May 30, 1967 J. V. HARMON 3,322,482

PANEL FOR CONTROLLING LIGHT TRANSMISSION BY THE SELECTIVE ORIENTATION OF FREE PARTICLES

Filed April 12, 1965

FIG. 2

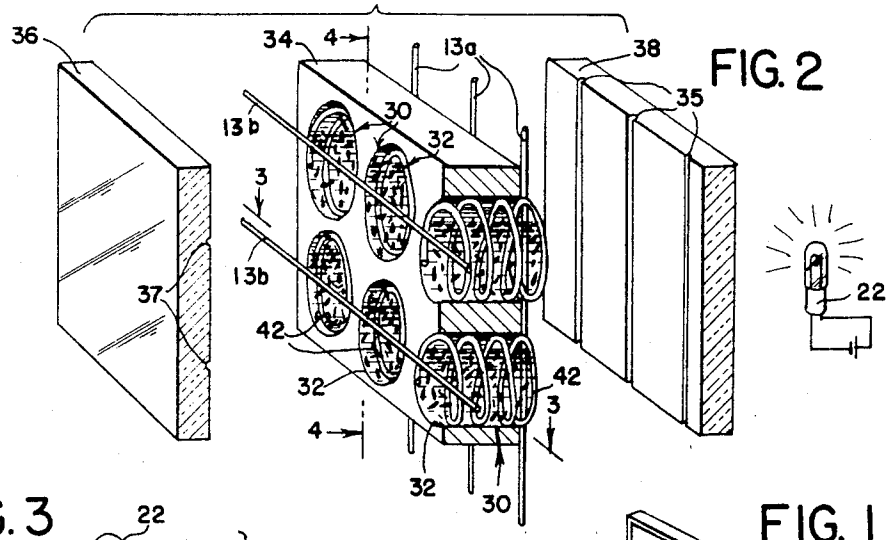


FIG. 3

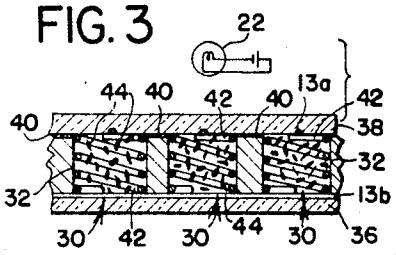


FIG. 1

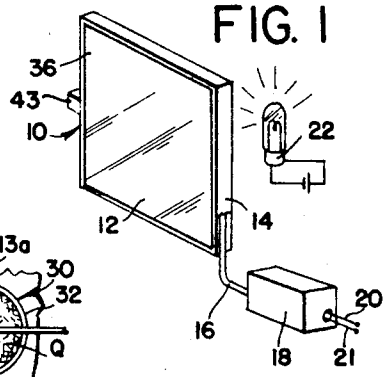


FIG. 4

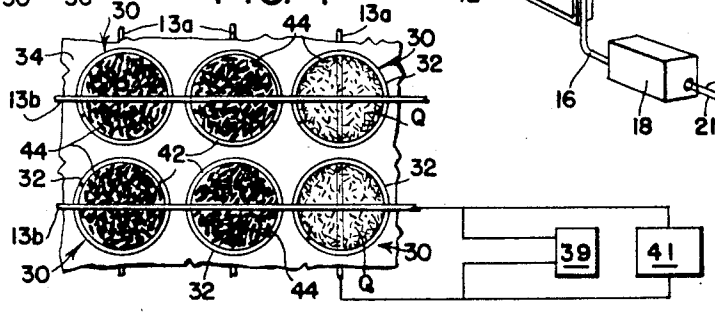


FIG. 5

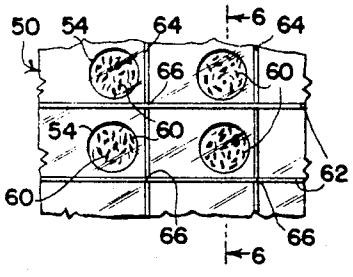


FIG. 6

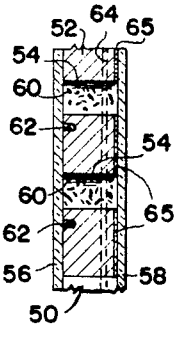
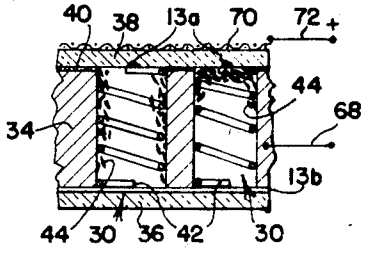


FIG. 7



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PANEL FOR CONTROLLING LIGHT TRANSMISSION BY THE SELECTIVE ORIENTATION OF FREE PARTICLES

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11 Claims. (Cl. 350—267)

The present application is a continuation in part of my prior application filed Nov. 13, 1961, bearing S.N. 151,629, for Display Apparatus, now abandoned.

This invention relates to display devices and more particularly to display panels of the type in which an electric signal can be used to make visible selected areas of a source of illumination and thereby present a graphic image. The invention also relates to an illumination control cell for such panels.

A number of devices have been previously described for displaying graphic information such as printing or moving pictures in response to an electric signal. Among the most commonly known of these display devices are the cathode ray tube, the kinescope and advertising displays utilizing a multiplicity of electric light bulbs and a control for turning on and off selected bulbs.

The cathode ray tube and kinescope both have good resolution but units having more than one or two square feet of screen area have been impractical to produce. Furthermore, these devices are relatively bulky due to the necessarily large size of the tube from its front surface to the base. Because of their large size and bulk, these tubes are poorly suited for many uses such as wall displays and advertising purposes.

Display devices which employ the selective operation of a plurality of electric lamps have relatively poor resolution. They also require a high signal current which makes it more difficult to activate the lamps in rapid sequence during the presentation of moving images. Moreover, image persistence is undesirably low for some applications.

In view of the deficiencies of the prior art, it is one object of the present invention to provide an improved display panel which is compact, relatively light in weight, and rugged in construction.

It is another object of the present invention to provide an improved display panel which can be readily made in large sizes.

It is another object of this invention to provide an improved display panel of the type described wherein the illumination control units or cells are sensitive to current flow and therefore can be operated with relatively low signal currents.

It is still another object of this invention to provide an improved display panel of the type described wherein the illumination control units or cells can readily be made small in size thereby permitting increased resolution.

It is yet another object of this invention to provide an improved display panel wherein the image can be made to persist after the signal current has been interrupted and wherein persistence can be varied as required.

These and other more detailed and specific objects will be disclosed in the course of the following specification, reference being had to the accompanying drawings, in which:

FIG. 1 is a perspective view on one form of the present invention.

FIG. 2 is an enlarged perspective view of a portion of the display panel of FIG. 1 with the several parts separated for clarity.

FIG. 3 is a horizontal sectional view taken along line 3—3 of FIG. 2.

FIG. 4 is a vertical sectional view taken along line 4—4 of FIG. 2.

FIG. 5 is an enlarged front elevational view of a portion of a display panel according to another form of this invention.

FIG. 6 is a vertical sectional view taken along line 6—6 of FIG. 5, and,

FIG. 7 is an enlarged horizontal sectional view of a portion of a panel according to another form of this invention.

Briefly stated, the present invention provides a two-dimensional array of illumination control units or cells for use in conjunction with a source of illumination. Conductors are provided in the area of each of the cells to produce a magnetic flux in the vicinity of each cell and a plurality of freely and independently movable magnetic particles are provided in each cell. A change in the position in these particles responsive to a change in flux through the cell is used to control the passage of illumination through the cell. The cells preferably comprise separate compartments.

The invention will be best understood with reference to the accompanying drawings which illustrate several forms of the present invention by way of example and wherein the same numerals refer to corresponding parts in the several figures.

With particular reference to FIG. 1, there is shown a display panel **10** for presenting graphic infromation such as numerals, letters or pictures. The panel **10** is preferably rectangular in shape and includes a display surface **12** on one side thereof. As can be best seen in FIG. 2, the panel is provided with a plurality of vertical conductors **13***a* and a plurality of horizontal conductors **13***b* which will be more fully described below.

A suitable frame **14** can be secured to the panel at its periphery. Portions of the frame **14** can be made hollow to accommodate lead wires **16**, each of which is connected between one of the conductors **13***a* or **13***b* and a control device **18**. Current can be supplied to the control **18** from a source of current (not shown) through conductors **20** and **21**.

While the control **18** will not be described in detail since it forms no part of the present invention, it can, for example, include a generator for producing direct current signals connected through suitable stepping switches to the conductors **13***a* and **13***b*. The stepping switches can be wired to sequentially connect each of the vertical conductors **13***a* with one terminal of the signal generator while the other terminal of the signal generator is connected to one of the horizontal conductors **13***b* and to repeat this operation continuously with each successive horizontal conductor.

Positioned adjacent the side of panel **18** opposite the display surface **12** is a source of illumination such as an electric lamp **22** and it is by allowing illumination to pass from lamp **22** through the panel **10** in selected areas as determined by the signal of the control **18** that an image is formed on the panel.

Refer now particularly to FIGS. 2, 3 and 4 which show an enlarged portion of the display panel **10**. The panel **10** includes a plurality of illumination control cells **30**, each preferably comprising a closed compartment. The cells **30** can be made in various ways but are conveniently formed by providing a plurality of spaced-apart openings **32** of any cross sectional shape in a flat plate **34** formed from a rigid material such as metal or plastic. The ends of these openings can be sealed by sheets of transparent material **36** and **38** bonded to opposite sides of the plate **34**. Because both end walls of each cell are transparent, light will be able to pass from the lamp **22** through each cell on an axis extending from one surface of the panel

10 to the other. If the plate 34 is formed from a transparent material, a layer of paint 40 is preferably provided between the cells 30 on at least one side of the plate 34 to prevent the transmission of light through the panel in areas between the cells.

When it is desired that the cells 30 be relatively small in size in order to obtain high resolution, the openings 32 can be formed by a known engraving or etching process. Thus, for example, the plate 34 can be formed from a photosensitive polyamide resin and the openings produced by dissolving away material after the plate has been exposed to light in the desired areas.

At least one conductor is positioned adjacent each of the cells to make possible the establishment of magnetic flux through each cell. In the embodiment of FIGS. 1 through 4, this conductor has the form of a solenoid or coil 42 positioned inside each opening 32 with its longitudinal axis extending between the front and rear walls of the panel.

Current is supplied to each coil 42 through one pair of conductors 13*a* and 13*b*. Each of the conductors 13*a* and 13*b* can be provided with a terminal (not shown) at one end to which one of the lead wires 16 may be connected. The conductors 13*a* are preferably parallel to each other and positioned on the rear surface of the plate 34. The conductors 13*b* are also preferably parallel each other and positioned on the front surface of the plate 34. The conductors 13*b* are preferably oriented at right angles with respect to the conductors 13*a*. The inward surfaces of sheets 36 and 38 can be provided with suitable grooves 35 and 37, best seen in FIG. 2, to accommodate the conductors 13*a* and 13*b* respectively.

While current can be transmitted between the conductors 13*a* and 13*b* and the coils 42 by contact engagement between the coils and the conductors, it is preferred that a positive connection be formed between them. To enable a positive connection to be readily made, the conductors 13*a* and 13*b* can be positioned to pass over the end of each of the coils 42. Thus, when the cells 30 are relatively small in size, the panel can nevertheless be easily constructed by first filling the cells with the coils 42, next stretching one of the conductors 13*a* or 13*b* which has been first coated with solder over a row or column of cells as shown in FIG. 1 and then running a soldering iron along the entire length of the conductor.

In the embodiment shown in FIGS. 1 through 4, it will be apparent that the axis of magnetic flux within each cell extends generally parallel to the optic axis of light passing from the source of illumination 22 as it intersects the panel 10, i.e. from the front surface 12 to the rear surface of the panel.

Within each of the cells 30, there is provided a plurality of freely and independently movable particles which are responsive to a magnetic flux such as opaque magnetic particles 44. Although the particles can be formed from nonmagnetic material, they are preferably formed from a highly magnetic material such as iron which responds well to a magnetic flux and is also relatively permeable thereto thereby concentrating flux lines where they are most needed, within the cell. The particles 44 can be round or elongated in one direction but it is preferred that they are elongated in two directions so as to have the form of flakes.

While such flakes can be formed in many ways, very thin flakes can be prepared by electrodepositing iron on a soluble substrate and thereafter dissolving the substrate. The thin metallic film thus formed can be chopped and the particles classified in any convenient way to obtain flakes of the desired size. The particles can also, for example, comprise iron oxide dust bonded to a base member such as resinous film. Flakes of from about $\frac{1}{100}$ inch in diameter to $\frac{1}{8}$ inch in diameter with the latter composition have the advantage of being oxidation resistant and are low enough in density so that stable suspensions are easily achieved.

In the embodiment of FIGS. 1 through 4, the particles 44 are suspended in a transparent liquid which fills each of the cells 30. Shading to indicate a liquid is clearly shown in FIG. 2 but has been omitted from the other figures for the sake of clarity. Either an organic or aqueous liquid can be used. The liquid can include a material for increasing its viscosity and a material such as sodium silicate for increasing its density. By the use of the latter material, the density of the liquid can be made to exactly equal that of the particles thus providing a very stable suspension.

In operation, the establishment of a magnetic flux in one of the cells by passing current through the coil 42 will cause each of the magnetic particles 44 within the cell to change its position and it is this change in position of the particles which causes a variation in the transmission of light from the source 22 through the cell.

In an experimental cell generally similar in construction to those in the embodiment illustrated in FIGS. 1 through 4, and employing magnetic flakes, I have found that the change in position of the flakes involves both rotational as well as translational movement. Thus when a current was passed through the coil, the plane of each of the flakes quickly became oriented parallel to the flux lines within the cell. In this position, only the edges of the flakes could be seen when the cell was viewed from its end. In this position, light from a lamp will pass readily through the cell.

As mentioned above, it was also noted that some translational movement was present. This movement was exhibited as a migration of at least some of the particles toward the sides of the cell apparently because of the greater flux density in this area.

Orientation of the particles, as described above, is illustrated in FIG. 4 wherein the coils in the cells designated Q at the right of the figure are energized. The other cells in the figure are un-energized, thus, the particles in them are randomly oriented. When the current is interrupted in the cells Q, the particles will return to the randomly oriented condition shown in the other cell.

While there is natural tendency for the particles to return to random orientation due to gravitational effects and minute convection currents within the cells, this tendency can be accelerated if necessary by impressing either a continuous or interrupted alternating current from either of current sources 39 or 41 respectively (FIG. 4) through the coils 42 or by securing a mechanical vibrator 43 (FIG. 1) to the panel. A strong mechanical vibration or pulse of alternating current through the coils 42 can be used to "erase" the entire panel. The use of a mechanical vibration or alternating current in this manner, will have the additional benefit of maintaining the particles 44 evenly suspended throughout the liquid in each cell.

In general, the thinner the flakes are made, the more easily they will stay in suspension and the greater will be the illumination contrast between the current "off" and current "on" conditions. If the flakes are too thin however, the time required for response to the magnetic field will be excessive since the force exerted on them will be small as compared with the resistance exerted by the fluid.

The resolution obtainable in a given panel can, of course, be increased by reducing the size of the cells. Since the magnetic particles can, if necessary, be microscopic in their dimensions it is possible to construct cells of a very small size with my invention.

The image persistance will, in general, be increased by decreasing the thickness of the magnetic flakes or by increasing the viscosity of the liquid in which the flakes are suspended. The persistance can also be modified as described above by means of mechanical vibration or by passing an alternating current through the coils 42 from the current source 39 or 41. The stronger this vibration or current is made, the shorter will be the duration of image persistance. If the magnetic field is of insufficient strength to hold the flakes in the oriented position with

the vibrator in operation, the vibrator **43** can be operated intermittently. The current through the coil **42** can then be used to re-orient the flakes each time the vibrator **43** is interrupted.

Refer now to FIGS. 5 and 6 which illustrate a portion of a display panel **50** according to another form of this invention. The panel **50** is in many respects similar to the panel **10** of FIGS. 1 through 4.

The panel **50** preferably comprises a three-layer laminate composed of a central plate **52** in which cells are formed by providing a plurality of perforations **54** therethrough, and a pair of transparent plates **56** and **58**, one being bonded to each surface of the plate **52**. The perforations **54** can be arranged in rows and columns as best seen in FIG. 5. Within each of the perforations there is provided a plurality of independently movable magnetic particles or flakes **60**. The flakes are freely suspended within a transparent liquid which fills each of the perforations **54**. For the sake of clarity, the liquid has not been illustrated in the figures.

Recessed within the plate **52** on one side thereof, are a plurality of parallel horizontally disposed conductors **62**. Recessed within the plate **52** on its other side are a plurality of parallel vertically disposed conductors **64**. The conductors **62** and **64** are positioned to form an intersection or junction **66** adjacent each of the perforations but do not contact each other. It should be noted that the conductors **62** are positioned adjacent the lower edge of each cell in one row and the conductors **64** are positioned adjacent the side of each cell at the opposite end thereof. The conductors **62** and **64** can each be connected in series with a suitable control (not shown) similar to the control **18**. A coating of paint **65** can be applied to one surface of the plate **52**.

In operation, with no current passing through either of the conductors **62** or **64**, the flakes **60** will be randomly oriented thus preventing the passage of light through the cell. When a current is passed through one of the conductors **62**, a magnetic flux will be set up around it thus causing the flakes **60** at the end of a perforation nearest the conductor **62** to become aligned parallel to the axis of the perforation. The particles at the opposite end of the perforation, since they are further away from the energized conductor, will be less well aligned and, moreover, to the extent they are aligned, the axis of alignment will be inclined with respect to the axis of the perforation thus blocking the passage of light through the cell. When a current is passed through a conductor **64**, as well as a conductor **62**, the particles at both ends of a cell at the intersection between the energized conductors will be oriented generally parallel to the axis of the cell thus allowing light to pass through the cell.

When the panel **50** is to be used, it is placed adjacent a source of illumination (not shown). By appropriate energization of the various conductors, **62** and **64**, the panel can be used to present the desired graphic image. Because no coils are required as in the embodiment of FIGS. 1 through 4, the cells can be made smaller in size and therefore resolution can be increased.

A third form of my invention is illustrated in FIG. 7 wherein the same numbers refer to corresponding parts in FIGS. 1 through 4. Thus the panel of FIG. 7 includes a central plate **34** with a transparent sheet **38** bonded to one side thereof and transparent sheet **36** bonded to the other side. Within the plate **34** are provided a plurality of spaced-apart hollow cells **30**, each having mounted in it a coil **42**. The cells contain freely movable magnetic particles **44** of any shape but the cells **30**, in this instance, are not filled with a liquid. The cells **30** can contain air or they can be evacutated. The plate **34** can be formed from the conductive material or in the alternative covered with a conductive coating.

The plate **34** is connected to a high voltage source (not shown) of a first polarity by a conductor **68**. On one surface of the panel there is suitably secured an electrode such as a wire screen **70**. The screen **70** is connected by means of a conductor **72** to a high voltage source (not shown) of the opposite polarity.

In operation, with current passing through the coil **42**, the particles **44** will be attracted to the area of greatest flux density, in other words, to a position adjacent to the coil **44** as illustrated in the cell at the left in FIG. 7. The particles then move in a group in this form of my invention. Under these conditions, light will pass readily through the cell. Since the particles in this position are adjacent the plate **34**, they will pick up a static charge of a first polarity, for example, negative. When the current through coil **42** is turned off, the particles **44** will fly toward the screen **70** which is charged in the opposite polarity and form a clump at the end of the cell **30** nearest the screen **70** thereby obstructing the passage of light through the cell. This condition is illustrated in the cell at the right in FIG. 7.

When the coil **42** is again energized, the particles will fly back to the coil. The value of current through the coils **42** and the value of the static charges on the plate **34** and screen **70** must, of course, be adjusted to enable the magnetic force to overcome the electrostatic force when the coil is turned on.

The embodiment of FIG. 7 is preferred when it is desired that the particles respond rapidly to the initiation and the interruption of current through the coil **42**.

It is understood that suitable modifications may be made in the structure as disclosed, provided such modifications come within the spirit and scope of the appended claims. Having now therefore fully illustrated and described my invention, what I claim to be new and desire to protect by Letters Patent is:

1. A planar display panel for use with a source of illumination and a control means, said panel comprising in combination:

(a) a plurality of spaced illumination control cells disposed to receive illumination from said source,

(b) a transparent liquid within each of said illumination control cells,

(c) a plurality of freely movable and highly permeable elongated ferromagnetic particles suspended in said transparent liquid for normally obstructing light from passing through said cells in the absence of a magnetic field,

(d) an electric conductor in the form of a solenoid enclosing the magnetic particles within each cell for establishing a magnetic flux through said cell,

(e) means for connecting said conductor to said control means,

(1) said control means being connected to pass current through selected conductors,

(f) said cells each including two opposed walls formed from a light transmissive material,

(g) the axis of said solenoid being positioned to extend between said two walls formed from light transmissive material,

(h) the establishment of a current through said conductors providing alignment of the particles with the lines of said magnetic flux,

(i) said source of illumination providing light rays for intersecting each of said cells in a direction substantially parallel to said flux lines,

(j) the magnetic particles serving to concentrate the flux lines and control the transmission of light through each cell,

(1) whereby said illumination will pass through the panel when the particles are in alignment.

2. A display panel including a plurality of light control cells comprising:

(a) a sheet of rigid material having

(1) a front and rear surface and a plurality of spaced openings therethrough from the front to the rear surface thereof,

(b) a coil formed from a conductive material positioned in each opening with the axis thereof extend-

ing between the front and rear surfaces for establishing a magnetic field within said openings along said axis,

(1) the walls of the opening defining the bounds of said cells and

(2) said coils abutting said walls and being supported thereby,

(c) a fluid in each opening,

(d) a plurality of elongated ferromagnetic particles responsive to a magnetic field suspended in said fluid in each opening for normally obstructing light from passing through said openings in the absence of a magnetic field and for concentrating the flux in said field within said opening when said coil is energized,

(e) conductor means connected to the coil for supplying energizing current thereto, and

(f) light transmissive walls at the ends of the openings adjacent the front and rear surfaces of the sheet.

3. A display panel comprising:

(a) an illumination control cell including a sealed enclosure,

(b) said enclosure having a pair of walls at opposite ends formed from a material adapted to transmit light,

(c) a plurality of small freely movable opaque ferromagnetic particles in said cell,

(d) at least a pair of spaced electric conductors adjacent said cell for establishing a magnetic flux within said cell,

(e) an electric potential impressed upon one of said conductors being adapted to exert a force upon the particles in one direction, and

(f) an electrical potential impressed upon the other electrical conductor being adapted to exert a force upon the particles in a different direction,

(g) each of said particles being adapted to move as a group between two spaced apart positions adjacent said spaced conductors responsive to the passage of a current through said conductors,

(1) said particles acting to obstruct the passage of light through the cell in one position, and

(2) said particles being adapted to allow the transmission of light through the cell in the other said position.

4. A display panel comprising:

(a) a source of illumination,

(b) a plate adjacent said source of illumination,

(1) said plate having a plurality of spaced openings therein,

(c) a solenoid in each opening positioned with the axis thereof normal to the surface of the plate for establishing a magnetic field within said openings along said axis,

(d) a plurality of small freely and independent movable ferromagnetic particles in each of the openings for controlling the passage of light through the openings,

(e) conductive side walls on said openings,

(f) end walls on said openings formed from a light transmissive material,

(g) a conductive material on one of said end walls connected to a source of current of a first polarity,

(1) said conductive side walls being connected to a current source of the opposite polarity.

5. The apparatus of claim 2 wherein said particles comprise a relatively heavy material formed from a ferromagnetic substance bonded to a relatively light weight material having a density below that of said fluid to help prevent the particles from settling to the bottom of the openings.

6. The apparatus according to claim 2 wherein said fluid has substantially the same density as said particles, said particles being thereby adapted to remain suspended in said fluid over an extended period of time.

7. A display panel for presenting graphic information and adapted to be used with a source of visible illumination, said display panel comprising:

(a) a plurality of spaced illumination control cells arranged in rows and columns on said panel,

(b) a first group of spaced apart conductors positioned parallel to the plane of said panel and to themselves for establishing a magnetic field within said cells along said axis,

(1) each of said conductors also being positioned adjacent one edge of the cells in one of said rows,

(2) the spacing between said conductors being the same as the spacing between the cells in one of said rows,

(c) a second group of conductors positioned parallel to the plane of said panel for establishing a magnetic field within said cells along said axis,

(1) each of said second group of conductors being positioned adjacent one side of the cells in one column,

(2) the spacing between each of the second group of conductors being the same as the spacing between said columns,

(d) said cells being positioned to receive illumination from said source of illumination and including,

(1) walls formed from a transparent material at opposite ends,

(e) a plurality of small, freely and independently movable ferromagnetic particles suspended in each of said cells,

(1) each of said particles being movable within the cells between a first position wherein the particles obstruct the passage of illumination from said source of illumination through said cell and a second position wherein said illumination is allowed to pass therethrough and said particles concentrating the flux in said field within said cells when said conductors are energized.

8. In a display panel for presenting graphic information, by controlling light transmission with a magnetic field:

(a) a plurality of spaced-apart illumination control cells,

(1) each of said cells comprising side walls and

(2) transparent end walls, a transparent liquid within each cell,

(b) a plurality of freely movable ferromagnetic particles suspended within each cell to control the passage of light through the cells and for concentrating the magnetic field in the cells.

(c) energizing conductors adjacent to each wall to selectively provide a magnetic field for changing the position of the particles, and

(d) a vibrator connected to the panel to impart mechanical vibratory movement to the particles.

9. A display panel for controlling light transmission with a magnetic field comprising:

(a) a plurality of spaced illumination control cells,

(b) a plurality of independently movable ferromagnetic particles in each of the control cells for controlling the passage of light through the cells and for concentrating the magnetic field through the cells, a transparent liquid within each of the cells,

(c) conductors adjacent the particles to establish a magnetic flux for changing the position of the particles,

(d) a source of alternating current,

(e) a source of direct current,

(f) means for connecting said conductors to said source of direct current, and

(g) means for connecting said conductors to said source of alternating current.

10. A display panel comprising:

(a) a plurality of spaced illumination control cells,

(1) each of said illumination control cells comprising an enclosure having

(2) transparent front and rear walls,

(b) energizing conductors so constructed and arranged with respect to said cells to provide a magnetic field in said cells with flux lines therefrom extending between said front wall and said rear wall,

(c) a liquid filling each of said enclosures,

(d) a plurality of elongated ferromagnetic bodies,

(e) a buoyant substances having a density below that of the liquid bonded to said bodies,

(1) said bodies being freely suspended within said liquid for normally obstructing light from passing through said openings in the absence of a magnetic field and for concentrating the flux in said field within said opening when said coil is energized, said buoyant substance helping to maintain the bodies in suspension within said liquid,

(f) the passage of current through said conductors thereby causing the bodies to become aligned in planes extending between the front and rear walls

and the interruption of said current allowing the bodies to become randomly oriented.

11. The apparatus according to claim **1** wherein a viscosity modifying material formed from a substance which is solid at room temperature and soluble in said liquid is dissolved within the liquid filling each of the cells for increasing the viscosity of the liquid to a selected value to regulate the movement of the magnetic particles responsive to changes in said magnetic flux.

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