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(71) Applicants:
- **Gómez Herrera, Ángel Manuel**
39100 Santander (ES)
- **Compostizo Olarte, Pedro Luis**
39010 Santander (ES)

(72) Inventors:
- **Gómez Herrera, Ángel Manuel**
39100 Santander (ES)
- **Compostizo Olarte, Pedro Luis**
39010 Santander (ES)

(74) Representative: **Balder IP Law, S.L.**
Paseo de la Castellana 93
5ª planta
28046 Madrid (ES)

(54) **METHOD OF MANUFACTURING A DECORATED SOUND ABSORBING PANEL AND DECORATED SOUND ABSORBING PANEL**

(57) A method of manufacturing a decorated sound absorbing panel, comprising: providing a sound absorbing panel (2) to a digital printer (1); applying a printing on the sound absorbing panel (2) by means of the digital printer (1), wherein applying said printing comprises applying an amount of ink per square metre of sound absorbing panel (2), said amount being selected such that it causes no variation in the acoustic properties of the decorated sound absorbing panel with respect to the acoustic properties time of the sound abosrobing panel (2) with no ink applied thereto. A decorated sound absorbing panel comprising a sound absorbing panel (2) having a printing applied thereto by means of a digital printer (1), wherein said printing comprises an amount of ink that causes no variation in the acoustic properties of the decorated sound absorbing panel with respect to the acoustic properties of the sound abosrobing panel (2) with no ink applied thereto.

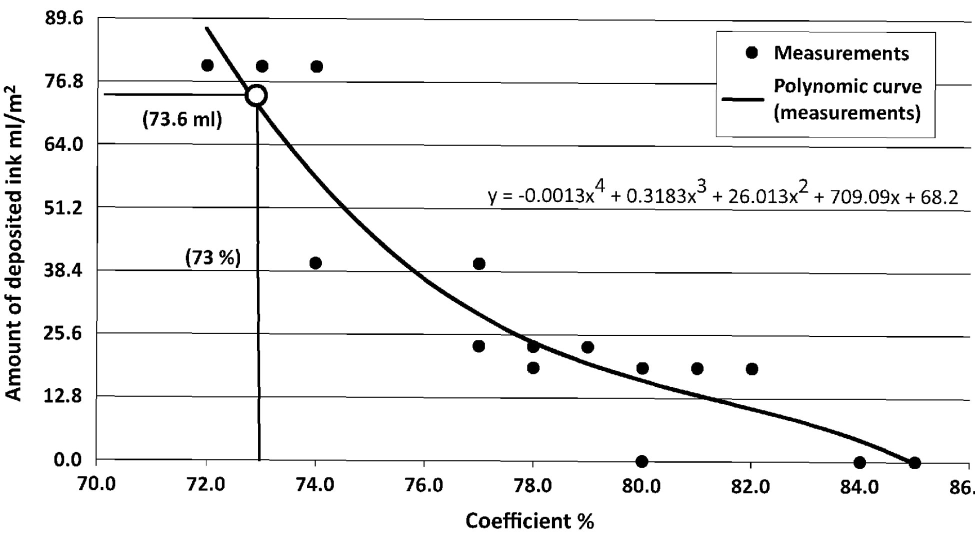

FIG. 4

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Description

TECHNICAL FIELD

[0001] The present invention relates to the field of acoustic isolation of indoor built structures, such as walls or ceilings. In particular, it relates to methods of decorating sound absorbing panels in order to provide good sound isolation properties while providing an aesthetic appearance of high quality.

STATE OF THE ART

[0002] Enclosed areas or indoor facilities, such as hospitals, schools, office facilities, libraries, museums, restaurants, shopping centers and so many others, need to reduce the increased level of noise, that is to say, the level of unwanted sound.

[0003] Sound waves striking an arbitrary surface are either reflected, transmitted or absorbed; the amount of energy going into reflection, transmission or absorption depends on acoustic properties of the surface. The expression "sound absorbing" indicates the capability of a material to absorb sound energy. A material is defined as sound absorbing when it allows for converting a good amount of the sound energy that crosses the material into energy. Sound energy is dissipated by simultaneous actions of viscous and thermal mechanisms. Sound absorbers are used to dissipate sound energy and to minimize its reflection. In other words, the function of sound absorbing materials is to reduce reverberation inside adjoining zones. Sound absorbing materials are capable of dissipating part of the sound energy in their interstices. In closed spaces, especially when the walls are made of smooth compact materials (also referred to as reflecting materials), substantially the total noise that is perceived is determined by the reflection of the sound waves by the walls that define the closed space. For this reason, a sound absorbing material must prevent reflection and impede the propagation of sound waves. In other words, a sound absorbing material must reflect the sound energy incident on the material as least as possible in order to reduce reverberation.

[0004] The absorption coefficient α is a common quantity used for measuring the sound absorption of a material and is known to be the function of the frequency of the incident wave. It is defined as the ratio of energy absorbed by a material to the energy incident upon its surface.The absorption coefficient of materials varies from 0 to 1. The sound absorption coefficient of a material can be measured by several well-known standard methods. The coefficient of commercial absorbing materials can be specified in terms of different indicators, such as the noise reduction coefficient (NRC), which refers to the average of absorption coefficients at 250 Hz, 500 Hz, 1,000 Hz and 2,000 Hz.

[0005] Sound absorbing materials are usually porous or fibrous materials. Porosity or void fraction is a measure of the void spaces (empty spaces) in a material, and is a fraction of the volume of voids over the total volume, between 0 and 1. In fact, porous materials, such as open cell foam - i.e. melamine or polyurethane - or fibrous materials, such as wood fibers, rock or glass wool, polyester fibers, heavy fabrics and felts, have a relatively high sound absorption coefficient. As a matter of example, a sheet of 100 mm mineral wool has a sound absorption coefficient of 0.65, which is considered relatively high. On the contrary, hard compact materials with a high specific weight, such as marble, ceramic, glass, cement and the like, have a relatively very low sound absorption coefficient and are therefore highly reflecting.

[0006] There exist different kinds of known sound absorbing products, for example in the form of interior space dividers and panels to be put in the ceiling, wall or floor during construction. These panels may for example be constructed by wood, paper board, metal, felt material and/or bonding materials. After construction of a building, there are also acoustic panels that may be installed on the ceiling or walls to absorb the sound.

[0007] In many environments, such as museums, restaurants or shopping centers, in addition to the need of providing sound isolation, there is also a need to provide an aesthetic appearance in the walls, ceilings and the like. A sound-absorbing panel with certain aesthetic appearance is disclosed in US8739927-B2, which refers to a gypsum panel having sound-absorbing properties in which a sound-absorbing cover layer having invisible micro through-holes is attached to a gypsum body having holes, thereby imparting aesthetically pleasing appearances. In turn, EP2819808-B1 discloses a method for manufacturing an acoustic absorbent panel from a sheet of glass, in which a plurality of through-slots is formed. Prior to making these through-slots, the sheet of glass can be decorated with ink, paint or varnish.

[0008] There are some commercial products that try to combine these two aspects: sound absorption and aesthetical appearance. As a matter of example, company Saint-Gobain provides (see website www.ecophon.com, last access dated 04-03-2019),a system composed of a panel called EcophonAkusto™ One SQ, made of high density glass wool as sound absorbing element, sandwiched between an outer surface made of a glass fiber tissue and by a back surface of glass tissue. The tissue of the outer surface (Akutex™ FT) can be painted, thus improving the appearance of the panel system. However, the three elements forming the panel system make this product complex. In particular, mounting the tissue on the high density glass wool makes the installation process inefficient in terms of cost. Besides, the thickness of the panel system makes its installation difficult in small facilities. What is more, the tissue mounted on the high density glass wool reduces the acoustic properties of the product.

[0009] EP2536569-B1 discloses a production installation and a method for printing surfaces of material panels, especially wooden panels. In turn, EP3109041-A1 discloses a nonwoven wall panel with noise absorption properties. The panel is made of polyester fibers. The fabric is printable using sublistatic or transfer printing process, in which the inks or dyes are printed on a release paper and then the paper and the fabric are placed in a heated press and, upon application of heat, the inks or dyes turn to gas and penegrate into the PET fibers. The fabrics could also be printed using conventional roller or screen printing methods with inks or dyes. One of the drawbacks these techniques is that printings suffer from color changes and it is practically impossible to perform repetitions of identical colorimetry because the amount of ink or dye deposited on the fabric cannot be controlled. In turn, they require long processes for machinery preparation, as a consequence of which only large amounts of printings make these methods profitable. Besides, screen printing requires negatives per each color.

DESCRIPTION OF THE INVENTION

[0010] The method and product described in the present invention intend to solve the shortcomings of prior-art methods and products.

[0011] The invention provides a method of manufacturing a decorated sound absorbing panel using a digital printing machine or digital printer, with which a printing is applied on a surface or side of the panel.

[0012] In the context of the present disclosure, a material is considered to have good sound absorbing properties when its characteristic porosity is equal to or higher than 0.50, such as higher than 0.60, or higher than 0.70, or higher than 0.80 or higher than 0.90, or higher than 0.95. The characteristic porosity of a material is usually associated to the absorbing coefficient, in such a way that the higher characteristic porosity a material has, the higher is its absorbing coefficient.

[0013] Such materials are typically porous or fibrous materials, such as open cell foam - i.e. melamine or polyurethane - or fibrous materials, such as wood fibers, rock or glass wool, polyester fibers, heavy fabrics and felts.

[0014] The inventors have observed that, when ink or dye is applied to a porous or fibrous material having sound absorbing properties, the ink or dye does not stay superficially on the material, but it penetrates and fills the porous. When the amount of ink exceeds a certain amount thereof, the sound absorbing properties of the material are reduced or even lost. For example, the sound absorption coefficient is reduced.

[0015] In order to overcome this problem, the digital printing machine is commanded/programmed to inject an amount of ink required to guarantee a high-quality definition of the images to be printed while maintaining the sound absorbing properties of the panel without ink.

[0016] A first aspect of the invention relates to a method of manufacturing a decorated sound absorbing panel, comprising: providing a sound absorbing panel to a digital printer; and applying a printing on the sound absorbing panel by means of the digital printer, wherein applying said printing comprises applying an amount of ink per square metre of sound absorbing panel such that the acoustic properties of the panel are maintained while guaranteeing a high-quality definition of the printed images, either in color or in black and white.The amount of ink is selected such that it causes no variation in the acoustic properties (i.e. reverberation time) of the decorated sound absorbing panel with respect to the acoustic properties of the sound absorobing panel with no ink applied thereto.

[0017] In embodiments of the invention, in order to apply the printing the sound absorbing panel is fixed to a printing table and the stage of applying a printing comprises moving a cartridge carrying printing heads at least along the X and Y axes while the sound absorbing panel remains fixed.

[0018] In embodiments of the invention, the surface of the sound absorbing panel opposite to the surface on which the ink is to be applied comprises an adhesive. The adhesive facilitates the attachment of the decorated sound absorbing panel to the wall, ceiling or other surface on which it is going to be installed. Alternatively, attachement means different from an adhesive may be used instead.

[0019] In embodiments of the invention, the printing applied on the sound absorbing panel is cured by means of UV radiation applied by drying lamps comprised in the digital printer.

[0020] In embodiments of the invention, the method further comprises providing instructions to the digital printer through a man-machine interface, said instructions comprising the amount of ink to be applied.

[0021] In embodiments of the invention, the thickness of the sound absorbing panel is equal or larger than 30 mm, such as larger than 40 mm or larger than 50 mm or larger than 60 mm. At thickness lower than 30 mm the absorption coefficient may be too low.

[0022] The amount of ink to be applied per square metre of sound absorbing panel does not depend on the thickness of the sound absorbing panel. The amount of ink is selected such that it does not compact the surface of the panel, so that the sound can penetrate and therefore the absorption coefficient is maintained.

[0023] In embodiments of the invention, the sound absorbing panel is made of a melamine resin foam.

[0024] In embodiments of the invention, the amount of ink to be applied per square metre of sound absorbing panel does not exceed 76 ml/m^2. For example, it varies between 10 and 76 ml/m^2 of sound absorbing panel, such as between

10 and 76 ml/m^2, or between 20 and 76 ml/m^2, or between 30 and 76 ml/m^2, or between 40 and 76 ml/m^2, or between 50 and 76 ml/m^2, or between 50 and 76 ml/m^2 thereof.

[0025] In embodiments of the invention, the amount of ink to be deposited has an effect on the sound absorption coefficient of the panel, said effect being adjusted to a fourth degree polynomial curve. More particularly, said effect is formulated as follows:

$$y = -0.0013 x^4 + 0.3183 x^3 - 26.013 x^2 + 709.09 x + 68.2$$

wherein x represents the absorption coefficient of the material, 0 < x < 1, and y is the amount of ink to be applied to the panel made of such material, in ml per squeare metre.

[0026] The sound absorption coefficient of a material is usually specified by the manufacturer or provider. It can also be measured by applying standard measuring methods.

[0027] The amount of ink necessary to digitally print an image on a sound absorbing panel while guaranteeing the maintenance of the acoustic properties (i.e. reverberation time or sound absorbing coefficient) of the panel, can be estimated according to the following method. The method comprises: applying different amounts of ink to a plurality of identical sound absorbing panels having certain absorption coefficient. A different amount of ink is applied to each panel. This is preferably done by means of a digital printer. A first panel is disposed at a certain position in a reverberant chamber. Then, at different positions within the chamber, the reverberation time is measured at different frequencies (i.e. 500 Hz, 1000 Hz and 2000 Hz). From the measured reverberation times, the sound absorbing coefficient at each frequency is calculated. The first panel is removed from the chamber. A second panel is disposed at the same position (as the one on which the first panel had been placed) in the reverberant chamber. Then, at the same different positions within the chamber, the reverberation time is measured at the same different frequencies. From the measured reverberation times, the sound absorbing coefficient at each frequency is calculated. This is repeated for all the panels of the plurality of panels, each of which having a different amount of ink. All the panels are disposed on the same position within the reverberant chamber. For each panel, the different measurements of reverberation time are taken at the same different positions within the chamber. From the different measured reververation times, the absorption coefficient of the material of which the panels (having no ink or a certain amount of ink) are made, can be obtained. The absorption coefficient varies depending on the amount of ink applied on the panel. This is because depending on the amount of ink applied, the sound absorbing coefficient may be reduced. Next, it is selected as maximum amount of ink to be applied, an amount of ink that causes no variation in the determination of the reverberation time with respect to a panel with no printing.

[0028] The absorption coefficient also varies with the frequenct. It is observed that the most critical frequency in terms of sound absorbind coefficient is 500 Hz. In embodiments of the invention, the selected values of measured absorption coefficients correspond to the frequency with worst values of absorption coefficients. In one embodiment, this frequency is 500 Hz.

[0029] In embodiments of the invention, the amount of applied ink is correlated -or compared- with the sound absorption coefficients obtained at different tested positions in the panels, thus determining a curve of maximum amounts of ink with respect to sound absorption coefficients.

[0030] A second aspect of the invention relates to a decorated sound absorbing panel obtainable by applying the method of manufacturing a decorated sound absorbing panel as already disclosed. The obtainable decorated panel maintains the acoustic properties (i.e. reverberation time or sound absorption coefficient) of the panel prior to being decorated, while presenting a decoration (image, picture, etc.) of high quality (i.e. resolution). The decorated sound absorbing panel is preferably made of a melamine resin foam. The amount of ink applied thereto preferably does not exceed 76 ml/m^2 of sound absorbing panel.

[0031] A third aspect of the invention relates to a decorated sound absorbing panel comprising a sound absorbing panel having a printing applied thereto by means of a digital printer, wherein said printing comprises an amount of ink that causes no variation in the acoustic properties (i.e. reverberation time) of the decorated sound absorbing panel with respect to the acoustic properties of the sound absorbing panel with no ink applied thereto.

[0032] In embodiments of the invention the sound absorbing panel is made of melamine resin foam.

[0033] In embodiments of the invention, the sound absorbing panel has a minimum thickness of 30 mm.

[0034] In embodiments of the invention the amout of ink does no exceed 76 ml/m^2.

[0035] In embodiments of the invention the characteristic porosity of the material of which the sound absorbing panel is made, is equal to or higher than 0.50, such as higher than 0.60, or higher than 0.70, or higher than 0.80 or higher than 0.90 or higher than 0.95.

[0036] Besides, by optimizing the amount of ink to be used in the digital printing, ink waste is prevented, thus contributing to preserve the environment.

[0037] Additional advantages and features of the invention will become apparent from the detail description that follows and will be particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0038] To complete the description and in order to provide for a better understanding of the invention, a set of drawings is provided. Said drawings form an integral part of the description and illustrate an embodiment of the invention, which should not be interpreted as restricting the scope of the invention, but just as an example of how the invention can be carried out. The drawings comprise the following figures:

Figure 1 shows an exemplary digital printer for printing an image on a sound absorbing panel according to embodiments of the invention.

Figure 2 schematically shows the multi-pass printing system or technique used for printing the sound absorbing panels of the present invention. In figure 2, the printing heads have been inverted in order to better show the different pairs of ink jets they can deliver.

Figure 3 shows the variation of the sound absorption coefficient of 5 panels made of melamine resin foam, with respect to the amount of ink (ml/m^2) deposited on each panel, measured at 4 different positions in a reverberant chamber.

Figure 4 shows the variation of the sound absorption coefficient (x axis) as a function of the amount of applied ink (y axis), at a frequency of 500 Hz.

Figures 5a and 5b show examples of sound absorbing panels decorated following the method described in the present invention.

DESCRIPTION OF A WAY OF CARRYING OUT THE INVENTION

[0039] Figure 1 illustrates a digital printer 1 that can be used in the manufacturing of a decorated sound absorbing panel 2 in accordance with an embodiment of the present invention. A picture, such as a color picture or black&white picture, or image in general, is printed on the panel 2, for example using a multi-pass printing system or technique, illustrated in Figure 2. Multi-pass printing produces a completed copy or printing in several, for example in three, passes. Other techniques employing more than three passes may be used as well. However, unlike conventional printing techniques, in which typically a flexible support, such as paper, on which ink is to be deposited by digital printing, travels along a belt or conveyor belt synchronized with the ink heads of the printer, in the present disclosure the panel 2 is fixed to the printing table 11 (also referred to as printing bed). For example, the panel 2 remains fixed on the printing bed 11 by means of a system comprising vacuum pumps (not shown in figure 2) disposed at different locations through the printing bed 11. This enables fixing light materials with high efficiency. During printing, the carriage carrying all the printing heads 12 moves along the X and Y axes. It may also move along the Z axes (height) in order to set the correct height from which the panel 2 will be printed. Figure 2 shows in detail the printing heads 12, which have been inverted with the sole purpose of showing them in detail. Although the colors are not appreciated in figure 2, the first pair of heads delivers two jets of black ink 12A, the second pair of heads delivers two jets of blue ink 12B, the third one delivers two jets of pink ink 12C, the fourth one delivers two jets of yellow ink 12D, the fifth one delivers two jets of green ink 12E, the sixth one delivers two jets of red ink 12F, the seventh one delivers two jets of purple ink 12G, the eighth one delivers two jets of grey ink 12H and the last one delivers two jets of white ink 121. In figure 1, drying lamps 13 are also shown. Drying lamps 13 dry the printing while after it has been applied on the panel 2. The drying lamps 13 may be, for example, UV drying lamps.

[0040] The digital printing machine 1 is commanded or programmed to inject through its ink heads 12 an amount of ink required to guarantee a high-quality definition of the images to be printed while maintaining the acoustic properties (i.e. reverberation time or sound absorption coefficient) of the panel 2. In embodiments of the invention, the amount of ink per square metre of panel 2 is selected such that the decorated panel 2 maintains the acoustuc properties of the panel 2 without printing, that is to say, the properties of the sound absorbing material of which the panel 2 is made. This is controlled by computing means 14. Computing means 14 may be, for example, a processor or a computer processing unit (CPU). The image or flat color to be printed on the digital printing machine 1 is pre-processed by a conventional specific software, known as RIP, which manages the amount of ink and how it will be distributed on the image (in general, on the panel 2 to form the image). In addition to this specific software, the digital printing machine 1 has its own software, which opens what the RIP software has pre-processed and sends it for printing. This software comprised in the digital printing machine 1 has several settings that can be adjusted, such as the number of passes, the drying power of the drying lamps 13, the percentage of ink to be applied per square metre of panel 2, etc. The settings may be customized, for example, through a man-machine interface, such as a keyboard or a tactile screen. For example, in the present invention, the number of passes is preferably adjusted to be 3, because the inventors have observed that the material of which the panel 2 is made, absorbs a lot of ink, as a consequence of which with only 2 passes the printing is too faint.

[0041] The sound absorbing panel 2 is maded of a material whose characteristic porosity is equal to or higher than 0.50, such as higher than 0.60, or higher than 0.70, or higher than 0.80 or higher than 0.90 or higher than 0.95. Non-limiting examples of such materials are wood fibers, rock wool (also referred to as mineral wool), glass wool, kenaf fibers, polyester fibers, felts, and open cell foams, such as melamine resin foam or polyurethane foam.

[0042] In a preferred embodiment, the sound absorbing panel 2 is made of melamine resin foam. Melamine foam is a foam-like material based on a formaldehyde-melamine-sodium bisulfite copolymer. The foam is manufactured by several manufacturers worldwide, for example by Germany-based BASF under the name Basotect®, which is an open cell foam based on melamine resin.

[0043] The sound absorbing panel 2 can be purchased in rolls, in order to make customized panels according to the user requirements or finished products, in the form of panels with predefined regular dimensions. Typically, the sound absorption of a porous material is very high for medium-high frequency waves. In order to achieve good absorption of low-frequency sound waves, the panel 2 must have certain thickness. In other words, the sound absorbing panel 2 for indoor use must have a good thickness-efficacy ratio in order to minimize the amount of material used, while guaranteeing good sound absorption. The sound absorbing panel 2 may adopt any shape, such as squared, rectangular, triangular, oval, round, or ay other irregular shape. The thickness of the panel 2 is preferably larger than 30 mm, -because with thickness lower than 30 mm the absorption coefficient may be too low-, such as larger than 40 mm or larger than 50 mm or larger than 60 mm. In a particular embodiment, the panel 2 is rectangular. Its shape can be customized once the panel 2 has been decorated with the digital printing.

[0044] The surface of the sound absorbing panel opposite to the surface on which the ink is to be applied may comprise an adhesive. The adhesive facilitates the attachment of the sound absorbing panel, once decorated, to the wall, ceiling or other surface on which it is going to be installed. Alternatively, attachement means different from an adhesive may be used instead.

[0045] Regarding the digital printer 1, as a matter of example, in a non-limiting way, the digital printer Nyala 2, provided by company swissQprint, may be used. Nyala 2 provides high performance, such as size of ink drop varying between 9 - 42 pl (picoliters, 10^{-12} liters), addressable resolution varying between 360 - 1080 dpi and visual resolution up to 2160 dpi. Its ink technology is piezoelectric inkjet technology (DOD). It provides output software on integraged PC and fast Ethernet 1000Base-T interface. Regarding ink, it provides integrated ink supply, white feed and maintenance system, low-odeur UV-curable inks and solvent-free. Its production speed varies between 28 - 180 m^2/h (square meters per hour), depending on the required application and therefore quality.

[0046] Once the panel 2 has been printed with the digital printer 1, or while the panel 2 is being printed with the digital printer 1, the printing applied on the sound absorbing panel 2 may be cured by means of UV radiation, applied for example by drying lamps 13.

[0047] Inventors have observed that when ink is applied to a panel made of a porous or fibrous material, such as a panel made of melamine resin foam, applying ink in the amounts typically recommended by the digital printers when printing on other materials, such as paper, the ink does not stay superficially on the material, but it penetrates and fills the porous. In particular, it has been observed that when ink is applied to a panel made of a porous or fibrous material, a percentage of ink varying between 30 and 50% penetrates within the material, for example within its pores, with respect to the total amount of applied ink. More particularly, the percentage of ink penetrating within the material may vary between 35 and 45%. In a particular example, this percentage is 40%. As a consequence of this, the quality of the printing is reduced, since the amount of ink remaining on the surface of the panel made of a porous or fibrous material varies between 50 and 70% with respect to the total amount of applied ink, such as between 55 and 65%, for example 60%. As a consequence, it has been observed that when ink is applied to a panel made of a porous or fibrous material, an increased amount of ink must be applied, with respect to the amount applicable to a panel made of non-porous material.

[0048] However, it has been observed that, when the amount of ink exceeds a certain amount thereof, the acoustic properties (i.e. reverberation time or sound absorption coefficient) of the panel are dramatically reduced because its sound absorbing capacity is blocked.

[0049] This problem is solved by the method of manufacturing a decorated sound absorbing panel of the present disclosure, in which, by calculating the maximum amount of ink that can be applied on the sound absorbing panel during digitally printing such that the acoustic properties of the material are preserved, the sound absorbing properties of the panel are guaranteed on the one hand, while maintaining the required quality of the printing, for example in terms of visual resolution, on the other hand. In applications in which the quality of the printing should not be impaired at all, or in applications in which a larger amount of ink is required due to, for example, the complexity of the printing, and therefore the amount of ink per square metre of panel should exceed said maximum amount of ink, the amount of ink to be applied to the panel is increased in a certain percentage with respect to said maximum amount of ink. For example it may be increased in 5%, or in 7%, or in 10%, or in 15%. In these cases, the amount of surface of sound absorbing panel may be increased in order to compensate for the decrease in sound absorbing properties of the decorated panel.

[0050] The inventors have determined the maximum amount of ink (ml, milliliters, 10^{-3} liters) to be deposited on the panel 2 by the digital printer 1, such that the decorated panel 2 maintains the acoustic properties of the panel 2 without printing. This is controlled by software instructions provided to the digital printer, for example through a man-machine interface. From these instructions, the digital printer 1 selects the percentage of ink of the different colors to be applied, such that the sum of the inks of different colors at each printing position (x, y) is the determined maximum amount of ink, and the exact position in the panel 2 at which said amout of ink must be deposited. The position in the panel at which ink must be deposited in order to print a certain picture, pattern or the like, is determined by the digital printer 1, as those skilled in the art are aware of.

[0051] The amount of ink to be deposited on the sound absorbing panel 2 has been studied and analyzed for different types of sound absorbing panels as a function of their acoustic properties. As explained next, in order to determine the maximum amount of ink to be applied to a sound absorbing panel such that the acoustic properties of the panel are guaranteed (that is to say, guaranteeing that its acoustic properties of the panel prior to applying the ink, are maintained), the inventors have concluded that the the amount of ink to be deposited has an effect on the sound absorption coefficient of the panel 2.

[0052] The maximum amount of ink to be deposided, such that the acoustic properties are maintained, has been analyzed for a material -melamine resin foam- having different sound absorption coefficients α at different frequencies. The sound absorption coefficient represents a percentage of absorbed sound at a certain wavelength (and therefore, at a certain frequency). This has been done by applying 5 different amounts of ink (0 ml, 18.816 ml/m^2, 23.168 ml/m^2, 39.872 ml/m^2, 79.872 ml/m^2) to 5 panels having the same sound absorption coefficient before depositing the ink. The panels were made of a melamine resin foam. The thickness of each panel was 50 mm.

[0053] According to current European legislation, the relevant frecuencies regarding control of reverberation with an closed environment are 500, 1000 and 2000 Hz. Thus, the mean value considering these 3 frecuencies may establish the maximum exposure time to reverberation for different environments (see for example the Document of protection against noise of the Spanish Technical Building Code CTE-DB-HR, in compliance with Spanish Law 38/1999 of 5 November). By analyzing the variation in the absorption coefficients at 1000 and 2000 Hz, inventors have observed that in both cases, the impact on the sound absorption coefficient of the amount of deposited ink at these frequencies is negligible. However, at 500 Hz, there is an impact of the amount of deposited ink on the absorption coefficient. This means that, depending on the amount of ink applied, at 500 Hz the actual sound absorption coefficient departs from the theoretical one, considering no ink applied to the panel. As a matter of example, Figure 3 shows a graph which shows the variation of the sound absorption coefficient of 5 panels (panel_1, panel_2... panel_5) made of melamine resin foam, with respect to the amount of deposited ink (ml/m^2) measured at 4 different positions (position_1, position_4) in a reverberant chamber. It is remarked that, instead of in particular 4 positions for measurement in the reverberant chamber, a different amount of positions could have also been selected. The goal of selecting several positions was to calculate an averaged reverberation time in the enclosure -chamber- because the reverberation time varies at each point in space. Also, a number of panels different from 5 panels could have been used instead.

[0054] The size of the panels was 1.25 x 1.25 m (meters) and the panels had 50 mm (millimeters, 10^{-3} meters) thickness. Cian color ink was applied using a Nyala 2i digital printer in the following amounts :in panel_1 0 ml, in panel_2 29.4 ml (that is to say, 18.816 ml/m^2), in panel_3 36.2 ml (that is to say, 23.168 ml/m^2), in panel_4 62.3 ml (that is to say, 39.872 ml/m^2), in panel_5 124.8 ml (that is to say, 79.872 ml/m^2). As can be seen in Figure 3, in average, the first panel (to which no ink has been applied) showed an absorption coefficient of 0.84, the second panel (to which 18.816 ml/m^2 of ink has been applied) showed an absorption coefficient of 0.80, the third panel (to which 23.168 ml/m^2 of ink has been applied) showed an absorption coefficient of 0.78, the fourth panel (to which 39.872 ml/m^2 of ink has been applied) showed an absorption coefficient of 0.76 and the fifth panel (to which 79.872 ml/m^2 of ink has been applied) showed an absorption coefficient of 0.73.

[0055] In order to determine the maximum amount of ink that can be deposited, in order not to alter the allowed reverberation value (i.e. reverberation time) for a closed environment, which means that the sound absorbing properties of the panel are maintained, the inventors have correlated the amount of applied ink with the absorbtion coefficients obtained at the different tested positions from the measured reverberation time, and have concluded that the amount of ink to be applied must be selected depending on the sound absorption coefficient (%) of the material of which the panel is made. In particular, they have concluded that, for panels made of melamine resin foam, the effect on the sound absorption coefficient of the panel 2, of the amount of ink to be deposited, can be adjusted to a fourth degree polynomial curve.

[0056] More specifically, the effect on the sound absorption coefficient of the amount of ink to be deposited can be expressed as follows:

$$y = -0.0013\,x^4 + 0.3183\,x^3 - 26.013\,x^2 + 709.09\,x + 68.2$$

wherein x represents the absorption coefficient of the material, $0 < x < 1$, and y is the amount of ink to be applied to the panel made of such material, in ml.

[0057] Figure 4 shows the variation of the sound absorption coefficient (%) (x axis) as a function of the amount of applied ink in ml per square metre (y axis), at a frequency of 500 Hz, for melamine resin foam panels having thickness = 50 mm. Dots represent real measurements, while the continuous line represents the polynomial curve obtained from the measurements. It has been observed that the maximum amount of ink to be deposited on a panel made of melamine resin foam -so that there is no variation in the determination of the reverberation time according to European regulations for a panel without treatment- is 73,6 ml/m^2. Starting with a panel with no ink, the absorption coefficient obtained from the measured reverberation time at 500 Hz was about 84.0%. Then panels having ink were tested. For example, as shown in Figure 4, when an amount of ink varying between 15.0 and 25.0 ml of ink per square metre of panel was applied, the absorption coefficient obtained from the measured reverberation time at 500 Hz varied between 77-82%. At these values, it was observed that the reverberation time used to evaluate enclosure conditioning was not modified according to European requirements. This means that the amount of applied ink does not affect the reverberation time imposed by the requirements. In turn, when around 39.0 ml of ink per m^2 was applied, the absorption coefficient obtained from the measured reverberation time at 500 Hz was around 74-77% and it was observed that the reverberation time used to evaluate enclosure conditioning was neither modified according to European requirements. What is more, when around 73.5 ml of ink per m^2 or panel was applied, the absorption coefficient obtained from the measured reverberation time at 500 Hz was around 73% and it was observed that the reverberation time used to evaluate enclosure conditioning was neither modified according to European requirements. However, when amounts of ink larger than about 73.6 ml/m^2 were applied to the panels, the absorption coefficient obtained at 500 Hz was lower than 73% and it was observed that the reverberation time used to evaluate enclosure conditioning was modified according to European requirements in 0.1 seconds. Taking into account that sound absorbing panels of different thickness may be used, for example a minimum thickness of 30 mm and a maximum thickness of 60 mm, it was established that the maximum amount of ink to be applied to a panel made of melamine resin foam varies between 70 and 76 ml/m^2, such as between 72 and 74 ml/m^2, for example 73.6 ml/m^2, if we want to guarantee that the reverberation time, and therefore the absorption coefficient, remains within requirements of the European regulation. In other words, when adding a maximum amount of ink varying between 70 and 76 ml/m^2, such as between 72 and 74 ml/m^2, for example a maximum amount of ink equal or lower than 73.6 ml/m^2, it is guaranteed that the sound aborption properties of the panel are the same as those of a panel with no ink.

[0058] In view of the former conclusion, the amount of ink to be applied to a panel 2 made of melamine resin foam, by the digital printer 1, in order to gurantee the maintenance of the acoustic properties of the panel 2, while achieving a decorated panel of high quality, is selected not to exceed 76 ml/m^2, such as to vary between 10 - 76 ml/m^2, or between 20 - 76 ml/m^2, or between 30 - 76 ml/m^2, or between 40 - 76 ml/m^2, or between 50 - 76 ml/m^2, or between 60 - 76 ml/m^2. Lower values, such as 10 or 20 ml/m^2 may suffice when printing certain color patterns, such as a very diluted blue shade. A higher amount of ink, such as between 60 - 76 ml/m^2, is recommended for quality printings equivalent to a printing speed of around 54 m^2/h, as for example provided by Nyala 2i digital printer.

[0059] As already mentioned, in applications in which the quality of the printing should not be impaired at all, or in which a specific printing requires an amount of ink higher than the maximum amount of ink already established, the amount of ink to be applied to the panel may be increased in a certain percentage with respect to said maximum amount of ink. For example it may be increased in 5%, or in 7%, or in 10%, or in 15%. In these cases, the amount of surface of sound absorbing panel may be increased in order to compensate for the decrease in sound absorbing properties of the decorated panel.

[0060] As already explained, the digital printing machine 1 has a software which in turn has several settings that can be adjusted or customized according to the application, for example through a man-machine interface, such as a keyboard or a tactile screen. The selected amount of ink to be applied to the panel 2 can be provided to the printing machine 1 through this man-machine interface (MMI), either as an amount of ml/m^2 or as a percentage (%) of ink to be applied, this percentage corresponding to a certain amount of ml/m^2. In other words, instructions are provided to the printer 1 through the MMI. From these instructions, the digital printer 1 selects the percentage of ink of the different colors to be applied (see for example figure 2), such that the sum of the inks of different colors is the selected amount of ink. Thus, the digital printer 1 selects the amount of ink to be deposited on the panel 2, required for maintaining the sound absorbing properties of the panel 2 while providing a high-resolution printing. As a consequence, the sound absorbing properties of the decorated panels are maintained after depositing the ink thereon. The result is a decorated sound absorbing panel having a high-resolution aesthetic appearance while maintaining its sound absorbing properties.

[0061] Thus, the method of manufacturing a decorated sound-absorbing panel of the present invention, guarantees when an amount of ink within the above mentioned ranges is applied, that a printed image on the panel is achieved with high quality, for any desirable design, without reducing the sound absorbing properties of the panel. This enables the personalization or customization of sound absorbing panels for use indoors.

[0062] Figures 5a and 5b show examples of sound absorbing panels decorated following the method described in the present invention. The illustrated panels are made of melamine resin foam. The thickness of each panel is 50 mm. Although shown in grey scale, the original panels are decorated in colors. In fact, the panels can be decorated with images printed in colors, having the same quality -equivalent to a printing speed of around 54 m^2/h, as for example provided by Nyala 2i digital printer- as images printed in other supports, such as paper.

[0063] Once printed and preferably dried, the size and shape of the decorated panel can be adjusted according to the client's preferences, adopting any irregular shape.

[0064] In this text, the term "comprises" and its derivations (such as "comprising", etc.) should not be understood in an excluding sense, that is, these terms should not be interpreted as excluding the possibility that what is described and defined may include further elements, steps, etc.

[0065] The invention is obviously not limited to the specific embodiment(s) described herein, but also encompasses any variations that may be considered by any person skilled in the art (for example, as regards the choice of materials, dimensions, components, configuration, etc.), within the general scope of the invention as defined in the claims.

Claims

1. A method of manufacturing a decorated sound absorbing panel, comprising:

   providing a sound absorbing panel (2) to a digital printer (1);
   applying a printing on the sound absorbing panel (2) by means of the digital printer (1), wherein applying said printing comprises applying an amount of ink per square metre of sound absorbing panel (2), said amount being selected such that it causes no variation in the acoustic properties of the decorated sound absorbing panel with respect to the acoustic properties of the sound abosrobing panel (2) with no ink applied thereto.

2. The method of claim 1, wherein the sound absorbing panel (2) is fixed to a printing table (11), the stage of applying a printing comprising moving a cartridge carrying printing heads (12) at least along the X and Y axes while the sound absorbing panel (2) remains fixed.

3. The method of any one of the preceding claims, further comprising curing the printing applied on the sound absorbing panel (2) by means of UV radiation applied by drying lamps (13) comprised in the digital printer (1).

4. The method of any one of the preceding claims, further comprising providing instructions to the digital printer (1) through a man-machine interface, said instructions comprising the amount of ink to be applied.

5. The method of any one of the preceding claims, wherein the thickness of the sound absorbing panel (2) is equal or larger than 30 mm.

6. The method of any one of the preceding claims, wherein the sound absorbing panel (2) is made of a melamine resin foam.

7. The method of claim 7, wherein the amount of ink to be applied per square metre of sound absorbing panel (2) does not exceed 76 ml/m^2.

8. The method of any one of claims 6-7, wherein the amount of ink to be deposited has an effect on the sound absorption coefficient of the panel (2), said effect being adjusted to a fourth degree polynomial curve.

9. The method of claim 8, wherein said effect is formulated as follows:

$$y = -0.0013\, x^4 + 0.3183\, x^3 - 26.013\, x^2 + 709.09\, x + 68.2$$

   wherein x represents the absorption coefficient of the material, $0 < x < 1$, and y is the amount of ink to be applied to the panel made of such material, in ml per squeare metre.

10. The method of any one of the preceding claims, wherein said amount of ink to be deposited on the sound absorbing

panel (2) is estimated as follows:

applying different amounts of ink, including no ink, to a plurality of identical sound absorbing panels,
disposing a first panel of said panels in a certain position within a reverberant chamber,
at different positions within the reverberant chamber, measuring the reverberation time at different frequencies,
from the measured reverberation times, calculating the sound absorbing coefficient at each frequency;
repeting the former steps for each panel of said panels, thus obtaining the sound absorbing coefficient at each frequency for each panel;
selecting as as maximum amount of ink to be applied, an amount of ink that causes no variation in the determination of the reverberation time with respect to a panel with no printing.

11. A decorated sound absorbing panel comprising a sound absorbing panel (2) having a printing applied thereto by means of a digital printer (1), wherein said printing comprises an amount of ink that causes no variation in the acoustic properties of the decorated sound absorbing panel with respect to the acoustic properties of the sound abosrobing panel (2) with no ink applied thereto.

12. The decorated sound absorbing panel of claim 11, wherein the sound absorbing panel (2) is made of melamine resin foam.

13. The decorated sound absorbing panel of any one of claims 11-12, wherein said amount of ink does no exceed 76 ml/m^2.

14. The decorated sound absorbing panel of any one of claims 11-13, wherein the characteristic porosity of the material of which the sound absorbing panel (2) is made, is equal to or higher than 0.50, such as higher than 0.60, or higher than 0.70, or higher than 0.80 or higher than 0.90 or higher than 0.95.

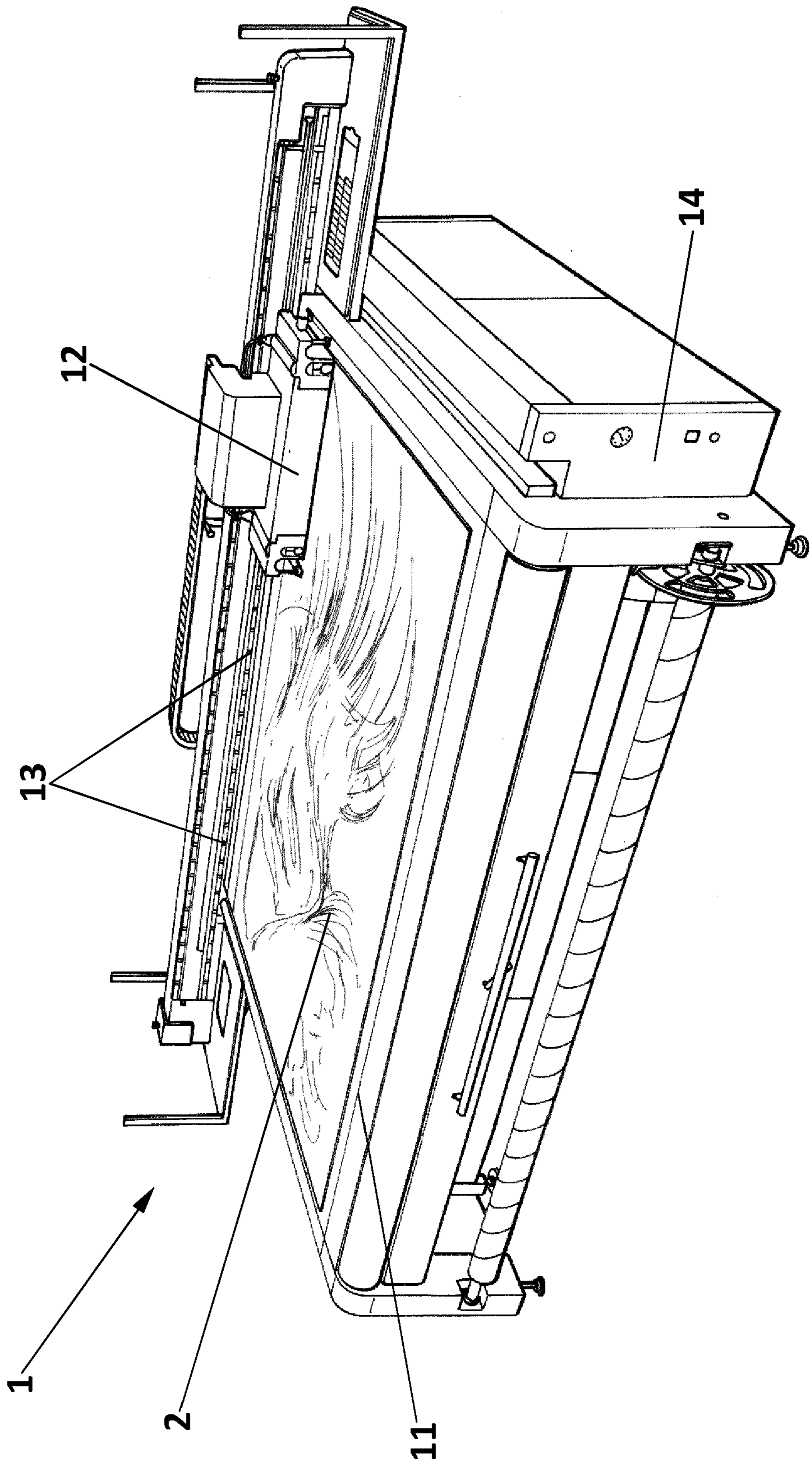

FIG. 1

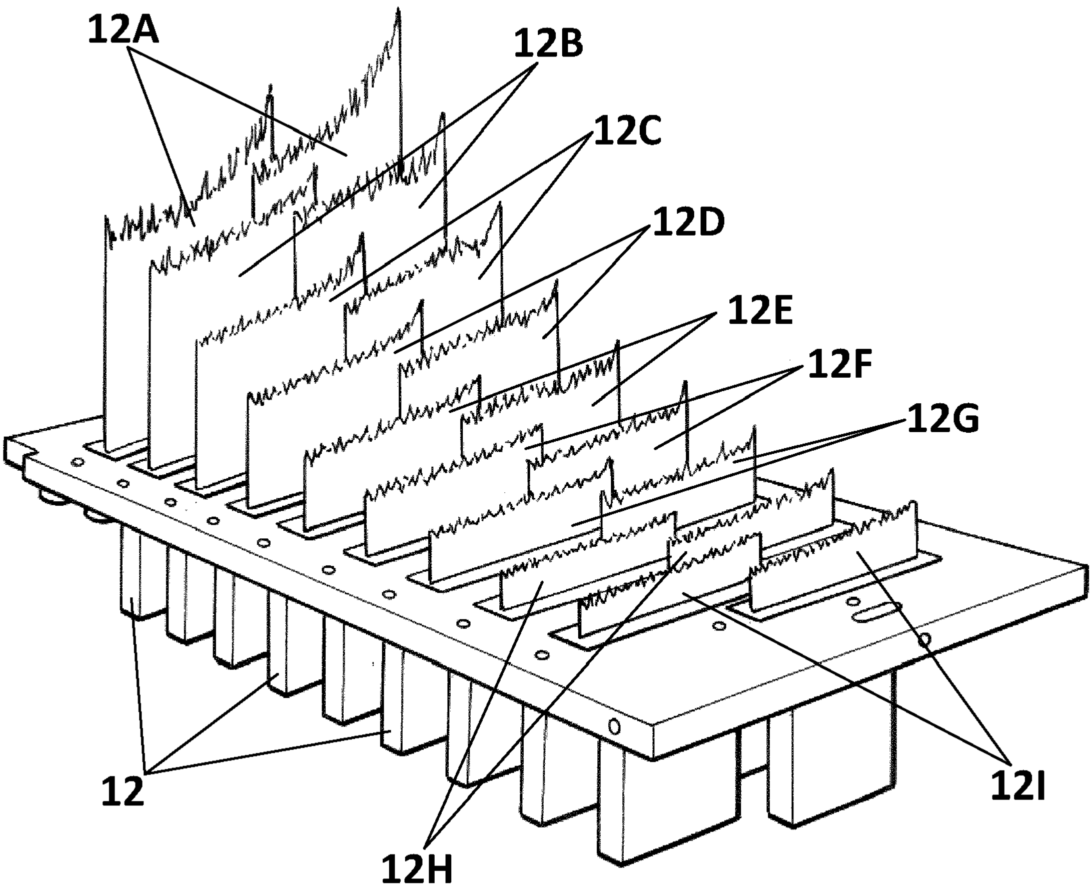

FIG. 2

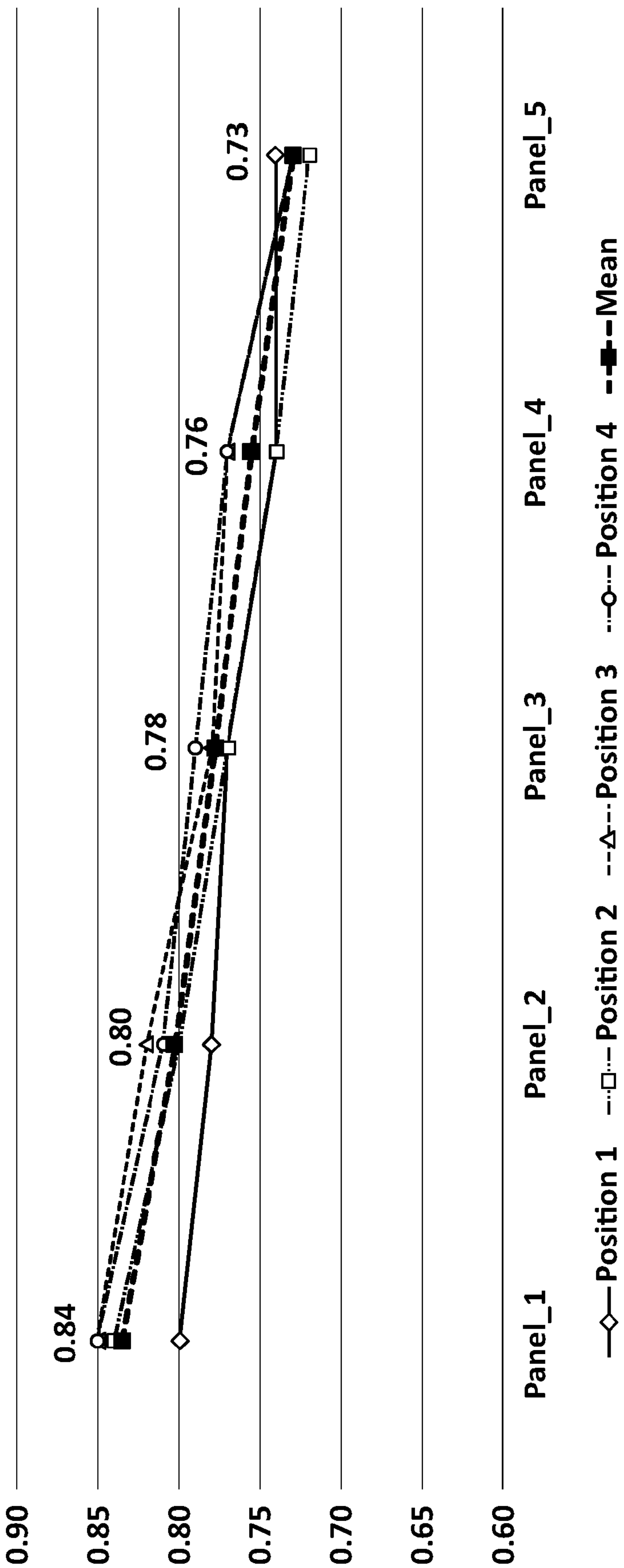
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.84
0.80
0.78
0.76
0.73
Panel_1
Panel_2
Panel_3
Panel_4
Panel_5
Position 1
Position 2
Position 3
Position 4
Mean

FIG. 3

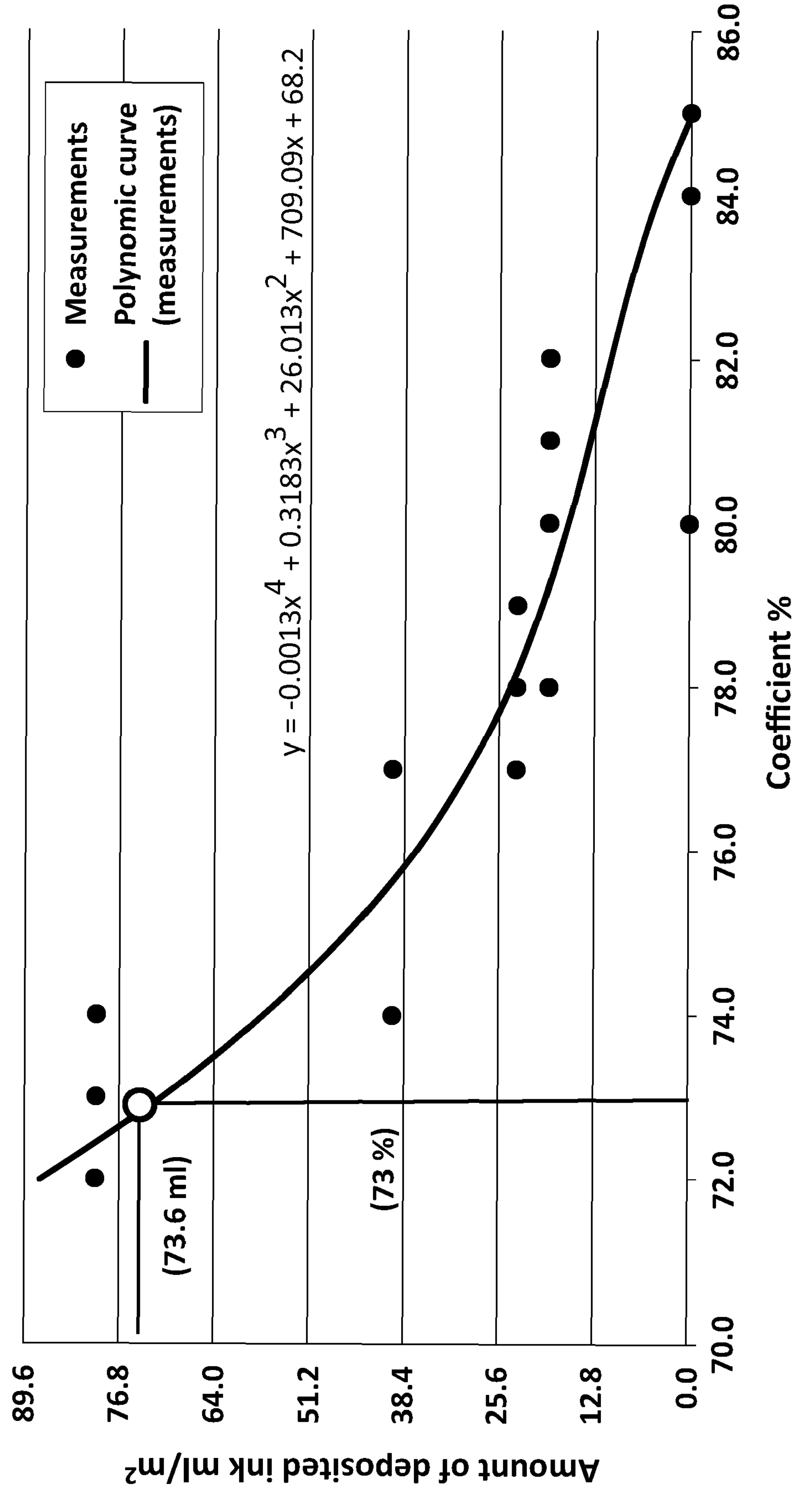
Measurements
Polynomic curve (measurements)
y = -0.0013x4 + 0.3183x3 + 26.013x2 + 709.09x + 68.2
(73.6 ml)
(73 %)
Amount of deposited ink ml/m2
Coefficient %
0.0
12.8
25.6
38.4
51.2
64.0
76.8
89.6
70.0
72.0
74.0
76.0
78.0
80.0
82.0
84.0
86.0

FIG. 4

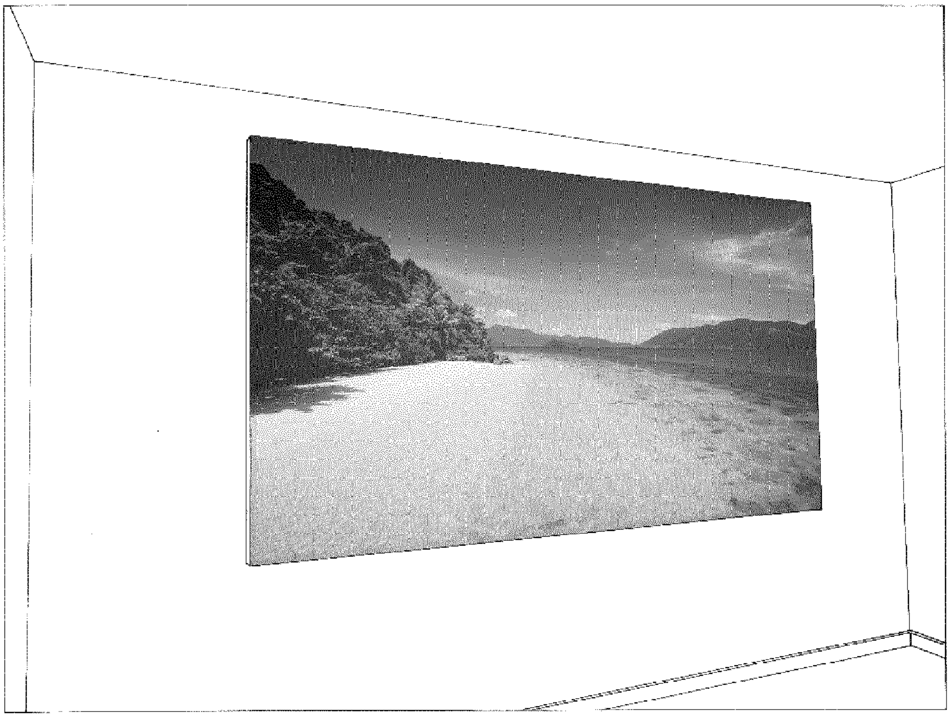

FIG. 5a

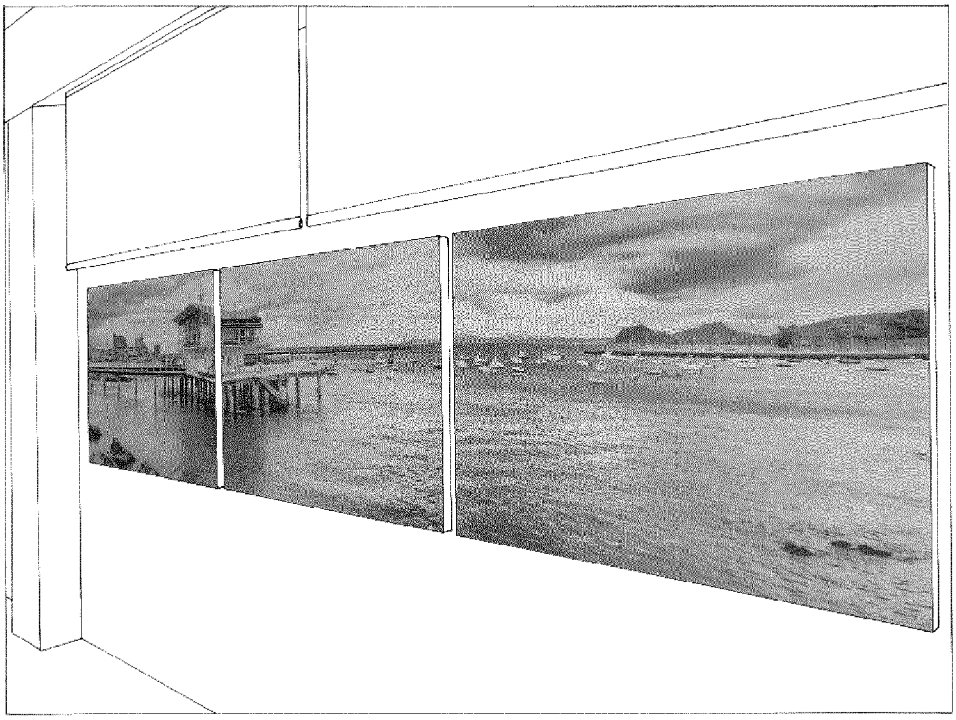

FIG. 5b

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Application Number
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	6 April 2020	Gassmann, Martin

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