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(54) METHOD FOR REGULATING THE HUMIDITY CONTENT LEVEL IN AN ELECTRICAL TRANSFORMER HAVING OIL-IMPREGNATED CELLULOSIC INSULATING ELEMENTS

(57) The invention relates to an electrical transformer (1) having oil-impregnated cellulosic insulation (4), the electrical transformer being characterized in that it further comprises humidity absorbers which are immersed in the oil (5), the humidity absorbers being molecular sieves (7), preferably 3A molecular sieves. The invention also relates to a method for regulating humidity content level of an oil-impregnated cellulosic insulation electrical transformer by the addition of molecular sieves in the oil, preferably 3A molecular sieves.

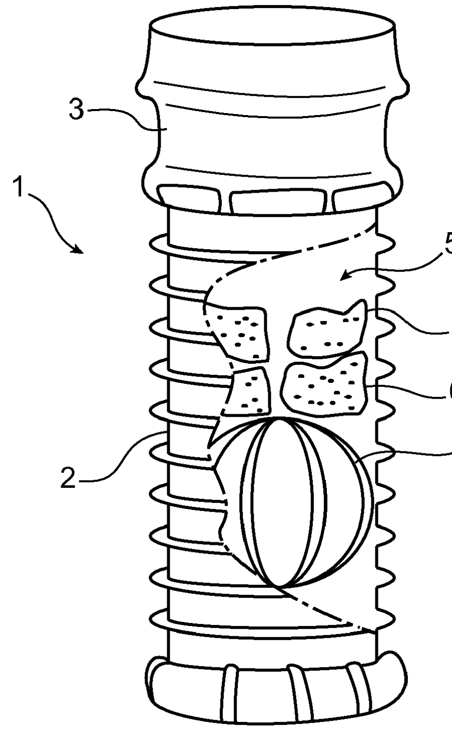

FIG. 1

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Description

TECHNICAL FIELD

[0001] The present invention related to the field of electrical transformers having oil-impregnated cellulosic insulation. In particular, the invention relates to the problem associated with the apparition of humidity in oil-impregnated cellulosic insulation over time.

PRIOR ART

[0002] In high voltage transformers based on oil-impregnated cellulosic insulation (Kraft paper, boards, wood, etc.), it is well-known that the humidity content of the oil-impregnated cellulose affects the insulation performance of the transformer. Indeed, the higher the humidity content is, the more it reduces the electrical resistance of the insulation.

[0003] However, the humidity content level of the cellulosic insulation generally increases during the operational life of the transformer. For example, instrument transformers encounter humidity ingress over time due to the poor tightness of the oil-expansion membrane.

[0004] Over time, the humidity is absorbed by the cellulosic insulation (which is very hygroscopic) and the dielectric withstand of the transformer is thus strongly reduced (partial discharges with sometimes explosion of the transformer).

[0005] A possible solution to this humidity issue would consist in changing the faulty element that allows the humidity entrance, for example changing the deficient breathing membrane by an hermitic one in an instrument transformer, but it would only enable to stop new humidity entrance, but not removing the already therein humidity.

[0006] Another solution such as oil drying obtained by a treatment under vacuum is not sufficient to remove all humidity trapped in the cellulose.

[0007] To remove this humidity, the only way would be to exchange the whole insulation of these transformers, which would imply costs as important as changing the transformer.

[0008] An object of the invention is to provide an electric transformer in which the humidity content level can be regulated.

DISCLOSURE OF THE INVENTION

[0009] To that end, the invention provides an electrical transformer having, as insulating elements, an oil and a solid dielectric material made of cellulose which is impregnated by, and immersed in, the oil, the electrical transformer being characterized in that it further comprises humidity absorbers which are immersed in the oil, the humidity absorbers being molecular sieves.

[0010] The solid dielectric material is generally made of cellulose (for example, Kraft paper, pressboard, wood, thermally upgraded paper).

[0011] By adding molecular sieves directly in the oil, humidity contained in the cellulosic insulation is absorbed by the molecular sieves through exchanges with the oil. Indeed, there exists a well-known humidity equilibrium between oil and cellulose in oil/cellulosic insulation systems: the molecular sieves dry the oil, then the oil being dried, humidity from the cellulose is removed and in the oil, and so on.

[0012] The choice of molecular sieves as humidity absorbers is ingenious since their behavior is not linked to temperature variations (contrary to dessicants, for example). Accordingly, humidity remains trapped even when temperature changes.

[0013] Molecular sieves (Zeolites) are crystalline metal aluminosilicates having a three-dimensional interconnecting network of silica and alumina tetrahedra and having uniform cavities which selectively adsorb molecules of a specific size.

[0014] Preferably, the humidity absorbers are 3A molecular sieves. 3A molecular sieves are molecular sieves which cavities selectively absorb molecules having a size inferior to 3 Å (0,3 nm). 3A molecular sieves are preferred since they are the smallest one able to trap only water (water molecule size being 2,7 Å).

[0015] Preferably, the 3A molecular sieves are in a concentration of no more than 40 g by liter of oil. In a preferred embodiment, the 3A molecular sieves are in a concentration of 20 g to 40 g by liter of oil. The concentration of 3A molecular sieves is chosen according to the humidity content level to be attained in the cellulosic insulant, as well as the oil volume and the cellulose quantity. This particular range of concentrations is the preferred ratio for instrument transformers. Indeed, the ratio cellulose/oil in instrument transformers is different from the one in other transformers, for example the one in power transformers (there are more cellulose in instrument transformers). In power transformers, a lower concentration of 3A molecular sieves by liter of oil could be used since they have a lower cellulose content versus oil volume.

[0016] Preferably, the humidity absorbers are gathered in at least one water permeable container, preferably a woven bag. Of course, the water permeable container will be chosen compatible with the insulating oil. With this particular conditioning, the handling and the future retrieval of the molecular sieves in the oil of the transformer are easier.

[0017] The electrical transformer may be chosen from an instrument transformer, a power transformer, a distribution transformer, a regulating transformer and a converter transformer. The presence of molecular sieves is especially preferred in instrument transformers equipped with soft membrane, since they contain a lot of cellulosic material (very hygroscopic) compared to oil volume.

[0018] The invention further relates to a method for regulating humidity content level of a solid dielectric material of an electrical transformer, the solid dielectric material being made of cellulose and being impregnated by, and immersed in, an oil, the method being characterized in that it comprises the addition, in the oil, of humidity absorbers configured to absorb humidity of the solid dielectric material by absorbing humidity contained in the oil, the humidity absorbers being molecular sieves. Preferably, the molecular sieves are conditioned in at least one water permeable container, preferably a woven bag, compatible with the insulating oil.

[0019] Preferably, the humidity absorbers are 3A molecular sieves.

[0020] Preferably, the 3A molecular sieves are in a concentration of 20g to 40g by liter of oil.

[0021] In a preferred embodiment of the invention, the method further comprises, after the addition in the oil of the humidity absorbers, heating the oil to accelerate an absorption rate of humidity contained in the oil by the humidity absorbers.

[0022] The adding may be achieved on-site when the transformer is in service.

[0023] The adding may be achieved before the transformer is put in service.

[0024] Accordingly, the process of regulating humidity content level of a solid dielectric material of an electrical transformer may be to reduce the humidity content level of the solid dielectric material made of cellulose. It is a particularly efficient technique to dry impregnated cellulosic insulation in on-site operating transformers, at a low cost and directly in the existing transformers. It allows a life extension of the operating transformers by a few years.

[0025] The process of regulating humidity content level may also be to maintain a low humidity content level in new transformers, the presence of molecular sieves preventing the humidity content level in cellulosic insulation to be too high.

[0026] It is to be noted that the electrical transformer according to the invention is preferably a high-voltage transformer, but it could also be a medium-voltage transformer. The terms "medium-voltage" and "high-voltage" are used in their habitual acceptance, namely the term "medium-voltage" means a voltage that is greater than 1 000 volts for alternating current and 1 500 volts for direct current, but that does not exceed 52 000 volts for alternating current and 75 000 volts for direct current, while the term "high-voltage" refers to a voltage that is strictly greater than 52 000 volts for alternating current and 75 000 volts for direct current.

[0027] Additional features and advantages of the present invention are described in, and will be apparent from, the detailed description of the preferred embodiments and the figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028]

FIG. **1** is a schematic perspective front view of an instrument transformer according to the invention, with a broken section showing the inside of the transformer.

FIG. **2** is a schematic perspective view of a mesh bag containing molecular sieves according to the invention, and an enlargement view of three molecular sieves (beads) contained in the bag.

FIG. **3** represents the cellulose humidity (%) as a function of time, of an oil-impregnated cellulosic insulation respectively comprised in a container having no molecular sieves or in a container having molecular sieves, at a constant room temperature.

FIG. 4 represents the cellulose humidity (%) as a function of time, of an oil-impregnated cellulosic insulation respectively comprised in a container having no molecular sieves or in a container having molecular sieves, during a cyclic temperature.

FIG. 5 represents the trend in tan δ as a function of frequency for a tested instrument transformer according to the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

[0029] Referring to FIG. 1 of the drawings, there is illustrated an instrument transformer 1 operating in accordance with the invention. The transformer 1 comprises a tank 2 having an opening sealed with a cover 3 (which is generally a membrane for oil expansion). The instrument transformer 1 comprises an oil impregnated cellulosic insulation 4 (paper, cotton, or other cellulosic material), is filled with oil 5 (a mineral oil, an ester oil or a silicone oil) and further comprises four woven bags 6 each containing molecular sieves 7 in the form of beads.

[0030] A bag 6 and the molecular sieves 7 in the form of beads are illustrated in FIG. 2. The bag 6 may be a mesh construction, for example a polyester woven bag, but can also be any other suitable water permeable container, compatible with oil and enabling exchanges between oil and molecular sieves.

[0031] The invention has been tested on a laboratory scale and on a real instrument transformer.

[0032] For these tests, the chosen molecular sieves were 3A (3A = 0,3 nm) molecular sieves made of zeolite, reference UPAMOL 3A by Upagchem conditioned in beads shape of a diameter comprised between 2,5 and 5 mm.

[0033] The molecular sieves 3A were conditioned in four woven polyester bags (size of 16 cm x 20 cm) in a specific ratio and added directly in the oil by removing the oil expansion system and cover of the instrument transformer. After insertion of the bags of molecular sieves, it is recommended to seal the enclosure containing the oil, the oil-impregnated cellulose and the molecular sieves, for example with a hermetic membrane, in order to avoid new humidity recapture (even if the molecular sieves can absorb it). For example, in an instrument transformer, the membrane for oil expansion (generally a polyurethane / polycarbonate membrane) can be replaced with a metallic membrane.

[0034] The ratio of the molecular sieves depends on the instrument transformer (i.e. cellulose mass and oil volume).

[0035] In the laboratory tests and the real-life tests, the maximum ratio oil/cellulose/humidity was supposed to be approximately 100 L/3 kg/200 g (6-7%). Accordingly, a ratio of 30 g/L was chosen for the 3A molecular sieves, the selected 3A molecular sieves being saturated at 20% of their weight (600 g for 3 kg). Thus, four bags of 750 g of 3A molecular sieves were conditioned in woven polyester (3 kg/100 L).

Laboratory tests

[0036] The laboratory tests were carried out with a closed casing test vessel containing 300 mL of mineral oil (Nytro 4000X from Nynas), 9 g of cellulose (Kraft paper) and the four bags of 750 g of 3A molecular sieves. Another closed test vessel containing the same 300 mL of mineral oil and 9 g of cellulose was used as a control (no sieve).

[0037] The humidity in cellulosic insulation is directly measured by the Karl Fisher coulometric titration (IEC 60814). Oil samplings were performed at different times.

[0038] Tests were carried out at a constant temperature (room temperature, i.e. 20°C) (FIG. 3) and during temperature cycles (the temperatures alternating between room temperature and 70°C) (FIG. 4).

[0039] The obtained results underline the significant efficiency of molecular sieves 3A for decreasing humidity in cellulose at an acceptable level at room temperature (FIG. 3). These results also show that the decrease in the cellulose humidity level is clearly speeded when the oil is heated at 70°C (FIG. 4).

[0040] Furthermore, these results show that when trapped, the humidity remains enclosed in the 3A molecular sieves.

Tests on a real instrument transformer

[0041] The real-life tests were performed on an instrument transformer. It was a 72,5 kV Combined Metering Unit (CMU) of the reference CMS from Alstom, having several years of operational time and having humidity in its cellulosic insulation.

[0042] The humidity in cellulosic insulation was measured by the FDS technique (Frequency Dielectric Spectroscopy), which consists in measuring tan δ over a very wide frequency (from 0,1 mHz to 1 kHz). This is an indirect measurement of the humidity content in the cellulosic insulation: the lower the tan δ is, the lower the humidity content is.

[0043] Regular electrical measurements were made on the CMU with the apparatus IDAX 300 from Megger (using the function tan δ *versus* frequency).

[0044] FIG. 5 shows these results.

[0045] Measurements were made at 25°C on the CMU, before the insertion of the four polyester woven bags containing 3A molecular sieves (curve n°1).

[0046] The four polyester woven bags containing 3A molecular sieves in the ratio 30 g/L were then added in the upper part of the oil compartment of the instrument transformer and the CMU was left at room temperature.

[0047] Measurements were made at 25°C, after 2 months at room temperature (curve n°2).

[0048] Measurements were made at 21°C, after 3 months at room temperature, followed by 20 days at 40°C and then 1 week at room temperature (curve n°3).

[0049] Measurements were made at 21°C, after 3 months at room temperature, 20 days at 40°C, 1 week at room temperature and 4 months at room temperature (curve n°4).

[0050] Measurements were made at 24°C, after 3 months at room temperature, 20 days at 40°C, 1 week at room temperature, 3 months at room temperature and 7 months of external storage during hot summer (curve n°5).

[0051] Measurements were made at 18°C, after 3 months at room temperature, 20 days at 40°C, 1 week at room temperature, 3 months at room temperature, 7 months of external storage during hot summer and 1 week at 18°C (curve n°6).

[0052] From FIG. 5, it clearly appears that tan δ regularly decreases with the addition of molecular sieves. For example, the obtained results of tan δ at 50 Hz are listed in the below table.

Curve number	1	2	3	4	5	6
tan δ at 50 Hz	2.59%	2.27%	1.45%	1.28%	1.11%	0.89%

[0053] In conclusion, the solution proposed according to the invention allows decreasing the humidity content level of an operational electrical transformer, thus saving money by keeping existing transformers with a cost effective solution.

[0054] This solution also allows maintaining a low humidity content level in new electrical transformers, by introducing molecular sieves before (or shortly after) the initial operation of the transformers.

Claims

1. An electrical transformer (1) having, as insulating elements, an oil (5) and a solid dielectric material made of cellulose (4) which is impregnated by, and immersed in, the oil, the electrical transformer being **characterized in that** it further comprises humidity absorbers which are immersed in the oil, the humidity absorbers being molecular sieves (7).

2. The electrical transformer according to claim 1, wherein the humidity absorbers are 3A molecular sieves.

3. The electrical transformer according to claim 2, wherein the 3A molecular sieves are in a concentration of no more than 40 g by liter of oil.

4. The electrical transformer according to claim 3, wherein the 3A molecular sieves are in a concentration of 20 g to 40 g by liter of oil.

5. The electrical transformer according to any one of claims 1 to 4, wherein the humidity absorbers are gathered in at least one water permeable container (6), preferably a woven bag.

6. The electrical transformer according to any one of claims 1 to 5, wherein the electrical transformer (1) is chosen from an instrument transformer, a power transformer, a distribution transformer, a regulating transformer and a converter transformer.

7. A method for regulating humidity content level of a solid dielectric material of an electrical transformer, the solid dielectric material being made of cellulose and being immersed in, and impregnated by, an oil, the method being **characterized in that** it comprises the addition, in the oil, of humidity absorbers configured to absorb humidity of the solid dielectric material by absorbing humidity contained in the oil, the humidity absorbers being molecular sieves (7).

8. The method according to claim 7, wherein the humidity absorbers are 3A molecular sieves.

9. The method according to claim 8, wherein the 3A molecular sieves are in a concentration of 20 g to 40 g by liter of oil.

10. The method according to any one of claims 7 to 9, further comprising, after the addition in the oil of the humidity absorbers, heating the oil to accelerate an absorption rate of humidity contained in the oil by the humidity absorbers.

11. The method according to any one of claims 7 to 10, wherein the adding is done on-site when the transformer is in service.

12. The method according to any one of claims 7 to 10, wherein the adding is done before the transformer is put in service.

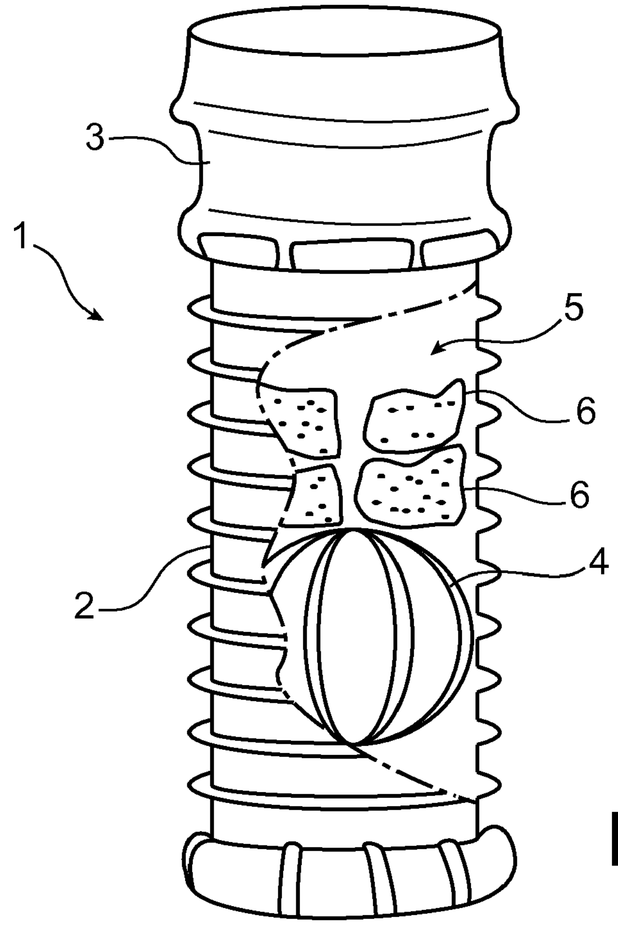

FIG. 1

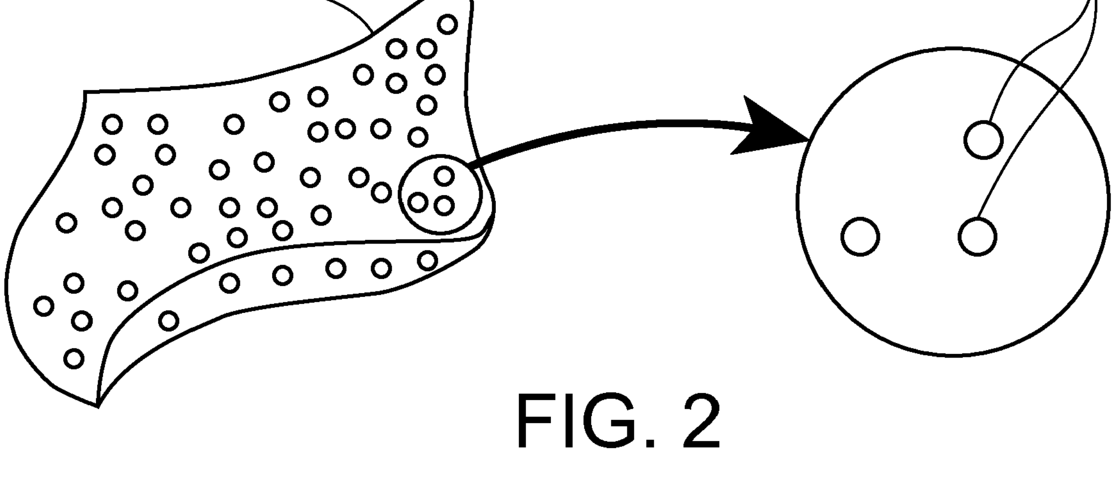

FIG. 2

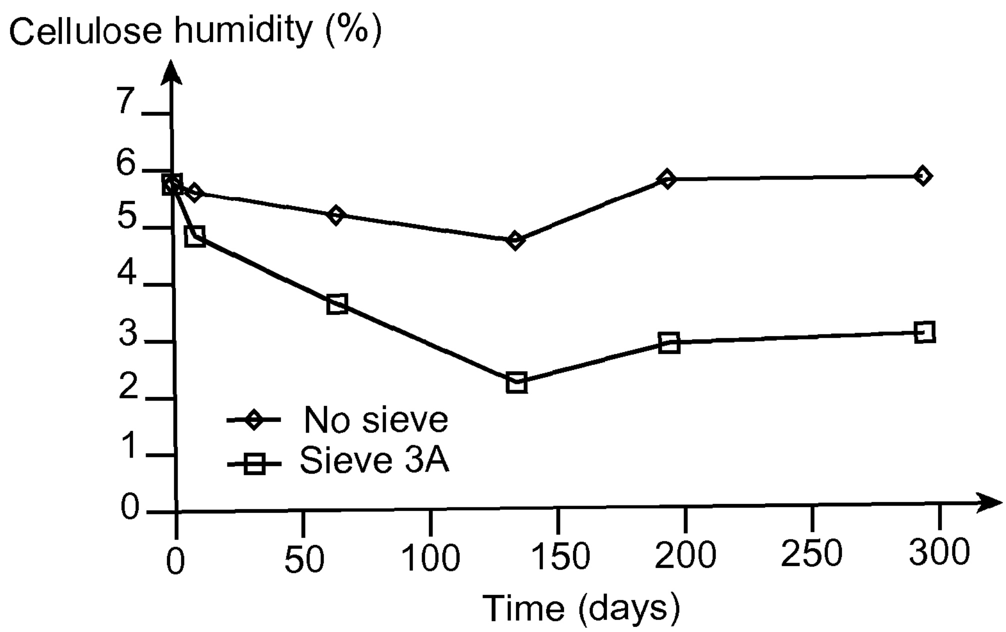
Cellulose humidity (%)
7
6
5
4
3
2
1
0
No sieve
Sieve 3A
0
50
100
150
200
250
300
Time (days)

FIG. 3

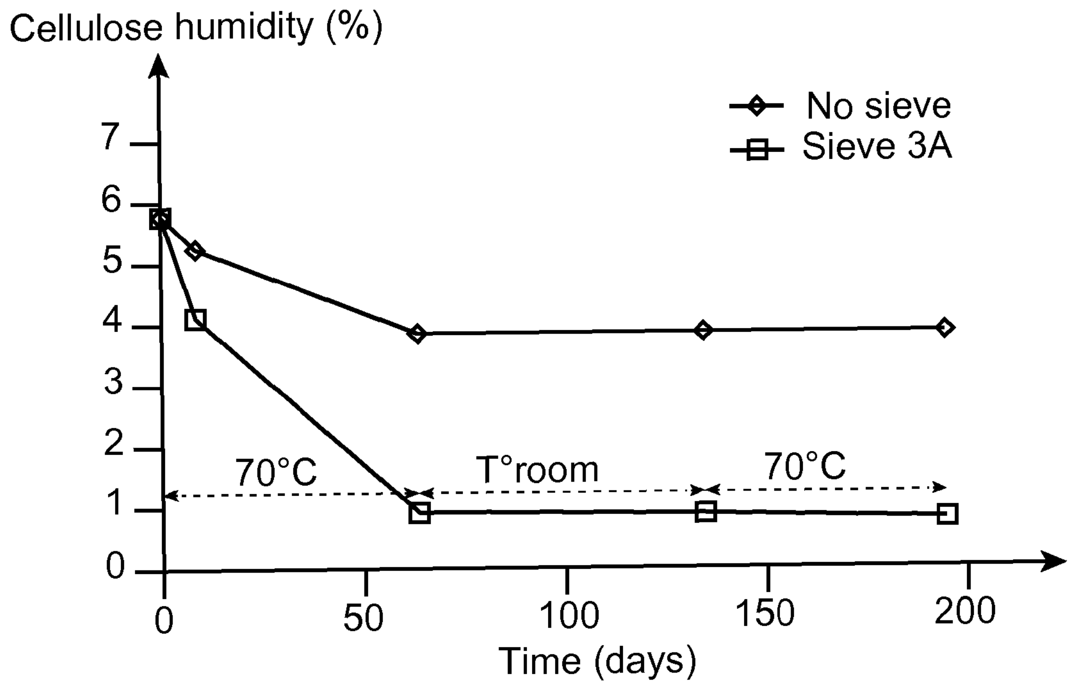
Cellulose humidity (%)
No sieve
Sieve 3A
7
6
5
4
3
2
1
0
70°C
T°room
70°C
0
50
100
150
200
Time (days)

FIG. 4

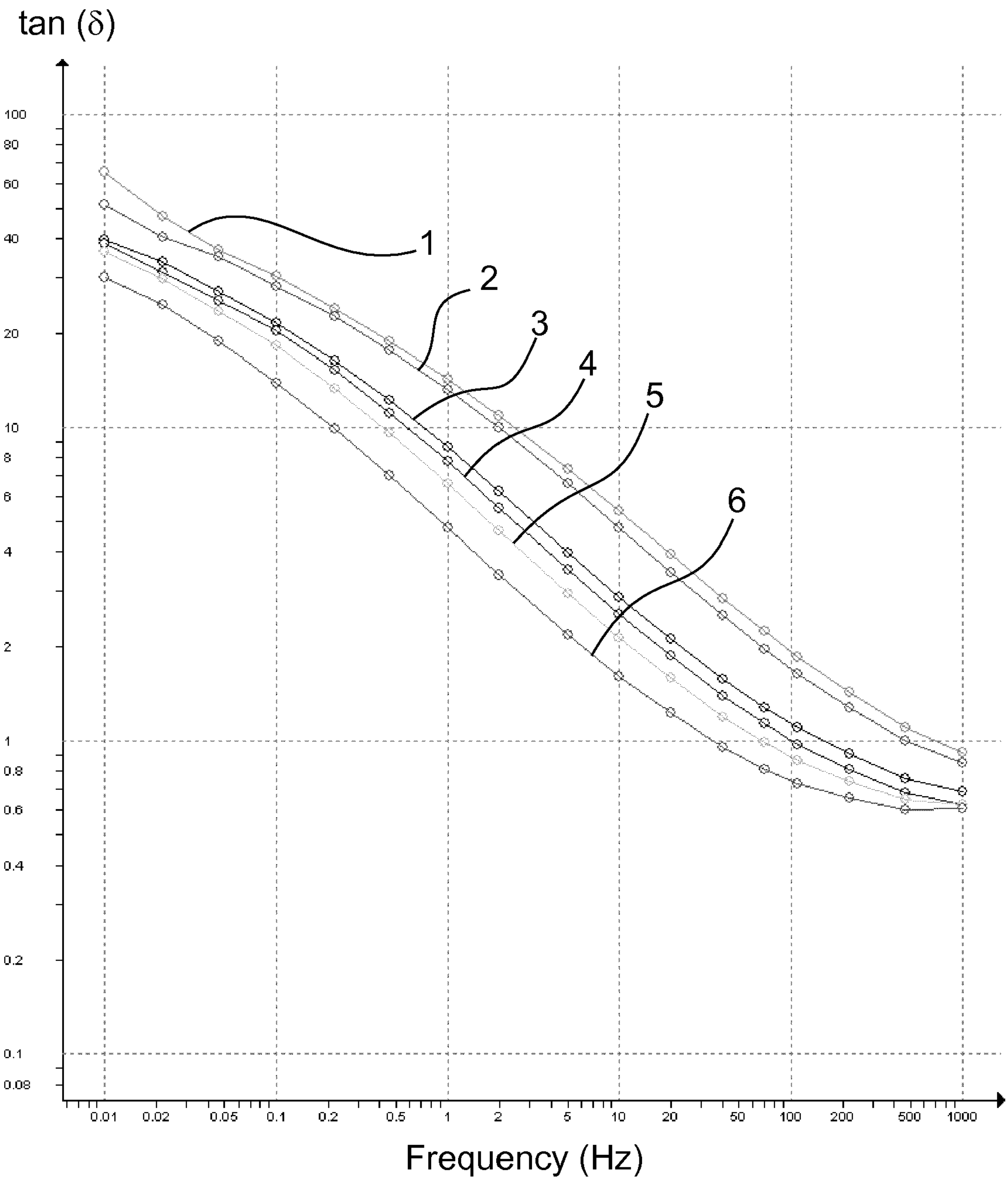
tan (δ)
100
80
60
40
20
10
8
6
4
2
1
0.8
0.6
0.4
0.2
0.1
0.08
1
2
3
4
5
6
0.01
0.02
0.05
0.1
0.2
0.5
1
2
5
10
20
50
100
200
500
1000
Frequency (Hz)

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 15 20 1769

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H01B
B01D
H01F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	20 June 2016	Van den Berg, G

CATEGORY OF CITED DOCUMENTS

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