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(54) Method and device for the speedy drying of a material by application of microwaves.

(57) The invention concerns a method and a device for the speedy drying of a material by the application of microwaves, the material itself possibly being fragile.

The invention concerns a method which consists in the application of microwaves with a quantity of energy enough to bring the temperatures of the surface and/or of the centre of the material up to a determined upper limit which is a function of the nature of the material, in the application thereafter of the microwaves, when the temperature or temperatures fall to a determined lower limit which too is a function of the material, until the temperature or temperatures again reach that upper limit, and in the renewal of the application of the microwaves in the same conditions until the desired degree of humidity is attained.

According to the method of this invention the application of microwaves takes place with waveguide means inclined in relation to the plane of positioning of the material, that is to say, inclined according to the inclination of the Brewster angle.

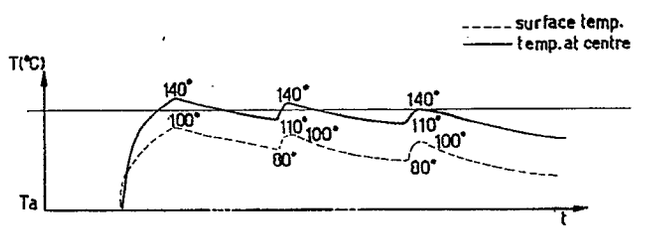

fig.1

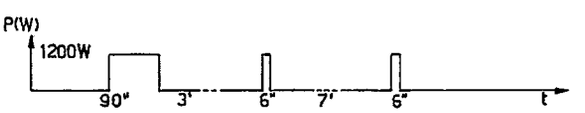

fig.2

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This invention concerns a method and device for the drying of a material of any kind by application of microwaves, advantageously according to the Brewster angle of incidence, as set forth in the main claim.

The material in question may be in the form of semifinished or finished elements having a section of a relatively small thickness, and the microwaves may be of the order of magnitude of the internal wavelength of the material.

The invention can be applied to the field of sterilization of materials for health purposes too.

The invention will be disclosed hereinafter in a particular application specifically for the drying of wood in boards, such as parquet blocks, panelling, joinery elements and articles made by coopers.

It is obvious, however, that the method according to the invention can be applied also to other wooden products having a section of a great thickness.

The invention can be applied to other products too, whether they have a continuous or divided form and are of another kind such as manufactured foodstuffs, agricultural foodstuffs, pharmaceuticals or other materials, ceramics, terracotta, cork, textiles, fabrics, yarns, sanitary and surgical materials, etc. to the extent which their dimensional configuration permits.

The Brewster angle is the name given to the angle of incidence of a wave in relation to a line normal to the surface of a product submitted to the electrical field of the polarized wave, on the basis of which a reflected wave does not exist, that is to say, that angle which has the effect that all the incident power is transmitted substantially into the product.

This angle of incidence varies for one and the same product as a function of its degree of humidity and, in a more general manner, as a function of its permittivity.

The invention is accomplished advantageously with a device to treat products with microwaves, in which device the products are moved in front of a plurality of microwave applicators the axes of symmetry of which are inclined, with various values too, in relation to the trajectory of movement of the products. These values of inclination are a function of the degree of humidity of the products passing each applicator, so that each applicator applies microwaves according to the Brewster angle.

The purpose of the invention is to eliminate the risks of damage resulting from the heat of the products or materials treated and to reduce at the same time the quantity of energy required for the optimum drying of such products or materials.

The method disclosed in FR-C-2.076.405, for instance, entails risks of damage of materials.

Another purpose of the invention is to shorten the drying time as much as possible.

The invention is set forth in the main claim, while the dependent claims describe variants of the idea of the original solution.

The invention provides a method for the speedy drying or sterilization of a material, which may in itself be fragile, by applying microwaves according to the Brewster angle.

The method arranges to apply the microwaves with enough energy to bring the surface temperature and/or the temperature of the core of the material to a given upper limit, which is a function of the nature of the material.

The method arranges also to apply the microwaves again thereafter when the temperature or temperatures fall to a given lower limit, which too is a function of that material. This subsequent further application of the microwaves lasts until the temperature or temperatures reach the upper limit once more.

Successive applications of the microwaves according to the invention are renewed in the same conditions until the required degree of humidity is reached.

Such a method, when applied to the drying of panels or wooden elements intended, for example, for joinery products, enables a quick, efficient drying to be achieved without deformations or loss of quality or of the appearance of the wood and with an appreciable reduction of the consumption of energy as compared to the known techniques of continuous application of microwaves.

The method is preferably, but not only, applied to material in movement; this relative movement is created between the product to be treated and the source or sources of microwaves.

The speed of movement, the gaps between the sources of microwaves or the duration of working of the source or sources are determined in such a way that the surface temperatures and/or core temperatures remain within such upper and lower limits.

According to a variant the sources of microwaves provide various specific microwaves with differentiated wavelengths.

According to another variant the slope of ascent of the applied power or the intensity of the applied power can be varied within a cycle.

Other features and advantages will appear in the following description, which gives as an example, as we said above, a method of performing the method according to the invention in relation to wood.

The description that follows is given only as an example and is connected to the attached drawings, in which:-

Fig.1 gives graphs of the surface and core temperatures of a material undergoing

a microwave treatment according to the invention;

Fig.2 is a diagram of the microwave energies applied to achieve the temperature curves of Fig.1;

Fig.3 is a diagram of a device to carry out the method according to the invention, and

Fig.4 is a graph of the losses of humidity as a function of the time for a sample of oak undergoing the method according to the invention.

Fig.1 shows with a continuous line the curve of evolution, as a function of time, of the temperature substantially at the centre of a piece of wood to be dried, for instance a stump of oak of a rectanglar section with a thickness of 40 mm. during a drying treatment according to the invention, whereby the microwaves are applied according to the incidence of the Brewster angle or at about that angle.

A line of dashes shows the parallel evolution of the surface temperature of the same piece of wood measured, for instance, by means of thermometers that do not interfere with the microwaves, such as infrared thermometers.

The temperature at the centre of the product is brought during the first step of the method from the ambient temperature (Ta) to an upper limit value established as 140 ° C in the case of the example shown.

Fig.2 shows a diagram of the powers of the microwaves applied during the process of drying a piece of wood being moved at a speed of one metre per minute, for instance, below emitters-applicators.

Emitters-applicators of 1200 W of returned power, which emit microwaves with a frequency of 2450 MHz, were employed. The use of this frequency is a good compromise since it corresponds to a wavelength of 12.24 cms. in free air. In fact, this frequency lies in the zone of intersection of the curves of absorption of the electromagnetic waves by the free water and captive water.

This frequency, which is suitable for the drying of boards, panels, flooring and joinery elements is restricted preferably to pieces having a section of the order of 200 x 100 mm, when these pieces are very damp, or a section of greater dimensions when their humidity is decreasing.

According to a variant including a plurality of wave emitters, these emitters emit waves with a frequency differing according to two or more values.

According to the diagram of Fig.2 the first stage of the method consists in applying microwaves to the piece of wood at the power indicated above for 90 seconds; this brings the temperatures at the centre and the surface of the piece from the ambient temperature to the upper limit temperatures of 140 ° C and 100 ° C respectively.

According to a variant which includes a plurality of wave emitters, these emitters emit waves at different powers, for instance progressively increasing or decreasing powers.

When the above upper limit temperatures are reached, the application of microwaves is stopped until these temperatures have fallen again to the minimum established limit values of 110 ° C and 80 ° C respectively. These temperatures are reached at the end of about 3 minutes.

A new application of microwaves lasting for a shorter period of 6 seconds is now carried out. This period is enough to bring the temperatures at the centre and surface up to the upper limits again of 140 ° C and 100 ° C respectively.

Thereafter these temperatures fall to the lower limit values but, to do so, they take a longer time of about 7 minutes owing to the reduction of the degree of humidity.

Figs.1 and 2 show a third application of microwaves for a period of 6 seconds to raise the temperatures again to the upper limit values, after which the piece of wood is not subjected again to microwaves and its temperature returns to the ambient temperature.

The application of microwaves in a sequence stops when the degree of humidity of the piece of wood has fallen to the desired level.

The upper and lower limit values of the temperatures at the centre and at the surface, the applied power of the microwaves and the duration of the various steps of application and of the pauses between the applications depend on differing factors or parameters such as the nature of the material (wood, ceramics, clay, etc.) to be treated, on the configuration and dimensions of the articles or products treated, on the initial humidity and on the required final humidity, etc.

The temperature limit values, in particular the upper limit value, are decided so as to prevent any cracking, breaking, weakening or other faults in the material.

Fig.3 is a diagram of a preferred way of carrying out the method according to the invention, whereby a relative movement is generated between the product to be treated, for instance a board of the panelling and the source of microwaves.

To be more exact, some stationary microwave emitters-applicators 1 operating according to the Brewster angle of incidence are positioned in relation to the trajectory of a product carried on a conveyor element 2, which passes through a horizontal tunnel 3 to which are secured waveguides 4 of the emitters-applicators 1.

The horizontal tunnel 3 may include screen means to prevent diffusion of the microwaves.

The number of the emitters-applicators 1 and the gap between two successive emitters-applicators 1 will, or may, vary according to the applications.

Although in Fig.3 the axes of the waveguides 4 are arranged, as an example, at the same angle to the axis of the tunnel 3, it is clear that this angle can be varied according to the invention.

This angle can be adjusted advantageously, even for each emitter-applicator 1, especially in view of the application of the waves of each waveguide according to the Brewster angle of incidence or approximately according to that angle of incidence.

The emitters-applicators 1 may have equal powers or may have different powers.

In particular, the first emitter-applicator encountered by the product entering the tunnel 3 may possess adantageously a greater power so as to take into account the degree of humidity and the initial temperatures of the wood.

It should be borne in mind that according to the invention the times of exposure of the pieces to be dried by means of the microwaves of each emitter-applicator are directly linked to the speed of the conveyor.

With such a device it is unnecessary to measure the temperatures of the product to be treated.

Preliminary trials, during which the temperatures are measured, enable the speed of the conveyor, the limit temperature values and the optimum drying cycle to be defined for each product and for each initial humidity of the product.

In a preliminary step in an industrial drying plant the parameters such as the number of emitters-applicators 1 of microwaves, the adjustment of the gaps therebetween and of their power and possibly of their frequency and of the inclination of their waveguides 4 and also the speed of the conveyor belt 2 are determined and controlled by making the material move inside the tunnel 3.

Thereafter, as these parameters have been defined and adjusted, it is not necessary to take any further corrective action except for checking and verification.

In this way the speed of movement of the product to be dried is constant and determines the stay time of the successive parts of the product to be dried, which runs beneath the various waveguides 4.

With identical materials and with identical adjustments of the waveguides the stay time of the material to be dried/sterilized will be identical.

As we said before, at the level of the first microwave emitter-applicator or of any successive one it is possible to apply a power greater than that of the other emitters-applicators, by increasing in this case the power of that particular emitter-applicator.

Fig.4 shows the application of the method according to the invention in a case where a piece of oak having a cross section of 80 mm. x 40 mm. is dried while positioned below an applicator fed by an emitter-applicator having a constant returned power (1200 W).

The abscissa gives the time in minutes, while the ordinate shows the percentage of humidity provided by the formula:

$$H\% + 100\ (m - m_{bs})/m_{bs}$$

where "m" is the mass of the treated product at the instant "t", while "m_{bs}" is the dry basic mass of the product after full extraction of the water.

The emitter-applicator and the piece of wood are stationary and action is taken by sending impulses of microwaves for variable periods separated by inactive intervals of the type shown in Fig.2. The microwave impulses are represented by vertical segments grouped in packets.

The first packet 5 corresponds to the first application of microwaves and its duration is greater than that of the other applications (6 to 15), which all last for the same time.

In the diagram of Fig.4 one segment represents an impulse lasting for 6 seconds.

The packets of impulses from 5 to 15 are separated by variable intervals of time.

The measurement, every two and a half minutes, of the degree of humidity has made possible the drawing of the curve of reduction of the degree of humidity of the sample tested.

The stopping of the first application of microwaves (5) and the starting and stopping of the subsequent applications (6 to 15) defined during measurements of the definition of the tunnel are controlled by measurements of the temperature on the surface of the sample, as shown in Fig. 1.

The sample is deemed to be dry enough at the end of 30 minutes, during which the duration of the application of the microwaves was only 3 minutes, 32 seconds.

The method is therefore economical and enables a homogeneous drying to be achieved to the desired degree together with an internal chemical conversion without any alteration, in particular without any cracking, of the faces of the product treated.

The industrial drying device according to the invention may require microwave emitters-applicators located on the two opposite faces of the product to be treated. This application is especially advantageous when the product is thick or very damp.

Together with the treatment according to the invention there can be combined a drying treat-

ment by a forced draught of hot air or just plain hot air, of which the whole or part may be the air to cool the magnetrons, before application of the microwaves and/or between two applications of microwaves.

The microwaves can be applied to the faces of the smaller sides of the product so as to increase the inner field by reduction of the field of depolarization.

The water removed in the form of a liquid at the inlet of the tunnel should be eliminated gradually by blowing, aspiration or scraping to prevent its presence leading to the dissipation of energy.

The relative movement as between the product and the emitters-applicators can be obtained by displacing the emitters-applicators while the product remains stationary.

In certain applications one single stationary emitter-applicator may be provided, while the products are positioned immovably under the waveguide, the period of the various applications being adjusted as shown in Fig.2.

Lastly, the invention is obviously not restricted to the methods of performance described above but covers all the variants, especially as regards the power of the applicators, the microwave frequency used, the forms and dimensions of the waveguides and of the irradiation windows and their position on any of the surfaces of the tunnel.

It is equally possible to provide two or three consecutive tunnels, for instance, one for intense humidity (greater than 45% for example) and the others for lesser humidity so as to have for each of them mean values of the Brewster angles as close as possible to the theoretical values without having to use adjustable-incidence emitters-applicators.

The other two equally available parameters are the power of the generators and the speed of movement, which can be governed by continuous measurement of the humidity and can therefore be continuously controlled and adjusted by means of known control and actuator instruments.

The products can be carried on a conveyor belt or a mesh preferably not made of a polar material or can be kept under pressure between rolls protruding within the tunnel.

The keeping of the products under pressure should be continued, especially on wooden products, after their emergence from the tunnel for enough time to prevent deformations.

On the contrary, if it is desired to create in the moving material a curvature for applications such as seats, joinery products or cooper's articles, the product can be bent during the drying or be curved beforehand; for instance, a curved tunnel can be employed in which the wood will be retained on the edge and at the exit.

If it is desired to economise in ground space, it is equally possible to arrange a spiral tunnel that climbs vertically.

Claims

1. Method for the speedy drying of a material by the application of microwaves, the material itself possibly being fragile, the method being characterized in that it consists in the application of microwaves with a quantity of energy enough to bring the temperatures of the surface and/or centre of the material to an upper limit determined as a function of the nature of the material, in the application thereafter of microwaves, when the temperature or temperatures fall and reach a lower limit determined also as a function of the material, until the temperature or temperatures again reach the above upper limit and in renewing the application of microwaves, also in the same conditions, until the required degree of humidity is attained.

2. Method as claimed in Claim 1, in which the microwaves are applied at least partly according to the Brewster angle of incidence.

3. Method as claimed in Claim 1 or 2, in which the various applications of microwaves are effected at a constant power but with variable durations, the material to be treated being positioned immovably below the microwave emitter-applicator.

4. Method as claimed in Claim 1 or 2, in which the various applications of microwaves are effected with a variable power, the material to be treated being positioned immovably below the microwave emitter-applicator.

5. Method as claimed in Claim 1 or 2, in which the material to be treated is moved at a constant speed through a series of microwave emitters-applicators, the gaps between which can be adjusted.

6. Method as claimed in Claim 1 or 2, in which the material to be treated is moved at a variable speed through a series of microwave emitters-applicators, the gaps between which can be adjusted.

7. Method as claimed in Claim 5 or 6, in which at least one microwave emitter-applicator generates a power substantially different from that of the other emitters-applicators.

8. Method as claimed in any claim hereinbefore,

in which the frequency of the emitters-applicators is the same for all of them.

9. Method as claimed in any of Claims 1 to 7 inclusive, in which at least one emitter-applicator emits a different frequency.

10. Method as claimed in any claim hereinbefore, in which the angle of the axis of the waveguides of the microwave emitters-applicators can be adjusted so as to have each microwave emitter-applicator arranged at least approximately according to the Brewster angle of incidence.

11. Method as claimed in any claim hereinbefore, in which the material to be treated is lapped with hot drying air at least between two microwave applications.

12. Device to carry out the method according to any of Claims 5 to 11 inclusive, characterized in that it comprises a tunnel (3) through which there can pass a system (2) to convey material to be treated, the tunnel (3) being equipped with at least one series of microwave emitters-applicators (1), of which waveguides (4) protrude within the tunnel (3) according to an angle of incidence of the microwaves in relation to the irradiated surface of the material, such angle being unchanging in relation to the irradiated surface of the material.

13. Device to carry out the method according to any of Claims 5 to 11 inclusive, which comprises a tunnel (3) through which there can pass a system (2) to convey material to be treated, the tunnel (3) being equipped with at least one series of microwave emitters-applicators (1), of which waveguides (4) protrude within the tunnel (3) according to an adjustable angle of incidence of the microwaves in relation to the irradiated surface of the material so as to position that angle at about the theoretical values of the Brewster angles.

14. Device as claimed in Claim 12 or 13, which comprises two series of microwave emitters-applicators, the waveguides of which are oriented towards two opposite faces of the material to be treated.

15. Device as claimed in any of Claims 12 to 14 inclusive, in which the conveyor system is structured in such a way as to keep the products under pressure while being conveyed so as to prevent any deformation during the drying process and also during a sufficient time after emerging from the tunnel (3).

16. Device as claimed in any of Claims 12 to 15 inclusive, in which the tunnel (3) and the conveyor system are structured in a spiral form so as to produce curved products and, in particular, curved wooden pieces.

17. Device as claimed in any of Claims 12 to 16 inclusive, which comprises means to displace at a constant speed the material to be treated.

18. Device as claimed in any of Claims 12 to 16 inclusive, which comprises means to displace at a variable speed the material to be treated.

19. Device as claimed in any of Claims 12 to 18 inclusive, which comprises means to adjust the power emitted by at least one emitter-applicator.

20. Device as claimed in any of Claims 12 to 18 inclusive, which comprises means to adjust the frequency emitted by at least one emitter-applicator.

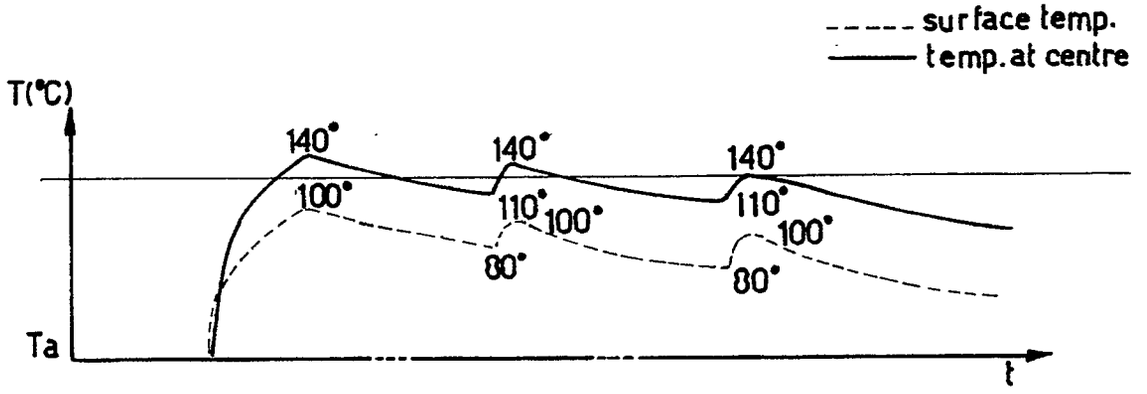


fig.1

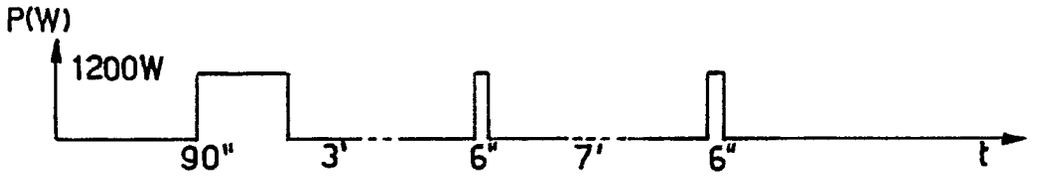


fig.2

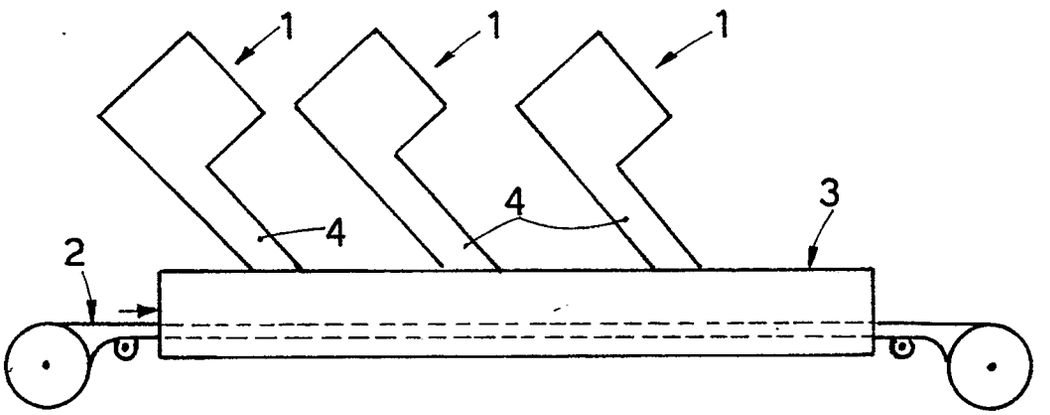
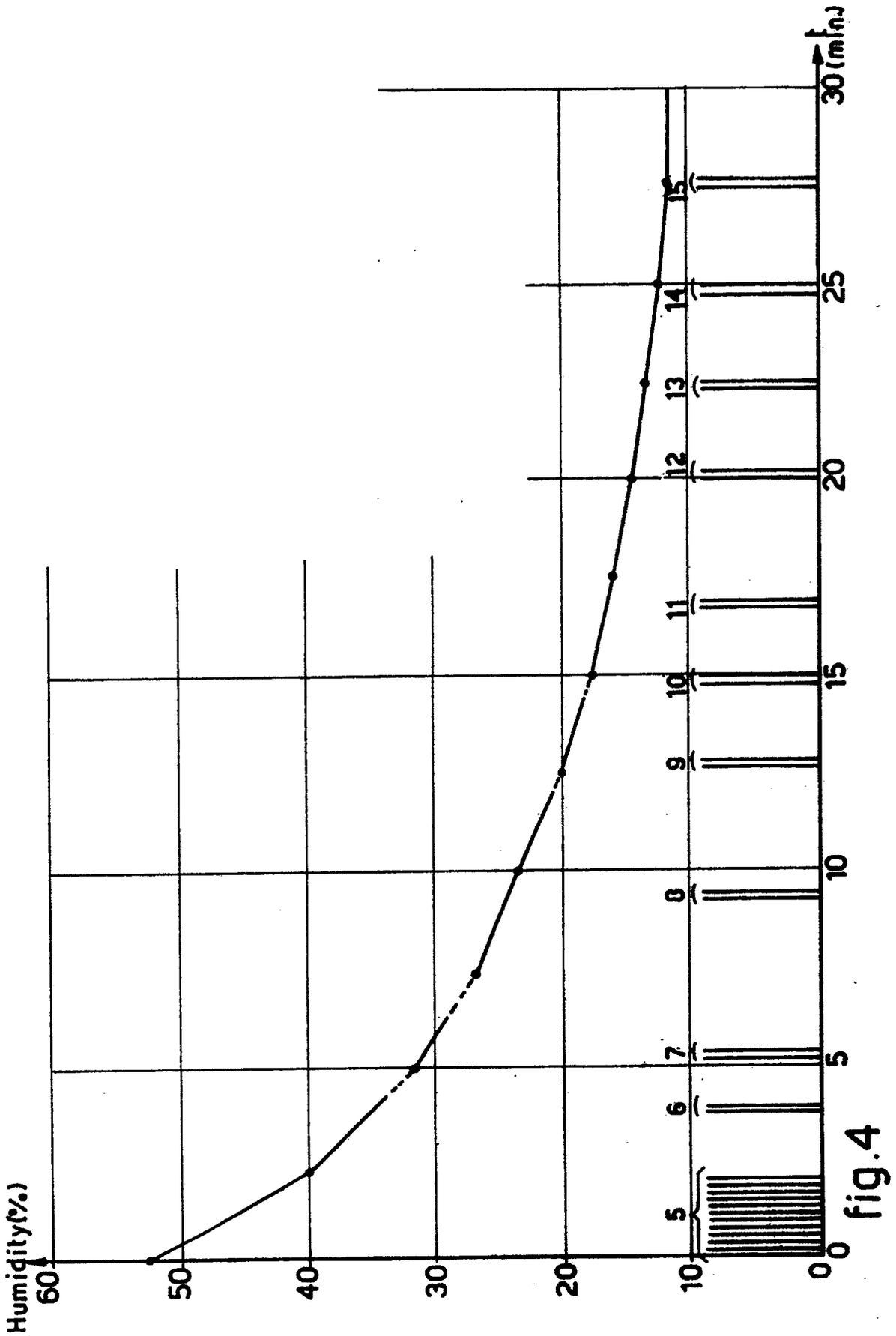


fig.3


Humidity(%)
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50
40
30
20
10
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5
6
7
8
9
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11
12
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14
15
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fig.4

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EUROPEAN SEARCH REPORT

Application Number

EP 91 10 7727

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
D,X,D,A	FR-A-2 076 405 (LE MATERIEL TELEPHONIQUE) * the whole document *	1,3,4,11, 7,12,13, 18,19	F 26 B 3/347
P,A	FR-A-2 651 874 (CHARPENTE MENUISERIE CHASSENEUILLAISE-C.M.C.) * the whole document *	1,2,4,5, 10-13,15, 17,19	
A	FR-A-2 147 456 (LE MATERIEL TELEPHONIQUE) * the whole document *	1,3,7	
A	DE-C-8 397 73 (SIEMENS-SCHUCKERTWERKE AG) * the whole document *	1,3	
A	DE-C-7 378 20 (SIEMENS-SCHUCKERTWERKE AG) * the whole document *	1,3	
A	US-A-3 277 580 (TOOBY) * the whole document *	1,5-7, 11-13, 17-19	
A	DE-A-2 431 522 (KLÖCKNER-HUMBOLDT-DEUTZ AG) * the whole document *	1,5,7, 11-13,17	TECHNICAL FIELDS SEARCHED (Int. Cl.5) F 26 B
A	FR-A-2 077 953 (PLESS) * the whole document *	1,5,12,13, 15	
A	US-A-4 714 812 (HAAGENSEN ET AL) * the whole document *	7-9,19,20	
A	FR-A-1 499 628 (PATELHOLD) * the whole document *	12-14	

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The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
The Hague	22 August 91	SILVIS H.

CATEGORY OF CITED DOCUMENTS

X: particularly relevant if taken alone
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D: document cited in the application
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A	DE-A-3 106 304 (TRÖBS) * the whole document *	12,13,15, 16,20	
A	GB-A-8 990 44 (STUBBER)		
A	US-A-3 721 013 (MILLER)		
A	FR-A-8 209 08 (SIEMENS-SCHUCKERTWERKE AG)		
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)

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