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Bezeichnung der Erfindung: Method of transferring ultrasonic energy to and
Title of invention: from an object and focused ultrasonic transducer
Titre de l'invention :

Klassifikation / Classification / Classement : G10 K 11/02, G10 K 11/26, H04 R 1/34

ENTSCHEIDUNG / DECISION

vom / of / du 16 July 1987

Anmelder / Applicant / Demandeur :

Patentinhaber / Proprietor of the patent /
Titulaire du brevet : Advanced Diagnostic Research Corporation

Einsprechender / Opponent / Opposant : Kretztechnik GmbH

Stichwort / Headword / Référence :

EPÜ / EPC / CBE Article 56

Kennwort / Keyword / Mot clé : "Inventive step: general material properties (no)"
"Use of an explicit substance for a new purpose (yes)"

Leitsatz / Headnote / Sommaire

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Case Number : T 207/85

D E C I S I O N
of the Technical Board of Appeal 3.4.1
of 16 July 1987

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Decision under appeal : **Decision of Opposition Division of the European Patent Office dated** 30 January 1985, posted on 5 June 1985, **revoking the European patent No.** 0 005 857 **pursuant to Article 102(1) EPC.**

Composition of the Board :

Chairman : E. Turrini

Members : H. Reich

O. Bossung

Summary of Facts and Submissions

I. The Appellant is the Patentee of European patent No. 0 005 857 granted on 14 October 1981, pursuant to European patent application No. 79 101 747.8, filed on 1 June 1979.

II. As a result of the opposition filed by the Respondent (Opponent) said patent was revoked by a decision of the Opposition Division dated 30 January 1985 and dispatched 5 June 1985.

III. The revocation was based on the ground of lack of inventive step in the subject-matter of independent Claims 1 and 4 with regard to the following facts: the features defined in the precharacterising parts of Claims 1 and 4 are generally known in the art. The acoustic impedance of the coupling layer material as defined in the characterising parts of both said claims would be known, in particular from:

US-A-4 016 530 (D4), or
L. Bergmann: "Der Ultraschall", S. Hirzel Verlag, Zürich, 1949, pages 120 and 121 (D2),

and the sonic velocity of the coupling layer material as defined in the remaining text of the characterising parts of both said claims would be obvious with regard to

US-A-3 529 465 (D3).

IV. On 9 August 1985, the Appellant (Patentee) lodged an appeal against this decision, requesting that it be set aside, and the patent be restored as granted. The appeal fee and the statement setting out the grounds of appeal were received in due time.

V. In a communication issued pursuant to Article 110(2) EPC the Rapporteur drew the Appellant's attention additionally to the alleged prior use of sonic head NB 2,5/20S by the Respondent, the technical content of which was evidenced by construction drawing No. 44 719, dated 22 December 1977 and the corresponding part list (D1) and to the alleged prior use of an oscillator unit by the company Dr. Lehfeldt & Co., the technical content of which was evidenced by drawing No. BE 501-51 dated 7 January 1965 (D5).

In answer to this communication the Respondent cited a new document: "Materialprüfung", volume 18, No. 3, March 1976, pages 81-86 (D6) and the Appellant filed new independent Claims 1 and 4, as well as corresponding amendments of the description, said claims and amendments being identically contained in the documents of his main request handed over during oral proceedings held on 16 July 1987. During this oral proceedings, the Appellant was invited to also comment on document D6.

VI. In said oral proceedings, the Appellant (Patentee) finally requested to set aside the impugned decision and:

1. to maintain the patent in amended form on the basis of his main request: New Claims 1 and 4, published Claims 11 to 13 and 15 (changed into 14) with

amendments and published description, column 1 to column 4, line 4, with amendments, handed over as main request during oral proceedings; published Claims 2, 3, 5 to 10 and the published Figure;

2. to maintain the patent in amended form on the basis of his auxiliary request: New Claims 1 to 13, published description, column 1 to column 4, line 4, with amendments, handed over as auxiliary request during oral proceedings; and the published Figure.

VII. The Respondent (Opponent) requested that the appeal should be dismissed.

VIII. Independent Claims 1 and 4 of the main request have the following wording:

1. A method of efficiently transferring ultrasonic energy to or from an interrogated object, the method comprising the steps of: coupling a source or receiver of electrical energy to a piezoelectric crystal having a concave active surface and an acoustical impedance substantially larger than the interrogated object; and coupling ultrasonic energy between the active surface of the crystal and the surface of the object through a coupling layer of material filling the concavity of the crystal and forming a flat surface facing away from the concave surface of the crystal, the acoustical impedance of the material being between that of the crystal and that of the object characterised in that the acoustical impedance of the material is substantially different from the acoustical impedances of the crystal and of the object, and the sonic velocity of the material is near that of the object.

4. A focused ultrasonic transducer comprising: a piezoelectric crystal having a concave active surface and an acoustical impedance substantially higher than that of water; and a coupling layer of material filling the concavity of the crystal and forming a flat surface facing away from the concave surface of the crystal, the acoustical impedance of the material being between that of the crystal and that of water, characterised in that the acoustical impedance of the material is substantially different from the acoustical impedances of the crystal and of water, and the coupling layer has a sonic velocity near that of water.

Claims 2 and 3 are dependent on Claim 1 and Claims 5 to 14 are dependent on Claim 4.

IX. Independent Claims 1 and 4 of the auxiliary request are worded as follows:

1. A method of efficiently transferring ultrasonic energy to or from body tissue or water, the method comprising the steps of: coupling a source or receiver of electrical energy to a piezoelectric crystal having a concave active surface and an acoustical impedance substantially larger than the body tissue or water; coupling ultrasonic energy between the active surface of the crystal and the surface of the body tissue or water through a coupling layer of material filling the concavity of the crystal and forming a flat surface facing away from the concave surface of the crystal, the acoustical impedance of the material being between that of the crystal and that of the body tissue or water, characterised in that the coupling layer consists of a tungsten-loaded epoxy and that the weight percentage between tungsten and epoxy is chosen

as such that the acoustical impedance of the material is substantially different from the acoustical impedance of the crystal and of the body tissue or water, and the sonic velocity of the material is near that of the body tissue or water.

4. A focused ultrasonic transducer comprising:

a piezoelectric crystal having a concave active surface and an acoustical impedance substantially higher than that of water; and a coupling layer of material filling the concavity of the crystal and forming a flat surface facing away from the concave surface of the crystal, the acoustical impedance of the material being between that of the crystal and that of water, characterised in that the coupling layer consists of a tungsten-loaded epoxy material, the weight percentage between tungsten and epoxy being chosen such that the acoustical impedance of the material is substantially different from the acoustical impedances of the crystal and of water, and the coupling layer has a sonic velocity near that of water.

Claims 2 and 3 are dependent on Claim 1 and Claims 5 to 13 are dependent on Claim 4.

X. With regard to his main request the Appellant (Patentee) argues mainly as follows:

(a) The prior art coupling layers for an efficient sonic energy transfer by acoustic impedance matching, in particular those known from documents D2 and D4, have a flat structure. There is no indication, in particular not in document D2, that the geometric mean of the impedances to be matched also forms the

optimum impedance value for non-flat layers. Thus, it would not be obvious to apply the teaching of document D2 in a curved, lens-shaped layer structure, which is indicated as generally known in the description of the impugned patent.

(b) In the apparatus known from document D3, the transducer of electric into sonic energy is not a single piezoelectric crystal with a concave active surface but a mosaic of a multitude of flat crystal transducer elements. Focusing of the sonic beam in this apparatus would not be effected by the transducer elements (12) but by a frusto-conical solid waveguide (11). This fact would be derivable from document D3, column 4, lines 37 to 40, 54, 55 and column 4, line 71 to column 5, line 4. Moreover, the indication in document D3, column 4, line 75 and column 5, line 1 - that equal sonic velocities in said waveguide (11) and in the neighbouring test piece constitute a reference situation for the focal point shift towards or from the waveguide surface at unequal velocities - in combination with the statement in column 3, lines 50-54 - that the acoustic impedance of the waveguide should not differ too much from that of the test piece in order to minimize reflection at the interface - would not suggest the claimed solution, i.e. one coupling layer material exercising simultaneously two functions: impedance matching and removal of the focal point shift (defocusing).

(c) The quantitative dependence of the focal point shift from the sonic velocity in a layer, filling the concavity of a single transducer crystal, which dependence is known from document D6, formula (9a), would incite a skilled person only to provide for an

additional curvature of the transducer crystal in order to compensate the defocusing effect of the coupling layer but not to look for an appropriate coupling layer material. In particular in document D3 there would be no indication with regard to the necessity of such additional compensation curvature nor with regard to means for avoiding it. Rendering said additional compensation curvature unnecessary by appropriate properties of the coupling layer material itself, would not be obvious over the cited prior art and represent a particular advantage of the present invention.

XI. As far as the Appellant's main request is concerned, the Respondent (Opponent) takes the following view:

(a) Producing an efficient sonic energy transfer by acoustic impedance matching is independent from the particular geometry of the apparatus, being a reflection problem and no refraction problem. In the prior art, no indication would exist that the teaching of documents D2 and D4 is restricted to plane transducer surfaces and that it would be rather difficult to apply it in curved transducers.

(b) Impedance matching and removal of defocusing, the two partial problems underlying both independent claims, concern each an effect which is independent from the other one. Thus, when applying the teaching of document D2 in a conventional piezoelectric crystal with a filler (coupling layer) between its concave active surface and a flat object surface, the defocusing of the lens-shaped filler would remain. Documents D3 and D6 clearly show that impedance matching by lens-shaped coupling layers always produces a defocusing effect. Moreover, it is known

from document D6 that the shifted focal distance has a value which is proportional to the ratio of the sonic velocities in the lens-shaped coupling layer material and in the object material. Thus, it would be obvious to a skilled person that there are only two possibilities to avoid defocusing. One way leads to take into account measured sonic velocity values already at the construction stage for the necessary additional curvature of the crystal in order to produce a desired focal distance. The second way would be not to admit diffraction, i.e. the claimed solution with sonic velocity values in the coupling layer and in the object material which are near to each other. The first way would be common practice. The second way would only consist in formulating the necessary requirements in respect of the relevant physical properties, which requirements belong to a skilled person's general knowledge.

(c) Because of the inphase-excitation of all crystal elements, the mosaic structure of the transducer known from document D3 does not prevent a skilled person to verify that its integral concave active surface is comparable with that of the claimed single crystal. For this reason, the indications in document D3, column 4, line 71 to column 5, line 4, clearly teach a skilled person what has to be done in order to avoid defocusing, namely to realise equal sonic velocities in the coupling layer and in the object material.

XII. Concerning the Appellant's auxiliary request, the Respondent presents the following arguments:

(a) Claims 1 and 4 would not be allowable with regard to Article 123(2) EPC. Published Claim 12, disclosing tungsten-loaded epoxy, is only referred back to published apparatus Claim 4, but not to published method Claim 1. The published description, column 3, line 64 to column 4, line 3, only relates the acoustic impedance but not the sonic velocity with the weight percentage between tungsten and epoxy.

(b) The prior use of tungsten-loaded epoxy as damping material, as shown in document D5, renders it obvious to use this material because of its known impedance properties also in a coupling layer. This obvious use would inevitably lead to also discovering the favourable velocity properties of this material.

(c) The weight percentage of tungsten with regard to epoxy has an upper limit, where the mixture stops to form a coherent solid body, so that there is no free choice of the weight percentage between epoxy and tungsten. Moreover, the sonic velocity in tungsten-loaded epoxy would be additionally dependent on the form and size of the tungsten grains. Thus, the invention, i.e. the optimum mixture ratio, would simply be found by systematical trial and error, and not by a non-obvious selection.

XIII. The Appellant contests that the tungsten grain parameters are additionally needed for a complete technical teaching.

Reasons for the Decision

1. The appeal complies with Articles 106 to 108 and Rule 64 EPC and is therefore admissible.

2. Concerning the Appellant's main request:

2.1 The essential amendments in new independent Claims 1 and 4 of the main request consist in shifting in published Claims 1 and 4 respectively, the feature - that the acoustical impedance of the coupling layer material is between that of the crystal and that of the object - from the characterising to the first part of the claims. Having thus identical subject-matter with regard to the published claims, claims 1 and 4 of the main request satisfy Article 123(3) EPC. Furthermore, the subject-matter of the claims, description and drawings is adequately based on the original disclosure. Thus, there is no objection to their current version as far as Article 123(2) EPC is concerned.

2.2 An examination of the citations revealed by the search or presented by the Respondent (Opponent) shows that none of them discloses an apparatus or method having all the features set out in Claims 1 and 4 of the main request. Since novelty has never been contested, no detailed substantiation of the matter is required here. Therefore, the subject-matter of Claims 1 and 4 is considered novel.

2.3 It remains to be examined whether the subject-matter of method Claim 1 or apparatus Claim 4 involves an inventive step. Due to their identical essential subject-matter, Claims 1 and 4 can be jointly dealt with.

2.3.1 The nearest prior art is the Appellant's own statement in the description of the patent under appeal, column 1, lines 22 to 33. This statement has not been contested. Therefore, it was unnecessary to invite the Respondent to substantiate the accessibility of his prior use of the sonic head represented in document D1.

The subject-matter of Claims 1 and 4 differs from said generally known method and apparatus in the following features:

(a) that the acoustical impedance of the material is substantially different from the acoustical impedances of the crystal and of the object, respectively water; and

(b) that the sonic velocity of the (coupling layer) material is near that of the object, respectively water.

2.3.2 Having regard to this prior art, an objective formulation of the technical problem to be solved refers to an efficient transfer of focused ultrasonic energy to an object without an appreciable defocusing during said transfer (see also the impugned patent column 1, lines 48 to 50).

Improving the efficiency of a method or apparatus is a generally known problem in each technical field. Moreover, when using said generally known lens-shaped coupling layer in practice, a skilled person will automatically get aware of its defocusing effect. Thus, the Board is satisfied that no inventive merit can be seen in the statement of the problem.

2.3.3 In practice, the energy transfer and the defocusing effect are interdependent via the properties of the used coupling layer material. However, both said partial problems have a different physical causality. The energy transfer from the crystal to a body is a reflection problem concerning the amplitude (phonon density) of the sonic beam. The defocusing removal is a diffraction problem concerning the

propagation direction of the beam. Due to the fact that the overall solution given in Claims 1 and 4 is not restricted to a special material and only worded in terms of two separate general conditions for impedance and velocity, the practical interdependence between them in any used material can be disregarded, when dealing with inventive step. Therefore, the Board takes the view that in this case, a skilled person can be expected to act in such a way that an independent, individual solution has to be found for each partial problem.

2.3.4 The realisation of an efficient energy transfer by feature (a) is known from document D2. The Board regards a skilled person to know - that the ratio of the intensity reflected from an interface depends on the impedance difference in the interface and on the angular distribution of the incident beam - and to foresee - that any change of the angular distribution of the beam incidence in the interfaces is negligible when passing from a flat to a lens-shaped coupling layer. Therefore, contrary to the Appellant's view in point X.a. above, a skilled person is regarded as being able to recognise that the teaching of document D2 applies for flat as well as for lens-shaped coupling layers. Thus, the Board is satisfied that it is obvious for a skilled person to apply the teaching of document D2 in said generally known method and apparatus.

2.3.5 It remains to answer the question, whether feature (b) and its use in said generally known method and apparatus are obvious with regard to document D3. In the Board's view, the inphase-excitation of the crystal elements in document D3 renders this known transducer in its integral form equivalent to the generally known one with one single crystal and a concave active surface. The sonic energy leaves both transducers in the form of a concave wave-

front. A skilled person is regarded as being able to see in the indication in document D3, column 4, lines 37 to 40, 54 and 55; and column 4, line 71 to column 5, line 4, (see also point X.b. above) that the described focusing by waveguide (11) has to be understood in the sense that waveguide (11) is the technical means, which helps to realise a concave active transducer surface. The convex end surface of waveguide (11) serves as a further mechanical fixing means for the crystal mosaic of the transducer.

The statement in document D3, column 3, lines 50-54, explicitly refers to the interface reflectivity. It is, furthermore, general basic knowledge that, passing through an interface, the amplitude of a sonic beam and its wavelength obey different physical laws. These facts prevent a skilled person to infer from an impedance condition conclusions for the defocusing behaviour dealt with in document D3, column 4, line 71 to column 5, line 4. Therefore, the Board regards the skilled person as being able to recognise the following facts. The diffraction of the sonic beam in the interface between waveguide (11) and specimen S in document D3 causes the described defocusing. This diffraction mechanism is directly comparable with the diffraction occurring in the interface between the coupling layer and the object (water) in said generally known method and apparatus. The reference situation VL1 = VL2 indicated in document D3 describes the generally known physical behaviour of a sonic beam in an interface, showing no change in its propagation direction (diffraction) at equal phase velocities in both interface forming materials. Thus, the Board is convinced that the skilled person is able to

discern feature (b) in document D3 and that it is obvious for a skilled person to apply feature (b) to said generally known method and apparatus after they are matched according to document D2.

2.3.6 Having regard to the Appellant's argument in point X.c. above, the Board takes the view that the VL1 = VL2 condition in document D3 clearly teaches a defocusing-removal by a material property of the coupling layer. The fact that this solution renders superfluous any additional compensation curvature of the crystal occurs to the skilled person right away.

2.3.7 For the reasons set out it points 2.3.1 to 2.3.6 above, the Board regards the subject-matter of Claims 1 and 4 not to imply an inventive step; Article 56 EPC. Therefore, the independent claims of the main request cannot be allowed with regard to Article 52(1) EPC.

2.3.8 Claims 2 to 3 are referred back to non-allowable Claim 1 and Claims 5-14 are referred back to non-allowable Claim 4. These dependencies also render Claims 2-3 and 5-14 of the main request not allowable.

3. Concerning the Appellant's auxiliary request:

3.1 The subject-matter of Claims 1 and 4 corresponds to that of original Claims 1, 9 and 13. The restriction to "body tissue or water" in Claim 1 is disclosed in the original description; see also column 2, line 16. The Board acknowledges the disclosure of the tungsten weight percentage relating to both, impedance and sonic velocity, in the fact that tungsten-loaded epoxy is disclosed as an embodiment of the claimed invention, satisfying thus simultaneously the general quantitative conditions for impedance as well as velocity. The original disclosure of

the tungsten-loaded epoxy embodiment in the description (cf. column 3, lines 33 to 48) is not restricted to any particular claim category and clearly discloses the relevant subject-matter in form of a method step: "tungsten powder ... was mixed (line 41)". Therefore, the Appellant is regarded as rightfully claiming tungsten-loaded epoxy also within a method claim. For these reasons, the Board regards Claims 1 and 4 of the auxiliary request to satisfy Article 123(2) EPC. Due to the fact that Claims 1 and 4 of the auxiliary request narrow the coupling layer material mentioned in published Claims 1 and 4 to tungsten-loaded epoxy, they also satisfy Article 123(3) EPC.

3.1.1 With regard to the Respondent's argument in point XII.c. above, the Board follows the Appellant's view that Claims 1 and 4 give a complete technical teaching. It is regarded to lie within the normal skill of the expert to take into account the influence of the form and size of tungsten grains, when realising the subject-matter of Claims 1-4. Moreover, the Respondent has not contested that the disclosed embodiment of 90 weight % tungsten allows to form a coherent solid body, and that the explicit values of its sonic velocity and acoustical impedance as indicated in the description are able to solve the technical problem underlying the invention. No facts have been put forward, which induce the Board to assume that the invention can exclusively be realised by the explicit parameters of said embodiment. Thus, there is no ground to also include the form and size of the tungsten grains into the subject-matter of Claims 1 and 4. Therefore, the Board regards these claims as clear (Article 84 EPC).

3.2 No prior art document describes a method of transferring ultrasonic energy to or from an object or a focused ultrasonic transducer, which method and transducer comprise a coupling layer between the piezoelectric crystal and the object consisting of tungsten-loaded epoxy.

3.2.1 In the nearest prior art, i.e. said generally known method and apparatus indicated in the description of the impugned patent, column 1, lines 22 to 33, the coupling layer consists of mica-loaded epoxy, not tungsten-loaded epoxy.

3.2.2 Even assuming that the prior use of the Kretztechnik-sonic head in document D1 and of the Dr. Lehfeldt & Co. oscillator unit in document D5 would have been accessible to the public before the priority date of the present invention, this fact would not destroy the novelty of Claims 1 and 4 because in document D1 the coupling layer consists of blackening-loaded araldite and in document D5, tungsten-loaded epoxy is used on the non-active crystal surface opposite the active one as damping material.

3.2.3 In document D2, a lithium-magnesium alloy is mentioned as optimal impedance-matched coupling layer material between quartz and water. The apparatus and method known from document D3 use a metal such as aluminium, steel or the like as waveguide material in combination with a liquid film of acetylene tetrabromide or methylene iodide between waveguide and specimen. The coupling layer materials known from document D4 are lithium niobate and lead zirconate-titanate ceramics, glass, araldite and aluminium-loaded araldite. Document D6 does not mention an explicit coupling layer material.

3.2.4 The remaining documents cited in the European Search Report do not come closer to the subject-matter of Claims 1 and 4, and need not be discussed for appreciating novelty.

3.3 The question now to be considered is whether the method according to Claim 1 and the transducer according to Claim 4 involve inventive step.

3.3.1 The nearest prior art and the technical problem underlying the subject-matter of Claims 1 and 4 of the auxiliary request is identical to those of the main request. As set out in point 2.3.2 above, no contribution to inventive step can be found in the recognition of the technical problem. Therefore, it remains to examine whether the prior art renders it obvious to replace the mica-loaded epoxy in said generally known method and apparatus by tungsten-loaded epoxy in order to provide an optimal impedance-matched coupling layer without defocusing effect.

3.3.2 No cited prior art document suggests a heavy metal loaded resin, or even explicitly tungsten-loaded epoxy as a coupling layer material; see also point 3.2.3 above. The only cited evidence mentioning tungsten-loaded epoxy is the Dr. Lehfeld & Co. oscillator unit in document D5. In this unit tungsten-loaded epoxy is used as damping absorber on the rear of the oscillator and does not intervene with the ultrasonic energy transferred to an object. The Board regards a skilled person as knowing that the purpose of this absorber is to shift the resonance frequency of the oscillator out of the working frequency region and to allow for short pulse times. Thus, the only property of tungsten-loaded epoxy, which the expert derives from document D5 is its ability to absorb sound but not to transmit sound, or even to be the optimal

impedance-match between a piezoelectric crystal and body tissue (water). Contrary to the Respondent's view in point XII.b. above, the Board takes the view that appropriate absorber qualities do not incite a skilled person to investigate the acoustic impedance in a damping material in order to find out whether it allows an optional energy transfer when used as coupling material between the crystal and body tissue or water. Moreover, the prior art does nowhere mention a heavy metal component in a coupling layer material. Thus, document D5 does not lead a skilled person to replace mica-loaded epoxy by tungsten-loaded epoxy, so that via impedance-matching its favourable velocity properties would not inevitably be found.

Due to the huge differences in the nucleus and electronic shell structure between water and tungsten, a skilled person would not expect that any compound material with tungsten would have a sound velocity near that of water. Therefore, the Board regards it not to be obvious that replacing mica (alumo-silicate of Na, Ka, LiC, Fe, Mg) by tungsten in the conventional epoxy-filler allows to increase the transferred sonic energy and to avoid defocusing at the same time. Tungsten-loaded epoxy is thus used in said generally known method and apparatus for a new purpose, involving a new, surprising effect. For this reason, even in the event that an oscillator-unit according to document D5 would have to be regarded as prior art, it would not make dubious an inventive step in the subject-matter of Claims 1 and 4.

3.3.3 Contrary to the Respondent's view in point XII.c. above, it follows clearly from the foregoing that an inventive merit has to be seen in the selection of tungsten in combination with epoxy and not in a particular mixture ratio between these two materials. The measure of

determining the optimum mixture ratio, i.e. the alleged trial and error routine, is only realised after the skilled person has already done the inventive step of selecting tungsten, and is therefore without relevance.

3.3.4 For the above reasons, the subject-matter of Claims 1 and 4 of the auxiliary request is considered to be novel (Article 54(2) EPC) and to involve an inventive step within the meaning of Article 56 EPC. Said claims are therefore allowable under Article 52(1) EPC.

3.3.5 Claims 2 to 3 and Claims 5-13 of the auxiliary request relate to particular embodiments of the invention claimed in Claims 1 to 4. They are, therefore, allowable as dependent claims in agreement with Rule 29(3) EPC.

Order

For these reasons, it is decided that

1. The decision under appeal is set aside.

2. It is ordered that the patent be maintained in amended form on the basis of the documents of the auxiliary request submitted during the oral proceedings.

The Registrar: The Chairman:

F.Klein E.Turrini