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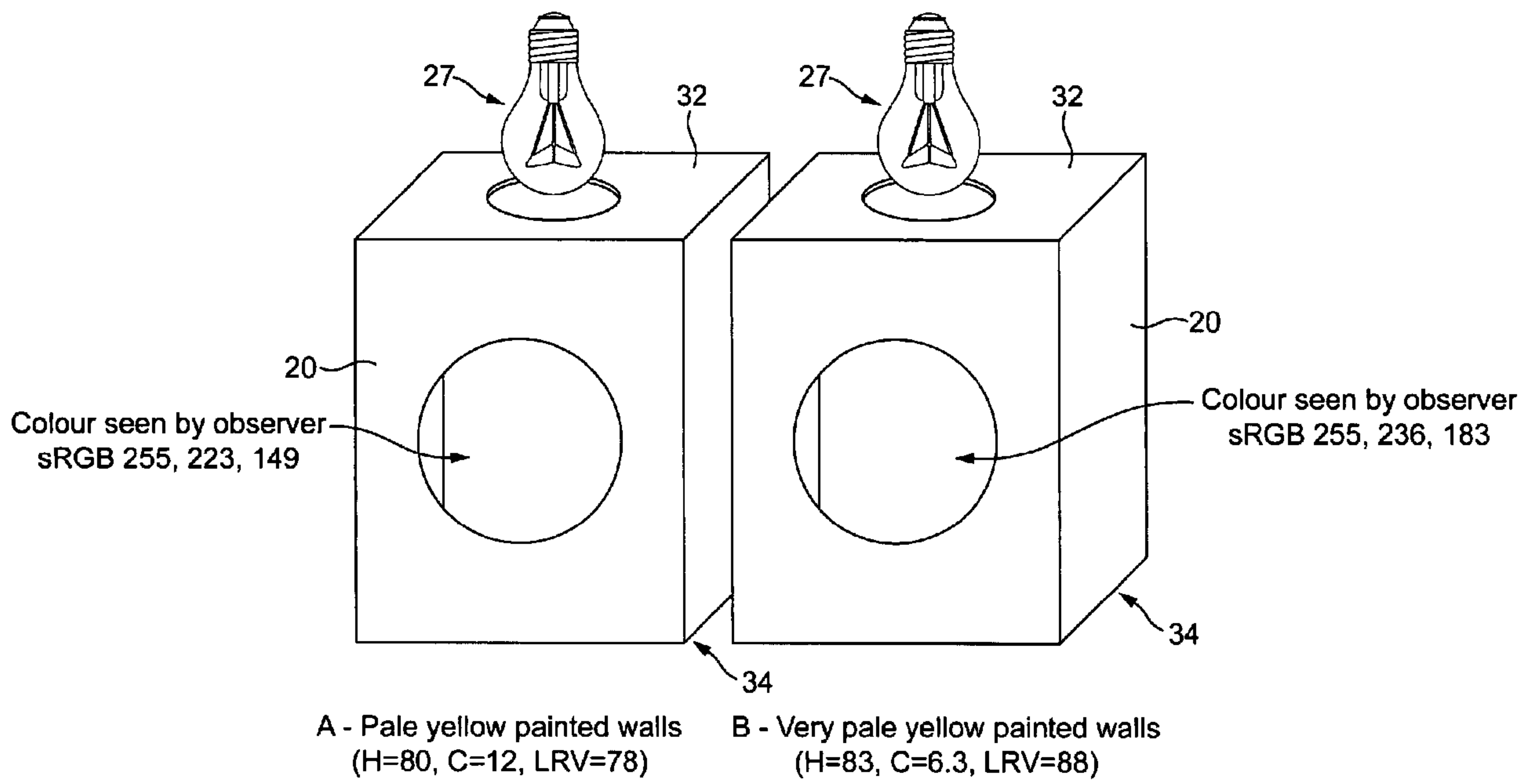

FIG. 3

(57) Abrégé/Abstract:
A display comprising at least two cavity structures substantially juxtaposed, the interiors of the cavity structures being respectively coloured, at least in part, with a test colour and a reference colour, wherein the test colour is related to the reference colour in that it has a substantially similar or the same hue characteristic, but a different lightness characteristic.

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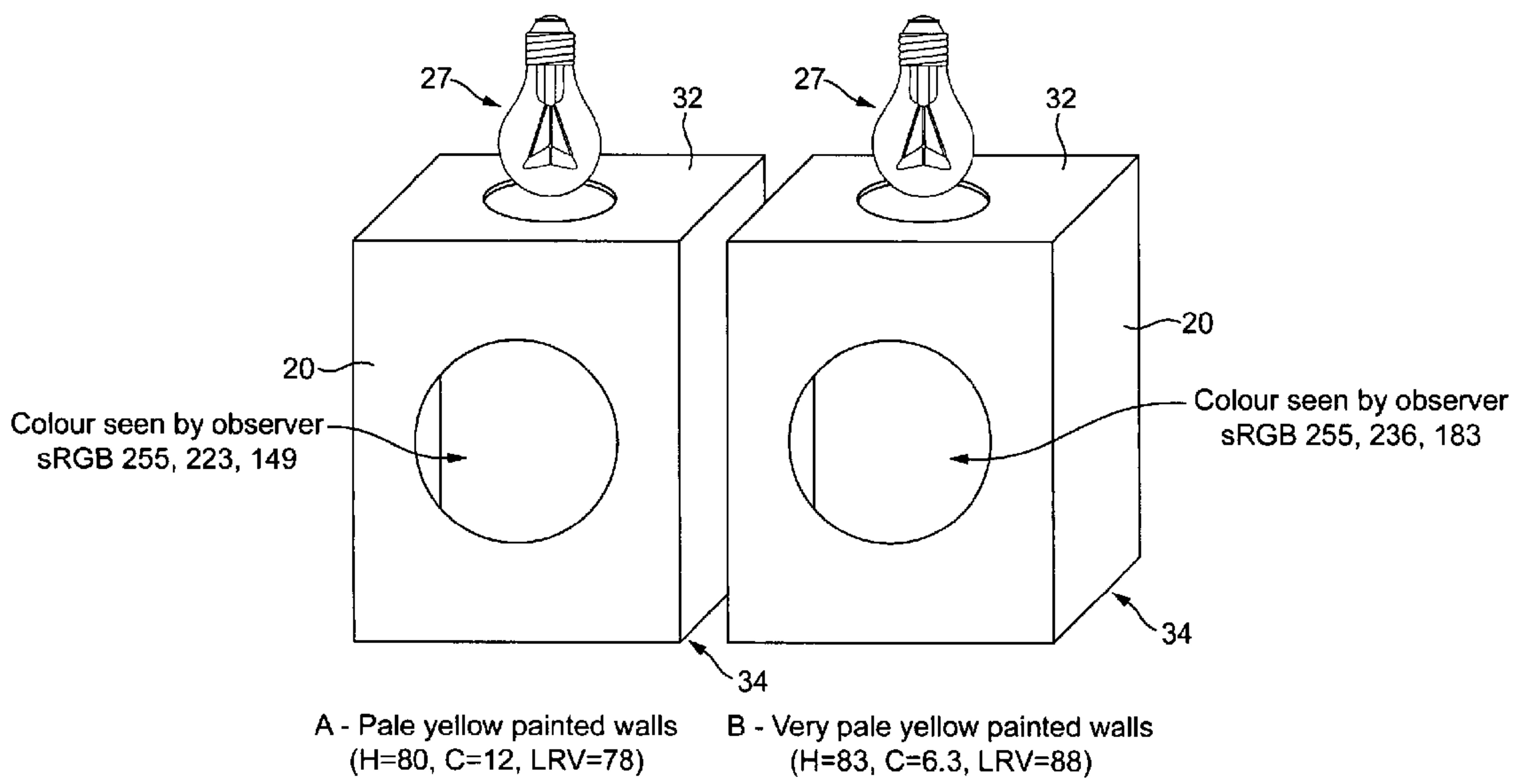


FIG. 3

(57) Abstract: A display comprising at least two cavity structures substantially juxtaposed, the interiors of the cavity structures being respectively coloured, at least in part, with a test colour and a reference colour, wherein the test colour is related to the reference colour in that it has a substantially similar or the same hue characteristic, but a different lightness characteristic.

WO 2009/015755 A1

Colour Display and Related Methods

The present invention relates to a display for displaying colours in a comparative fashion, a method of such displaying, and a method for testing viewer perceptions of cavity size in dependence on colour.

Imperial Chemical Industries PLC has recently launched a new paint product under the brand name "Light and Space". The new paint product is an emulsion type paint which is formulated to reflect light back into a room, thus making the room appear more light and spacious than in fact it is. This effect is achieved not through specular reflection i.e. through the paint having a gloss or silk finish, but instead through the addition of ingredients to the paint which increase the light reflecting properties whilst maintaining the matt appearance.

The space creating effect of the paint becomes apparent generally when the paint has been applied to each of the walls of a cavity such as a room, such that light reflection can take place off each surface, and multiple reflections can occur. However, traditionally paints are marketed using small sample pieces of card, known as "chips", with the paint applied thereto to demonstrate the colour, and by the sale of tester pots to allow a small piece of wall to be painted, again simply to demonstrate the colour. Whilst such techniques can be used in respect of the new paint to demonstrate its colour, such techniques fail to adequately represent the additional light reflecting property of the paint when applied to a whole room and which acts to make the room appear more spacious. It would therefore be useful to provide a means by which demonstration of this effect can be made to prospective purchasers of the paint, preferably in a retail environment, wherein store space is at a premium.

Various items of prior art are known as background to the present invention, and particularly the use of miniature room models to perform colour research. For example, *'Colour Combination Effects in Experimental Rooms'*, Monica Billger, Color Research and Application, 24(4), 1999, pp.230-242 describes a miniature room, with painted walls, where an observer places their head inside a window on one wall. The position of the window is adjustable along this wall. Billger used it to study the effects on colour appearance of combined effects of simultaneous contrast (from colours in the visual field surrounding the test surface) and mixed illumination (from multiple reflections from room surfaces of different colours). Similarly, *'Evaluation of a Colour Reference Box as an Aid for Identification of Colour Appearance in Rooms'*, Monica Billger, Colour Research and Application, 25(3), 2000, pp.214-225 describes a method for comparing a coloured surface in a full-size room with a series of reference colours with the latter being viewed under realistic conditions of illumination and adaptation. The method makes use of an illuminated box containing a surface with the reference colour, which is located in the full-size test room.

Miniature room models have also been used to study perceived lightness. More particularly, Yoko Mizokami, Mitsuo Ikeda and co-workers have reported the use of miniature rooms to study psychological effects of illumination and colours of surroundings on our perceptions of colour and lightness of an object. They have developed a model based on the concept of a recognised visual space of illumination (RVSI) where we use visual cues in the scene to make unconscious assumptions about the colour and strength of the illumination incident on an object. Manipulation of these cues can significantly alter our perceptions of the colour of an object, including its lightness. References to their work include the following:

1. *'Lightness changes as perceived in relation to the size of recognized visual space of illumination'*, Y Mizokami, M Ikeda and H Shinoda, Optical Review, volume 5 number 5, September 1998, pp.315 - 319.

2. *'Recognised visual space of illumination : No simultaneous color contrast effect on the light source colors.'*, Cunthasaksiri, Prasit, Colour Research and Application, 31(3), 2006, pp 184-190.

3. *'Color Appearance of a Patch Explained by RVSI for the Conditions of Various Colors of Room Illumination and of Various Luminance Levels of the Patch'*, Ikeda, Mitsuo, Optical Review, 9(3), 2002,pp.132-139.

4. *'Color Property of the Recognised Visual Space of Illumination Controlled by Interior Color as the Initial Visual Information*, Mizokami, Yoko, Optical Review, 7(4), 2000, pp.358 - 363.

5. *'Walls surrounding a space work more efficiently construct a recognized visual space of illumination than do scattered objects,* Yamauchi, Rumi, Optical Review, 10(3), 2003,pp.166-173.

6. *'Recognized visual space of illumination : A new account of center-surrounded simultaneous colour contrast,* Cunthasaksiri, Prasit, Colour Research and Application, 29(4), 2004, pp.255-260.

7. *'Effect of Space Recognition on the Apparent Lightness of Gray Patches Demonstrated on Printed Patterns'*, Ikeda, Mitsuo, Optical Review, 10(5), 2003, pp.382-390.

8. *'Phenomena of Apparent Lightness Interpreted by the Recognized Visual Space of Illumination'*, Optical Review, 5(6), 1998, pp.380-386.

Miniature room models have also been described as being used for showing perceived size effects. For example, E. Aksugur : *'Effects of Surface Colors of Walls Under Different Light Sources on the 'Perceptual Magnitude of Space' in a Room',* F.W. Billmeyer and G. Wyszecki, eds., AIC Color 77, Proceedings of the Third Congress of the International Colour Association, Adam Hilger Ltd. (Bristol), 1977, pp.388 - 391 describes how subjects made paired comparisons of perceived magnitude for two model rooms viewed side-by-side. The variables were the type of illumination (tungsten-filament incandescent and daylight fluorescent) and in the hue of the colours on the walls (red, yellow, green and blue), at equal (high) Munsell brightness and (low) saturation.

In V.Ramkumar and C.A. Bennett : *'How Big is Dark ?* Proceedings of the Human Factors Society -23rd Annual Meeting, 1979, pp.116 - 118 these authors also tested space perception within a model room while varying the parameters of the wall colours. They inferred the effects on perceived spaciousness by varying the scale size of cutout figures placed in the room. Subjects were asked to choose the scale figure that appeared ' just right' for the room size and also asked to estimate the distance of the figure away from the rear wall. Wall colours were white, grey, black and saturated and unsaturated blue and red. An external incandescent light source kept illumination at a constant 60 foot-candles in the model room.

Additionally, A. Baum and G.E. Davis : *'Spatial and Social Aspects of Crowding Perception'*, Environment and Behaviour, 8 (1976), pp.527 - 544 discuss the impact of wall colour, visual complexity and social orientation on the perception of crowding, using scale figures in miniature rooms. Subjects were asked to metaphorically place themselves in the room by positioning a scale figure and then to successively place other figures in the room until they perceived the room to be crowded. They were also asked to rate the rooms on a number of adjective descriptors. Two scenarios were studied, a social situation and a non-social one.

Finally, comparative type displays have also been used in the art, in the field of lighting effects. More particularly, Philips Lighting UK of Philips Centre Guildford Business Park, Guildford, Surrey GU2 8XH, UK recently introduced a box display in UK retail outlets (B&Q). A picture of this is shown in Figure 1. The centre compartment contained a standard light bulb for reference while the outer ones contained new types of bulbs giving illumination with different qualities. The box allows an observer to make side-by-side comparisons of the lighting effects.

Embodiments of the invention provide a display which has at least two cavities provided substantially next to each other to an extent that the interiors thereof can be compared by a viewer. The two cavities are respectively coloured with a test colour the subject of the demonstration, and a reference colour, to allow the properties of the test colour to become apparent to the viewer. In this respect, to provide for a fair comparison the reference colour is selected with respect to the test colour to provide as similar a perceived colour as possible, exploiting properties of the human vision system. More particularly, the human vision system is more sensitive to changes in hue and chroma, and particularly hue, of a colour than it is to changes in lightness of the colour. Therefore, the reference colour is selected with respect to the test colour to provide, as far as is possible given the available subset of colours, a colour which is substantially similar or the same in terms of hue and chroma, and particularly hue, to the test colour but which differs in its lightness characteristic, preferably having a lower, hence "darker", lightness value. The result is that the reference colour will appear to the viewer to be the same or substantially the same as the reference colour, but when compared with the test colour in the display, will allow the test cavity having the test colour to appear lighter and more spacious than the reference cavity to the viewer. In preferred embodiments the reference colour is selected with respect to the test colour by applying a predefined colour difference algorithm, and weighting hue and chroma more than lightness. Most preferably, the colour difference algorithm is the CIE Delta E 2000 algorithm, defined by the standards body the Commission Internationale d'Eclairage (CIE).

In view of the above, from a first aspect the present invention provides a display comprising at least two cavity structures substantially juxtaposed, the interiors of the cavity structures being respectively coloured, at least in part, with a test colour and a reference colour, wherein the test colour is related to the reference colour in that it has a substantially similar or the same hue characteristic, but a different lightness characteristic. In this way a reference colour which appears to the human vision system to be similar to the test colour can be used, which will enhance space perception properties of the test colour. In the preferred embodiments, therefore, the test colour has a higher lightness characteristic than the reference colour, and moreover the reference colour has a substantially similar or the same chroma characteristic than the test colour.

Moreover, preferably the reference colour is selected from a set of possible reference colours by the application of a colour-difference algorithm in dependence on the characteristics of the test colour. The use of a colour difference algorithm permits the properties of the human vision system to be exploited further so as to ensure that a colour is selected which has at least a similar hue, but the different lightness property. In view of this, more preferably the colour difference algorithm is adapted so as to weight higher the hue and chroma values of the possible reference colours than the lightness values, and more preferably so as to weight higher the hue value of the possible reference colours than the chroma values.

Several standardised colour difference algorithms are known which can be used. In embodiments of the invention the colour difference algorithm is preferably an algorithm selected from the set comprising: CIE Delta -E 1974; CIE Delta-E 1994; or CIE Delta-E 2000, defined by the standards body the Commission Internationale d'Eclairage (CIE).

Moreover, preferably the colour properties of the available test and reference colours are defined, in terms of hue, chroma, and lightness, with reference to the CIE Lab colour model.

In preferred embodiments the cavity structures are of a shape so as to cause illuminating light to undergo multiple reflections within the cavity before exiting the cavity. This enhances the light reflecting effect of the test colour, as on each reflection less light is absorbed by the test colour than by the reference colour, hence the perception by the viewer of the light reflecting properties of the test colour are enhanced. In order to provide this feature, preferably the cavity structures are each provided with a viewing aperture, wherein the apertures each account for less than 25%, and preferably less than 10%, of the interior surface areas of the cavities.

In order to provide for a fair comparison between the test colour and the reference colour the cavity structures are preferably arranged to provide internal cavities of substantially the same size. Additionally, in view of the perception of space of a cavity being dependent at least in part on the illumination, for the same reason of providing a fair comparison the cavity structures are each preferably provided with an identical illuminating light source.

As an alternative to relying on the viewer's qualitative perceptions of the relative sizes of the test and reference cavities in order to provide a quantitative measurement of the differences in lightness in the tow cavities at least one luminance or illuminance measuring sensor may be provided in at least one of the cavities so as to detect the luminance or illuminance therein. Then a quantitative measurement of luminance or illuminance can be provided to a viewer, as a confirmation of their own perceptions.

The perception of spaciousness of a cavity is also influenced by the contents of the cavity, in that a sparsely populated cavity may appear more spacious than a densely populated cavity. In order to improve the viewer's space perception preferably at least one, and more preferably both, of the cavities is populated with objects. Again, in order to provide for a fair comparison between the test and the reference cavities, preferably the objects are arranged in each cavity in an identical configuration.

The cavities may be any suitable shape, although rectilinear shapes and cylindrical shapes are preferred. Rectilinear shapes are particularly preferred as they are the same shape as a typical room. In order to allow the display to be used in a retail situation where space is at a premium, preferably such cavities have a longest dimension between 30mm and 5000mm. Where cylindrical cavities are used, preferably the cavities have a longest dimension (diameter or height) between 30mm and 3000mm.

In order to colour the cavities, in some embodiments at least one of the cavities, and preferably both or all of the cavities, is coloured by painting the interiors with paint of the respective colour. This represents the simplest solution to colouring the cavities and allows the actual paint product to display its properties. However, painting the cavities directly has the drawback that where the colours are to be changed the display must be withdrawn from display to customers, repainted, and then allowed to dry, which may take a considerable amount of time. Therefore, to alleviate this problem in other embodiments at least one of the cavities, and preferably both or all of the cavities, is coloured by inserting into the cavity an insert of the respective colour. The insert can be prepared in advance in the desired colours, and then the colours of the cavities may be changed in a quick operation by removing the previous inserts and inserting the new inserts.

From a second aspect the invention also provides colour display method, comprising the steps: selecting a test colour and a reference colour, the test colour being related to the reference colour in that it has a substantially similar or the same hue characteristic, but a different lightness characteristic; and providing, substantially juxtaposed, at least two cavity structures, the interiors of the cavity structures being respectively coloured, at least in part, with the test colour and the reference colour.

The second aspect present s the same advantages, and same further features and advantages, as previously described in respect of the first aspect.

In order to further validate the properties of the test paint in terms of improving viewer perception of space, it is possible to use the display of the first aspect and method of the second aspect in a testing method, in order to obtain a quantitative measure of viewer perception of spaciousness of the test and reference cavities, for further comparison purposes. From a third aspect, therefore, the present invention also provides a method of testing cavity colour on viewer perception of cavity size, comprising the steps: displaying a reference cavity of a reference colour and a test cavity of a test colour to one or more viewers at least one or more times; recording the viewers' perceptions of spaciousness of the cavities on a predetermined scale to provide one or more sets of space perception measurements; processing the sets of space perception measurements to obtain one or more measures indicating perceived size of the reference cavity and perceived size of the test cavity; wherein the test colour is related to the reference colour in that it has substantially similar or the same hue and chroma characteristics, but a different lightness characteristic. As mentioned, such a testing method permits viewer perceptions of the spaciousness of the reference cavity and test cavity to be quantitatively measured and compared. Further features of the testing method will be apparent from the appended claims.

Further features and advantages of the present invention will become apparent from the following description of embodiments thereof, presented by way of example only, and by reference to the accompanying drawings, wherein like reference numerals refer to like parts, and wherein: -

Figure 1 is a photograph of a prior art display apparatus;

Figure 2 is a diagram illustrating perspective, top, and front side views of a part of a display apparatus according to an embodiment of the invention;

Figure 3 is a drawing illustrating a first embodiment of the present invention;

Figure 4 is a drawing illustrating a second embodiment of the present invention;

Figure 5 is a photograph of an arrangement according to a third embodiment of the present invention;

Figure 6 is a diagrammatic cut away according to the third embodiment of the present invention;

Figure 7 is a graphic illustration of a side perspective view of a fourth embodiment;

Figure 8 is a front view of the fourth embodiment of the invention;

Figure 9 is a perspective graphic illustration of a fifth embodiment of the present invention;

Figure 10 is a photograph of an arrangement according to a sixth embodiment of the present invention;

Figure 11 is a diagram illustrating how average illuminance can be found for particular colours;

Figure 12 is a flow diagram illustrating the steps involved in a testing method according to an embodiment of the invention;

Figure 13 is a table illustrating several scene configurations used in the embodiment of the testing method;

Figure 14 is a photograph of an example scene used in the embodiment of the testing method;

Figure 15 is an arbitrary predetermined scale for recording viewer perceptions as used in the embodiment of the testing method;

Figure 16 is a graph of viewer perception measurements as used in the embodiment of the testing method; and

Figure 17 is a collection of measures indicating the perceived size of two cavities collected from a plurality of users as used in an embodiment of the testing method of the invention;

Various embodiments of the invention will be described. However, before the specific embodiments are described, various common aspects of the embodiments will be discussed in more detail.

To demonstrate the beneficial effect of using lighter paint colours on the background illumination level paints for the rooms are chosen on the basis of their Light Reflectance Value (LRV). This is a measure of Lightness, which is one of the three dimensions used scientifically to define a colour. It is equivalent to the total amount of visible light reflected from the coloured surface relative to the amount reflected by a perfect white reflector. The amount of light here is defined in photometric units (lumens) which means that the spectral composition of the reflected light is weighted by the response function for human scotopic (daytime) vision. LRV can be determined using a spectrophotometer using standard methods published by the Commission Internationale d'Eclairage (CIE) in Technical Report CIE 15:2004 3rd Edition, 'Colorimetry', Commission Internationale de l'Eclairage, ISBN 3 901 906 33 9.

The second dimension used scientifically to define a colour is hue, which identifies where the colour is located with respect to primary colours such as red, yellow, green and blue. A colour, for example, may have a hue that lies between red and yellow, i.e. an orange. The third dimension is chroma, which measures how intense the colour is. Colours with a chroma of zero are called achromatic and lie on a scale of greys from white to black depending on the lightness. Colours with a very high chroma are highly saturated, e.g. pure spectral lines.

To demonstrate the beneficial effect of using lighter paint colours on the background illumination level it is also necessary to choose a suitable reference colour of lower LRV that otherwise appears related to the featured lighter colour. This comprises finding reference colours that closely match the featured one in hue, chroma and lightness. It further comprises giving greatest weight to the match in hue, the next level of importance to the match in chroma and the least weight to the match in lightness. Because human visual systems are most sensitive to differences in hue and least sensitive to differences in lightness the result is a reference colour that resembles the featured higher LRV one. Generally this method provides a more visually satisfactory reference colour than one chosen by colour difference algorithms that more evenly weight the importance of differences in hue, chroma and lightness. A useful way to implement this in embodiments of the invention is to apply the delta-E 2000 algorithm produced by the CIE, and described in CIE Publication 142-2001, 'Improvements to Industrial Colour Difference Evaluation', Commission Internationale de l'Eclairage, ISBN 3 901 906 08 8, and *'The Development of the CIE 2000 Colour-Difference Formula : CIEDE2000'*, M R Luo, G Cui, B Rigg, Color Research and Application, 26(5), October 2001, pp.340-350. The CIE delta E 2000 colour difference algorithm takes as some of its parameters weighting parameters k_L, k_C and k_H, which relate respectively to the degree to which lightness , chroma, and hue of a colour are taken into account when comparing it to another colour. In particular, the k_L, k_C and k_H weighting parameters are adjusted from their default values of 1,1,1 to higher ones for k_L and k_C. This produces the required effect of reducing the importance of differences in Lightness and chroma relative to the differences in hue.

An example of using this colour matching algorithm is given in Table 1. Here, the left hand column shows example colours from an available subset of colours (identified by colour reference codes) which have been ranked in order of colour difference as determined by the Delta E 2000 algorithm when compared to a test colour of interest. In the left hand column k_L, k_C and k_H are equal and set to 1, such that lightness is given equal weight to hue and chroma in the colour difference algorithm. In the left hand column the weightings k_L, k_C and k_H have been changed to 4, 3, and 1 respectively, such that, more generally, lightness is weighted less than chroma, which is itself weighted less than hue. In this respect, in the Delta E 2000 algorithm, a higher coefficient means that the colour property is weighted less. Other coefficient values which meet these criteria could of course be used. Furthermore, other colour difference algorithms, such as, for example, CIE Delta E 1974, and CIE Delta E 1994 may also be used. The colour difference algorithm is used, with the coefficients set as described above, to find a reference colour from the available set of reference colours which has the lowest colour difference when compared to the test colour.

A) using kL = kC = kH = B) using kL = 4, kC = 3, kH =

Match No.	Colour Referenc	δE2000	δL	δc	δh		Colour Referenc	δE2000	δL	δc	δh
1	40YY8306	1.3	-	0.3	2.9		29YY8406	0.4	-	0.6	-
2	20YY8306	1.3	-		-		20YY8306	0.4	-	-	-
3	45YY8306	1.3	-	-	3.8		20YY8305	0.4	-	-	-
4	29YY8406	1.4	-	0.6	-		40YY8306	0.5	-	0.3	2.9
5	50YY8305	1.4	-	-	6.2		20YY8307	0.6	-	1.2	-
6	20YY8305	1.5	-	-	-		30YY7907	0.6	-	0.8	-
7	10YY8305	1.5	-	-	-		45YY8306	0.6	-	-	3.8
8	20YY8307	1.6	-	1.2	-		20YY8303	0.7	-	-	-
9	51YY8306	1.7	-	-	5.5		30YY7905	0.7	-	-	2.4
1	53YY8707	1.8	-	1.2	8.5		40YY8308	0.7	-	2.3	2.1

Table 1 : An example showing how to choose a suitable reference colour to compare the featured higher LRV colour with.

Having selected the test and reference colours, embodiments of the invention provide an enclosed cavity whose surfaces are coated with decorative paint colours, which could be whites or greys as well as chromatic colours. Below we call such a cavity a 'room'. The room dimensions could range from a size that is suitable for hand-held use, through sizes that are suitable for display to a group of observers on a table or a shelf, up to a full-size mock-up of a domestic room standing on the floor. The room preferably has one or more light sources, which could be artificial light fittings in the room or an aperture lit from the outside either by artificial lighting or by daylight. It also has one or more viewing apertures so that observers can see into the room or light measuring devices can be directed into it.

The shape of the room is preferably adaptable for different marketing approaches, e.g. it could be rectilinear to look like a conventional room or cylindrical to resemble a paint can.

An important aspect of some embodiments of the invention is that the room is designed so that light from the light source(s) undergoes multiple reflections before reaching the eye of the observer or the aperture of the measuring device. This necessitates that the total area of apertures for viewing and illumination are small relative to the total area of reflecting surfaces enclosing the cavity. For example, preferably the total surface area of the apertures is less than 25 % of the total interior surface are of the cavity, and more preferably less than 10 %. Within the cavity as much of the surfaces as possible should be coated with the paints of interest. Darkly coloured surfaces (e.g. flooring) will absorb light and reduce the number of reflections from the painted surfaces and should be avoided. When the conditions for multiple reflections are satisfied relatively small differences in the Light Reflectance Value of pale colours give rise to large differences in background illumination level in the room.

The approximate formula relating average illuminance (<E>) to the average Light Reflectance Value of the interior surfaces is (as described in *'Code for Lighting 2004'*, The Society of Light and Lighting, Chartered Institute of Building Service Engineers (CIBSE), ISBN 1-903287-47-2, and *'Lamps and Lighting'*, S T Henderson and A M Marsden, Edward Arnold, 2nd Edition, 1972, chapter 1 p.19 and chapter 4 p.76:

$$\langle E \rangle = \frac{\Phi}{A(1 - Y_{AV})} \qquad \text{Equation 1}$$

where Φ is the luminous flux entering the room, A is the total area of all interior reflecting surfaces and Y_{AV} is the average LRV of all the interior reflecting surfaces. If two rooms are compared, labelled '1' and '2' and differing only in the average LRV of the interior colours ($Y_{AV,1}$ and $Y_{AV,2}$), the ratio of their average illuminances ($\langle E_1 \rangle / \langle E_2 \rangle$) would be given by,

$$\frac{\langle E_1 \rangle}{\langle E_2 \rangle} = \frac{(1 - Y_{AV,2})}{(1 - Y_{AV,1})} \qquad \text{Equation 2}$$

So, for example, if the average LRVs of the paints are 80 and 90 for rooms 1 and 2 respectively the ratio of the average illuminances would be two.

One use of embodiments of the invention is to demonstrate this effect to interested observers, e.g. prospective customers for paint products with higher LRV.

Embodiments of the invention can comprise two or more rooms preferably viewable simultaneously to demonstrate differences in background illumination level and perceived size resulting from the use of different interior paint colours.

Details of several specific embodiments of the invention will now be described.

Figure 2 illustrates a component of a first embodiment of the present invention; and in particular gives a perspective view, a top view, and a front side view.

More particularly, as shown in Figure 2a, a cavity structure 20 forming a component of a first embodiment of the invention is provided. The cavity structure 20 in this case comprises a rectilinear structure, in the form of a cuboid shaped box. The side walls 24 and rear wall 25 of the box are preferably made of hardboard, as is the floor 21. The ceiling and front wall of the box are preferably made of folded card 23. Provided in the ceiling of the box is an aperture 26, through which illumination can be provided into the interior of the box via a light source 27. In the front wall of the box is a viewing port 22. Figures 2b and 2c illustrate preferred dimensions of the box, to make it particularly suitable for use in a retail environment. Of course, in other embodiments of the invention, these dimensions may be varied.

The side and rear walls of the box internally are painted a desired colour, being either a test colour, or reference colour, as will be described later. The ceiling and floor of the box may be painted different colours, or may instead be painted the same colour. In many real rooms, the ceilings are often painted white, and hence the ceiling of the box may also be painted white.

Figure 3 illustrates a first embodiment of the invention, which comprises two of the cavity structures 20 substantially juxtaposed side by side. Respective light sources 27 are provided, which are in this embodiment identical, so that the same illumination is provided into each cavity structure 20. The ceilings 32 of each of the cavity structures 20 are painted internally with the same white paint, for example, having a light reflectance value of 89. The floors 34 of the cavity structures 20 are also painted the same colour.

One of the cavity structures 20 has its side, rear and front walls painted with a reference colour, in this case a pale yellow reference colour, having a hue value of 80, a chroma of 12 and a light reflectance value of 78. The other cavity structure 20 is painted internally on its side, rear and front walls with a test colour, in this case being a very pale colour having a hue value of 83, a chroma of 6.3, and a light reflectance value of 88. The test colour is selected as the colour which it is intended the display to demonstrate. The reference colour is then selected in dependence on the properties of the test colour, by selecting a colour from an available set of colours which has hue and, preferably, chroma values which are the same, or substantially the same, but which has different lightness values. As discussed previously, preferably the reference colour is selected using a colour difference algorithm such as the CIE Delta E 2000 colour difference algorithm, and weighting both the hue and chroma coefficients used in the colour difference algorithm higher than the lightness coefficient. This results, as previously described, in a reference colour which looks very similar to the human vision system as the test colour, but which in fact has a lower lightness value.

A second embodiment of the invention is shown in Figure 4. Here, a display unit 48 is provided, in which are provided cylindrical containers 40, which may be, for example, standard 2.5 litre plastic paint cans. Identical illumination sources 27 are provided above each can 40, and an annular piece of white card 42 is provided to fit into the open upper end of each can, so as to provide an aperture into the can, through which the illumination from the light sources 27 may pass. Viewing holes 46 are provided in the front cylindrical surface of each can. Each of the cans 40 may be lined with a coloured insert 44, with one of the coloured inserts being of the test colour, and the other of the coloured inserts being the reference colour. As in the case of the first embodiment, the test colour is selected as that colour which it is wished to display, whereas the reference colour is then selected preferably using the colour difference algorithm, to provide a colour which is the same or substantially similar in hue and chroma, but with a different, preferably darker, lightness value. The use of the coloured inserts 44, which are preferably made of card, allows the test and reference colours for the arrangement to be changed very easily, as the original inserts in each can can be removed, and replacement inserts, of different test and reference colours inserted.

Figures 5 and 6 illustrate a third embodiment of the display according to the present invention. More particularly, within the third embodiment a model house 50 is provided, having a roof 52, and apertures into two rooms 54 and 56 of the house, in the front wall thereof. Decorations in the form of, for example, shutters and a door can be provided on the front wall, as shown in Figure 5. Figure 6 illustrates a cut away diagrammatic view of the house from the top. Here, the roof 52 is shown, with identical illumination sources 58 and 58' shown mounted in the roof portion, above each room. Furniture 540 may be provided in each room. The ceilings of each room are preferably painted white, and have apertures in them through which illumination from the illumination sources 58 and 58' can pass into the rooms. One of the rooms is painted a test colour, and the other of the rooms is painted a reference colour. As in the previous embodiments, the test colour is that colour which is selected for display, whereas the reference colour is selected using the colour difference algorithm in dependence upon the test colour, in the same manner as described previously.

Figures 7 and 8 illustrate a fourth embodiment of the invention. This embodiment is particularly adapted for use in retail outlets. In particular, the display 70 comprises a battery pack 72, which supplies electrical power to matching LED lights mounted in the ceiling of the display structure. The display structure comprises a curved front wall extending from the battery pack outwards and downwards to meet with a floor of the structure. A central partition 78 is provided underneath the curved front wall, to divide the structure into two compartments 74 and 76. One of the compartments 74 or 76 is coloured with a test colour, and the other of the compartments is coloured with a reference colour. Several apertures are cut into the curved front wall, to allow a viewer to look into the compartments 74 and 76. The apertures are preferably arranged contiguously, to give the impression of multiple paned windows. Various advertising literature can be printed on the front surface of the curved front wall.

Figure 9 illustrates a further embodiment of the present invention. More particularly, here a display 90 comprises a cardboard box having two illumination apertures 98 provided in the upper surface thereof. Cut into the front surface is a first viewing aperture 92, and a second viewing aperture 94. The interior of the box is divided into two cavities via an interior partition. One of the illumination apertures 98, and the first viewing aperture 92 open into a first one of the cavities, and the other of the illumination apertures 98, and the second viewing aperture 94, open into the second of the cavities. The rear wall 96 of the box may extend above the upper surface provided with the illumination apertures 98, and have printed thereon advertising literature and the like. One of the two internal cavities of the box is coloured with a test colour, whereas the other of the cavities is covered with a reference colour. As before, the test colour is selected to be that colour which it is intended to display, and the reference colour is then selected in dependence on the test colour, using the colour difference algorithm, in the same manner as described previously. Preferably, the colouring of the cavities is performed by painting the cavities the appropriate colours, although other techniques, such as, for example, inserting appropriately coloured inserts, may also be used.

Finally, Figure 10 illustrates a yet further embodiment of the invention. More particularly, according to this further embodiment the cavities are provided as full size model rooms, for example constructed of hardboard or the like. A first model room 102 is provided, having a doorway 106 cut therein, and a second model room 104 is provided, having a doorway 108 cut therein. Preferably, illumination of substantially the same type is provided in the ceilings of each of the model rooms 102 and 104. One of the model rooms has at least the interior surfaces of its walls painted a test colour, and the other of the rooms has at least the interior of its walls painted a reference colour. As in the previous embodiments, the test colour is selected to be that colour which it is intended to display, whereas the reference colour is selected in dependence on the test colour, preferably using the colour difference algorithm discussed previously.

Other embodiments falling within the scope of the appended claims will of course be apparent to the person skilled in the art.

The use of the various displays according to the embodiments of the invention will now be described.

To gain an impression of the background light level observers stand or sit in front of the room such that they can see through the viewing aperture. They can either use a short viewing distance to look into the room or a longer one to see the amount of light emerging from the aperture. In the latter situation it is essential to have low ambient lighting conditions.

To qualitatively show the difference between two rooms differing in the average LRV of their colour schemes it is useful to place two rooms of identical design and illumination side-by-side so that the viewing apertures of both rooms can be inspected simultaneously. If an impression of the amount of light emerging the rooms is required it is essential to have low ambient lighting conditions.

An alternative to gaining a qualitative impression by eye is to use the viewing apertures of the rooms to quantitatively determine the light level with a measuring device.

The preferred type of suitable measuring device is one that can measure Luminance. This is the amount of light, in photometric units of lumens, emitted from a unit area of surface into a unit of solid angle in a particular direction. It has units of lumens per sterradian per metre-squared or candelas per metre-squared. An example of a suitable device for measuring Luminance is a Minolta CS 100 Chromameter, available from Konica Minolta Business Solutions Europe GmbH, Europaallee 17, 30855 Langenhagen.. If identical rooms are being used to demonstrate the relative effects of different paint schemes single Luminance values measured at a set point from a set direction will probably be sufficient.

If the average illuminance in the room is required this can be obtained by measuring Luminance at as many points on the surfaces of the room as possible. Making the common assumption that surfaces coated with conventional non-glossy decorative paints are Lambertian, i.e. have the same Luminance regardless of angle of view, the illuminance at a particular point (E) can be related to its luminance (L) via the formula,

$$E = \frac{\pi.L}{\left(\frac{Y}{100}\right)} \qquad \text{Equation 3}$$

where Y is the Light Reflectance Value of the surface at that point.

The point illuminances can then be used to determine an area-weighted averaged illuminance (<E>) which can be used in Equations 1 and 2.

A variation on this method is to use standard white tiles, for which a Y of 100 can be assumed. These tiles can be positioned at the points in the room at which Luminance measurements are required. This allows a value to be obtained for the average illuminance

An example of the use of the invention to derive quantitative information on the average illumination level in painted rooms is given in figure 11. Here, two cavities 20 in accordance with the first embodiment of the invention as described previously are shown, provided with test and reference colours having the characteristics shown. The tables underneath each cavity structure illustrate the measured luminance values L, and then the calculated illuminance values E for the light reflectance values Y, for each cavity.

An alternative suitable device is one that measures Illuminance directly. This is the total amount of light, in photometric units of lumens, incident on unit area of a surface at a particular point (from all directions). It has units of lumens per metre-squared or lux. The sensor of such a device may be placed against the viewing port to measure illuminance at this particular point in the room. An example of such a device is a RS 180-7133 'Lux meter with light type selection', available from RS Components Ltd., Birchington Road, Corby, Northants, NN17 9RS, UK. If identical rooms are being used to demonstrate the relative effects of different paint schemes single illuminance values measured at the viewing port will probably be sufficient.

The benefit of using paints with high LRV to increase the light level in a real room is usually largest for a small room, i.e. one with width and depth that are not large with respect to the height. This is because, in this case, the area of painted surfaces (usually the walls and ceiling) is maximised relative to surfaces that are not painted, such as the floor. The latter are usually darker in colour than the painted surfaces. It is useful, therefore, to simulate the dimensions of a small room, with respect to the relative areas of painted and unpainted surfaces, in the miniature rooms.

To demonstrate the benefit of painting rooms with paints of high LRV on the perceived size of a room it is useful to populate miniature rooms with scale figures and furniture. Observers can then make a qualitative assessment of the degree of crowding of the scene and so gain an impression of the size of the room. Side-by-side comparisons of rooms containing identical scenes but differing in the average LRV of the paint schemes allow observers to make instantaneous assessments of the effect of LRV on the apparent crowdedness of a scene. This gives an impression of the role of room lightness in determining the perceived size of a room.

Further details of a testing method to obtain a measure of perceived spaciousness of a cavity in dependence on the colour of the cavity will now be described. Such a testing method allows for comparative measures to be obtained for cavities coloured with a test colour and a reference colour related to the test colour in a manner as described previously.

More particularly, a testing method according to an embodiment of the invention will be described with respect to Figures 12 to 17.

Prior to commencing the testing method, it is necessary first of all to determine the test and reference cavities, and the test and reference colours. Preferably, these are the cavity structures 20 in accordance with the first embodiment described previously, a test colour being selected for a test cavity as a colour which it is intended to test, and a reference colour being selected for the reference cavity, in dependence on the test colour, using the colour difference algorithm as described previously.

Next, a number of scenes are defined, comprising different objects located in each of the test and reference cavities. More particularly, in the present embodiment five scenes are defined, each comprising a different number of objects, and different objects positioned within the cavities. Figure 13 shows the definition of each scene used for the test and reference cavities. Therefore, by way of example, scene 1 comprises all of a dining table, a coffee table, a sofa, a seated figure and chair, a second seated figure and chair, a third seated figure and chair, a fourth seated figure and chair, a fifth seated figure and chair, a seated figure in an armchair and a standing figure. Figure 14 illustrates this scene, which is the most "crowded" scene set. In particular, object 142 is the first seated figure and chair, object 143 is the dining table, object 144 is the fifth seated figure and chair, object 145 is the seated figure plus armchair, object 146 is the standing figure, object 147 is the sofa, object 148 is the fourth seated figure and chair, object 149 is the third seated figure and chair, and object 140 is the coffee table. The other scenes are created by removing the appropriate objects, in accordance with the table shown in Figure 13.

Having defined the test and reference cavities, and the scenes, as described previously, a number of test participants must then be gathered, in order to perform the testing method. Furthermore, as shown in Figure 15, a predetermined arbitrary scale measuring the participants perceived estimate of spaciousness of each cavity is defined, in order to record each participant's perception of each scene. With all of these elements, it is then possible to commence the testing method. Figure 12 shows an example embodiment of the procedure of such a testing method.

More particularly, the testing method starts at step 14.2 wherein each participant is tested, at step 14.4 each participant is then presented with a test cavity, and at step 14.6 a results graph is opened to record the results for a particular participant being tested, in accordance with the arbitrary predetermined scale of Figure 15, as discussed previously. Then, at step 14.8 testing commences wherein each scene is shown to each participant, for each test cavity. Please note that the scenes are not necessarily shown in order, and the order of viewing of each scene for each cavity by each participant is preferably randomised.

For a particular scene for a particular cavity for a particular participant, at step 14.10 a record of the participant's perception of the crowding of the cavity on the predetermined scale of Figure 15 is recorded on the results graph for that test cavity, for that participant. Steps 14.12, 14.14 and 14.16 close the iteration loops, such that after all of the iteration loops of steps 14.2 to step 14.16 have been completed, each participant would have viewed each scene, in each test cavity (i.e. the test cavity and the reference cavity), and the participant's perception of crowding for each scene has been recorded. The set of results obtained from each participant for each test cavity represents an individual set of results which can then be processed, in accordance with the following steps.

More particularly, following steps 14.18, and step 14.20, for each set of results for each test cavity from each participant, at step 14.22, a best fit curve is plotted on the results graph, using known linear regression techniques. An example of this is shown in Figure

16. Here, a participant has recorded the perception of very crowded for scene 1, crowded for scene 2, crowded for scene 3, spacious for scene 4, and very spacious for scene 5, for a particular cavity (i.e. either the test cavity or reference cavity). A best fit line can then be plotted between the results, and at step 14.24 a turning point found from the best fit line, being that point in the scene index where, according to the best fit curve, the user's perception is "neither crowded nor spacious". The turning point scene index is then recorded for the particular set of results. An identical such process is performed for each set of results obtained from each participant, for each test cavity. Thus, after step 14.28, for each test cavity which has been tested (i.e. the test cavity with the test colour, or the reference cavity with the reference colour) a collection of scene index turning points can be obtained, one from each participant for each test cavity, as shown in Figure 17. More particularly, Figure 17 shows results for a test cavity A, and a test cavity B, with the circles showing the turning point scene index obtained from each participant, for each cavity.

Next, the individual results from each participant are preferably averaged, using processing steps 14.30, to 14.34. This averaging operation then provides a single measure of viewer perception of the degree of spaciousness of each cavity, in dependence on the colour of each cavity. In this respect, and with reference to Figure 15, a lower average scene index turning point for a cavity means that the average viewer would perceive that cavity to be more spacious. In Figure 17, first cavity A was coloured with a very pale yellow having characteristics H=101, C=6.8 and Y=91, whereas cavity B was coloured with a reference yellow, having characteristics H=91, C=50 and Y=79. Thus, as will be seen, the cavity coloured with the colour having the higher lightness value was perceived as more spacious than cavity B, which had a lower lightness value.

At step 14.36, the results are output. These results may be used to further vindicate the claimed effect of a paint product that it renders a room more spacious to a viewer.

Various modifications and adjustments may be made to the above described embodiments to provide further embodiments, any and all of which are intended to be encompassed by the appended claims.

Claims

1. A display comprising at least two cavity structures substantially juxtaposed, the interiors of the cavity structures being respectively coloured, at least in part, with a test colour and a reference colour, wherein the test colour is related to the reference colour in that it has a substantially similar or the same hue characteristic, but a different lightness characteristic.

2. A display according to claim 1, wherein the test colour has a substantially similar or the same chroma characteristic as the reference colour.

3, A display according to claim 2, wherein the reference colour is selected from a set of possible reference colours by the application of a colour-difference algorithm in dependence on the characteristics of the test colour.

4. A display according to claim 3, wherein the colour difference algorithm is adapted so as to weight higher the hue and chroma values of the possible reference colours than the lightness values.

5. A display according to claim 4, wherein the colour difference algorithm is adapted so as to weight higher the hue value of the possible reference colours than the chroma values.

6. A display according to any of claim 3 to 5, wherein the colour difference algorithm is an algorithm selected from the set comprising: CIE Delta -E 1974; CIE Delta-E 1994; or CIE Delta-E 2000.

7. A display according to any of the preceding claims, wherein the cavity structures are of a shape so as to cause illuminating light to undergo multiple reflections within the cavity before exiting the cavity.

8. A display according to claim 7, wherein the cavity structures are each provided with a viewing aperture, wherein the apertures each account for less than 25%, and preferably less than 10%, of the interior surface areas of the cavities.

9. A display according to any of the preceding claims, wherein the cavity structures are arranged to provide internal cavities of substantially the same size.

10. A display according to any of the preceding claims, wherein the cavity structures are each provided with an identical illuminating light source.

11. A display according to any of the preceding claims, wherein at least one luminance or illuminance measuring sensor is provided in at least one of the cavities so as to detect the luminance or illuminance therein.

12. A display according to any of the preceding claims, wherein at least one of the cavities is populated with objects.

13. A display according to claim 12, wherein both the cavities are populated with objects.

14. A display according to claim 13, wherein the objects are arranged in each cavity in an identical configuration.

15. A display according to any of the preceding claims, wherein the cavities are rectilinear in shape.

16. A display according to claim 15, wherein the cavities have a longest dimension between 30mm and 5000mm.

17. A display according to any of claims 1 to 14, wherein the cavities are cylindrical in shape.

18. A display according to claim 17, wherein the cavities have a longest dimension (diameter or height) between 30mm and 3000mm.

19. A display according to any of the preceding claims, wherein at least one of the cavities, and preferably both or all of the cavities, is coloured by painting the interiors with paint of the respective colour.

20. A display according to any of claims 1 to 18, wherein at least one of the cavities, and preferably both or all of the cavities, is coloured by inserting into the cavity an insert of the respective colour.

21. A colour display method, comprising the steps:

selecting a test colour and a reference colour, the test colour being related to the reference colour in that it has a substantially similar or the same hue characteristic, but a different lightness characteristic.

providing, substantially juxtaposed, at least two cavity structures, the interiors of the cavity structures being respectively coloured, at least in part, with the test colour and the reference colour.

22. A method according to claim 21, wherein the test colour has a substantially similar or the same chroma characteristic as the reference colour.

23, A method according to claim 22, wherein the reference colour is selected from a set of possible reference colours by the application of a colour-difference algorithm in dependence on the characteristics of the test colour.

24. A method according to claim 23, wherein the colour difference algorithm is adapted so as to weight higher the hue and chroma values of the possible reference colours than the lightness values.

25. A method according to claim 24, wherein the colour difference algorithm is adapted so as to weight higher the hue values of the possible reference colours than the chroma values.

26. A method according to any of claim 23 to 25, wherein the colour difference algorithm is an algorithm selected from the set comprising: CIE Delta -E 1974; CIE Delta-E 1994; or CIE Delta-E 2000.

27. A method according to any of claims 21 to 26, wherein the cavity structures are of a shape so as to cause illuminating light to undergo multiple reflections within the cavity before exiting the cavity.

28. A method according to claim 27, wherein the cavity structures are each provided with a viewing aperture, wherein the apertures each account for less than 25%, and preferably less than 10%, of the interior surface areas of the cavities.

29. A method according to any of claims 21 to 28, wherein the cavity structures provide internal cavities of substantially the same size.

30. A method according to any of claims 21 to 29, and further comprising illuminating the cavities with an identical light source.

31. A method according to any of claims 21 to 30, and further comprising measuring a luminance or illuminance value at one or more points within at least one, but preferably both or all, of the cavities, and displaying the measured value or values to a viewer.

32. A method according to any of claims 21 to 31, and further comprising the steps of populating at least one of the cavities with objects.

33. A method according to claim 32, comprising populating both the cavities with objects.

34. A method according to claim 33, further comprising arranging the objects in each cavity in an identical configuration.

35. A method according to any of claims 21 to 34, wherein the cavities are rectilinear in shape.

36. A method according to claim 35, wherein the cavities have a longest dimension between 30mm and 5000mm.

37. A method according to any of claims 21 to 34, wherein the cavities are cylindrical in shape.

38. A method according to claim 37, wherein the cavities have a longest dimension (diameter or height) between 30mm and 3000mm.

39. A method according to any of claims 21 to 38, comprising painting the interior of at least one of the cavities, and preferably both or all of the cavities, with paint of the respective colour.

40. A method according to any of claims 21 to 38, comprising inserting into at least one of the cavities, and preferably both or all of the cavities, an insert of the respective colour.

41. A method of testing cavity colour on viewer perception of cavity size, comprising the steps:

displaying a reference cavity of a reference colour and a test cavity of a test colour to one or more viewers at least one or more times;

recording the viewers' perceptions of spaciousness of the cavities on a predetermined scale to provide one or more sets of space perception measurements;

processing the sets of space perception measurements to obtain one or more measures indicating perceived size of the reference cavity and perceived size of the test cavity;

wherein the test colour is related to the reference colour in that it has substantially similar or the same hue and chroma characteristics, but a different lightness characteristic.

42. A method according to claim 41, wherein the reference and test cavities are shown to each viewer a plurality of times, the reference cavity containing a different number of objects on each viewing, and the test cavity containing a different number of objects on each viewing; the viewer's perceptions of spaciousness on the predetermined scale being recorded for each viewing within the set of perception measurements for that viewer.

43. A method according to claim 41 or 42, wherein the processing step comprises processing the sets of space perception measurements according to a linear regression to obtain a best-fit trend line through said set; and determining a turning point on said spaciousness scale using said best fit trend line.

44. A method according to claim 43, wherein a turning point is determined for every set of space perception measurements for a particular cavity, and an average of said turning points obtained for use as said measure of perceived size for the particular cavity.

45. A display apparatus substantially as hereinbefore described, with reference to any of Figures 3 to 11.

46. A display method substantially as hereinbefore described.

47. A method of testing cavity colour on viewer perception of cavity size substantially as hereinbefore described, with reference to Figures 12 to 17.

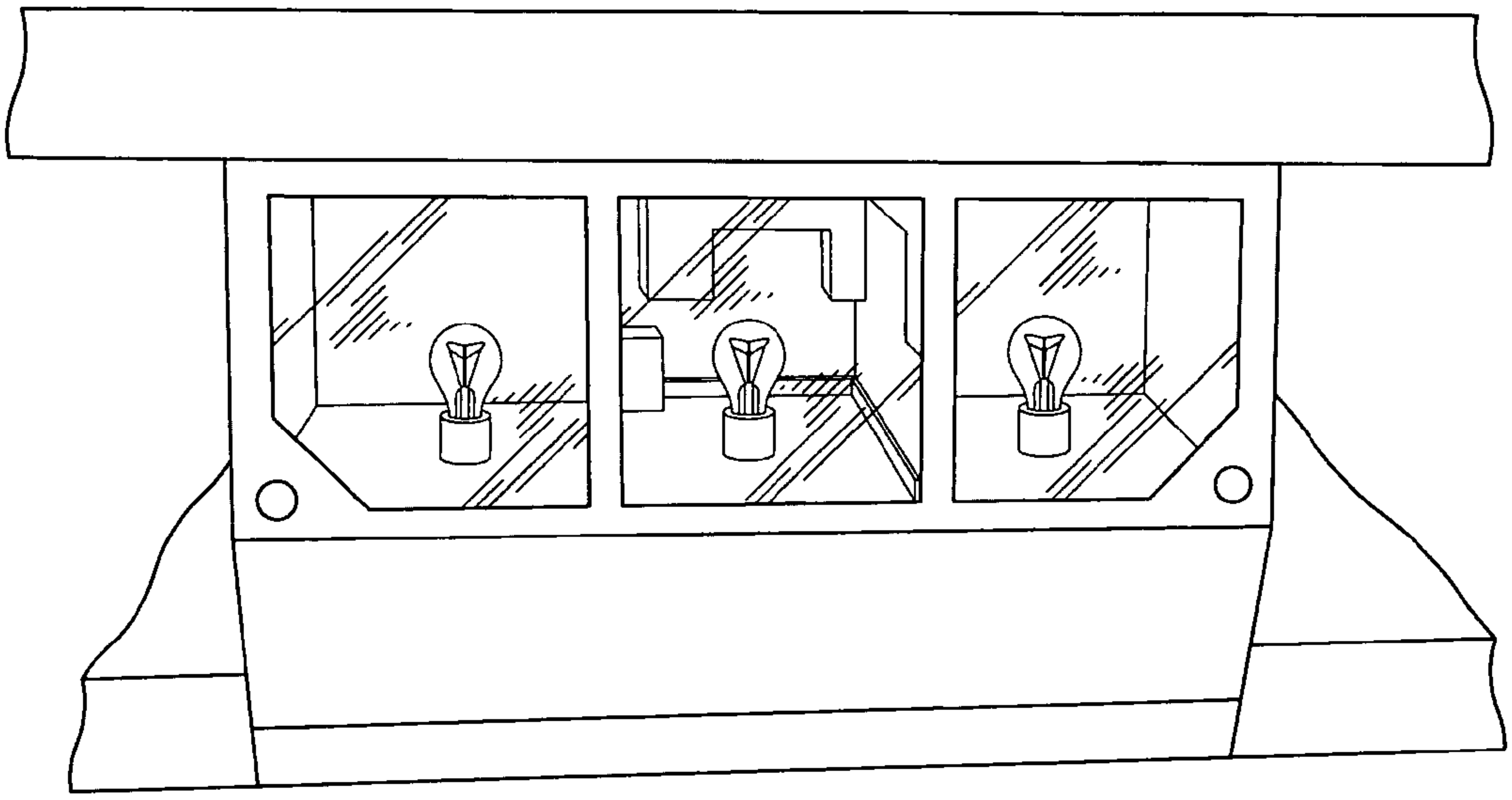


FIG. 1
(PRIOR ART)

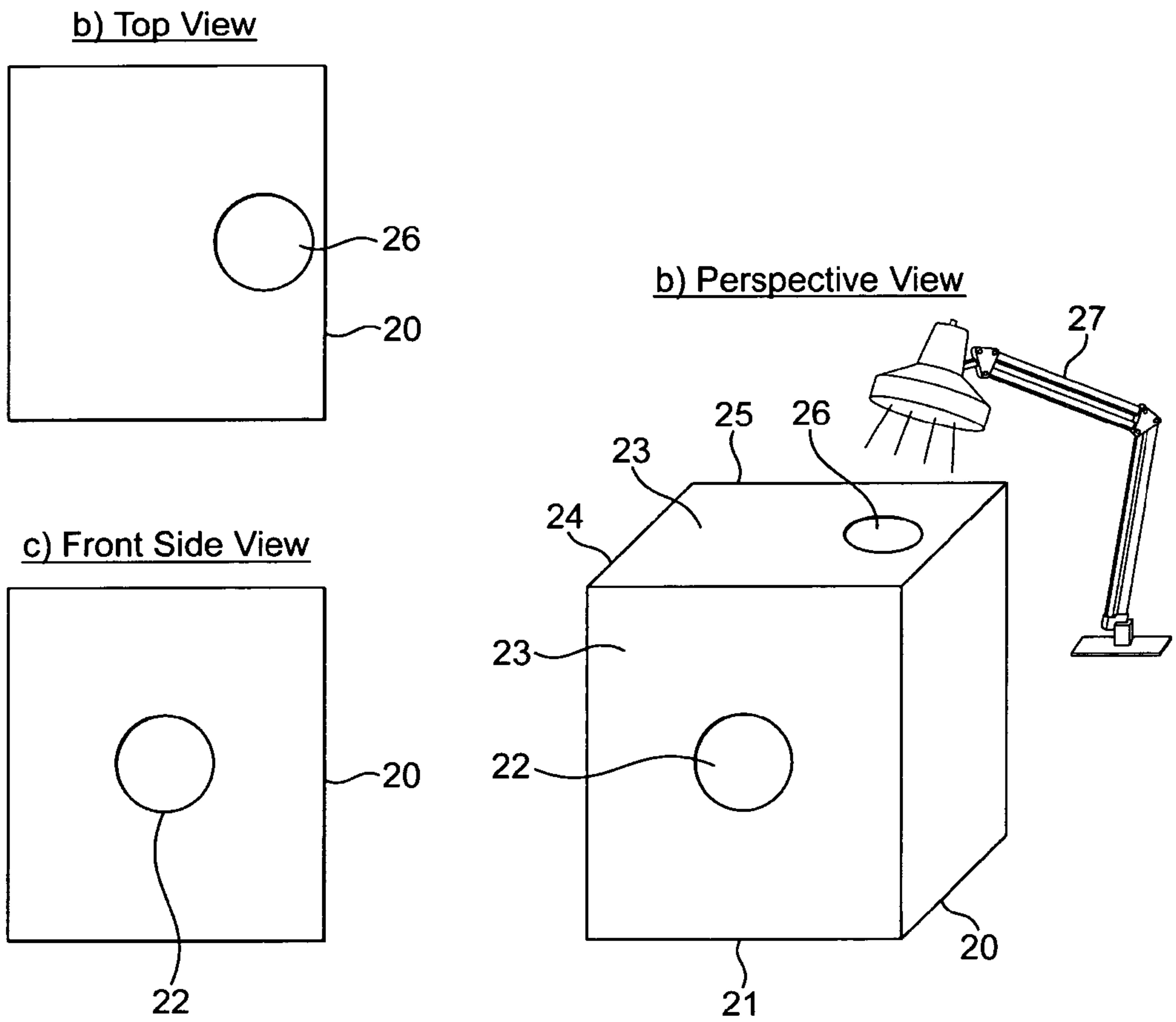

b) Top View
26
20
c) Front Side View
20
22
b) Perspective View
27
25
26
23
24
23
22
20
21

FIG. 2

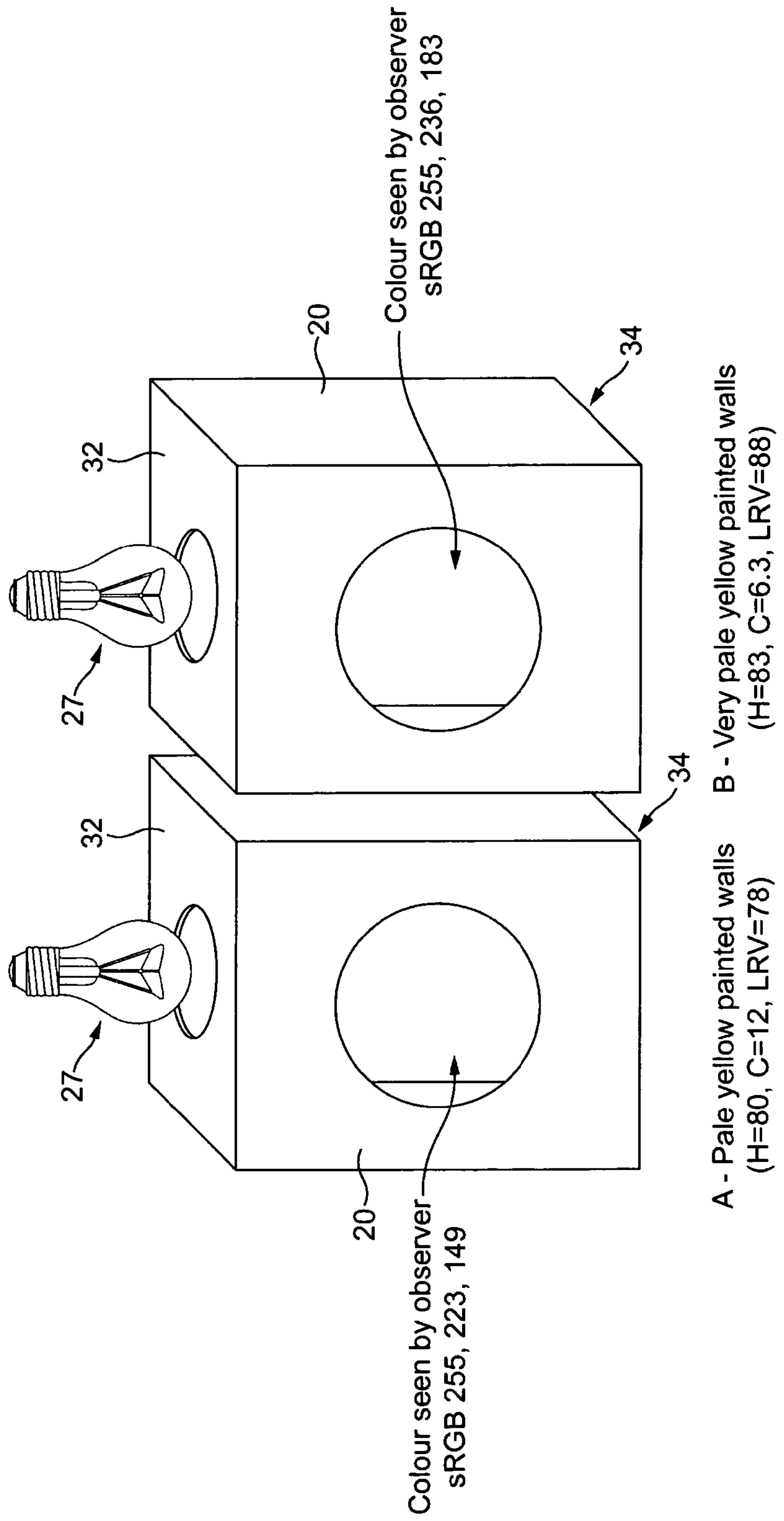

Colour seen by observer
sRGB 255, 236, 183
20
34
32
27
32
34
27
20
Colour seen by observer
sRGB 255, 223, 149
A - Pale yellow painted walls
(H=80, C=12, LRV=78)
B - Very pale yellow painted walls
(H=83, C=6.3, LRV=88)

FIG. 3

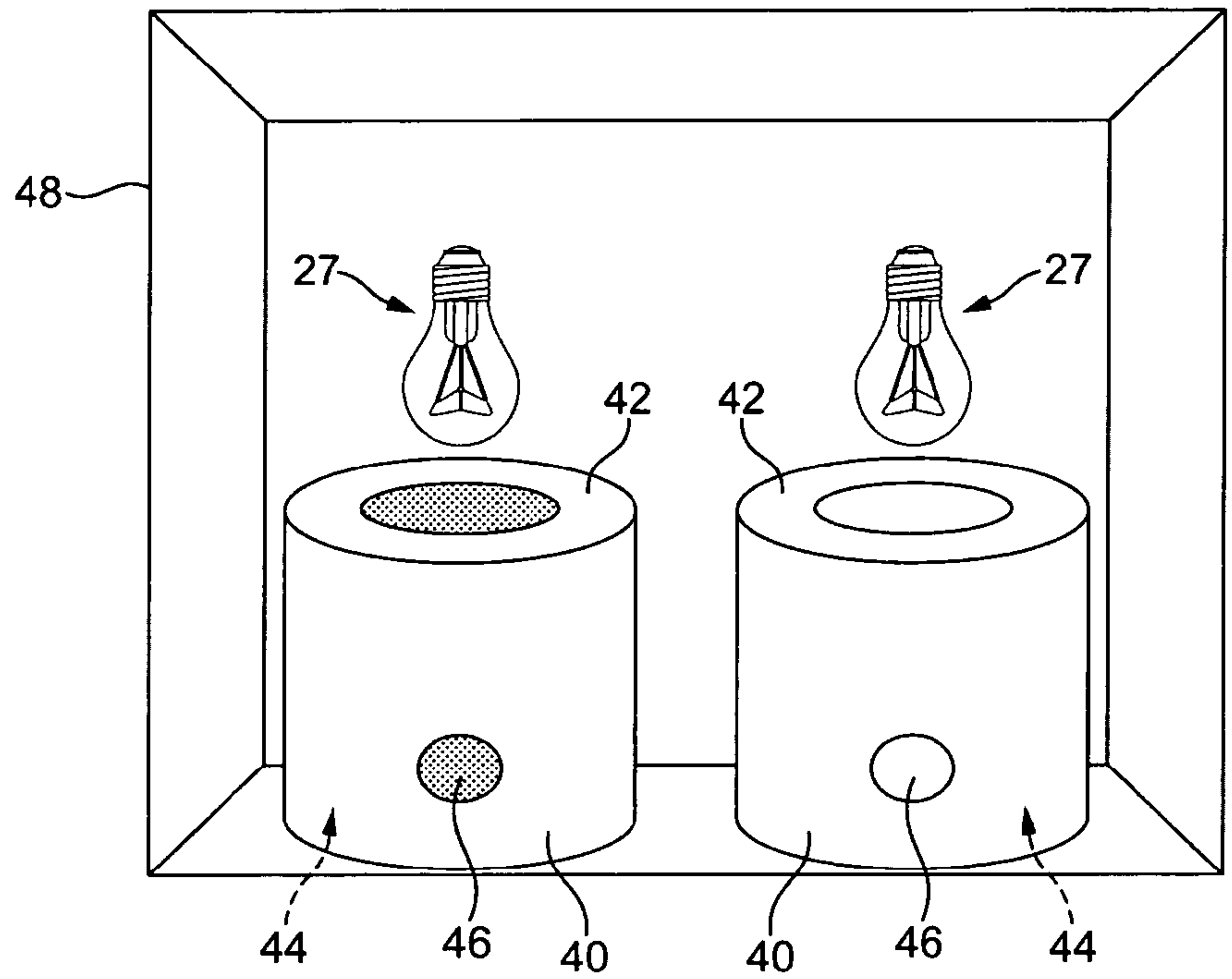


FIG. 4

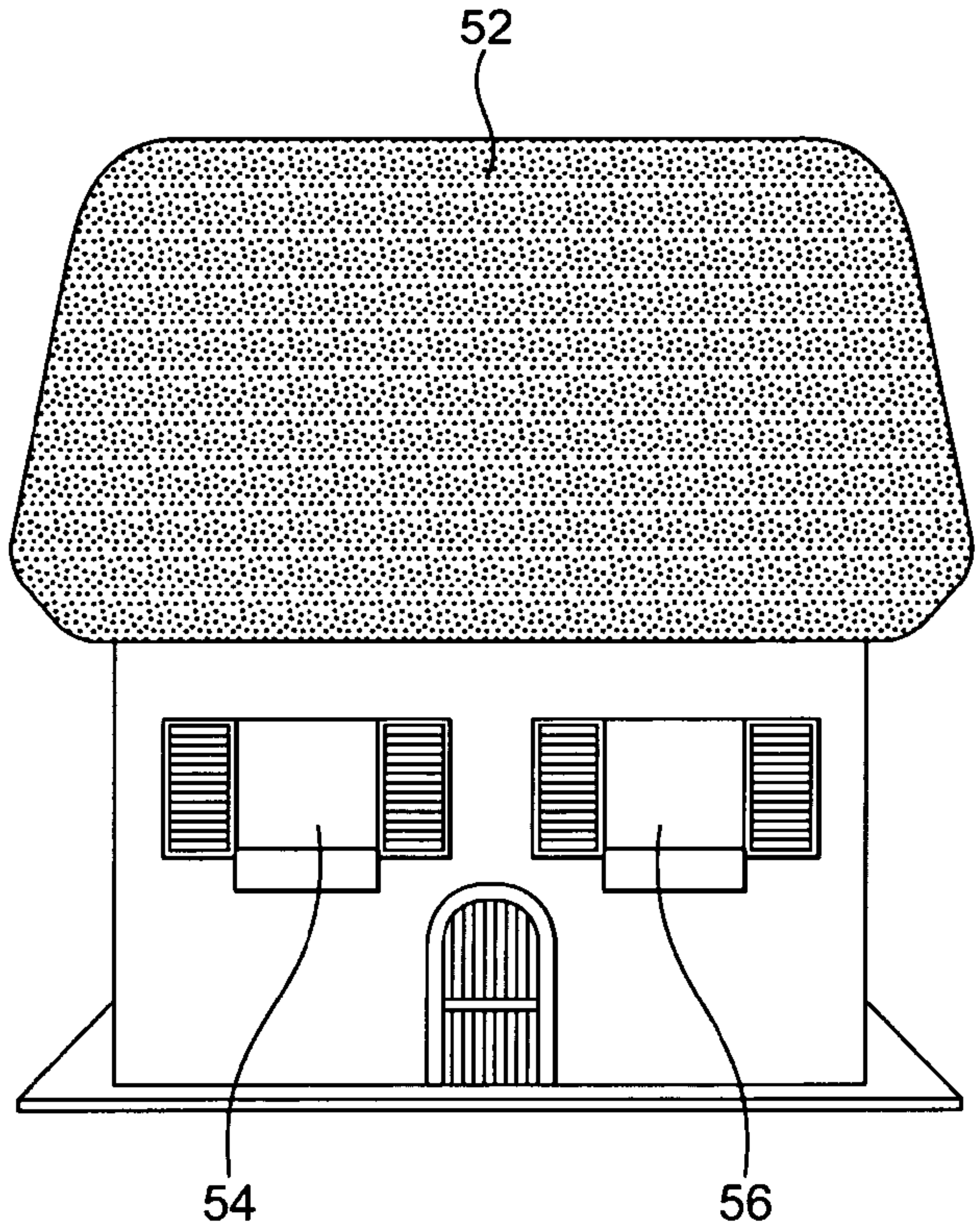


FIG. 5

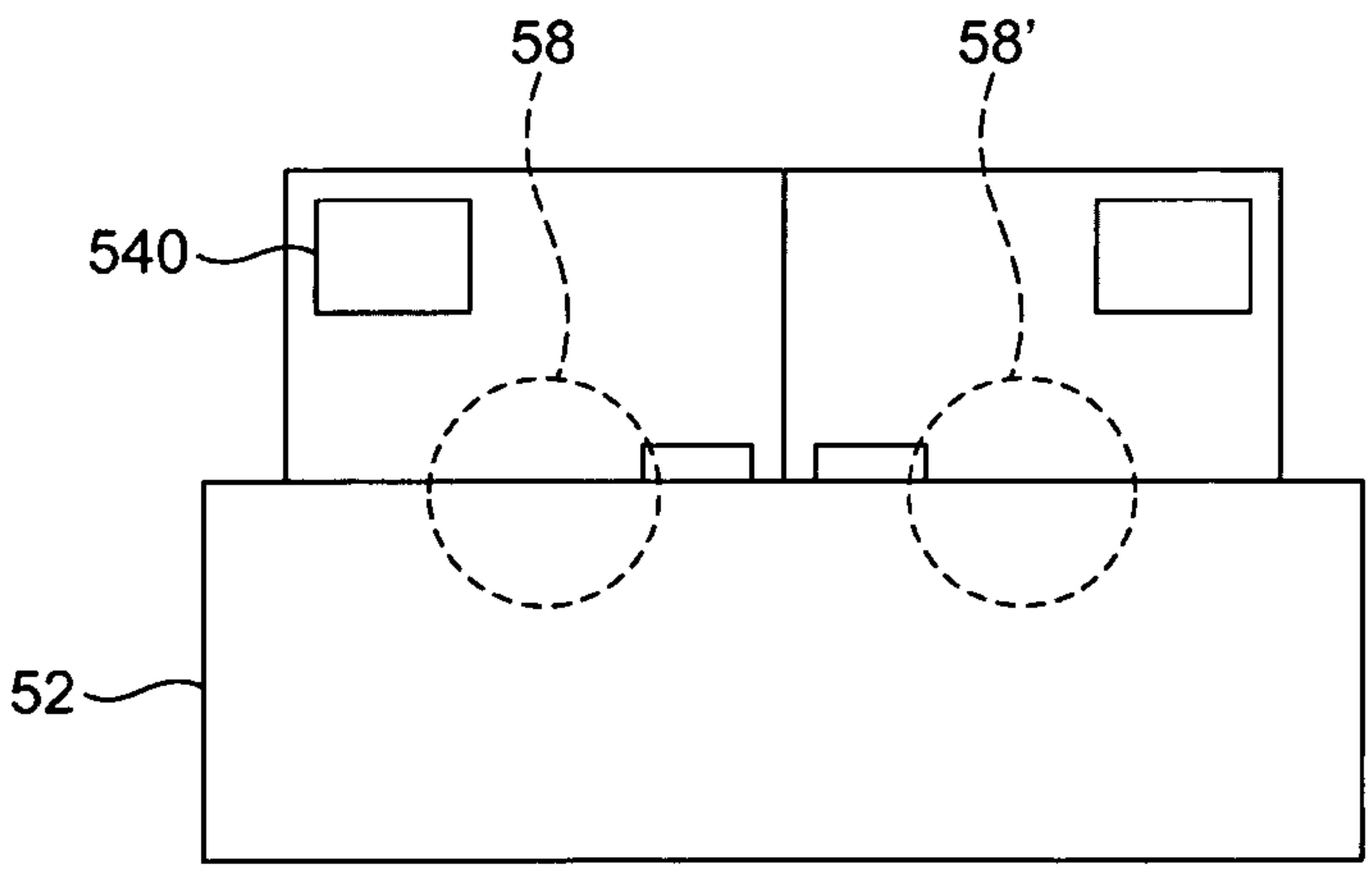


FIG. 6

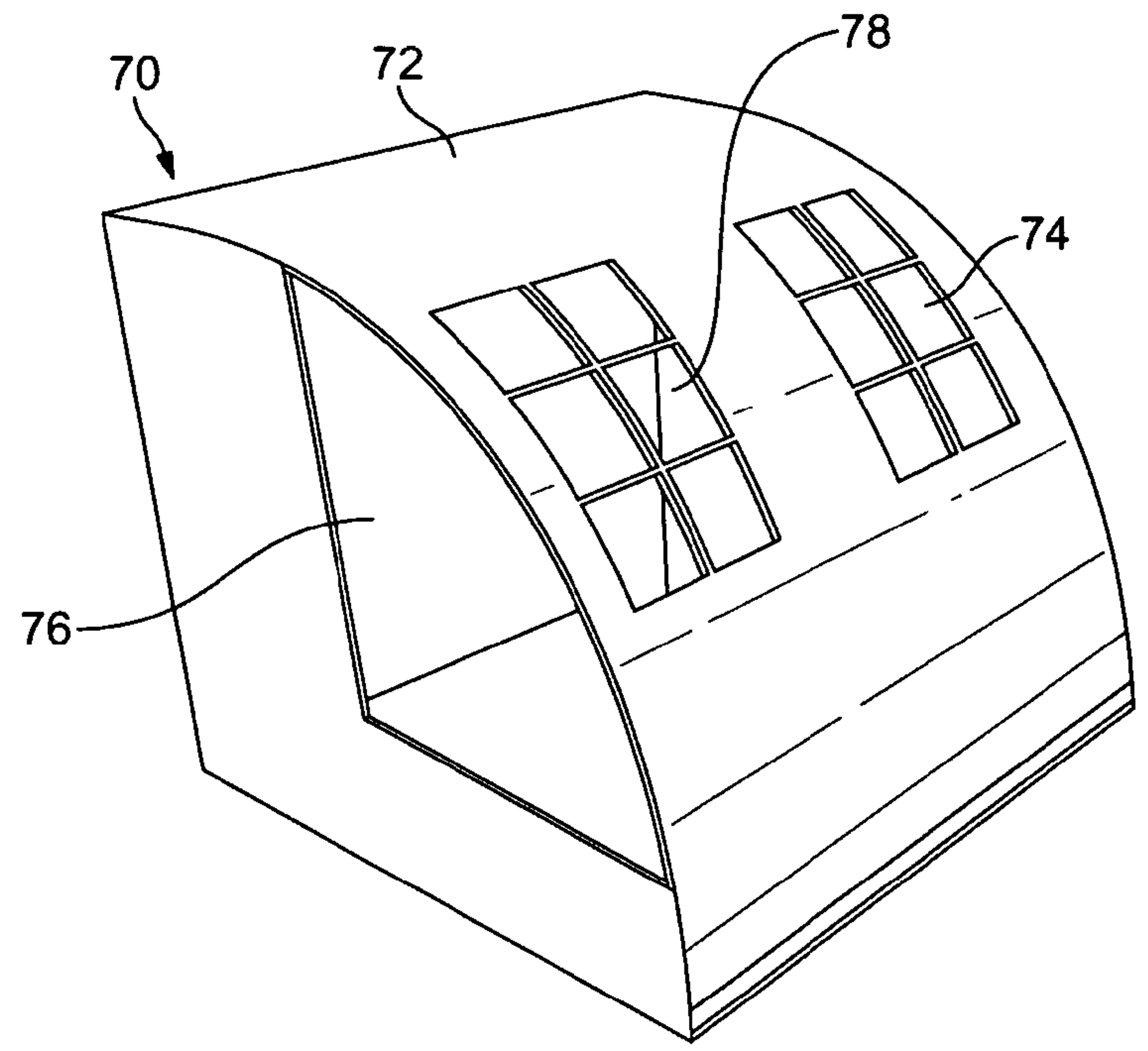


FIG. 7

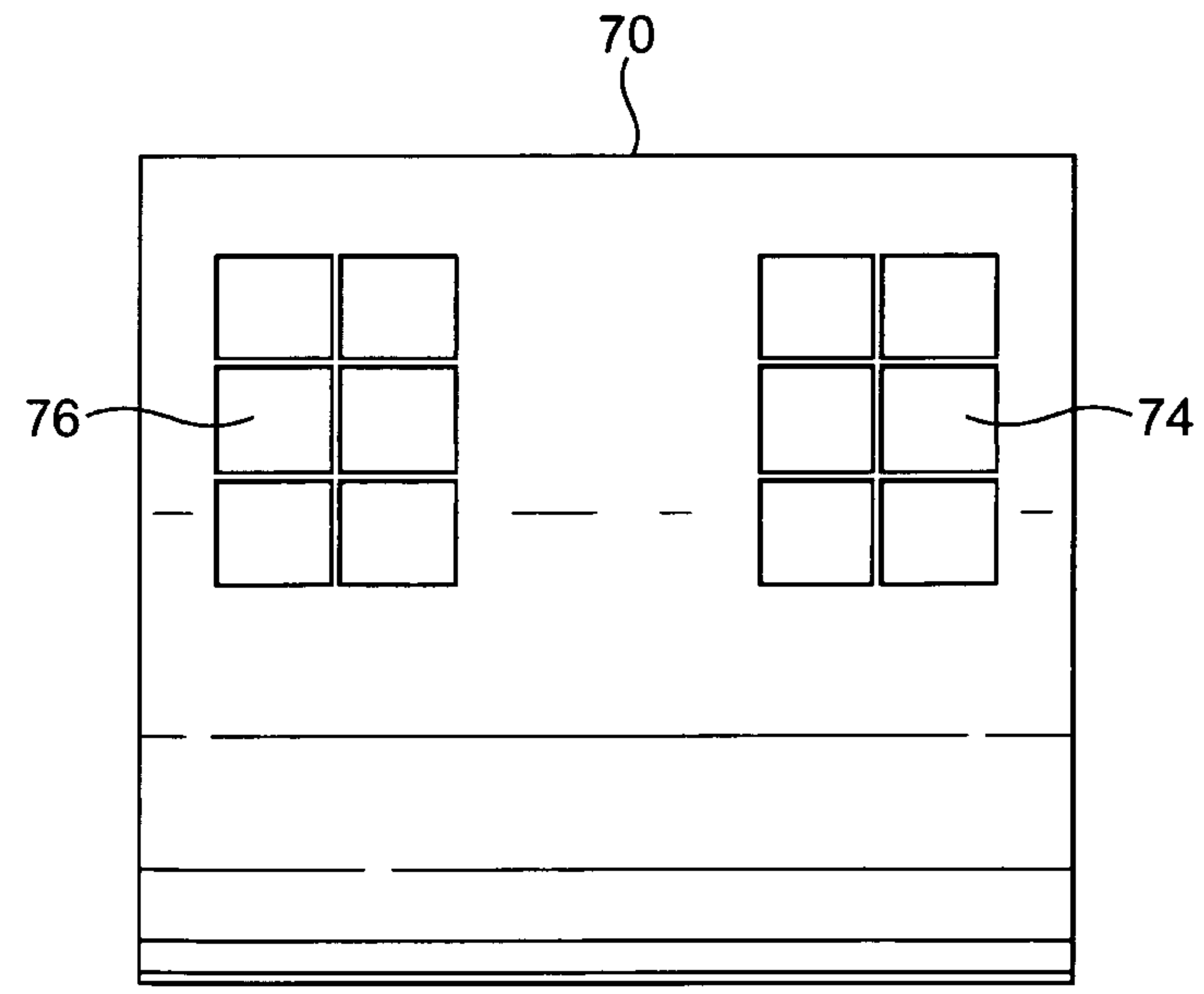


FIG. 8

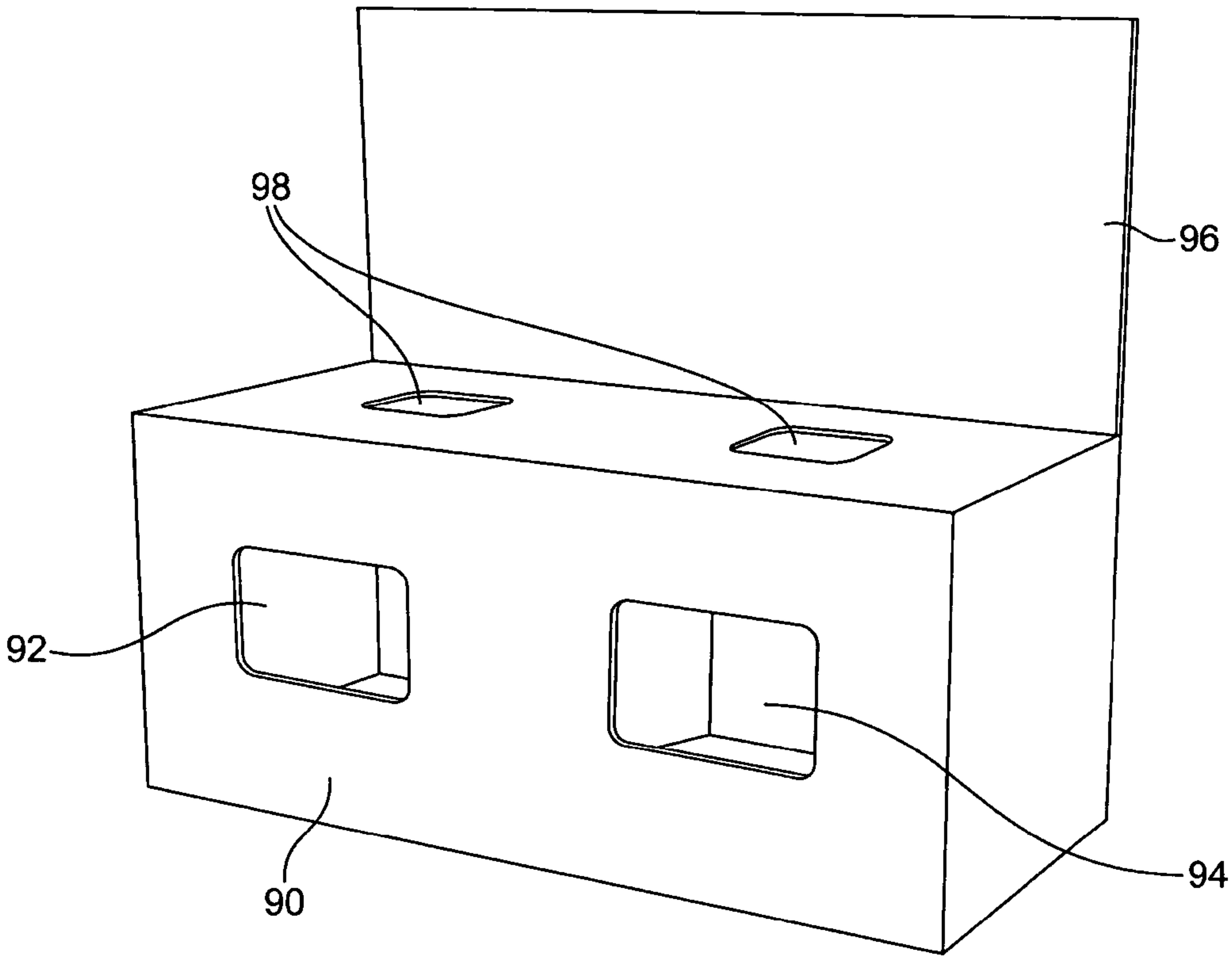


FIG. 9

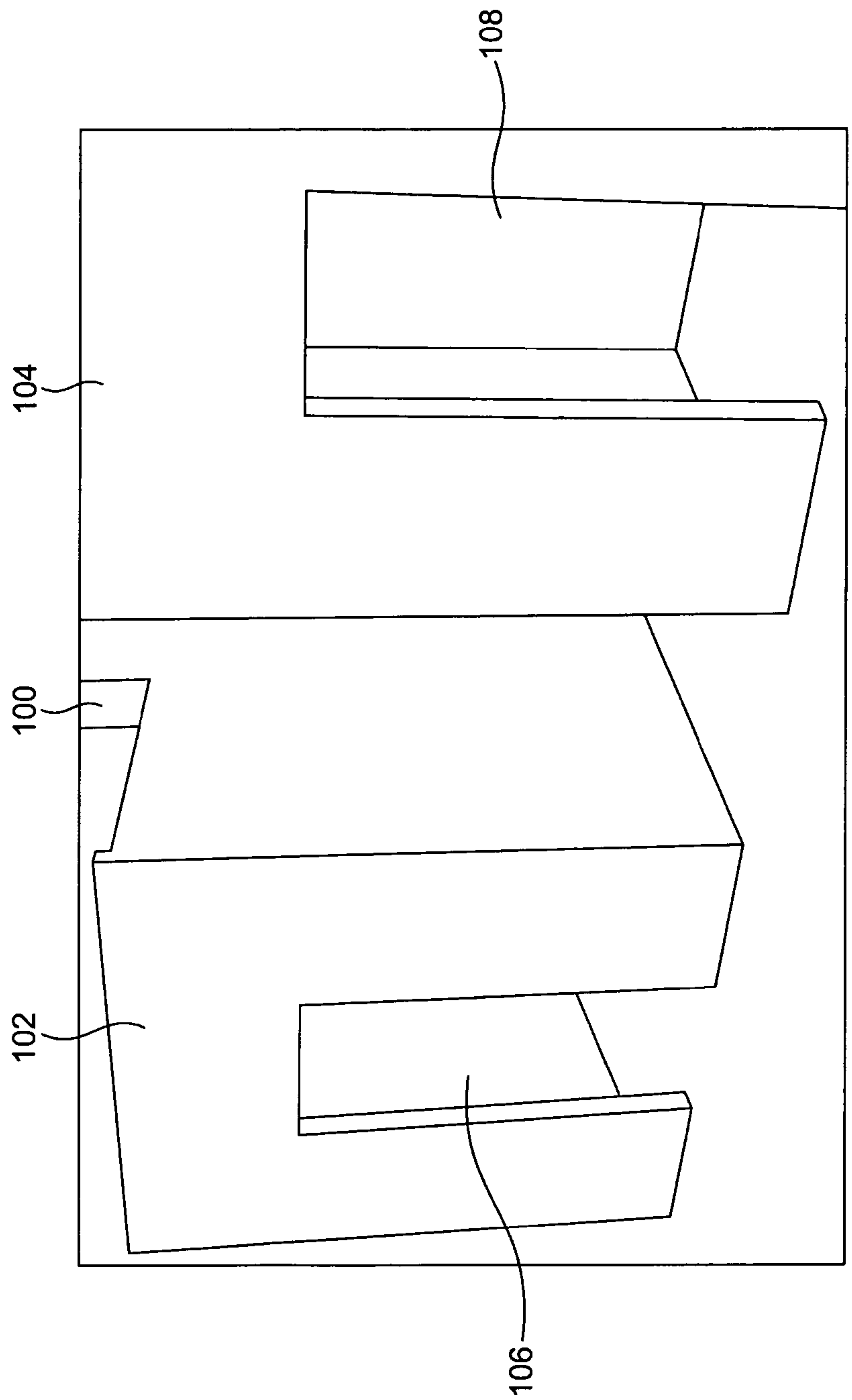
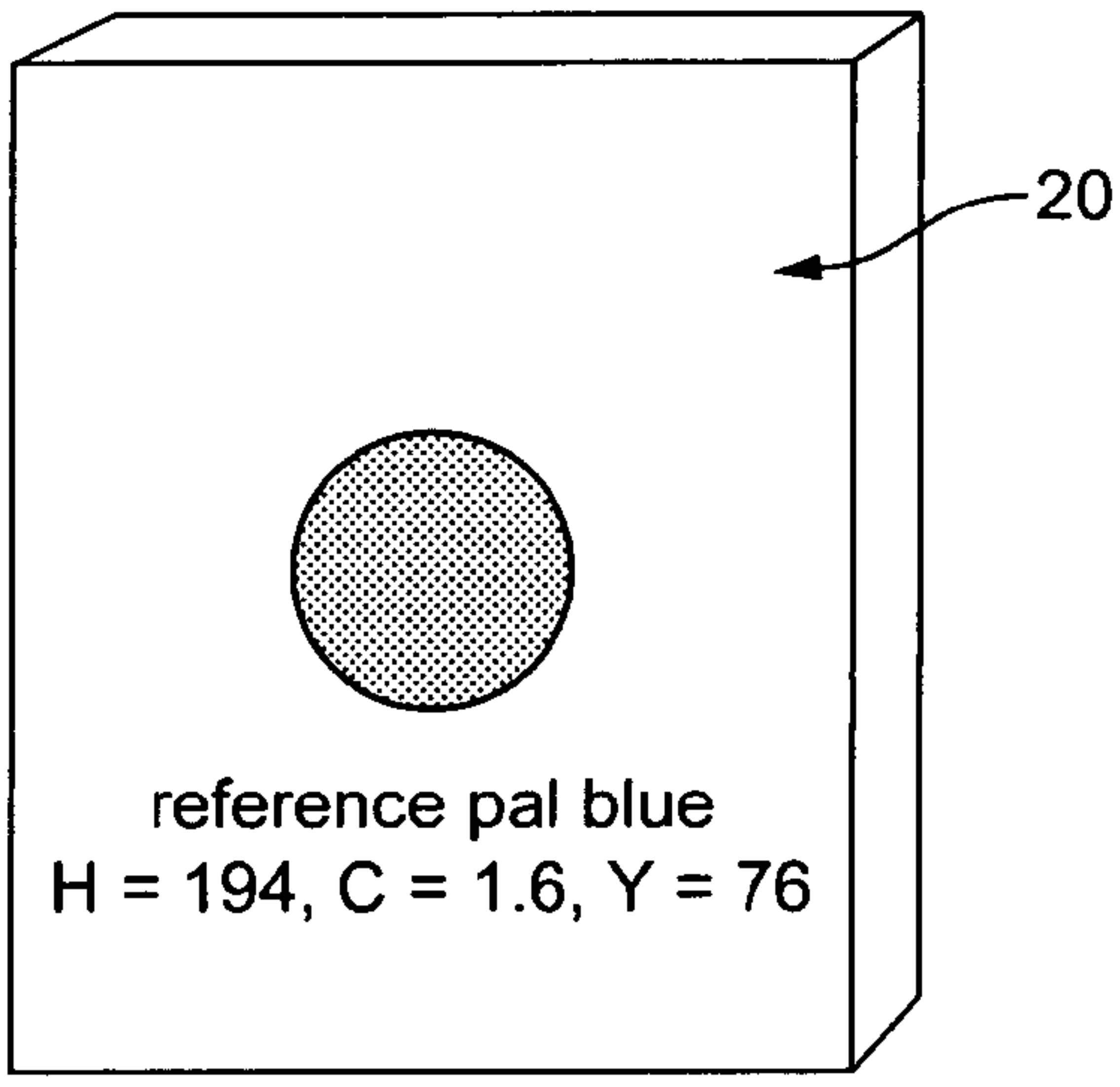
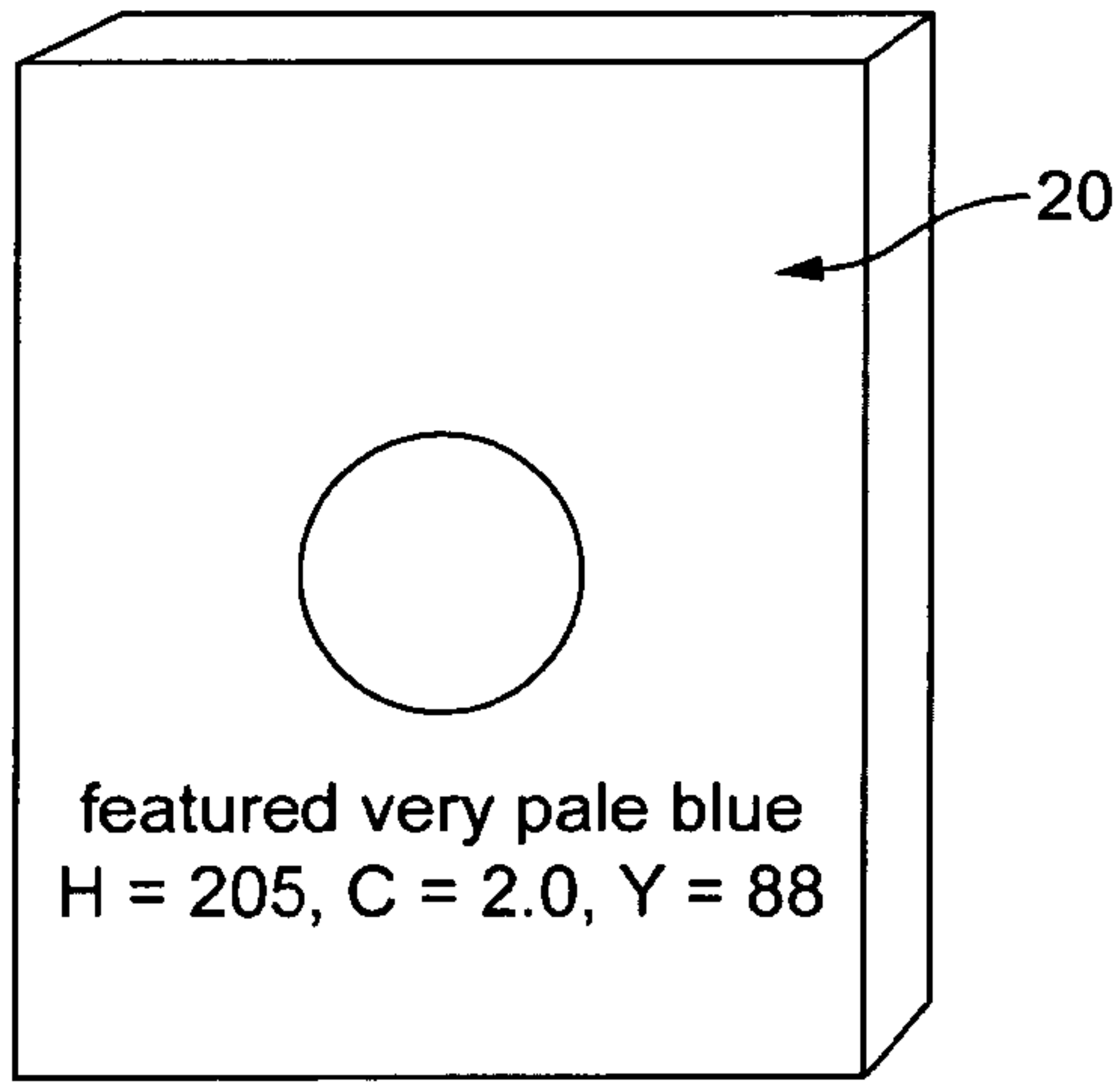


FIG. 10



	L exptl cd/m²	Y exptl	E calc lux
middle rear wall	42.1	76	174
v.pale yellow floor rear left corner	39.0	88	139
white tile rear right corner	49.0	100	154
AVERAGE			**156**



	L exptl cd/m²	Y exptl	E calc lux
middle rear wall	130	88	464
v.pale yellow floor rear left corner	109	88	389
white tile rear right corner	145	100	456
AVERAGE			**436**

FIG. 11

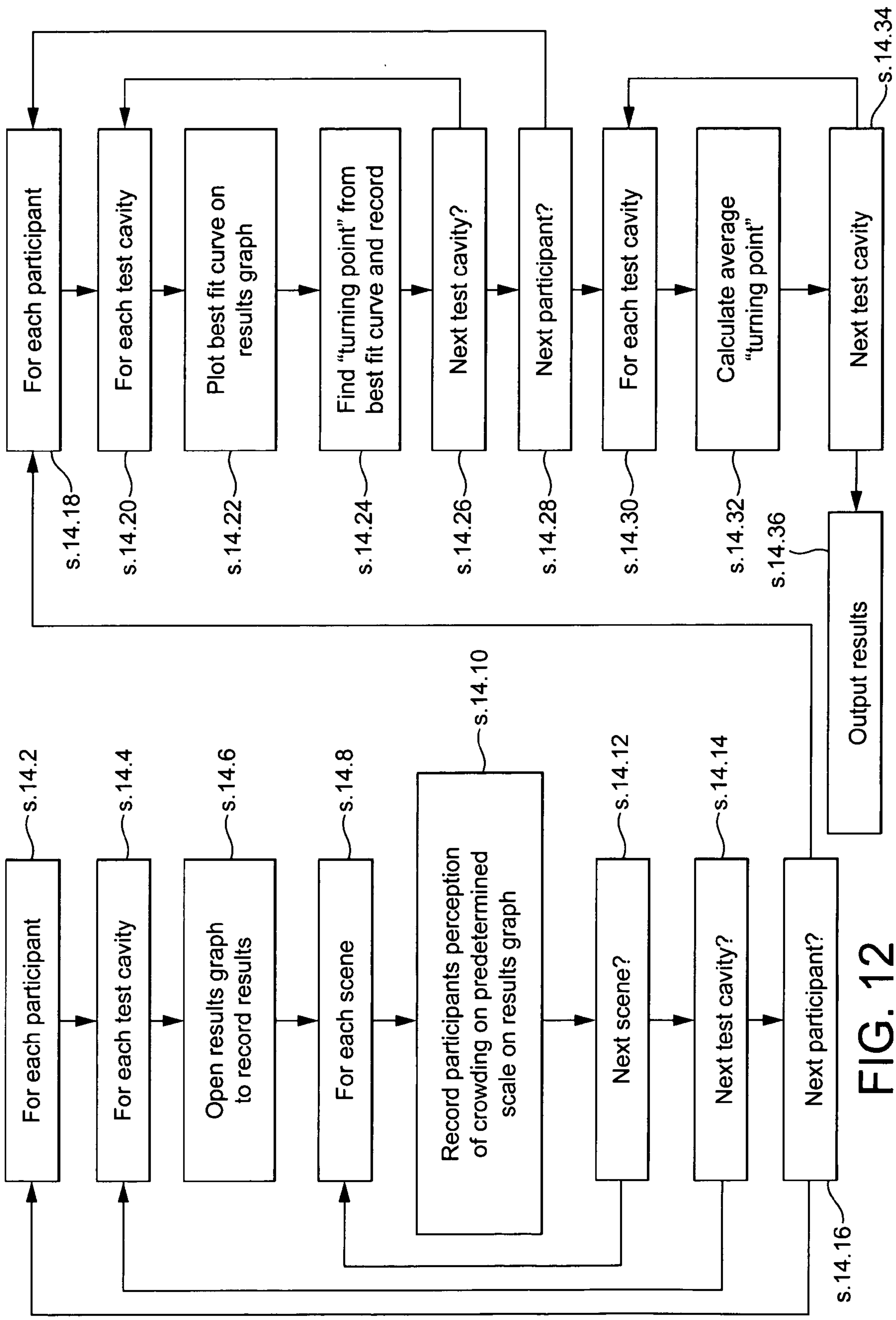

For each participant
s.14.2
For each test cavity
s.14.4
Open results graph to record results
s.14.6
For each scene
s.14.8
Record participants perception of crowding on predetermined scale on results graph
s.14.10
Next scene?
s.14.12
Next test cavity?
s.14.14
Next participant?
s.14.16
For each participant
s.14.18
For each test cavity
s.14.20
Plot best fit curve on results graph
s.14.22
Find "turning point" from best fit curve and record
s.14.24
Next test cavity?
s.14.26
Next participant?
s.14.28
For each test cavity
s.14.30
Calculate average "turning point"
s.14.32
Next test cavity
s.14.34
Output results
s.14.36

FIG. 12

Scene	Dining table	Coffee table	Sofa	Seated figure 1 + chair	Seated figure 2 + chair	Seated figure 3 + chair	Seated figure 4 + chair	Seated figure 5 + chair	Seated figure + arm-chair	Standing figure
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2	✓	✓	✓	✓	✓	✓	✓		✓	✓
3	✓	✓	✓	✓	✓	✓			✓	
4	✓	✓	✓	✓		✓			✓	
5	✓	✓	✓	✓		✓				

FIG. 13

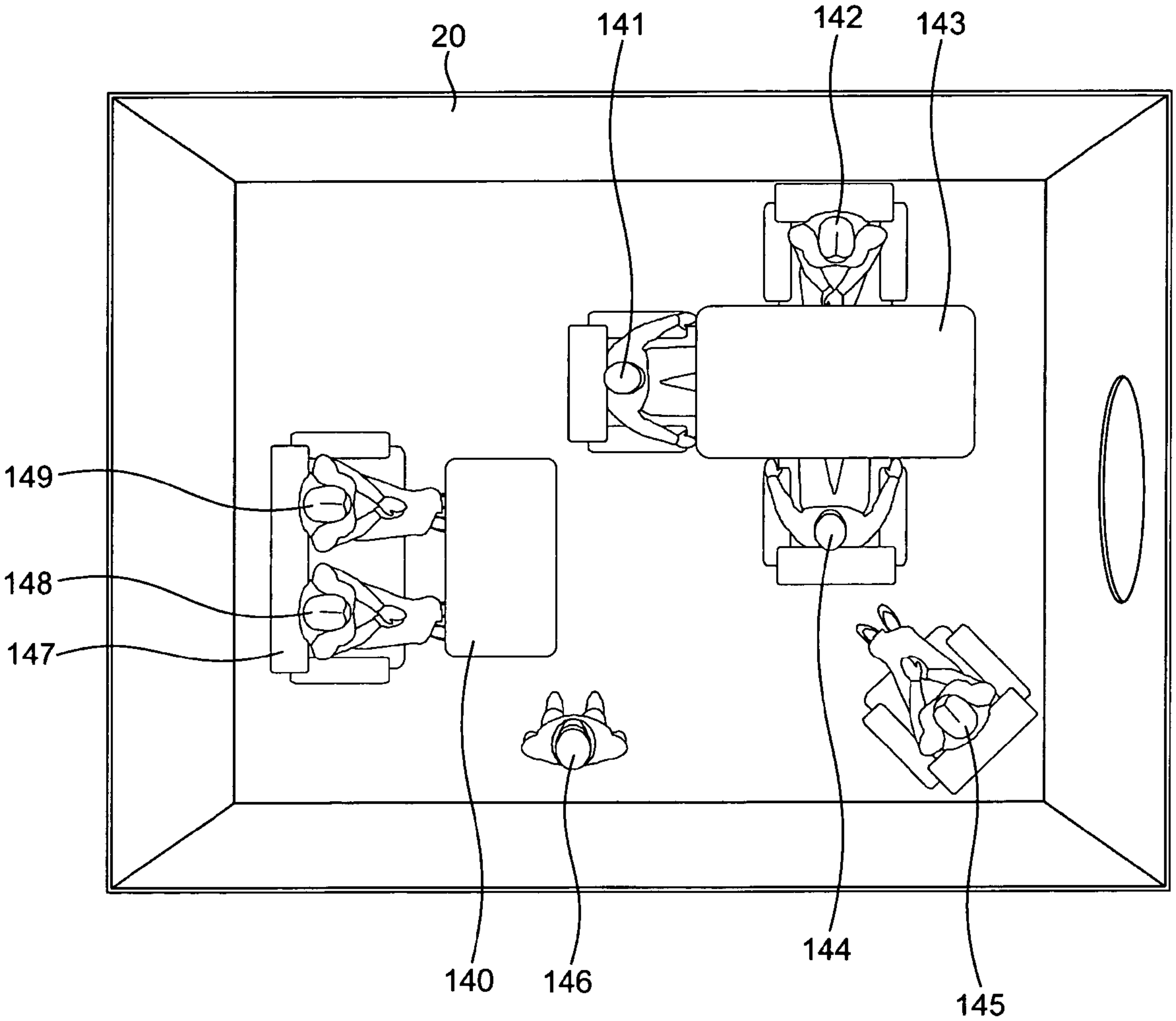


FIG. 14

1 Very spacious	2 Spacious	3 Neither crowded nor spacious	4 Crowded	5 Very crowded

FIG. 15

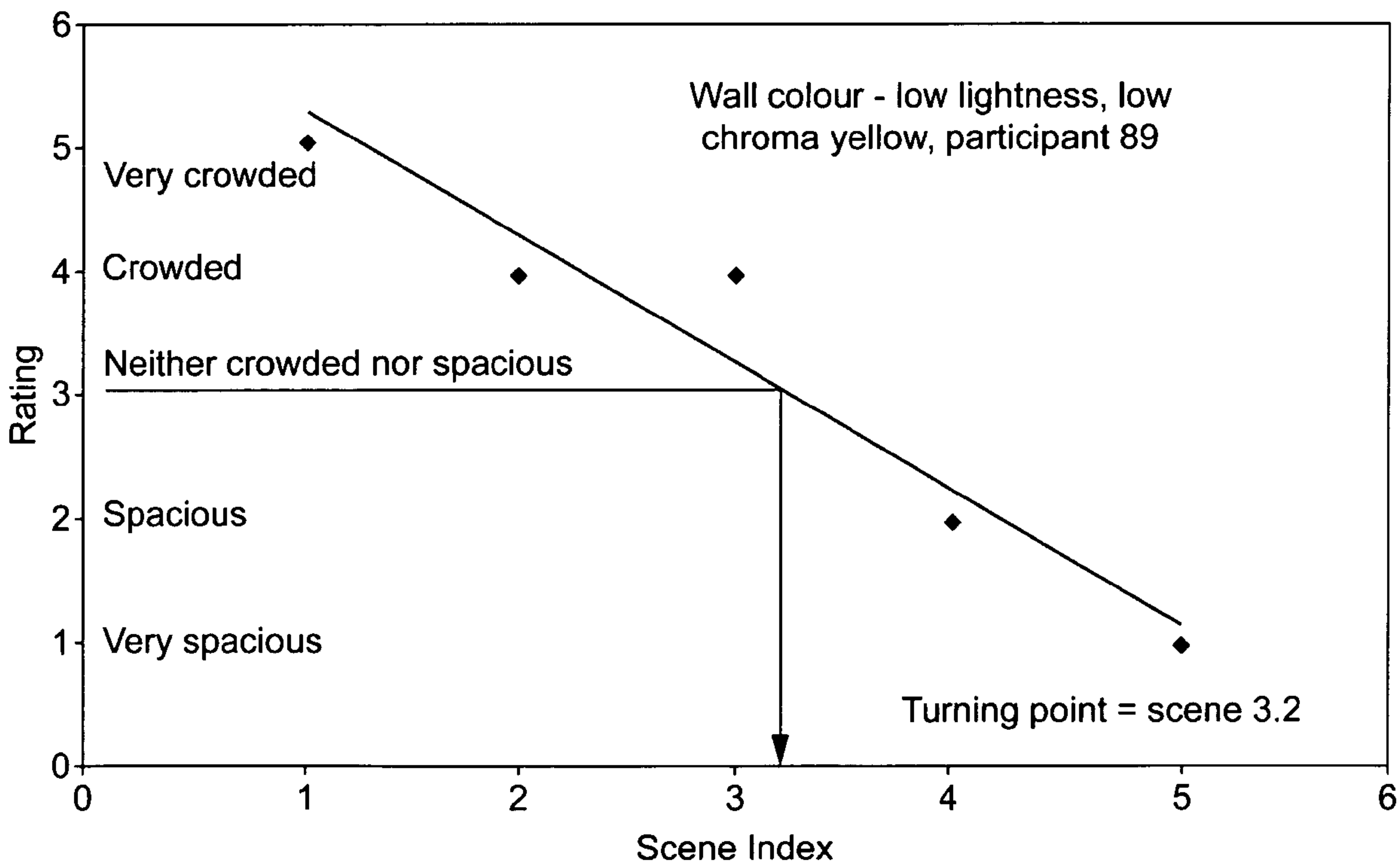


FIG. 16

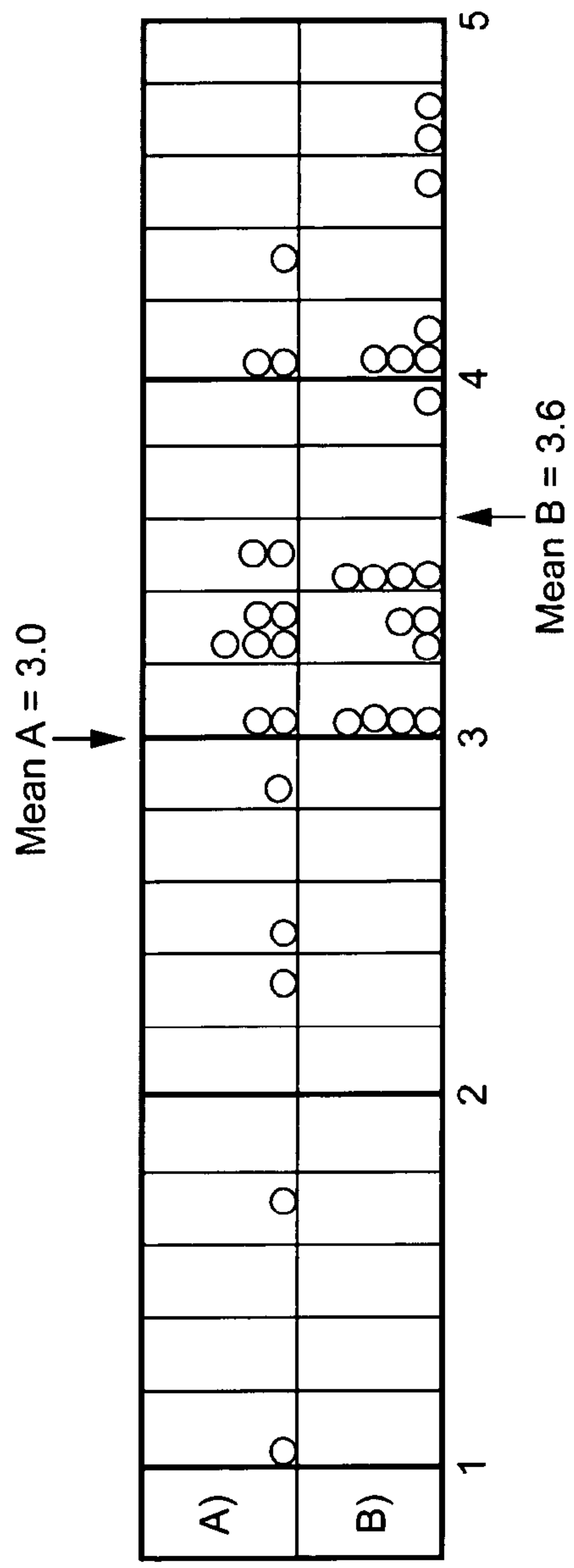


FIG. 17


27
32
27
32
20
20
Colour seen by observer
sRGB 255, 223, 149
Colour seen by observer
sRGB 255, 236, 183
34
34
A - Pale yellow painted walls
(H=80, C=12, LRV=78)
B - Very pale yellow painted walls
(H=83, C=6.3, LRV=88)

FIG. 3