

AUSTRALIA

Patents Act

NON-CONVENTION

623014

APPLICATION FOR A STANDARD PATENT



SECTION 34(4)(a) DIRECTION SEE FOLIO 9
NAME DIRECTED 3D Technology Ltd
hereby Chloplatz 19, 7001 Khar, Switzerland

DISPLAY DEVICE

which is described in the accompanying complete specification.

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DATED this THIRTIETH day of MAY 1990

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By:

David J. Fitzpatrick

Our Ref : 175914
POF Code: 1649/11778

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DECLARATION FOR A PATENT APPLICATION

▼ INSTRUCTIONS

(a) Insert "Convention" if applicable
(b) Insert FULL name(s) of applicant(s)

(c) Insert "of addition" if applicable
(d) Insert TITLE of invention

(e) Insert FULL name(s) AND address(es) of declarant(s) (See headnote*)

(f) Insert FULL name(s) AND address(es) of actual inventor(s)

(g) Recite how applicant(s) derive(s) title from actual inventor(s) (See headnote**)

(h) Insert country, filing date, and basic applicant(s) for the/or EACH basic application

(k) Insert PLACE of signing

(l) Insert DATE of signing

(m) Signature(s) of declarant(s)

Note: No legalization or other witness required

In support of the (a) non-convention application made by
(b) Screenform Inc., 165 Ontario Street, Kingston, Ontario, Canada, K7L 2Y6

(hereinafter called "applicant(s) for a patent (c) for an
invention entitled (d) Display Device

I/We (e) John Davidson
Title: **PRESIDENT** of Screenform Inc.: 165 Ontario Street,
Kingston, Ontario, Canada K7L 2Y6

do solemnly and sincerely declare as follows:

1. ~~I am/We are the applicant(s).~~
(or, in the case of an application by a body corporate)
1. I am/We are authorized to make this declaration on behalf of the applicant(s).
2. ~~I am/We are the actual inventor(s) of the invention.~~
(or, where the applicant(s) is/are not the actual inventor(s))
2. (f) John Davidson, 326 King Street East, Apartment 2, Kingston, Ontario
Canada, K7L 3B4 and
Geoffrey Davidson, 81 King Street East, Apartment 3, Kingston,
Ontario, Canada, K7L 2Z6

is/are the actual inventor(s) of the invention and the facts upon which the applicant(s)
is/are entitled to make the application are as follows:

- (g) Applicant is the assignee of the invention from the actual inventor

(Note: Paragraphs 3 and 4 apply only to Convention applications)

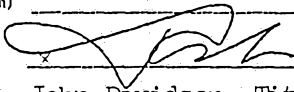
~~3. The basic application(s) for patent or similar protection on which the application is based
is/are identified by country, filing date, and basic applicant(s) as follows:~~

- (h) Not Applicable

~~4. The basic application(s) referred to in paragraph 3 hereof was/were the first application(s)
made in a Convention country in respect of the invention the subject of the application.~~

Declared at (k) Toronto, Ontario

Dated (l) May 23, 1990

(m) 

John Davidson Title: **PRESIDENT**

To: The Commissioner of Patents

(54) Title
DISPLAY DEVICE

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(57) Claim

1. A process for creating a three-dimensional display device, comprising the steps of:

a) photographing multiple perspective views of a three-dimensional object using a plurality of cameras oriented at respective predetermined positions relative to one another and to said object;

b) projecting said multiple perspective views of said object onto a plane work surface using a plurality of projectors oriented at said respective predetermined positions, thereby recreating a three-dimensional image of said object;

c) raising a three-dimensional topographic mold on said work surface for matching exactly said ^{three-dimensional} ~~projected~~ image;

d) thermoforming a first sheet of thermoformable plastic over said mold, said sheet having a first grid pattern on ^a ~~the~~ surface thereof, whereby in the step of thermoforming said grid pattern becomes distorted as a result of stretching and vertical displacement of the grid pattern over said mold;

e) projecting said multiple perspective views of said object onto said first sheet of thermoformable plastic using said plurality of projectors oriented at said respective predetermined positions, thereby recreating said three-dimensional image superimposed on top of said distorted grid pattern;

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(10) 623014

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f) translating said three-dimensional image from said distorted grid pattern onto a second two-dimensional undistorted grid pattern, whereby during translation said image becomes predistorted;

g) transferring said predistorted image from said two-dimensional undistorted grid pattern onto one or more additional sheets of thermoformable plastic; and

h) thermoforming successive ones of said additional sheets over said mold for creating said three-dimensional display device.

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COMPLETE SPECIFICATION

(ORIGINAL)

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Lodged:

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Complete Specification for the invention entitled:

DISPLAY DEVICE

The following statement is a full description of this invention, including the best method of performing it known to applicant(s):

DISPLAY DEVICE~~Field of the Invention~~

The present invention relates in general to display devices, and more particularly to a method for creating
5 a display device having a three-dimension appearance to provide a striking visual effect.

~~Background of the Invention~~

Advertising displays and posters often bear photographic reproduction of an object or objects
10 offered for sale in a two-dimensional appearance. Such advertising displays and posters may be suitable for point of purchase displays, bill-boards, mall displays or home display, etc.

To a limited extent, thermoforming technology has
15 been used in the past in conjunction with photographic imaging for creating bas-relief three-dimension displays. However, the results have been unimpressive due to distortion involved in translating from a two-dimensional image to a three-dimensional object, and
20 vice versa.

There are three major forms of distortion that occur when a two-dimensional image derived from a single (primary) point of view is thermoformed over a three-dimensional topography. Of these three types of
25 distortion, only one has been partially addressed by currently available technology. The effects of stretch and flow upon lettering colour boundaries, as plastic is thermoformed over a topographic mold is known in the prior art and has been partially corrected for a number
30 of years. However, the method of such correction has not been found to be sufficiently accurate for creating detailed three-dimensional display devices.

Furthermore, two other forms of distortion are equally important to the process of translating from two to
35 three-dimensions, especially when incorporating a



photographic rather than purely graphic image into a three-dimensional thermoform.

The second major form of distortion is known as parallax distortion or shadowing, and occurs when areas of a three-dimensional object cannot be recorded on a two-dimensional photograph because the line of sight from the primary point of view is obstructed by some portion of the object. After vacuum forming of the two-dimensional image over the three-dimensional mold, these areas of the final image are filled with information from adjacent regions by stretching of the thermoformable plastic sheet, resulting in a severe form of distortion.

The third major form of distortion is known as foreshortening, and occurs when areas of the three-dimensional object which are at an acute angle to the primary point of view are visually compressed and photographed onto a two-dimensional film. When the resulting image is vacuum formed over a topographic mold, the visually compressed information is not large enough to fill the topographic area from which it was derived, even taking into account the stretch and flow distortion which occurs in these areas.

Traditionally, the above discussed problems have been overcome by one of two methods. The effects of foreshortening and parallax distortion have been minimized by decreasing the amount of relief of the three-dimensional mold so that areas of sharp vertical relief, where the distortion is greatest, are substantially reduced. The effects of stretching on the contours and location of embossed lettering and simple colour boundaries have been overcome in the prior art by plotting the location of the lettering and other details on a blank sheet that has been thermoformed over a topographic mold. The sheet is then thermally

flattened and the resulting distorted contours and locations are plotted using an overlay grid.

The present invention may provide a method for extending and improving the prior art basic techniques for
5 correcting distortion by projecting multiple perspective photographic views of the original three-dimensional object onto a topographically correct surface. This may allow the resulting vacuum formed image to have the full relief of the original object with all visual information
10 in its correct location and with little or no distortion.

According to one aspect of the present invention there is provided a process for creating a three-dimensional display device, comprising the steps of:

a) photographing multiple perspective views of a
15 three-dimensional object using a plurality of cameras oriented at respective predetermined positions relative to one another and to said object;

b) projecting said multiple perspective views of said object onto a plane work surface using a plurality of
20 projectors oriented at said respective predetermined positions, thereby recreating a three-dimensional image of said object;

c) raising a three-dimensional topographic mold on said work surface for matching exactly said
25 three-dimensional image;

d) thermoforming a first sheet of thermoformable plastic over said mold, said sheet having a first grid pattern on a surface thereof, whereby in the step of thermoforming said grid pattern becomes distorted as a
30 result of stretching and vertical displacement of the grid pattern over said mold;

e) projecting said multiple perspective views of said object onto said first sheet of thermoformable plastic using said plurality of projectors oriented at
35 said respective predetermined positions, thereby recreating said three-dimensional image superimposed on top of said distorted grid pattern;

f) translating said three-dimensional image from



said distorted grid pattern onto a second two-dimensional undistorted grid pattern, whereby during translation said image becomes predistorted;

g) transferring said predistorted image from said
5 two-dimensional undistorted grid pattern onto one or more additional sheets of thermoformable plastic; and

h) thermoforming successive ones of said additional sheets over said mold for creating said three-dimensional display device.

10 According to a further aspect of the present invention there is provided a process for creating a three-dimensional display device, comprising the steps of:

a) photographing multiple perspective views of a
15 three-dimensional object using a plurality of cameras oriented at respective predetermined positions relative to one another and to said object;

b) projecting said multiple perspective views of
20 said object onto a plane work surface using a plurality of projectors oriented at said respective predetermined positions, thereby recreating a three-dimensional image of said object;

c) raising a three-dimensional topographic mold on
said work surface for matching exactly said three-dimensional image;

25 d) coating a heat resistant positive photo emulsion onto a translucent sheet of thermoformable plastic;

e) thermoforming said sheet over said mold;

f) projecting said multiple perspective views of
30 said object onto said photo emulsion coated sheet of thermoformable plastic using said plurality of projectors oriented at said respective predetermined positions, thereby exposing said photo emulsion with said three-dimensional image; and

g) developing said photo emulsion for producing
35 said three-dimensional display device.

According to a still further aspect of the present invention there is provided a process for creating a three-dimensional display device, comprising the steps of:



a) photographing multiple perspective views of a three-dimensional object using a plurality of cameras oriented at respective predetermined positions relative to one another and to said object;

5 b) projecting said multiple perspective views of said object onto a plane work surface using a plurality of projectors oriented at said respective predetermined positions, thereby recreating a three-dimensional image of said object;

10 c) raising a three-dimensional topographic mold on said work surface for matching exactly said three dimensional image;

d) coating a heat resistant negative photo emulsion onto a translucent sheet of thermoformable plastic;

15 e) thermoforming said sheet over said mold;

f) projecting said multiple perspective views of said object onto said photo emulsion coated sheet of thermoformable plastic using said plurality of projectors oriented at said respective predetermined positions, thereby exposing said photo emulsion with said three-dimensional image;

20 g) developing said photo emulsion for producing a negative of said image on said sheet;

h) flattening said sheet and negative of said image for producing a predistorted negative of said image;

25 i) printing from said predistorted negative images on one or more additional sheets of thermoformable plastic; and

30 j) thermoforming said one or more additional sheets over said mold for creating said display device.

According to a still further aspect of the present invention there is provided a display device comprising a sheet of thermoformable plastic having a three-dimensional topographic surface representing a three-dimensional object, and a predistorted two-dimensional image applied to said topographic surface for depicting said object, wherein said image is created by photographing multiple perspective views of said object, projecting said multiple



perspective views on a three-dimensional topographic mold,
and translating said image from a three-dimensional
representation as projected on said mold to a
two-dimensional representation thereby pre-distorting said
5 image, the two-dimensional representation of the image
being predistorted so as to eliminate the effects of
stretch and flow of said plastic sheet during
thermoforming as well as the effects of parallax and
foreshortening.

10 According to a still further aspect of the present
invention there is provided a three-dimensional display
device for displaying a three-dimensional image of a
three-dimensional object having an irregular topographic
surface and visible surface features distributed over
15 various surface portions of the object positioned at
various angles to a work surface defining a reference
plane, the display device comprising:

means defining a three-dimensional topographical
display surface substantially replicating the irregular
20 topographic surface of the three-dimensional object,
including first and second surface portions oriented at
first and second angles, respectively, to said reference
plane; and

a composite photographic image on the display
25 surface, the composite photographic image including:

a first perspective image portion forming a visible
replica of a first visible surface feature of the object
on the first surface portion; and

a second perspective image portion forming a visible
30 replica of a second visible surface feature of the object
on the second surface portion;

each image portion displaying the visible surface
features such that the composite image on the display
surface creates the visual effect of viewing the three-
35 dimensional object in perspective.

According to a still further aspect of the present
invention there is provided a two-dimensional intermediate
transparency for use in making a three-dimensional display



of a three-dimensional object having a topographic surface and visible surface features distributed over portions of the surface of the object positioned at various angles to a work surface defining a reference plane, the intermediate transparency comprising:

a two-dimensional thermoformable translucent plastic sheet having a flat surface and formable in a third dimension to define a three-dimensional topographical display surface substantially replicating the topographic surface of the three-dimensional object; and

a predistorted, composite image formed on the surface of the two-dimensional plastic sheet, the composite image including a first image portion on a first surface portion of the sheet and a second image portion on a second surface portion of the sheet;

the first image portion being a true, substantially untransformed image of the visible surface features of a first surface portion of the object lying approximately parallel to the reference plane;

the second image portion being a transformed image of the visible surface features of a second surface portion of the object lying at an angle to the reference plane sufficient to be subject to foreshortening or parallax when the object is viewed normal to the reference plane;

the transformed second image portion being compressed laterally of the surface of the sheet in a transformation having a direction and quantity determined by the topographic surface of the three-dimensional object including said angle, so that forming the sheet in said third dimension to form said three-dimensional topographical display surface decompresses the transformed second image portion to substantially replicate the visible surface features of the second surface portion of the object on a corresponding portion of the display surface without foreshortening or parallax.

According to a still further aspect of the present invention there is provided a system for making a



three-dimensional display of a three-dimensional object having a topographic surface and visible surface features distributed over various surface portions of the object, the system comprising:

5 a primary camera directed at the object at a first viewing angle so as to view a first surface portion of the object at a first angle and a second surface portion at a second angle, the second angle being smaller than the first angle so that the surface features of the second
10 surface portion are subject to foreshortening or parallax as viewed by the primary camera, the camera forming a first perspective image of the object including at least said first surface portion viewed at said first angle;

15 a second camera directed at the object at a second viewing angle so as to view the second surface portion of the object at a third angle greater than said second angle so that the surface features of the second surface portion are subject to less foreshortening or parallax than when such portion is viewed by the primary camera, the camera
20 forming a second perspective image of the object including at least said second surface portion viewed at said third angle;

25 a topographical mold having display surface substantially replicating the topographic surface of the three-dimensional object, including first and second display surface portions replicating the topography of the first and second portions, respectively of the object;

primary and secondary projectors for projecting the first and second images, respectively, onto the first and
30 second surface portions of the display surface at angles congruent to the viewing angles of said cameras, the projected images including a first image portion projected onto the first display surface portion defined by the first perspective image and a second image portion
35 projected onto the second display surface portion defined by the second perspective image, thereby substantially replicating the visible surface features of the object on the display surface.



A preferred embodiment of the present invention will be described in greater detail below with reference to the accompanying drawings in which:

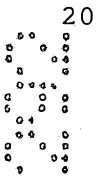
Figure 1 is a cross section of a three-dimensional object showing locations of graphic details;

Figure 2 is a cross sectional schematic showing a two-dimensional photographic image of the three-dimensional object in Figure 1 taken from three different perspective views;

Figure 3 is a cross sectional schematic showing the multiple two-dimensional images from Figure 2 projected back onto a topographically correct mold of the original three-dimensional object shown in Figure 1;



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Figures 4a and 4b show a cross section view and plan view respectively of an arrangement for photographing multiple perspective views of a three-dimensional object in accordance with the preferred embodiment;

Figures 5a and 5b are cross-sectional and plan views showing an arrangement for projecting multiple perspective views of the three-dimensional objects onto a work surface for the purpose of constructing a topographical mold, in accordance with the preferred embodiment;

Figures 6a and 6b show two steps for thermoforming plastic sheet over the topographical mold;

Figures 7a and 7b are cross section and plan views respectively of apparatus for projecting perspective views of an original object onto a thermoformed plastic grid in accordance with the preferred embodiment;

Figure 8 is a plan view of a distorted two-dimensional image produced by plotting an undistorted three-dimensional projection point by point onto an undistorted grid pattern in accordance with the preferred embodiment;

Figure 9 is a schematic illustration of a device for coating photo emulsion onto a thermoformable plastic sheet in accordance with an alternative embodiment of the present invention;

Figure 10 is a schematic illustration of a device used to laminate a coating onto a thermoformable plastic sheet coated with photo emulsion in accordance with the alternative embodiment;

Figure 11 is a cross sectional schematic of apparatus for projecting perspective views of an original object onto an emulsion coated thermoformed plastic sheet in accordance with the alternative embodiment; and

Figures 12a and 12b are cross sectional views of apparatus for thermal flattening a plastic sheet over a flat surface.

~~Detailed Description of the Preferred Embodiment~~

5 Turning to Figure 1, a cross section of a three-dimensional object 1 is illustrated showing the location of graphic details provided by surfaces 3 and 5 which are fully visible from above and surfaces 7 which become compressed when viewed from above. The regions 5
10 and 7 of object 1 produce both parallax and foreshortening in a two-dimensional image taken from an orthogonal point of view, as discussed above with reference to the Background of the Invention.

Turning to Figure 2, a cross sectional schematic
15 is illustrated showing two-dimensional photographic images of the three-dimensional object 1 taken from three different perspective views by means of lenses 9, 11 and 13. The respective photographic images are depicted as 15, 17 and 19. The arrows 21 show light
20 paths through the lenses 9-13. It will be noted that the photographic images 15, 17 and 19 each exhibit parallax and foreshortening distortions, but in different locations and to differing degrees in accordance with respective perspective views of the
25 object 1.

Turning to Figure 3, a cross sectional schematic is illustrated showing the multiple two-dimensional images 15, 17 and 19 projected back onto an accurate
topographical mold 21 of the three-dimensional object 1
30 (Figure 1). In this respect, projectors 23, 25 and 27 are provided for projecting the images 15, 17 and 18 through lenses 9, 11 and 13 thereby recreating the three-dimensional image on the topographic surface 21. It will be noted that all graphic details 3, 5 and 7
35 project back to their correct locations without distortions.



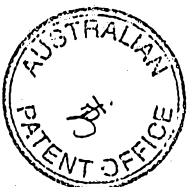
The invention will now be described in greater detail with reference to a preferred embodiment thereof. Turning to Figures 4a and 4b, multiple perspective views of a three-dimensional object 41 on a horizontal surface 40 are photographed via primary perspective camera 42 shown in Figure 4a, and secondary cameras 43-46 positioned at 45° to the line of sight of primary camera 42 and positioned at four compass point locations relative to the primary camera 42. Camera 42 is not shown in Figure 4b for ease of illustration.

The congruency symbols on the lines of sight depicted in Figures 4a and 4b indicate that the cameras 42-46 are at fixed distances and predetermined angles relative to the three-dimensional object 41. In the illustrated preferred embodiment, angles of 45°, 90° and 135° are shown. However, in practice, the number, distance, and angles of the cameras may be determined by the size and three-dimensional complexity of the object. Once determined, the exact camera and object positions are fixed and recorded.

Thus, as discussed above with reference to Figure 2, the multiple cameras 42-46 photograph the object 41 so as to provide multiple two-dimensional perspective views of the object.

Next, the aforementioned multiple two-dimensional perspective views of the object are projected onto the work surface 40 with the object 41 removed, as shown in Figures 5a and 5b. In this respect, a primary projector 51 and secondary projectors 52, 53, 54 and 55 are configured using matched optics and the original predetermined angles and distances from which the views derived from cameras 42-46 in Figure 4b.

A topographic mold 56 (dashed outline) of the three-dimensional object is then raised or created on the work surface 40 to match the projected views exactly. The mold 56 can be created by hand or more



practically from a cast (e.g. plaster cast) taken of the original object 41.

5 All optics, distances and angles of the projectors 51-55 are matched exactly to the configuration of cameras used to photograph the multiple perspective views in Figures 4a and 4b.

10 Once the topographic mold 56 has been built to match the projected views, and in the event the photographic image includes a perspective background with greater depth than may be achieved by thermoforming limits, the topographic mold 56 can be modified to include bas-relief perspective by flattening the relief in the background and opening up the perspective angles, using the primary point of view projection from projector 51 as a main reference and the secondary
15 (i.e. 45°) projections from projectors 52-55 for regions with missing information caused by line of sight obstructions relative to the primary point of view.

20 Next, a sheet of thermoformable plastic is thermoformed over the mold as shown with reference to Figures 6a and 6b. In particular, a thermoformable plastic sheet 61 is formed over topographic mold 56 by means of a thermoforming apparatus designated generally as 62. The thermoforming system 62 includes a heater
25 63, a hydraulically operated mold lifting surface 64 for supporting the topographic mold, a vacuum pump 65 and vacuum seals 66, all constructed in accordance with well known prior art.

30 Although not shown in Figures 6a and 6b, the thermoformable plastic sheet 61 is printed with a grid pattern or rectangular array of symbols, (Figure 7b) which distorts due to stretching and flow of the plastic sheet, as is well known.

35 The perspective views of the original object are then projected onto the thermoformed grid sheet 61 using the same optical arrangement as discussed above

with reference to Figures 5a and 5b, as depicted in Figures 7a and 7b. This produces an undistorted, three-dimensional image with a superimposed distorted grid pattern, as designated by reference numeral 71 in Figure 7b. The distortion of the grid pattern is caused by both stretching of the plastic during thermoforming (as discussed above) and vertical displacement of the grid pattern from the horizontal plane during thermoforming.

5 Next, the image 71 is transferred (point by point relative to the distorted grid pattern on sheet 61) to a regular (i.e. undistorted) two-dimensional grid surface 80. This results in a predistorted image 81 superimposed on regular grid pattern 80.

10 This image transference may be accomplished by several means.

15 According to one approach, numbered coordinates may be assigned to each point detail on the projected three-dimensional surface 71, and then carefully plotted or painted onto the two-dimensional reference grid 80. 20 Using this plot, the predistorted image may be printed onto a thermoformable plastic sheet and then thermoformed over the topographic mold 56 using the apparatus discussed above with reference to Figures 6a and 6b. The end result is a three-dimensional image 25 (i.e. display device) which is identical to the original object 41 (Figures 4a and 4b).

30 According^{to} a second approach, a video scanner (not shown) may be connected to the cameras 42-46 (Figures 4a and 4b) for scanning and digitizing the multiple views of the object 41 into a computer. Multiple views of the thermoformed grid 61 may then be photographed and digitized using the configuration of cameras as shown in Figures 7a and 7b with the same angles, distances and matched optics used to produce the original multiple 35 photographic views. Next, from an identical set-up,



photographs of the undistorted grid 80 ^{may} ~~be~~ be scanned and digitized.

Using one perspective view at a time, and a coordinate approach, the computer can then generate movement vectors for each point on the distorted grid 61, to superimpose it onto the matching point on the undistorted grid 80 scanned from the same perspective. The computer can then produce movement vectors to correct each of the original scanned perspective views of the object on a pixel by pixel basis to their new positions on the scanned regular array 80. Each of these corrected images will be exactly the same except for areas where information is missing because of obstructions in the line of sight of each view. These multiple views are then combined to fill in the blank areas or missing information.

The resulting predistorted two-dimensional computerized image may then be printed onto a thermoformable plastic sheet and then thermoformed over the original topographic mold 56 as shown with the apparatus of Figures 6a and 6b.

According to a first alternative embodiment of the present invention, multiple perspective views of the object 41 are photographed using the matched optics from predetermined angles and distances as discussed above with reference to Figures 4a and 4b. As with the preferred embodiment discussed above, the number and positions of the cameras 42-46 are determined by the complexity of the three-dimensional object 41. Multiple perspective views are then projected back onto the work surface 40 using matched optics and the original angles and distances as discussed with reference to Figures 5a and 5b, and topographic mold 56 of the three-dimensional object is created to match the projected views, as discussed above.



However, in accordance with the alternative embodiment, a heat resistant photoemulsion is then coated onto an optically clear thermoformable material, such as a translucent sheet of thermoformable plastic 91, as shown in Figure 9. More particularly, the plastic sheet 91 is coated with a liquid photoemulsion coating 92 which is applied by means of a laminating roller 93.

The thermoformable material 91 may then be coated with an opaque stripable coating, such as reflective MILARtm by means of the apparatus shown with reference to Figure 10. More particularly, the plastic sheet 91 is coated with MILARtm sheet 101 by means of a further laminating roller 102.

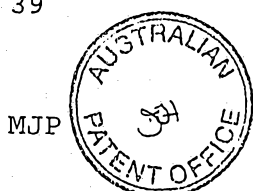
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~~However, in accordance with the alternative~~
embodiment, a heat resistant photoemulsion is then
coated onto an optically clear thermoformable material
as shown in Figure 9. More particularly, the plastic
5 sheet 91 is coated with a liquid photoemulsion coating
92 which is applied by means of a laminating roller 93.

The thermoformable material 91 may then be coated
with an opaque stripable coating, such as reflective
Milartm by means of the apparatus shown with reference
10 to Figure 10. More particularly, the plastic sheet 91
is coated with Milartm sheet 101 by means of a further
~~laminating roller 102.~~

Next, the sheet 91 is thermoformed over the
topographic mold 56 using the equipment of Figures 6a
15 and 6b. The opaque layer 101 is subsequently stripped
off of the sheet 91 within a dark room and the emulsion
coated thermoformed plastic sheet is exposed using the
original perspective views of the object with the
arrangement of Figures 5a and 5b or 7a and 7b.

20 As an alternative, the stage of applying opaque
coating 101 may be omitted and the steps of
thermoforming the sheet over the topographic mold and
exposing the emulsion may both be conducted in a dark
room.

25 The photographic emulsion 92 may be either positive
or negative. In the event a negative photoemulsion is
used, the resulting negative is thermoformed flat using
the apparatus depicted in Figures 12a and 12b. The
apparatus of Figures 12a and 12b is similar to that of
30 Figures 6a and 6b except that an additional flat surface
120 is employed.

The negative 91 is then developed and the resulting
image used to produce predistorted images on additional
thermoplastic sheets by screenprinting, lithography or
35 traditional photography. The images are then
thermoformed over the topographic mold 56 to produce



three-dimensional images identical to the original object 41.

5 In the event that the photoemulsion is positive, after thermoforming and exposing the sheet, the image is then directly developed without thermoflattening to produce the final three-dimensional photographic print.

Modifications and variations of the present invention are possible within the sphere and scope of the claims appended hereto.

~~WE CLAIM~~ The claims defining the invention are as follows:

1. A process for creating a three-dimensional display device, comprising the steps of:

5 a) photographing multiple perspective views of a three-dimensional object using a plurality of cameras oriented at respective predetermined positions relative to one another and to said object;

10 b) projecting said multiple perspective views of said object onto a plane work surface using a plurality of projectors oriented at said respective predetermined positions, thereby recreating a three-dimensional image of said object;

15 c) raising a three-dimensional topographic mold on said work surface for matching exactly said ^{three-dimensional} ~~projected~~ image;

20 d) thermoforming a first sheet of thermoformable plastic over said mold, said sheet having a first grid pattern on ^a ~~the~~ surface thereof, whereby in the step of thermoforming said grid pattern becomes distorted as a result of stretching and vertical displacement of the grid pattern over said mold;

25 e) projecting said multiple perspective views of said object onto said first sheet of thermoformable plastic using said plurality of projectors oriented at said respective predetermined positions, thereby recreating said three-dimensional image superimposed on top of said distorted grid pattern;

30 f) translating said three-dimensional image from said distorted grid pattern onto a second two-dimensional undistorted grid pattern, whereby during translation said image becomes predistorted;

g) transferring said predistorted image from said two-dimensional undistorted grid pattern onto one or more additional sheets of thermoformable plastic; and

35 h) thermoforming successive ones of said additional



sheets over said mold for creating said three-dimensional display device.

2. The process of claim 1 wherein said steps of
5 translating and transferring further comprise the steps of:

a) assigning numbered coordinates to each point of said projected three-dimensional image on said distorted grid pattern;

10 b) plotting each said numbered coordinate onto a corresponding location on said second grid pattern for creating said predistorted image; and

c) printing said predistorted image onto said one or more additional sheets of thermoformable plastic.

15 3. The process of claim 1 comprising the additional steps of:

a) scanning and digitizing said multiple perspective views of said object into a computer;

20 b) scanning and digitizing additional multiple perspective views of said distorted first grid pattern into said computer in accordance with said predetermined positions;

c) scanning and digitizing further multiple perspective views of said undistorted second grid pattern in accordance with said predetermined positions;

25 d) generating a plurality of movement vectors for each point of said projected three-dimensional image on said distorted first digitized grid pattern to a corresponding location on said second digitized grid pattern for each successive one of said multiple views;

30 e) applying said movement vectors to said digitized multiple perspective views of said object for translating said image from said distorted first grid pattern onto said undistorted second grid pattern,
35 thereby creating said predistorted image; and

f) printing said predistorted image onto said one or more additional sheets of thermoformable plastic.

5 4. A process for creating a three-dimensional display device, comprising the steps of:

a) photographing multiple perspective views of a three-dimensional object using a plurality of cameras oriented at respective predetermined positions relative to one another and to said object;

10 b) projecting said multiple perspective views of said object onto a plane work surface using a plurality of projectors oriented at said respective predetermined positions, thereby recreating a three-dimensional image of said object;

15 c) raising a three-dimensional topographic mold on said work surface for matching exactly said ^{three-dimensional} ~~projected~~ image;

d) coating a heat resistant positive photo emulsion onto a translucent sheet of thermoformable plastic;

20 e) thermoforming said sheet over said mold;

f) projecting said multiple perspective views of said object onto said photo emulsion coated sheet of thermoformable plastic using said plurality of projectors oriented at said respective predetermined positions, thereby exposing said photo emulsion with said three-dimensional image; and

25 g) developing said photo emulsion for producing said three-dimensional display device.

30 5. A process for creating a three-dimensional display device, comprising the steps of:

a) photographing multiple perspective views of a three-dimensional object using a plurality of cameras oriented at respective predetermined positions relative to one another and to said object;

35



b) projecting said multiple perspective views of said object onto a plane work surface using a plurality of projectors oriented at said respective predetermined positions, thereby recreating a three-dimensional image of
5 said object;

c) raising a three-dimensional topographic mold on said work surface for matching exactly said three dimensional image;

d) coating a heat resistant negative photo emulsion
10 onto a translucent sheet of thermoformable plastic;

e) thermoforming said sheet over said mold;

f) projecting said multiple perspective views of said object onto said photo emulsion coated sheet of thermoformable plastic using said plurality of projectors
15 oriented at said respective predetermined positions, thereby exposing said photo emulsion with said three-dimensional image;

g) developing said photo emulsion for producing a negative of said image on said sheet;

h) flattening said sheet and negative of said image for producing a predistorted negative of said image;

i) printing from said predistorted negative images on one or more additional sheets of thermoformable plastic; and

j) thermoforming said one or more additional sheets over said mold for creating said display device.

6. A display device made according to the process of any one of the preceding claims.

7. A display device comprising a sheet of
30 thermoformable plastic having a three-dimensional topographic surface representing a three-dimensional object, and a predistorted two-dimensional image applied to said topographic surface for depicting said object, wherein said image is created by photographing multiple
35 perspective views of said object, projecting said multiple perspective views on a three-dimensional topographic mold, and translating said image from a three-dimensional representation as projected on said mold to a
39 two-dimensional representation thereby pre-distorting said



image, the two-dimensional representation of the image being predistorted so as to eliminate the effects of stretch and flow of said plastic sheet during thermoforming as well as the effects of parallax and foreshortening.

8. A three-dimensional display device for displaying a three-dimensional image of a three-dimensional object having an irregular topographic surface and visible surface features distributed over various surface portions of the object positioned at various angles to a work surface defining a reference plane, the display device comprising:

means defining a three-dimensional topographical display surface substantially replicating the irregular topographic surface of the three-dimensional object, including first and second surface portions oriented at first and second angles, respectively, to said reference plane; and

a composite photographic image on the display surface, the composite photographic image including:

a first perspective image portion forming a visible replica of a first visible surface feature of the object on the first surface portion; and

a second perspective image portion forming a visible replica of a second visible surface feature of the object on the second surface portion;

each image portion displaying the visible surface features such that the composite image on the display surface creates the visual effect of viewing the three-dimensional object in perspective.

9. A display device according to claim 8 in which the first perspective image portion lies primarily in a plane approximately parallel to the first angle and the second perspective image portion lies primarily in a plane approximately parallel to the second angle, so that the second image portion provides a substantially undistorted image on the visible surface feature of the second surface portion which, in the first image portion, is subject to distortion in the plane of the second angle or cannot be



seen due to foreshortening or parallax.

10. A display device according to claim 8 in which the means defining a three-dimensional topographical display surface is a two dimensional thermoformable plastic sheet thermoformed into an irregular three dimensional topographic shape so as to substantially replicate the irregular topographic surface of the three-dimensional object, the composite photographic image being formed on the display surface of the thermoformed plastic sheet as an irregular transformation of the first perspective image portion and the second perspective image portion in accordance with the topographic surface of the three-dimensional object.

11. A two-dimensional intermediate transparency for use in making a three-dimensional display of a three-dimensional object having a topographic surface and visible surface features distributed over portions of the surface of the object positioned at various angles to a work surface defining a reference plane, the intermediate transparency comprising:

a two-dimensional thermoformable translucent plastic sheet having a flat surface and formable in a third dimension to define a three-dimensional topographical display surface substantially replicating the topographic surface of the three-dimensional object; and

a predistorted, composite image formed on the surface of the two-dimensional plastic sheet, the composite image including a first image portion on a first surface portion of the sheet and a second image portion on a second surface portion of the sheet;

the first image portion being a true, substantially untransformed image of the visible surface features of a first surface portion of the object lying approximately parallel to the reference plane;

the second image portion being a transformed image of the visible surface features of a second surface portion of the object lying at an angle to the reference plane sufficient to be subject to foreshortening or parallax when the object is viewed normal to the reference



plane;

the transformed second image portion being compressed laterally of the surface of the sheet in a transformation having a direction and quantity determined by the topographic surface of the three-dimensional object including said angle, so that forming the sheet in said third dimension to form said three-dimensional topographical display surface decompresses the transformed second image portion to substantially replicate the visible surface features of the second surface portion of the object on a corresponding portion of the display surface without foreshortening or parallax.

12. A two-dimensional intermediate transparency according to claim 11 in which the topographic surface of the three-dimensional object is irregular and the transformation of the second image portion is correspondingly irregular.

13. A system for making a three-dimensional display of a three-dimensional object having a topographic surface and visible surface features distributed over various surface portions of the object, the system comprising:

a primary camera directed at the object at a first viewing angle so as to view a first surface portion of the object at a first angle and a second surface portion at a second angle, the second angle being smaller than the first angle so that the surface features of the second surface portion are subject to foreshortening or parallax as viewed by the primary camera, the camera forming a first perspective image of the object including at least said first surface portion viewed at said first angle;

a second camera directed at the object at a second viewing angle so as to view the second surface portion of the object at a third angle greater than said second angle so that the surface features of the second surface portion are subject to less foreshortening or parallax than when such portion is viewed by the primary camera, the camera forming a second perspective image of the object including at least said second surface portion viewed at said third angle;



a topographical mold having display surface substantially replicating the topographic surface of the three-dimensional object, including first and second display surface portions replicating the topography of the first and second portions, respectively of the object;

primary and secondary projectors for projecting the first and second images, respectively, onto the first and second surface portions of the display surface at angles congruent to the viewing angles of said cameras, the projected images including a first image portion projected onto the first display surface portion defined by the first perspective image and a second image portion projected onto the second display surface portion defined by the second perspective image, thereby substantially replicating the visible surface features of the object on the display surface.

14. A process according to claim 1, 4 or 5 substantially as herein described with reference to the accompanying drawings.

15. A display device according to claim 6 or 8 substantially as herein described with reference to the accompanying drawings.

16. A two-dimensional intermediate transparency according to claim 11 substantially as herein described with reference to the accompanying drawings.

17. A system according to claim 13 substantially as herein described with reference to the accompanying drawings.

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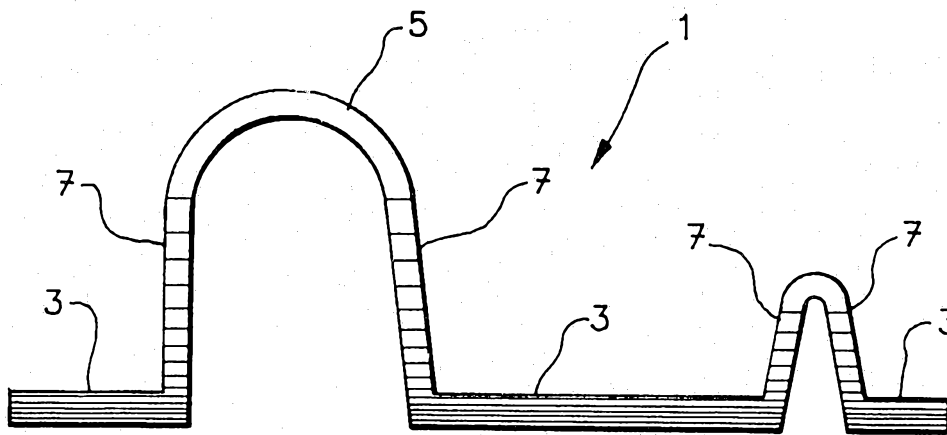


FIG. 1.

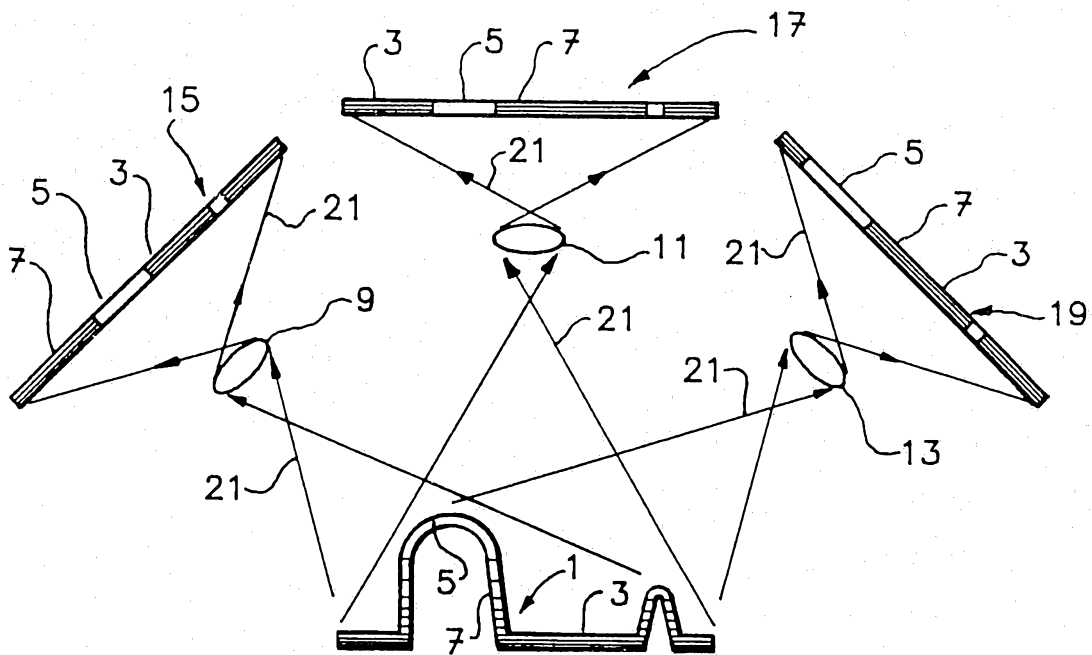


FIG. 2.

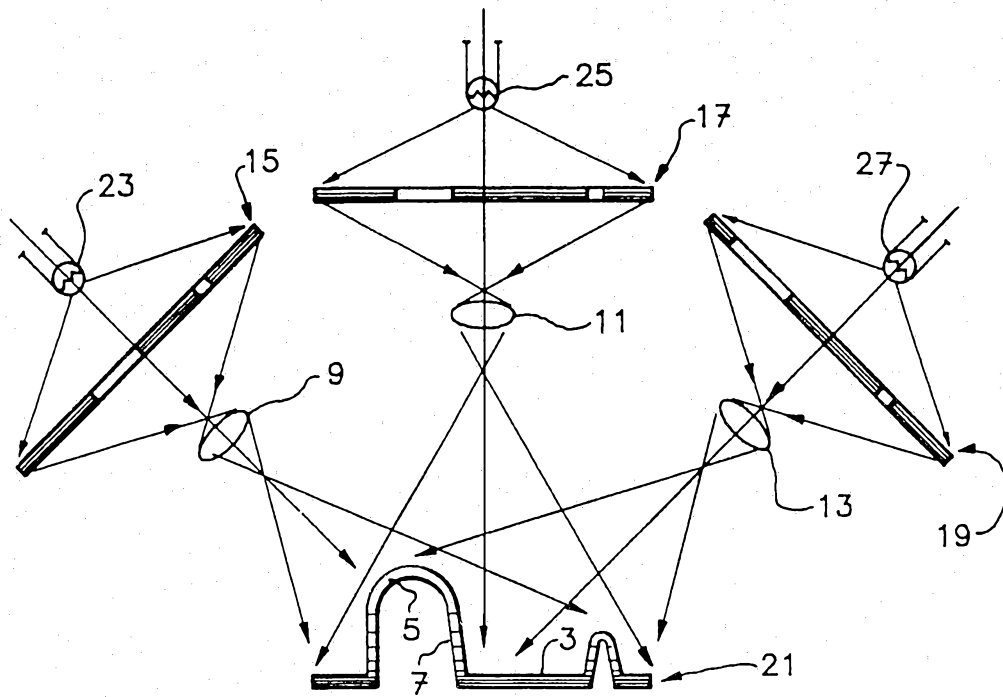


FIG. 3.

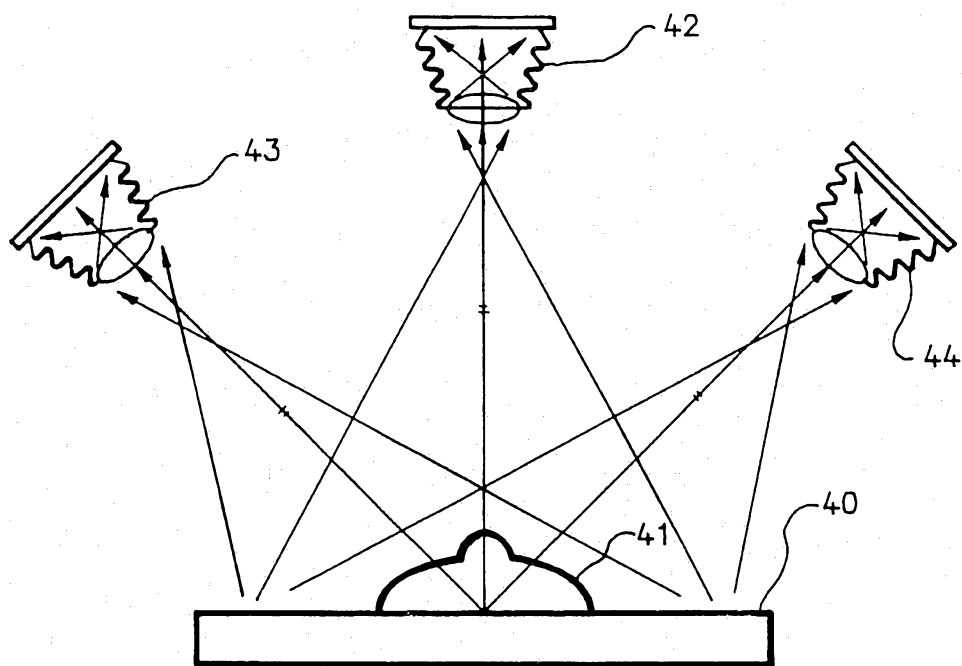


FIG. 4A.

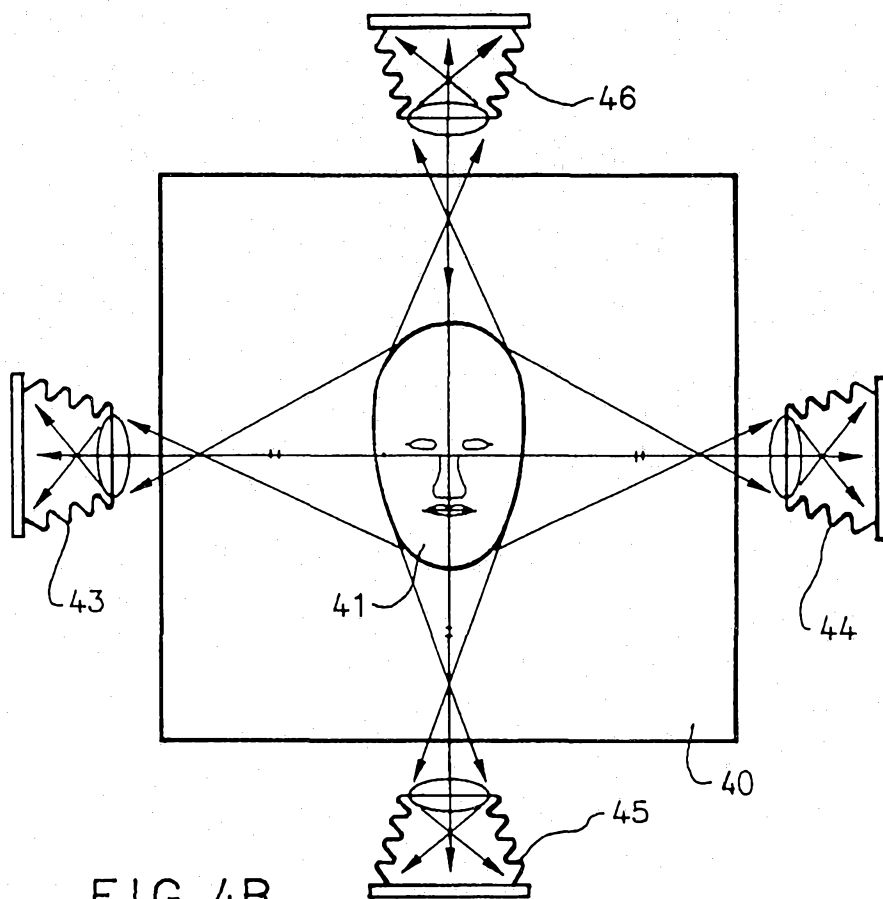


FIG. 4B.

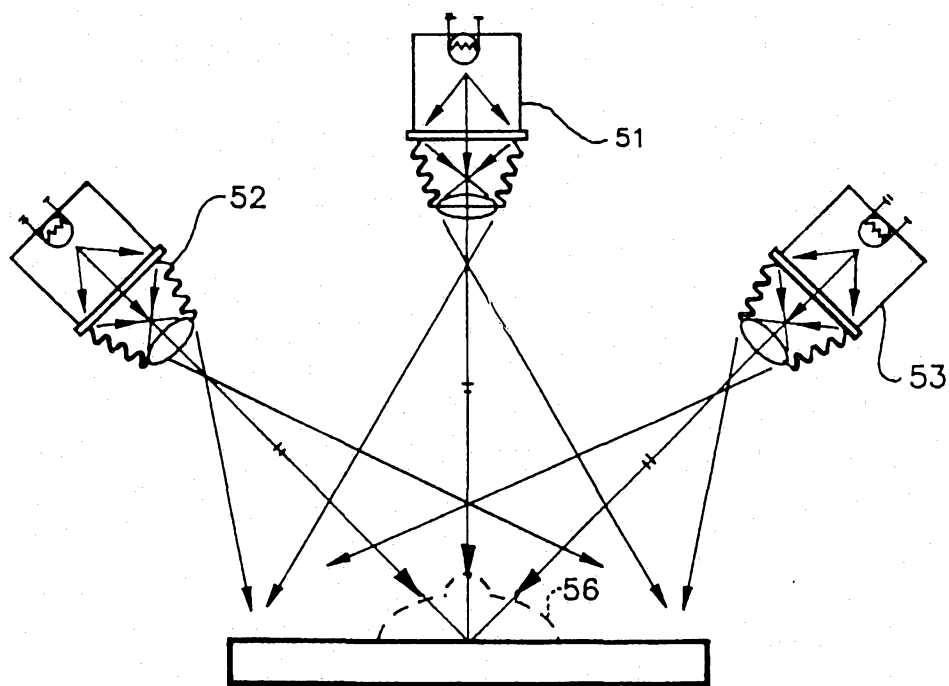


FIG. 5A.

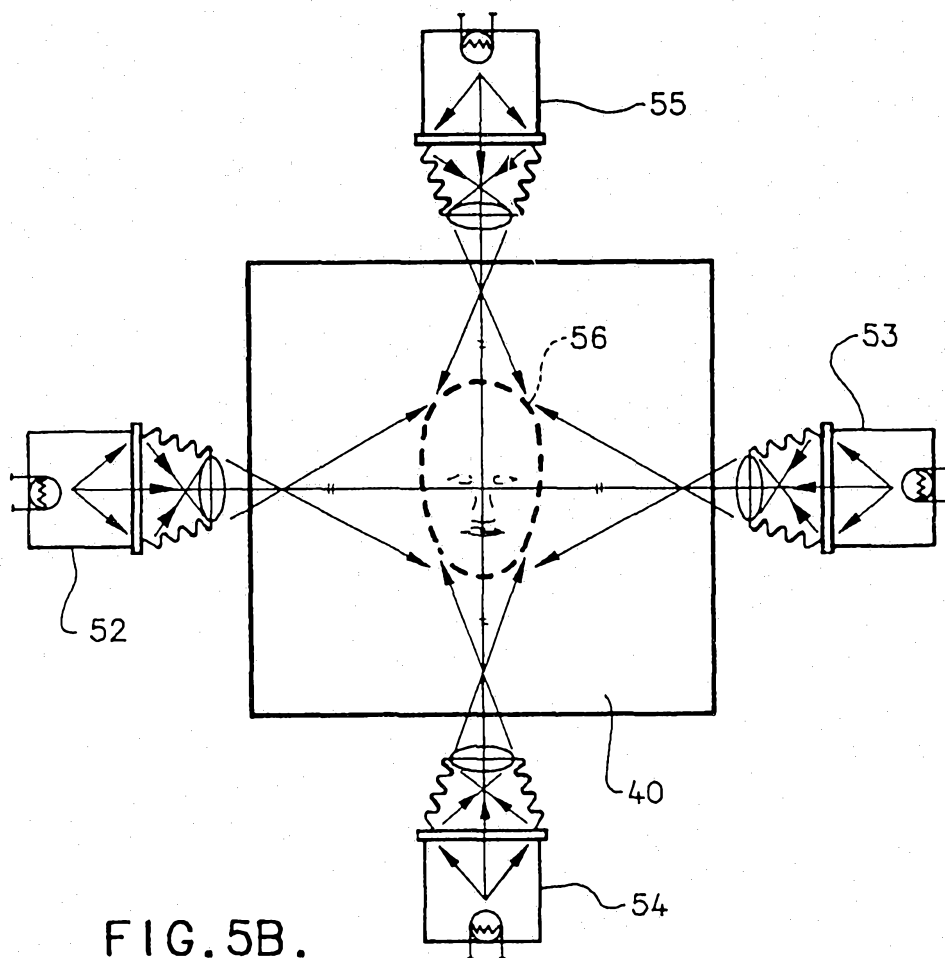


FIG. 5B.

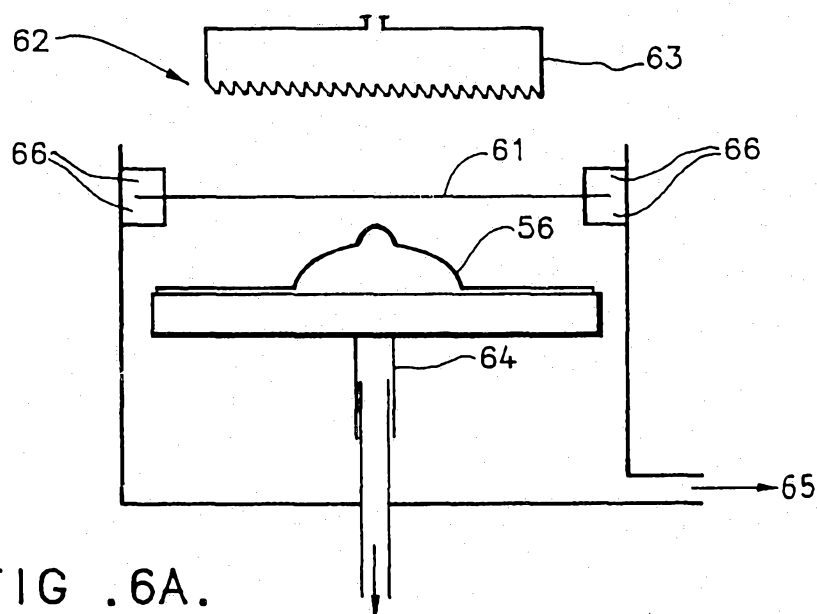


FIG. 6A.

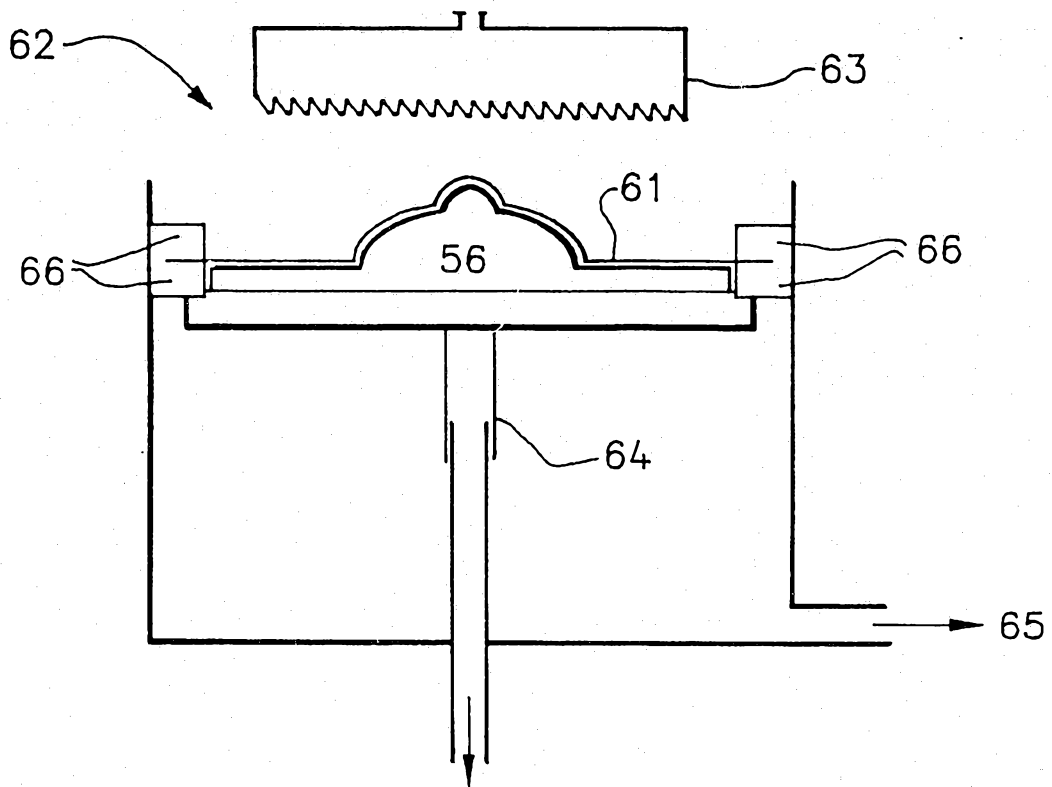


FIG. 6B.

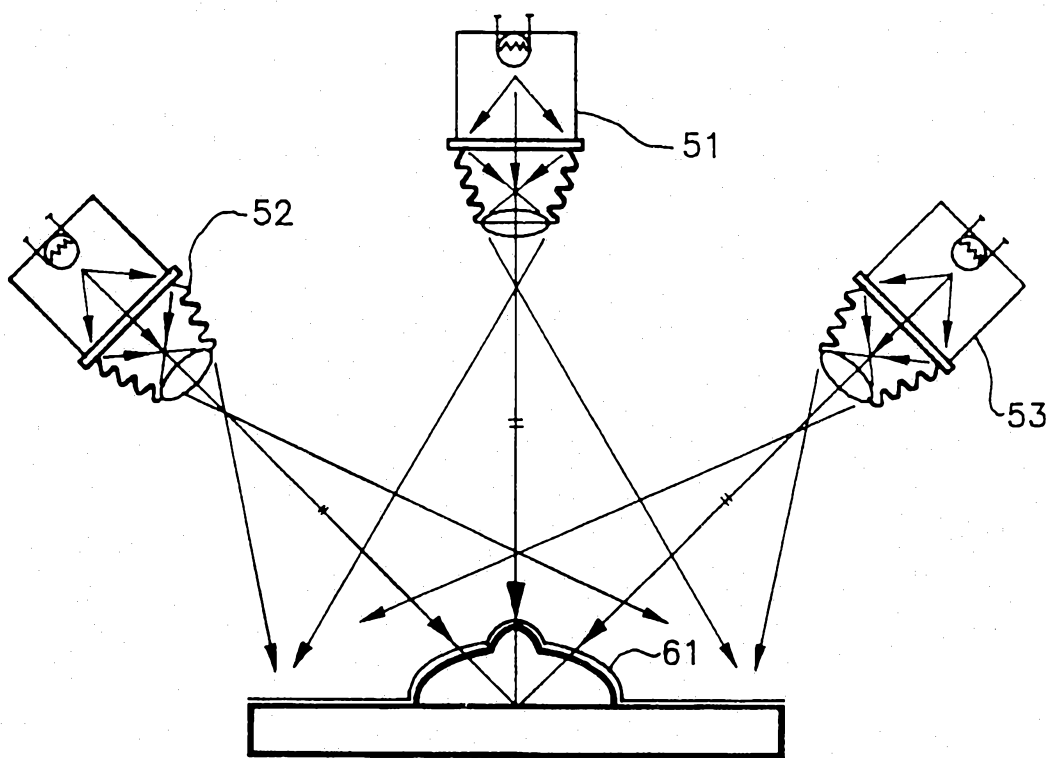


FIG. 7A.

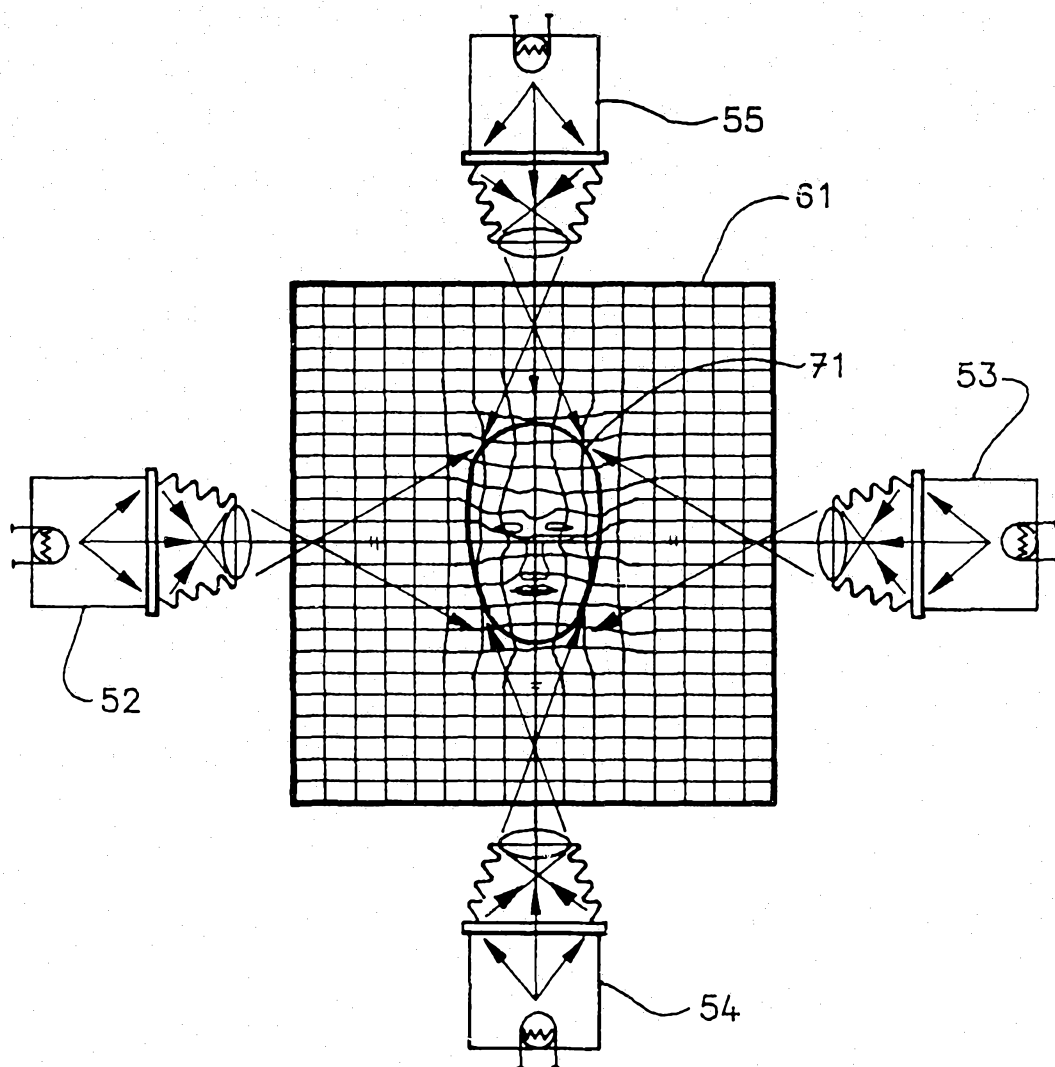


FIG. 7B.

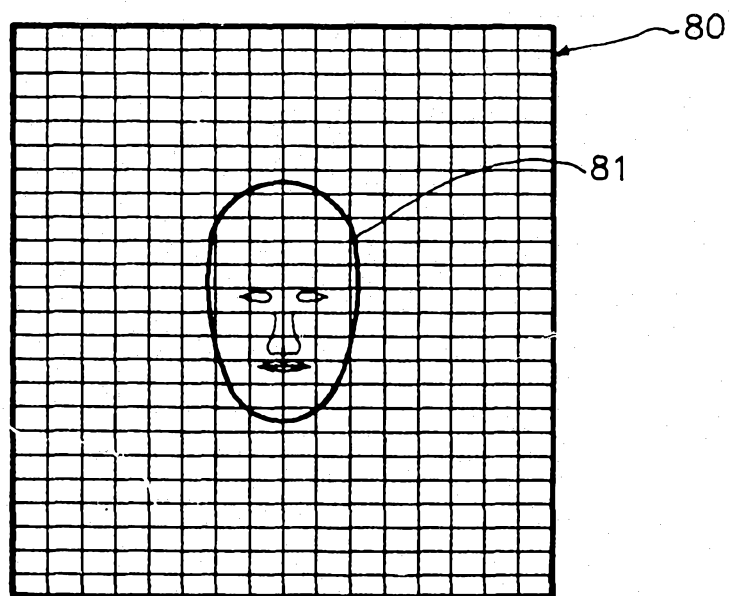


FIG. 8.

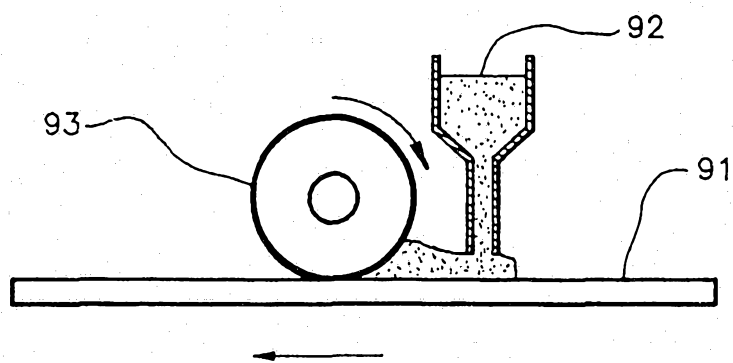


FIG. 9.

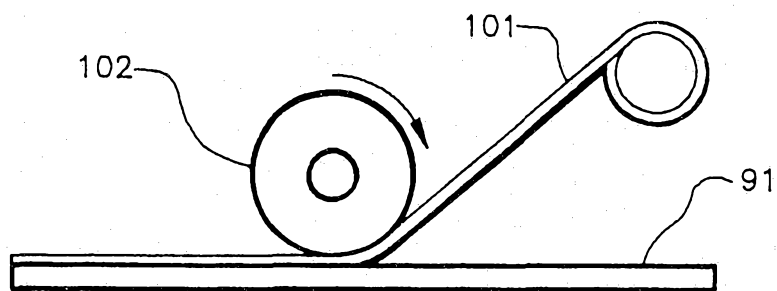


FIG. 10.

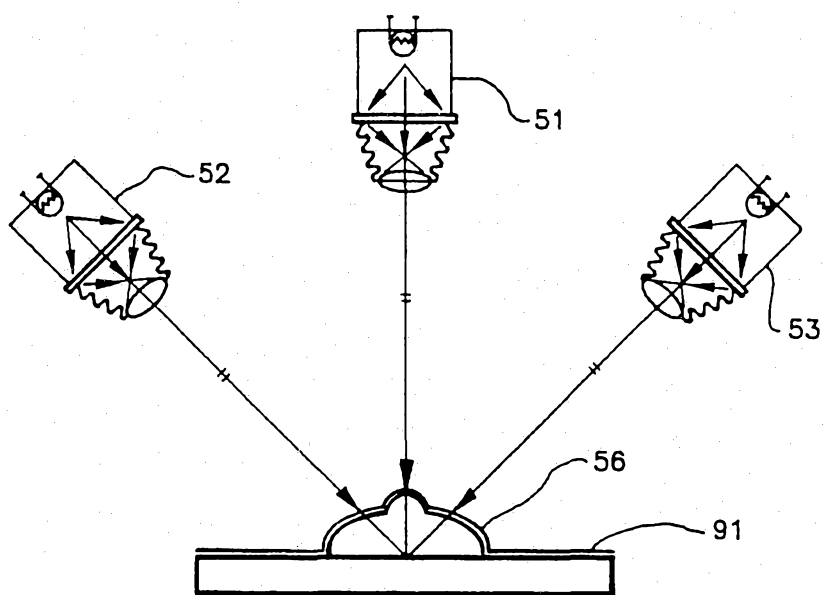


FIG. 11.

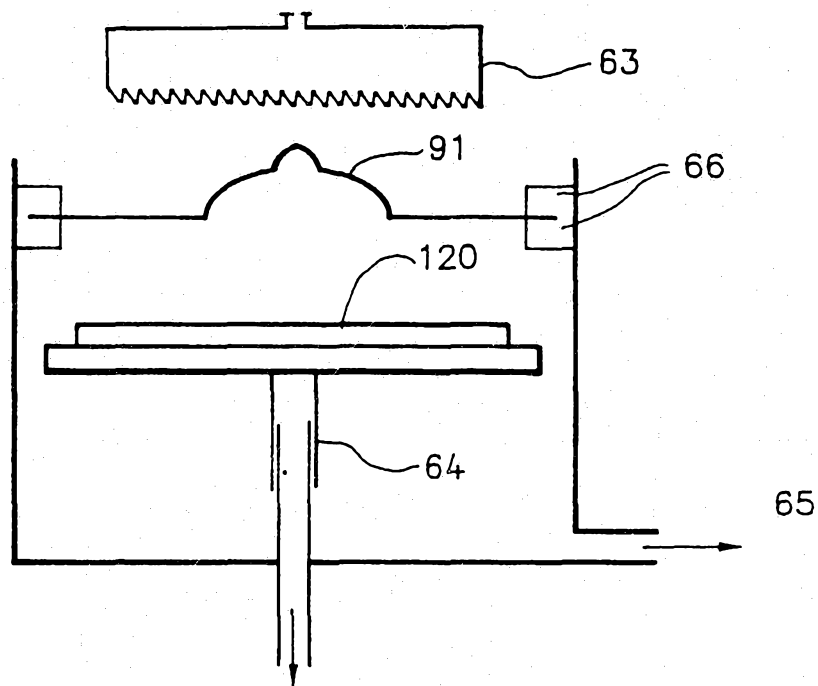


FIG. 12A.

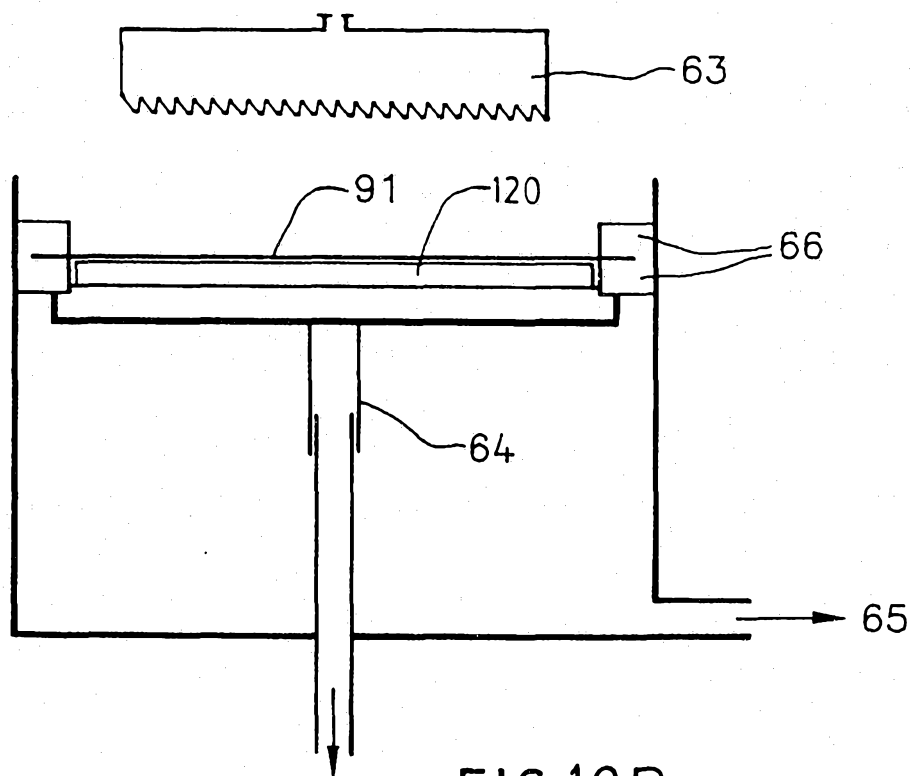


FIG. 12B.