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Veröffentlichung im Amtsblatt	Ja/Nein
Publication in the Official Journal	Yes/No
Publication au Journal Officiel	Oui/Non

Aktenzeichen / Case Number / N° du recours : T 240/89 - 3.4.1

Anmeldenummer / Filing No / N° de la demande : 82 303 957.3

Veröffentlichungs-Nr. / Publication No / N° de la publication : 0 071 456

Bezeichnung der Erfindung: Rotary anode X-ray tube
Title of invention:
Titre de l'invention :

Klassifikation / Classification / Classement : H01J 35/10

ENTSCHEIDUNG / DECISION

vom / of / du 2 August 1990

Anmelder / Applicant / Demandeur :

Patentinhaber / Proprietor of the patent / Titulaire du brevet : Kabushiki Kaisha Toshiba

Einsprechender / Opponent / Opposant : 01) Forschungszentrum Jülich GmbH
02) Padana AG

Stichwort / Headword / Référence :

EPÜ / EPC / CBE Article 56

Schlagwort / Keyword / Mot clé : "Inventive step (denied)"

Leitsatz / Headnote / Sommaire

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Case Number : T 240/89 - 3.4.1

DECISION
of the Technical Board of Appeal 3.4.1
of 2 August 1990

Appellant : (Opponent 01)
Forschungszentrum Jülich GmbH
Postfach 1913
D-5170 Jülich

Other parties: (Opponent 02)
Padana AG
Baarer Straße 57
CH-6300 Zug

Representative :
Patentanwälte Ruff und Beier
Neckarstrasse 50
D-7000 Stuttgart 1

Respondent : (Proprietor of the patent)
Kabushika Kaisha Toshiba
72, Horikawa-cho, Sawai-ku
Kawasaki-shi
Kanagawa-Ken 210
(JP)

Representative :
Freed, Arthur Woolf
Marks & Clerk
57-60 Lincoln's Inn Fields
London WC2A 3LS
(GB)

Decision under appeal :
Interlocutory decision of the Opposition Division of the European Patent Office dated 7 February 1989 concerning maintenance of European patent No. 0 071 456 in amended form.

Composition of the Board :

Chairman : K. Lederer
Members : Y. van Henden
L.C. Mancini

Summary of Facts and Submissions

I. European patent No. 0 071 456 was granted on the basis of European patent application No. 82 303 957.3.

II. The Appellant (Opponent I) filed a notice of opposition against the European patent and requested full revocation thereof on the ground that the subject-matter of all claims was lacking an inventive step. To that purpose, the Appellant drew attention to, inter alia, the documents

D1: US-A-4 167 671,
D2: DE-B-1 750 602,
D5: DE-B-2 213 470,
D6: DE-B-2 420 814.

III. A second notice of opposition was filed against the European patent by the firm PADANA AG. The second opponent cited inter alia the documents

D3: article of Dr. E.A.W. Müller headed "die Belastbarkeit von Röntgenröhren, part III. Bewegte Anoden" in "ATM Archiv für Technisches Messen", April 1941,

D4: US-A-3 860 300,

and he too requested the patent to be revoked in its entirety on the ground that, in view of the disclosed state of the art, the subject-matter of its claims lacked an inventive step.

IV. The Opposition Division having issued a communication pursuant to Rule 58(4) maintained the European patent in amended form.

V. The Appellant lodged an appeal against this interlocutory decision and further cited inter alia

D7: "Lexikon der Feinwerktechnik" Band 14, 1949, pages 337-339.

VI. Oral proceedings were held, at the end of which the Appellant requested that the decision under appeal be set aside and the patent be revoked.

The Respondent requested that the appeal be dismissed and the patent be maintained on the basis of the documents cited in the communication under Rule 58(4) of 23 March 1988 with the further amendment to insert the phrase "in axial direction" after the words "hollow cylindrical member (8a, 8b)" in Claim 1 and the same amendment in column 2, line 61 of the description (main request)
or
on the basis of Claim 1 filed on 30 July 1990 with dependent claims and description to be adapted (auxiliary request).

VII. Claim 1 according to Respondent's main request reads:

"A rotary anode X-ray tube comprising a rotary anode (3a); a cathode (4); a rotor (6) in the form of a hollow cylindrical member of a material other than a ferromagnetic material and integral with said rotary anode (3a); an evacuated casing (2) which accommodates the rotary anode, the cathode and the rotor and includes an outer tube (2a) covering the outer periphery of said rotor (6) and an inner tube (2b) covering the inner periphery of the rotor (6) and united to said outer tube (2a) by a uniting portion covering an open end of said rotor (6); magnetic bearing providing means including at least one hollow cylindrical member (8a, 8b) of a ferromagnetic material provided on the

inner periphery of said rotor (6), at least one permanent magnet (12a, 12b) magnetised in the radial direction of said rotor and having one pole (N) in contact with the inner periphery of said inner tube (2b), a yoke (10) provided inside said inner tube (2b) and in contact with the other pole (S) of said permanent magnet (12a, 12b), said yoke (10) having first and second pole members (10a, 10c, 10b) provided on the inner periphery of said inner tube (2b), said first pole member (10a) being provided for giving magnetic flux to one end portion of said hollow cylindrical member (8a) in a radial direction and said second pole member (10b) being for giving magnetic flux to the other end portion of said hollow cylindrical member (8a, 8b) in the axial direction, said magnetic fluxes effecting radial and axial stabilisation of the rotor, and a control winding (11a, 11b, 11c) being so wound on at least one of said first and second pole members (10a, 10b, 10c) as to supply magnetic flux overlapping said magnetic flux generated from said permanent magnet (12a, 12b) at an end portion of at least one pole member (10a, 10c) facing said one end portion of the hollow cylindrical member (8a, 8b); a stator (16) provided on the outer side of said evacuated casing (2) for driving said rotor (6); and cooling means for forcibly conducting cooling medium along the inside of said inner tube (2b, 2d) so as to remove heat which is transmitted to the tube (2b, 2d) from said rotary anode (3a)."

Claims 2 to 21 are dependent on Claim 1.

Claim 1 according to his auxiliary request reads:

"1. A rotary anode X-ray tube comprising a rotary anode (3a); a cathode (4); a rotor (6) in the form of a hollow cylindrical member of a material other than a ferromagnetic material and integral with said rotary anode (3a); an

evacuated casing (2) which accommodates the rotary anode, the cathode and the rotor and includes an outer tube (2a) covering the outer periphery of said rotor (6) and an inner tube (2b) covering the inner periphery of the rotor (6) and united to said outer tube (2a) by a uniting portion covering an open end of said rotor (6); magnetic bearing providing means including first and second axially spaced hollow cylindrical members (8a, 8b) of a ferromagnetic material provided on the inner periphery of said rotor (6), at least one permanent magnet (12a, 12b) magnetised in the radial direction of said rotor and having one pole (N) in contact with the inner periphery of said inner tube (2b), a yoke (10) provided inside said inner tube (2b) and in contact with the other pole (S) of said permanent magnet (12a, 12b), said yoke (10) having first, second and third pole members (10a, 10c, 10b) provided on the inner periphery of said inner tube (2b), said first pole member (10a) being provided for giving magnetic flux to the end portion of said first hollow cylindrical member (8a) remote from the second hollow cylindrical member (8b) in a radial direction and said second pole member (10b) being for giving magnetic flux to the other (adjacent) end portions of said first and second hollow cylindrical members (8a, 8b) in the axial direction, said third pole member (10c) being provided for giving magnetic flux to the end portion of said second hollow cylindrical member (8b) remote from the first hollow cylindrical member (8a) in a radial direction, said magnetic fluxes effecting radial and axial stabilisation of the rotor, and a control winding (11a, 11b, 11c) being so wound on at least one of said first, second and third pole members (10a, 10b, 10c) as to supply magnetic flux overlapping said magnetic flux generated from said permanent magnet (12a, 12b) at an end portion of at least one pole member (10a, 10c) facing said one end portion of the hollow cylindrical member (8a, 8b), a stator (16) provided on the outer side of said evacuated casing

(2) for driving said rotor (6); and cooling means for forcibly conducting cooling medium along the inside of said inner tube (2b, 2d) so as to remove heat which is transmitted to the tube (2b, 2d) from said rotary anode (3a)."

VIII. The Appellant substantiated his request as follows.

The essential difference between the claimed X-ray tube and the one described in (D1) consists in the provision of an internal magnetic bearing. The other differences are rendered necessary by, or result from, the choice of such bearing. Such is the case for the provision of means circulating a cooling medium along the inner tube (2b). Heat produced at the anode is indeed not exclusively evacuated through thermal radiation and would reduce bearing efficiency as a result of the temperature rising above the Curie point, whereas the windings could be damaged. Nevertheless, cooling arrangements for X-ray tubes and constituent parts thereof are known in the art and envisaging their use does not require the exercise of inventive ingenuity.

Providing internal magnetic bearings does not involve an inventive step either, for such bearings are known from (D2) and, contrary to the Respondent's contention, no reason would deter the skilled person from using them while designing an X-ray tube with rotary anode, all the more since the use of internal bearings for rotary anodes in X-ray tubes is common ground as evidenced by "Lexikon der Feinwerktechnik" Band 14, 1969, page 338, Fig. 2 (document D7). Moreover, whether a tube with internal magnetic bearing would be more compact than a tube with external bearing is not yet certain. The compactness also depends on the presence of outer elements, such as the stator of the motor, which are not otherwise defined in Claim 1.

In the device according to (D1), the permanent ring magnets (7) alone are only suitable for providing axial stabilisation. Nevertheless, they also serve for premagnetising the magnetic members (6) and their fluxes overlap those of the co-operating electromagnets (8,9), thereby providing radial stabilisation. As a matter of fact, this principle is of general application in the technical field of the invention and similar teachings are to be found in (D5) and (D6). Now, said ring magnets (7) are cheap ones, made of baryum ferrite pressed axially, which determines their direction of strongest possible polarisation. That these rings are polarised axially does not, therefore, deter the skilled person from using radially polarised ring magnets. Moreover, as can be seen from (D5), using yokes and pole pieces to lead the field lines of permanent magnets to appropriate places is part of said person's basic technical knowledge. Considering that (D6) furthermore discloses the use of two cylindrical members of ferromagnetic material with facing ends receiving fluxes from a magnetic pole, it thus lies within the range of capability of the skilled person to arrange the magnets as explained in Claim 1. Finally, the amount of energy spared by providing short air gaps cannot be more than a few watts, whereas isolation problems are made more acute.

IX. To support his view, the Respondent substantially argued as follows.

The most important novel aspects of the invention are using an internal magnetic bearing, which is not obvious in an X-ray tube, a ring shaped permanent magnet with radial magnetisation and a yoke. Paths with reduced reluctance being thereby provided between permanent magnet and hollow cylindrical member, making the bearing small while ensuring

efficiently both radial and axial stabilisation is thus possible. This enables in turn the tube to be small and compact, so that it can satisfactorily be rotated around a prone patient. The use of an internal bearing also permits internal cooling allowing higher heat transfer from both the bearing and the rotor, which is advantageous and not obvious from any of the cited documents. Furthermore, the sensors are better shielded against electromagnetic radiation from the anode since the rotor is not made of ferromagnetic material.

In the X-ray tube according to Figure 1 of (D1), the inner portion of the casing covers the extent of the member (6) only partly and does not face any part of the magnetic bearing, no internal cooling is provided, no flux overlapping takes place and the flux leaving one terminal of the magnet ring (7) has to follow a very long path in air before entering the member (6). The arrangement has thus a very low magnetic efficiency, especially as regards axial stabilisation, and it is not suggested to obviate this drawback by providing a yoke and pole pieces. Said arrangement is not compact either since the portion of the member (6) that bears the copper cylinder (18) does not contribute to support and stabilisation of the rotating assembly. Furthermore, it might be contested that a hollow cylindrical member of ferromagnetic material is provided on the inner periphery of a tube and that the rotor (18) is integral with the anode. The whole member (6) is indeed made of ferromagnetic material and the rotor (18) is supported by this member (6) which in turn is separated from the anode by an annular connecting piece (5).

Now, starting from the disclosure in (D1), the consideration of the other cited documents would not lead the skilled person to the claimed invention. There is an inherent incompatibility between the teachings of (D1) and

(D5), whereas (D6) teaches away from using an internal bearing in a device comprising a shaft, which is the case for the X-ray tube described in (D1). As a matter of fact, attention must be paid to paragraph C-IV, 9.7 of the Guidelines for it is impossible to arrive at the invention without combining teachings found in more than two documents.

Reasons for the Decision

1. The appeal is admissible.

2. Novelty

2.1 The Board does not share the Respondent's interpretation of features such as "a rotor integral with the anode", "an inner tube covering the inner periphery of the rotor" and "a hollow cylindrical member of a ferromagnetic material provided on the inner periphery of said rotor". The Board takes indeed the view that the rotor (16) of the claimed X-ray tube being mounted on an anode shaft through an isolating plate (5), the expression "integral with" just means that anode and rotor are parts of a rigid arrangement, which is also the case in the rotary anode X-ray tube known from (D1). The Board also takes the view that, in the latter device, the section of the ferromagnetic tube (6) bearing the rotor (18) is necessarily provided on the inner periphery thereof, since it is stated that said rotor is affixed and embedded in said section - see column 6, lines 5 to 7. Finally, Claim 1 according to either of both versions does not state to which extent the inner tube (2b) covers the inner surface of the rotor (6), nor whether the bearing arrangement faces the totality of said inner surface.

2.2 The magnetic bearing of the rotary anode X-ray tube described in relation with Figure 1 in (D1) comprises permanent magnet rings (7) for stabilising the drive shaft (3) of the anode in the axial direction and coils having an annular core (8) of ferromagnetic material for stabilising said drive shaft in radial direction - cf. column 5, lines 8 to 16.

The Board nevertheless observes that a cylindrical core of ferromagnetic material surrounded by a coaxial ring magnet having axial polarisation is not subjected to the action of an axial force if its geometrical centre coincides with that of the magnet. Likewise, no axial force of appreciable intensity is developed if the core is entirely located in a region where the magnetic field is substantially uniform. Consequently, for an appreciable force to be developed in order to oppose an axial load and achieve good axial stability, one end of the core must project beyond an end face of the ring magnet, whereby the magnetic field lines extending between said end of the core and said end face of the ring magnet have substantially radial directions.

It thus appears that, despite the lack of any explicit mention to that effect in (D1), the ring magnets (7) play a part in axial stabilisation of the rotor and that their flux overlaps that of the coils (8,9). These inferences are actually implicitly confirmed by the passage of (D1) covering the lines 36 to 55 of column 2.

2.3 With regard to the preceding, the Board takes the view that the subject-matter of Claim 1 according to the Respondent's main request distinguishes over the prior art known from (D1) in that the permanent magnet (12a, 12b) is magnetised in the radial direction of the rotor (6) and has one pole (N) in contact with the inner periphery of the inner tube (2b); the magnetic bearing includes a yoke (10) provided

inside the inner tube (2b), in contact with the other pole (S) of the permanent magnet (12a, 12b) and having first pole members (10a, 10c) and a second pole member (10b) provided on the inner periphery of the inner tube (2b) for giving the magnetic flux in a radial direction to a first end portion of the hollow cylindrical member (8a, 8b) and the magnetic flux in axial direction to the other end portion of said hollow cylindrical member, respectively; the control winding (11a, 11b, 11c) is wound on at least one of the first and second pole members, and cooling means are provided for circulating a cooling medium along the inside of the inner tube (2b) so as to remove heat transmitted from the rotating anode (3a) to the inner tube (2b).

2.4 Document (D3) discloses rotary anode X-ray tubes with cooling means, but not with any magnetic bearings.

2.5 D2, 4, 5 and 6 disclose different kinds of internal and external magnetic bearings, but not in connection with rotary anode X-ray tubes.

2.6 Document D7 discloses a rotary anode X-ray tube with internal ball bearings.

The subject-matters of Claim 1 according to Respondent's main and auxiliary request, therefore, are new within the meaning of Article 54 EPC.

3. **Inventive step**

3.1 As to the problems defined in the specification of the patent in suit, column 2, lines 28 to 33, the Board is of the opinion that the achievement of improvements is a constant preoccupation in technical circles - cf. decision T 15/81 - 3.4.1 (OJ EPO 1982, pages 2-5), point 3 of the

grounds. Therefore, no inventive step can be perceived in attempting to provide a highly reliable rotary anode X-ray tube consuming less power for stably holding the anode drive shaft and having high cooling efficiency. Now, the need for a compact X-ray tube is related to the use thereof in a station where said tube is to be rotated around a prone patient. Such a need being felt without any further ado while designing a station of that kind, no inventive step either can be perceived in setting the last part of the technical problem to be solved by the invention. The same considerations also apply to the achievement of an improved shielding of the bearing sensors.

3.2 As to the solution of said problems, according to Claim 1 of the main request, the following considerations apply. Document (D2) pertains to magnetic bearings for supporting rotors. No particular application of the invention disclosed in (D2) being mentioned there, the Board takes the view that this document deals with the solution of a general technical problem which the invention disclosed in the European patent seeks to solve in the specific field of rotary anode X-ray tubes. With regard to the recommendations of decision T 195/84 - 3.2.1 (OJ EPO 1986, 121-128), said document (D2) thus appears to be relevant in the present case and the skilled person concerned with magnetic bearings for rotary anode X-ray tubes is deemed to take its teachings into consideration.

Document (D2) teaches that a radial bearing comprising a permanent ring magnet for axial stabilisation, electromagnets for radial stabilisation and sensors can be made very small by locating the electromagnets and sensors inside a hollow end part of the rotor - see column 7, lines 51 to 55 and Figure 1. Reading this and comparing the respective arrangements of Figures 1 and 2, the skilled person readily understands that electromagnets provided for

acting upon a hollow cylindrical member of ferromagnetic material may be arranged inside or outside said member. Now, the action of a magnetic field being determined by its intensity and configuration, and not be the nature of its source, the skilled person understands that permanent magnets too may be arranged inside or outside such a hollow cylindrical member for acting upon it.

3.3 Comparing Figures 1 and 2 of (D2) now makes clear that, in the above-mentioned passage of column 7, "very small" actually means "shorter". Obviously, the bearing would not be made shorter if both the permanent magnet and the electromagnet were arranged inside the hollow end part of the rotor and, considering that (D2) reveals nothing as regards how the rotor is made to rotate, this may be the reason why no such arrangement is disclosed in (D2). Nevertheless, starting from the state of the art known from (D1) and bearing in mind the teachings of (D2), the skilled person understands that the known X-ray tube can be made the shortest by arranging two elements of the group comprising the permanent ring magnet (7), the electromagnet (8,9) and the stator (19) inside the hollow member (6), and the remaining one of said elements outside the member (6). Furthermore, the magnetic bearing of the tube described in (D1) acting upon member (6) and not upon the shaft (3), no reason is liable to deter him, as the Respondent nevertheless contends, from envisaging this design, so all the more since the use of internal bearings per se with rotary anode X-ray tubes is common ground as evidenced by document D7. The number of combinations being limited and the selection of the most advantageous one rendered easy by comparing longitudinal and/or radial dimensions of the above-mentioned elements, no exercise of inventive ingenuity is required to arrange the magnetic bearing means of a rotary anode X-ray tube inside the hollow cylindrical

member of ferromagnetic material of the rotating anode assembly and the stator outside.

3.4 The Board furthermore takes the view that providing the static elements of a magnetic bearing inside the co-operating cylindrical member of a rotating assembly is not liable to produce any unexpected advantageous effects. Moreover, it is known that the efficiency of magnetic bearings depends on the intensity of magnetic fluxes, i.e. on the section of magnets and yoke parts, on the volume of windings and on the length of air gaps. Therefore, in the present case, the diminution of the tube length goes on a par with an increase of its diameter which, depending on the application, could even be a disadvantage.

3.5 The Board shares the Appellant's view that the direction of polarisation of the permanent magnets (12a, 12b) is not a feature of critical importance and that providing a yoke (10) with pole pieces (10a, 10c, 10b) so arranged as to lead the flux of said magnets to places where it penetrates radially into the cylindrical members (8a, 8b) and to places where it penetrates axially into said members, if needed, lies within the range of capability of the skilled person. Such is also the case for making one pole of the permanent magnet and the pole pieces of the yoke come into contact with the inner tube (2b), and for providing the windings (11a, 11b, 11c) on said pole pieces. It is indeed part of the skilled person's basic technical knowledge to reduce the length of air gaps and not to wind excitation coils on pieces where the flux they produce is not intended to circulate, to wit the permanent magnets (12a, 12b) in the embodiments of the present invention.

3.6 Document (D1) essentially pertains to tubes designed for generating X-rays during exposure times that typically are in the range of a few milliseconds, i.e. tubes in which

cooling is not a problem - see column 1, lines 4 to 22. Nevertheless, from lines 10 and 11 of the latter passage of (D1), it may be inferred that rotary anode X-ray tubes cooled by circulation of a fluid medium are known in the art, which is confirmed by document (D3). The need to maintain the temperature of the permanent magnets (12a, 12b), the yoke (10) and the windings (11a, 11b, 11c) low being, as the Appellant rightly pointed out, obvious, no inventive step either can be perceived in providing cooling means such as defined in Claim 1.

3.7 From the preceding sections of the present decision, it appears that, having regard to the state of the art disclosed in documents (D1) and (D2), and bearing in mind the basic knowledge of the relevant technician, the subject-matter of Claim 1 according to Respondent's main request lacks an inventive step. Furthermore, the features recited in Claim 1 according to any one of the Respondent's submissions form separate groups, whereby each of said groups provides effects that would normally be expected by anyone skilled in the art, for instance a better shielding of the sensors, without any unexpected combinatory effect, for instance an extra energy sparing, being produced.

The Board further takes the view that the above considerations fully comply with the recommendations of paragraph C-IV, 9.7 of the Guidelines, because there is no inherent incompatibility in disclosed features essential to the invention.

3.8 Thus, the subject-matter of Claim 1 according to Respondent's main request lacks an inventive step (Article 56 EPC) and this request, therefore, is to be rejected.

3.9 The subject-matter of Claim 1 according to Respondent's auxiliary request differs from that of Claim 1 of his main request in that the hollow cylindrical member is split up into two parts (8a and 8b) coaxially supported by the rotor 6 and so positioned relatively to the pole members (10a, 10b and 10c) that they receive magnetic fluxes in radial as well as in axial direction. Magnetic bearings with such an arrangement of hollow ferromagnetic cylinders being generally known from document (D6), Figure 3, which according to the principles outlined in paragraph 3.2 above has to be taken into account, its application together with the features of Claim 1 according to the main request cannot be considered to involve an inventive step either. All the more since there is obviously no combinatory effect with any of the other features of the claim.

Therefore, Respondent's auxiliary request is to be rejected too, and the patent in suit has to be revoked.

Order

For these reasons, it is decided that:

1. The decision under appeal is set aside.

2. The patent is revoked.

The Registrar: The Chairman:

M. Beer K. Lederer