermal coefficients of expansion and due to temperature gradients.

[0026] Fig. 4 is a flowchart illustrating a method 400 of preparing the X-ray tube assembly 100 for operation. The method comprises, at step 402, filling the housing 102 with the coolant oil 104 during a vacuum impregnation procedure, and, at step 404, during the vacuum impregnation procedure, encapsulating by the barrier structure 302 the sacrificial reservoir 304 of coolant oil 104 to form the shield thermally insulating the surrounding body 306 of the coolant oil 104 from the hotspot formation portion 308. The method optionally also comprises, during the vacuum impregnation procedure, immersing the one or more heat-retention elements in the sacrificial reservoir 304 of coolant oil 104. Additionally or alternatively, the method may also comprise using an ingress port or permeable structure in the barrier structure 302 to admit ingress of coolant oil 104 to form the sacrificial reservoir 304 during the vacuum impregnation procedure and to inhibit egress of carbon flakes from the sacrificial reservoir 304 during use.

[0027] During the vacuum impregnation procedure, the coolant oil 104 enters the sacrificial reservoir 304 to form the thermal insulation layer and in doing so displaces air between the heat retention elements, for example

the particles of filler material. It will be appreciated that it is not important how the filler material is immersed in the coolant fluid, only that it is at least partially immersed at the end of the impregnation procedure. Alternatively, the filler material could be immersed in oil before assembly but doing so during the vacuum impregnation procedure is simpler. During the vacuum impregnation procedure, the containment (i.e. the housing 102 or a fluid chamber thereof) is evacuated and then filled under vacuum with the coolant oil 104. At this stage, the coolant oil 104 has not yet entered any previously unoccupied volume. Once the vacuum is released, voids remaining inside the containment are compressed by a ratio of vacuum- to normal-pressure, so by a factor of ten or more. Under the forces resulting from the pressure difference, additional coolant oil 104 is urged from a supply reservoir into the containment while the voids are compressed and thus removed. Ultimately, all small cavities in the containment are completely filled with coolant oil 104.

[0028] Fig. 5 is a flowchart illustrating a method 500 of operating the X-ray tube assembly 100. The method comprises, at 502, operating the X-ray tube 100 thereby causing the hotspot to arise at the hotspot formation portion 308 on the fluid-facing surface of the X-ray tube 100. At 504, the method comprises cooling the X-ray tube 100 using the coolant oil 104. At 506, the method comprises using the barrier structure 302 encapsulating the sacrificial reservoir 304 of coolant oil 104 to form the shield thermally insulating the surrounding body 306 of the coolant oil 104 from the hotspot formation portion 308. The order of the steps shown in Fig. 5 is not critical: the steps may be performed in any order.

[0029] To summarize, in fluid-cooled X-ray tubes, exceeding certain temperatures may result in unwanted surface buildup of carbon following cracking of the coolant fluid, leading to delamination of the carbon and pollution of the fluid with carbon flakes. There is provided therefore a fluid-cooled X-ray tube, a fluid-facing surface of the X-ray tube having a hotspot formation portion at which a hotspot is known to arise in use as a consequence of operation of the X-ray tube, the X-ray tube comprising a barrier structure configured in use to encapsulate a sacrificial reservoir of coolant fluid to form a shield thermally insulating a surrounding body of the coolant fluid from the hotspot formation portion. Advantageously, cracking of the fluid thus occurs solely or mainly within the sacrificial reservoir to provide partial or complete containment of pollutants, while the sacrificial reservoir insulates the surrounding body of fluid from the hotspot.

[0030] While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered exemplary and not restrictive; the invention is not limited to the disclosed embodiments.

[0031] Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of

the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

LIST OF REFERENCE SIGNS:

[0032]

100	X-ray tube assembly
102	housing assembly
104	insulating oil
106	X-ray window
108	X-rays
110	X-ray tube
112	tube envelope
114	bearing system
116	rotor body
118	hotspot in anode shaft
120	plastics insulator
122	anode support shaft
124	stator
126	anode disc
128	metal shield
130	primary electron beam
132	cathode
134	backscattered electrons
202	oil cake
204	carbon flakes
302	barrier structure
304	sacrificial reservoir
306	surrounding body of coolant fluid
308	hotspot formation portion

Claims

1. A fluid-cooled X-ray tube (110), wherein a fluid-facing surface of the X-ray tube includes a hotspot formation portion (308) at which a hotspot is known to arise in use as a consequence of operation of the X-ray tube, the X-ray tube comprising a barrier structure (302) configured in use to encapsulate a sacrificial reservoir (304) of coolant fluid (104) to form a shield thermally insulating a surrounding body (306) of the coolant fluid from the hotspot formation portion.
2. The X-ray tube of claim 1, wherein the barrier structure (302) encloses one or more heat-retention elements to be immersed in use in the sacrificial reservoir (304) of coolant fluid (104).

3. The X-ray tube of claim 2, wherein the one or more heat-retention elements comprise a solid thermally insulating material in granular form.
4. The X-ray tube of claim 2 or 3, wherein the one or more heat-retention elements comprise a plurality of hollow particles. 5
5. The X-ray tube of claim 4, wherein the hollow particles comprise hollow glass spheres. 10
6. The X-ray tube of claim 5, wherein the hollow glass spheres are gas-filled.
7. The X-ray tube of claim 5 or 6, wherein the hollow glass spheres are formed of an inorganic material. 15
8. The X-ray tube of any preceding claim, wherein the barrier structure (302) comprises an ingress port or permeable structure configured to admit ingress of coolant fluid (104) to form the sacrificial reservoir (304) during a vacuum impregnation procedure and to inhibit egress of carbon flakes from the sacrificial reservoir during use. 20
9. An X-ray tube assembly (100) comprising a housing (102) in which the fluid-cooled X-ray tube (110) of any preceding claim is disposed. 25
10. The X-ray tube assembly of claim 9, further comprising the coolant fluid (104) contained in the housing (102). 30
11. A method of preparing the X-ray tube assembly (100) of claim 9 or 10 for operation, the method comprising: 35
 - filling the housing (102) with the coolant fluid (104) during a vacuum impregnation procedure, and
 - during the vacuum impregnation procedure, encapsulating by the barrier structure (302) the sacrificial reservoir (304) of coolant fluid to form the shield thermally insulating the surrounding body (306) of the coolant fluid from the hotspot formation portion (308). 40
12. The method of claim 11, further comprising, during the vacuum impregnation procedure, immersing the one or more heat-retention elements in the sacrificial reservoir (304) of coolant fluid (104). 45
13. The method of claim 11 or 12, further comprising using an ingress port or permeable structure in the barrier structure (302) to admit ingress of coolant fluid (104) to form the sacrificial reservoir (304) during the vacuum impregnation procedure and to inhibit egress of carbon flakes from the sacrificial reservoir during use. 50
14. A method of operating the X-ray tube assembly (100) of claim 9 or 10, the method comprising:
 - operating the X-ray tube (110) thereby causing the hotspot to arise at the hotspot formation portion (308) on the fluid-facing surface of the X-ray tube;
 - cooling the X-ray tube using the coolant fluid (104); and
 - using the barrier structure (302) encapsulating the sacrificial reservoir (304) of coolant fluid to form the shield thermally insulating the surrounding body (306) of the coolant fluid from the hotspot formation portion. 55

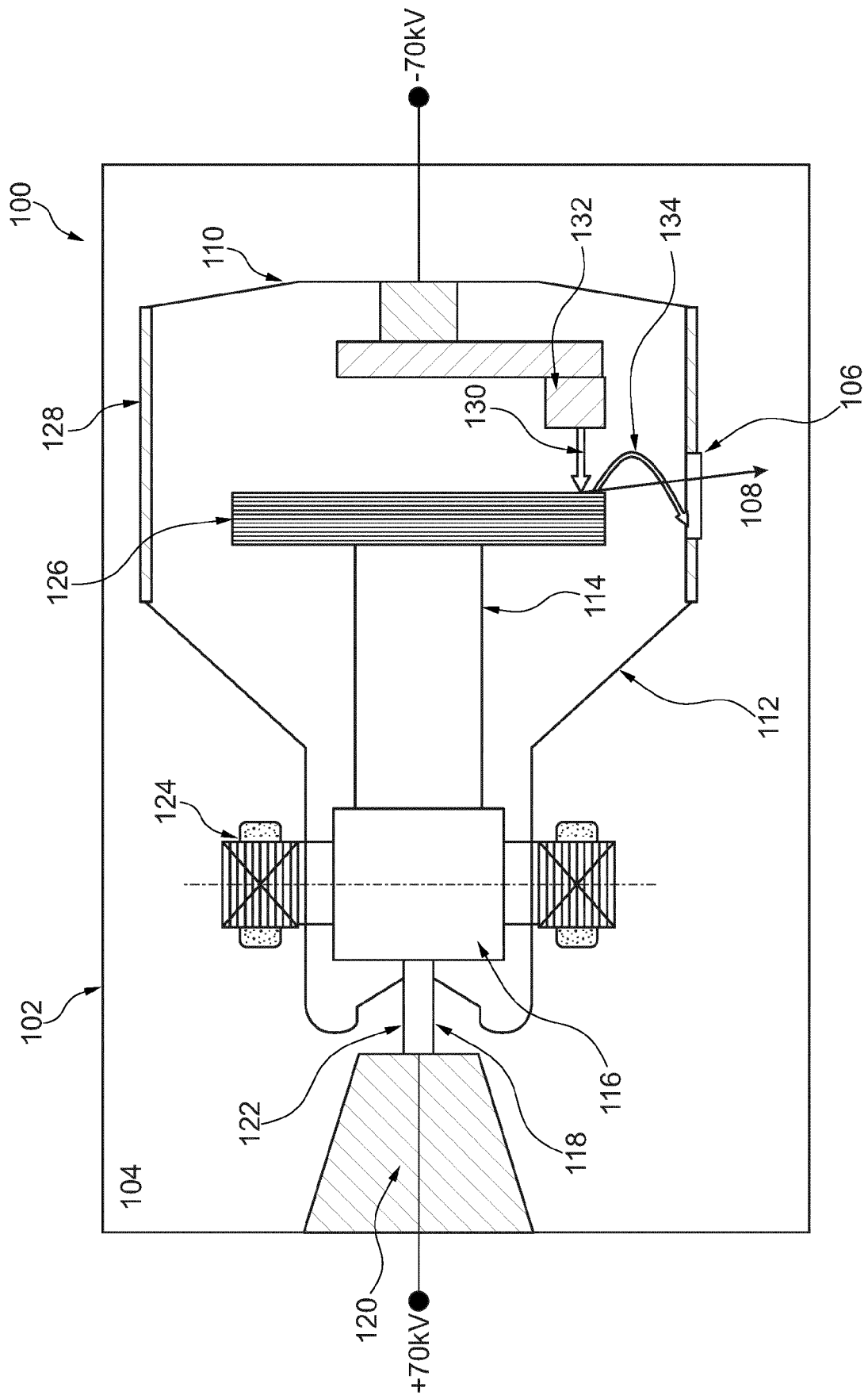


Fig. 1

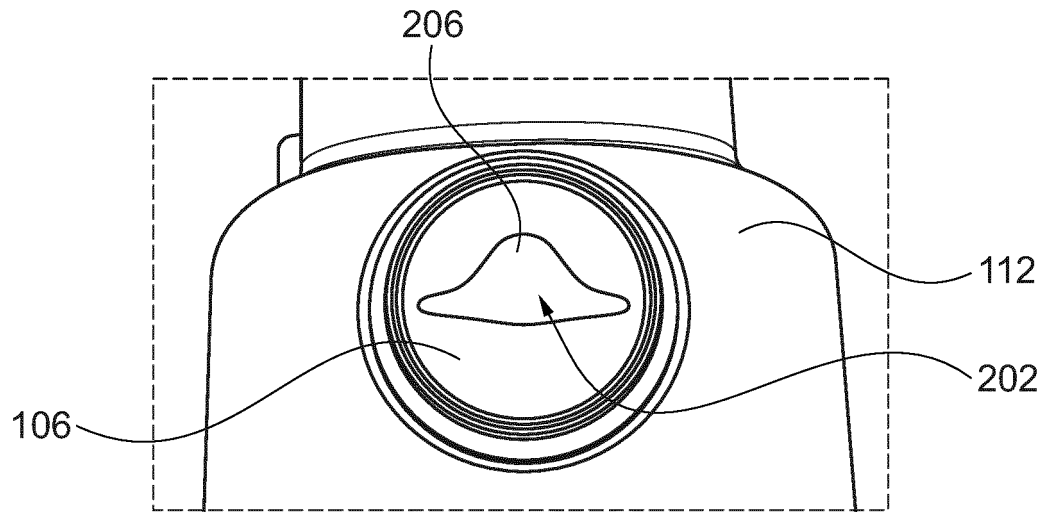


Fig. 2A



Fig. 2B

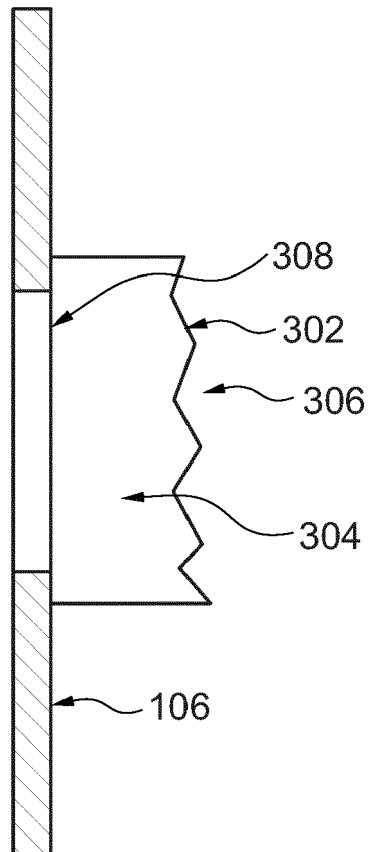


Fig. 3

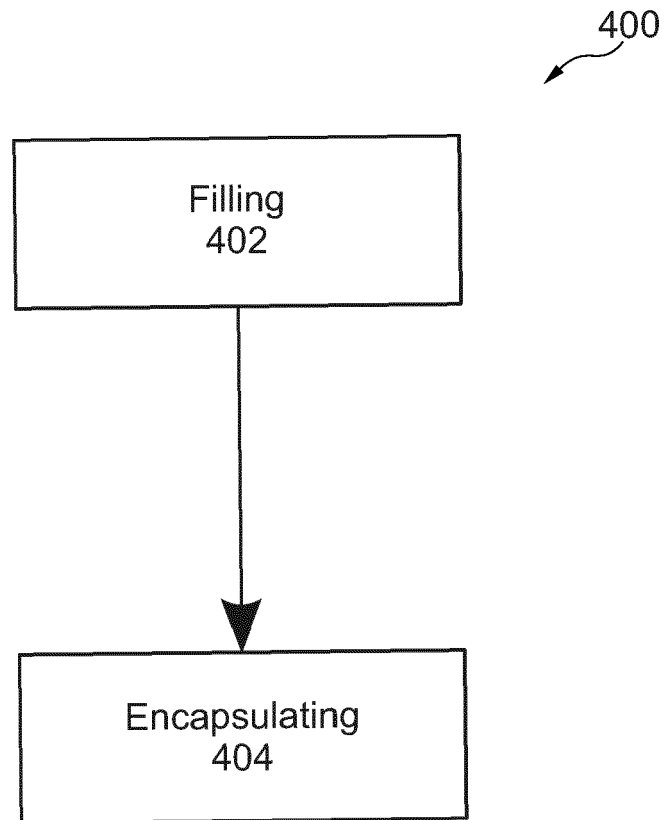


Fig. 4

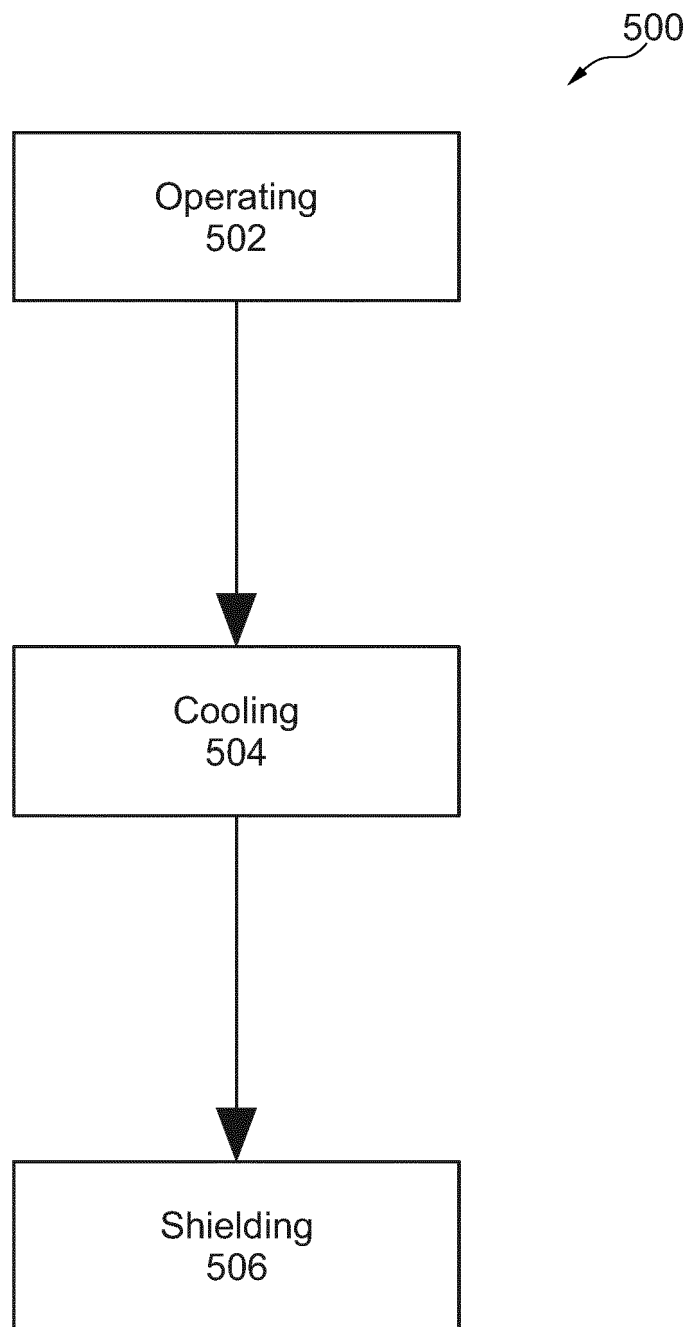


Fig. 5



EUROPEAN SEARCH REPORT

Application Number
EP 20 19 9885

5

10

15

20

25

30

35

40

45

50

55

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	DE 332 894 C (EMIL RAFFLER) 15 February 1921 (1921-02-15) * the whole document * -----	1-8	INV. H05G1/02 H05G1/04
			TECHNICAL FIELDS SEARCHED (IPC)
			H05G
1 The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 1 March 2021	Examiner Angloher, Godehard
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			

EPO FORM 1503 03.82 (P04C01)



Application Number

EP 20 19 9885

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.

☐ 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:

1-8

☐ 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).



**LACK OF UNITY OF INVENTION
SHEET B**

Application Number

EP 20 19 9885

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: 1-8

A fluid cooled X-ray tube according to claim 5;
special technical feature of claim 6:
the hollow glass spheres are gas-filled;

1.1. claims: 7, 8

see the additional features of claims 7, 8;

2. claims: 9-14

A fluid cooled X-ray tube according to e.g. claim 1;
A method of preparing the X-ray tube assembly of e.g. claim 9;
A method of operating the X-ray tube assembly of e.g. claim 9;
special technical feature common to claims 9 - 14:
a housing (102) in which the fluid-cooled X-ray tube (110)
of e.g. claim 1 is disposed;

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.

01-03-2021

10	Patent document cited in search report	Publication date	Patent family member(s)	Publication date
	DE 332894	C	15-02-1921	NONE
15	-----			
20				
25				
30				
35				
40				
45				
50				
55				

EPO FORM P0459

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