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Iwata

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[45] **Oct. 7, 1975**

[54] **LIGHT CONTROL DEVICE**

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[73] Assignee: **West Electric Company, Ltd.,** Osaka, Japan

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Sept. 20, 1972	Japan	47-94763
Sept. 20, 1972	Japan	47-94764
Sept. 20, 1972	Japan	47-94765
Oct. 12, 1972	Japan	47-102529

[52] **U.S. Cl.** **350/267;** 354/50; 354/226
[51] **Int. Cl.**[2] **G02B 9/14**
[58] **Field of Search** .... 350/160 R, 266, 267; 354/50, 29, 60, 226, 227, 234; 149/2

[56] **References Cited**

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3,215,572	11/1965	Papell	149/2
3,322,482	5/1967	Harmon	350/267
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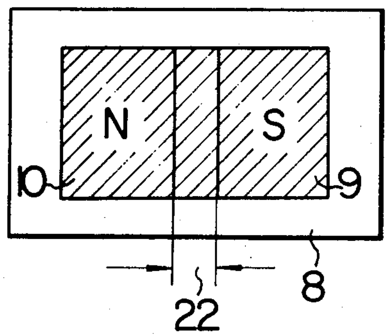
Primary Examiner—Vincent P. McGraw
Assistant Examiner—Paul K. Godwin
Attorney, Agent, or Firm—Stevens, Davis, Miller & Mosher

[57] **ABSTRACT**

There is provided a light control device wherein a magnetic fluid consisting of a colloidal solution prepared by mixing together a powdered activated magnetic material such as nickel, cobalt, iron or various iron oxides and oleic acid, heptane or the like and a substance transparent to light such as glycerin or silicone oil are placed within a hermetically sealed container, whereby the position of the magnetic fluid is controlled by the imposition of an external magnetic field to transmit and intercept light.

8 Claims, 12 Drawing Figures



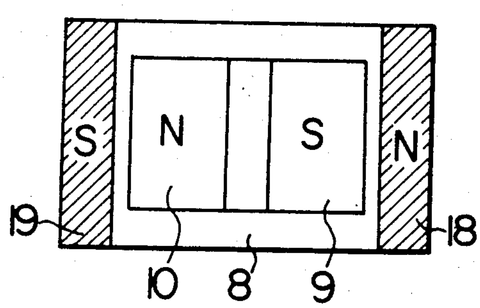


FIG.1

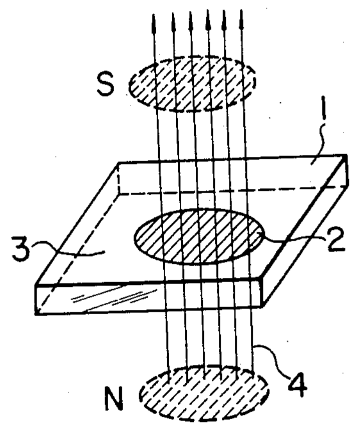


FIG.2

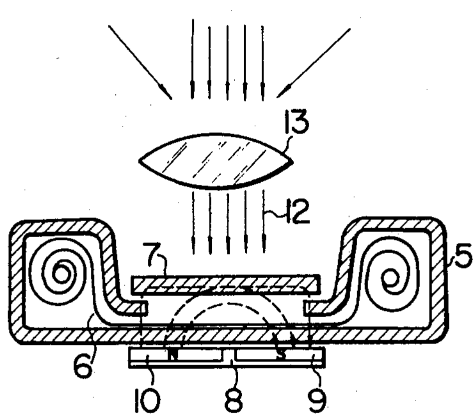


FIG.3A

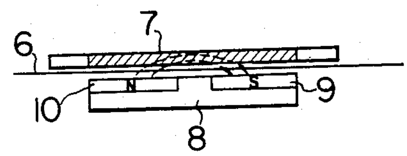


FIG.3B

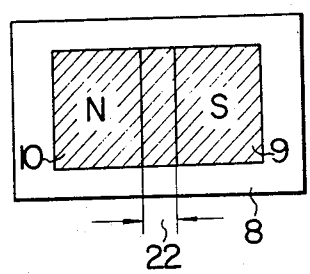


FIG.4A

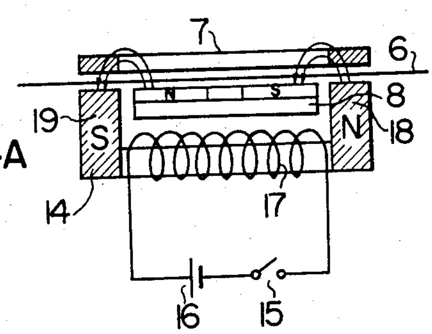


FIG.4B

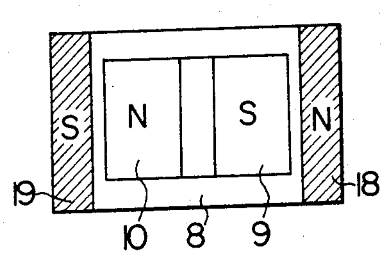


FIG.5

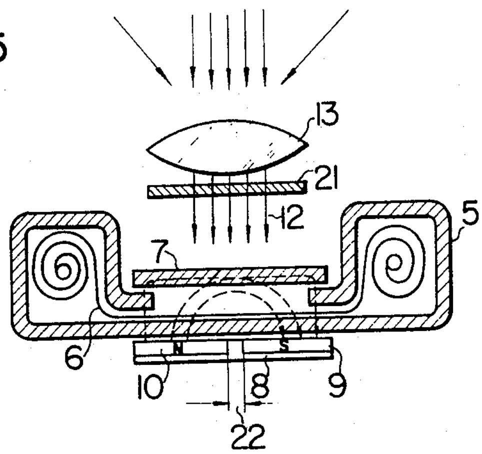


FIG.6

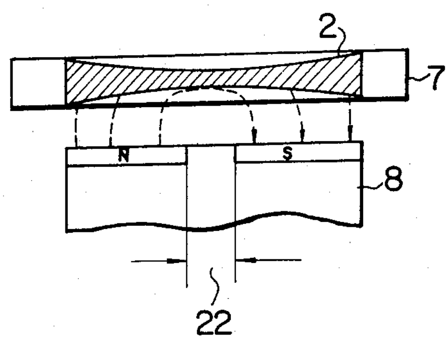


FIG.7A

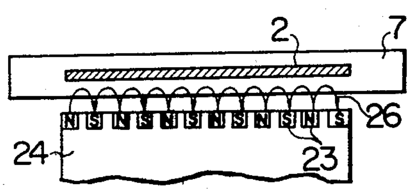


FIG.7B

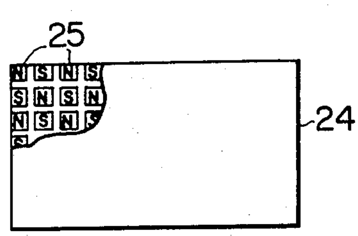
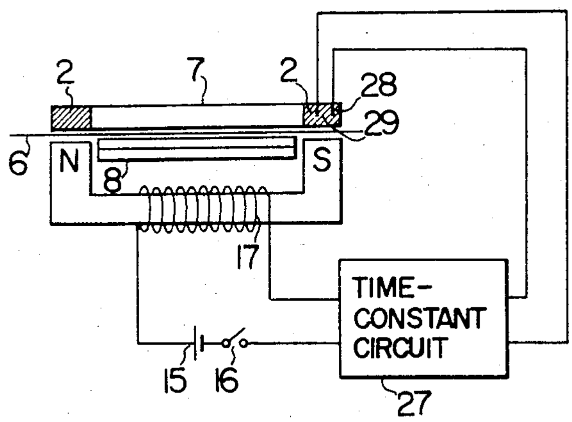


FIG.8


2
7
2
28
29
6
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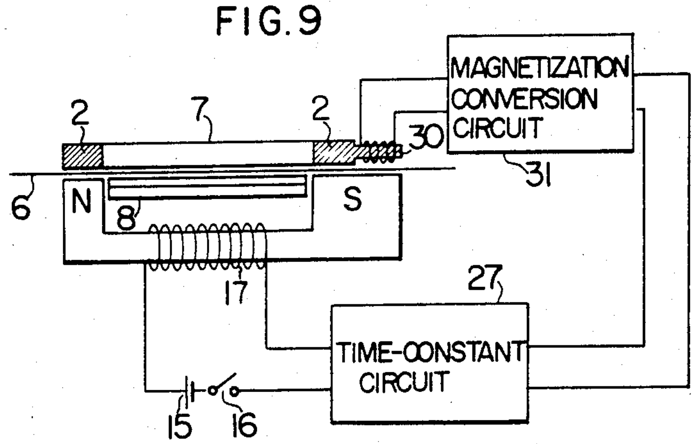
8
S
17
TIME-
CONSTANT
CIRCUIT
15
16
27

FIG.9


MAGNETIZATION
CONVERSION
CIRCUIT
2
7
2
30
31
6
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8
S
17
27
TIME-CONSTANT
CIRCUIT
15
16

LIGHT CONTROL DEVICE

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to a light control device employing a magnetic colloidal fluid and magnetic field generating means.

DESCRIPTION OF THE PRIOR ART

Optical shutters which are not based on the use of conventional mechanical means have been proposed, in which a substance that utilizes the so-called polarization phenomenon of light according to the Kerr effect or the Faraday effect, i.e., the double refraction phenomenon of light or the rotation of the vibration plane of a linearly polarized light caused by the application of a strong electric field or magnetic field to a dielectric material, and polarizers for producing linearly polarized light are arranged in the form of sandwich and an external electric field or magnetic field is applied to the dielectric substance to vary the rotary polarized light and thereby to control the transmission of the light, or alternately an organic substance, e.g., a so-called liquid crystal plate of particularly the nematic type is used so that the molecular orientation of the substance is disturbed by the imposition of an external electric field to effect the double refraction of the light and thereby to control the transmission of the light.

A disadvantage of the former which is based on the use of the dielectric substance and the rotary polarized light is that since the operating principle of the device requires the polarizers for producing linearly polarized light be placed respectively on the front and back sides of the device, the incident light is inevitably decreased considerably as it passes through the polarizers. Particularly, if the device is incorporated for example in photographic cameras which are subject to constant efforts to use as bright a lens system as possible to ensure an increased incident light, such a loss in the incident light is a serious problem. Further, the means for generating the required electric field or magnetic field generally tends to become bulky and elaborate and therefore the device cannot lend itself for use in conjunction with apparatus intended to be carried on a person.

On the other hand, a disadvantage of optical control devices of the latter type employing the liquid crystalline phenomenon of the nematic type is that since the liquid crystal is normally transparent to light, that is, it is rendered opaque by the imposition of an electric field, if it is used for example as a shutter for photographic cameras, the electric field must be normally applied to the liquid crystal plate to meet the requirement that the passage of light be normally intercepted, thus requiring considerable power consumption and making practical use of the device impossible.

In addition, the use of either one of these photoelectric phenomena has a drawback in that since the resultant device is based on the use of the polarization phenomenon of light, there is a relationship between the incident light and the transmitted light which depends on the wavelength of light; that is, the operating principle is such that it is impossible to completely intercept the light and at the same time to provide it with a flat transmission characteristic which has no dependency on the wavelength for transmission.

SUMMARY OF THE INVENTION

It is the object of the present invention to provide an entirely novel light control device which overcomes the above-mentioned deficiency and in which a magnetic colloidal fluid is suspended in a medium which is transparent to light, whereby the position of the magnetic fluid is controlled in accordance with the strength of a magnetic field.

In accordance with the present invention, there is thus provided a light control device which is not subject to any mechanical restrictions such as those which are due to the shutter speed and which is capable of performing very high-speed opening and closing operations.

DESCRIPTION OF THE DRAWING

FIg. 1 is a schematic diagram useful for explanining the principle of the present invention.

FIG. 2 is a schematic view showing the construction of a light control device according to an embodiment of the present invention.

FIG. 3A is a partial side view of the device shown in FIG. 2.

FIG. 3B is a plan view of the device of FIG. 3A.

FIG. 4A is a partial side view of another embodiment of the device according to the present invention.

FIG. 4B is a plan view of the device of FIG. 4A.

FIG. 5 is a schematic view showing the construction of still another embodiment of the present invention.

FIG. 6 is a schematic view showing an exemplary distribution of the magnetic fluid used with the present invention.

FIG. 7A is a side view showing the construction of magnetic field generating means used in still another embodiment of the present invention.

FIG. 7B is a plan view of the device of FIG. 7A.

FIG. 8 is a schematic view showing the construction of still another embodiment of the present invention.

FIG. 9 is a schematic diagram showing the construction of still another embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Prior to the description of preferred embodiments of the present invention, the general description of magnetic fluid as for example disclosed in U.S. Pat. No. 3,215,572 will be made hereunder.

An activated magnetic material such as nickel, cobalt, iron or any of various iron oxides is milled in a stainless steel ball mill to produce the activated magnetic material having a partical size between approximately 0.06 to 0.24 micron and the material is then mixed with oleic acid, heptane or the like to produce a colloidal solution in which the finely powdered magnetic material is properly distributed in the dispersion medium such as oleic acid. Thus, the resultant magnetic fluid is one in which the colloidal solution itself performs its function by the imposition of an external magnetic field.

In a device wherein such a magnetic fluid is distributed, with a proper volume ratio, in a liquid base of a different kind such as water, glycerin or silicone oil transparent to light and contained in a hermetically sealed container, the magnetic fluid and the liquid base are not mixed together, but the magnetic fluid is suspended in the liquid base and therefore the operation of the magnetic fluid such as the movement and fixing of the magnetic fluid in the hermetically sealed container can be readily effected at all times in accordance with the application of an external magnetic field.

FIG. 1 shows a schematic diagram for use in explaining the base principle of the light control device according to the present invention. A magnetic fluid 2 and a liquid base 3 of a material transparent to light are sealed in a hermetically sealed transparent container 1 so that when a magnetic flux 4 is applied in the manner shown in FIG. 1, the magnetic fluid 2 is gathered in the same shape as the transmitted flux 4.

In this device, the material used to intercept the passage of light comprises an activated magnetic material such as nickel, cobalt or iron and therefore when the light is interrupted, the transmission of the light is completely shut off and moreover the transmission of light in the visible range has no dependency on the wavelength. Thus, if the magnetic flux 4 is controlled to move and fix the magnetic fluid 2 in the transparent container 1, the function of a light control device such as a shutter can be accomplished.

In FIG. 2 showing an exemplary embodiment of the above-described light control device according to the present invention, the present invention is applied to a shutter for a camera unit, for example. A light control element 7 comprising the previously described magnetic fluid, etc. is disposed in front of the film exposure section of an optically intercepted cartridge 5 for photographic film or the like. To normally intercept the passage of an incident light 12 through a lens 13, a permanent magnet 8 made for example of barium ferrite has its magnetic domains magnetized as shown at 9 and 10 in FIG. 2 and it is disposed at the back of a light-sensitive material 6 such as a photographic film so that the magnetic field produced by the magnetized domains 9 and 10 is applied to the magnetic fluid of the light control element 7 and thus the magnetic fluid is gathered by the magnetic flux to intercept the passage of the light to the light-sensitive material 6 such as the film.

This is shown in greater detail in the plan view of FIG. 3B. As will be seen from FIG. 3B, the permanent magnet 8 is magnetized so that the magnetic domains 9 and 10 are magnetized horizontally and thus the resultant magnetic flux spread horizontally. Consequently, the magnetic fluid of the light control element 7 placed in the path of the magnetic flux is fixed in the shape shown by the hatching. Therefore, by placing the light-sensitive material 6, e.g., a film in such a manner that it is completely covered by the magnetic fluid, the passage of the incident light to the light-sensitive material 6 can be completely intercepted.

To move the magnetic fluid from its fixed position so that the light falls on the light-sensitive material or the film 6, as shown in FIGS. 4A and 4B, an electromagnet 14 is disposed around the permanent magnet 8 and an electromagnetic coil 17 is energized from a DC power supply 16 through a switch 15 to magnetize the electromagnet 14. As a result, each of the ends 18 and 19 of the electromagnet 14 produces a magnetic flux with the polarity shown. Accordingly, if sufficient energy is supplied from the power supply 16 so that the magnetic flux of the electromagnet 14 cancels that of the permanent magnet 8, the magnetic flux of the light control element 7 can be moved to the north and south poles of the electromagnet 14 to permit the transmission of the light to the light-sensitive material 6.

Accordingly, with the switch 15 arranged so that the supply of energy from the DC power supply 16 is enabled only for a period of time required to permit the passage of light to the light-sensitive material, e.g., the film 6, the transmission of light can be controlled by the opening and closing of the switch 15. Thus, by incorporating the light control device of this invention in a camera unit, the function of a shutter having no mechanical elements can be provided.

Against these advantages there is, however, a disadvantage due to the operating principle of the invention itself. That is, since the interception of the incident light is based on the use of the above-described means for indirectly fixing the magnetic fluid by means of the magnetic flux of the permanent magnet, etc., there is the danger that the application of a strong external mechanical shock or a strong external local magnetic field tends to momentarily expose the sensitive surface of a film 6 or the like to light.

The foregoing difficulty is overcome by the embodiment of this invention shown in FIG. 5. This embodiment differs from the embodiment of FIG. 2 in that a simple light shielding plate 21 of the type having for example a single vane is disposed in the path of the incident light. In this way, while the magnetic fluid is normally fixed by means of the permanent magnet, etc. to intercept the passage of the light, the light shielding plate 21 prevents any optical exposure due to the impact of a shock on the magnetic fluid. When the shutter button for example is depressed, the light shielding plate 21 is moved first to permit the passage of the incident light toward the light-sensitive material 6 or the section of a film and thereafter the magnetic fluid fixed by the permanent magnet 8, etc. is moved by the supply of current to the electromagnetic coil 17 to obtain a desired exposure characteristic.

While, in the embodiments described above, the magnetic fluid is fixed by means of the permanent magnet with the result that when the present invention is applied to a camera unit or the like where the light intercepting property is required in the normal condition of the unit, the supply of external energy is completely eliminated and hence the deficiency of the prior art is entirely overcome, there is still another disadvantage in that if a distance 22 between the magnetized portions, i.e., the magnetic poles of the permanent magnet becomes too wide, the flux density varies at the unmagnetized portions of the permanent magnet with the result that the thickness of the magnetic fluid in its fixed position varies and thus it becomes uneven as will be seen from FIG. 6, thereby failing to completely intercept the passage of light to the light-sensitive material, e.g., the film 6.

FIG. 7 illustrates still another embodiment of the present invention which incorporates a modification to overcome the foregoing difficulty. In other words, the magnetic poles of a plurality of permanent magnets are arranged as shown in FIG. 7 to ensure a uniform thickness of the magnetic fluid in the fixed position.

A magnetic material 24 of for example barium ferrite is employed and a plurality of magnetic poles are induced on one side of the material in the form of a mosaic as shown at 23 and 25 in FIG. 7. This produces the magnetic flux distributed as shown by 26 and hence a magnetic field which is irregular microscopically, but substantially flat is produced.

Consequently, the magnetic fluid 2 disposed in the magnetic flux path is dispersed evenly with a substantially uniform thickness and thus the foregoing difficulty is completely eliminated.

FIG. 8 illustrates still another embodiment of the present invention in which the exposure time (e.g., the speed of the shutter) of the light control device is associated with the time-constant circuit of a photographic camera. In this embodiment, the value of the electric resistance of the magnetic fluid is approximately $10^2 - 10^{10}\Omega$cm and electrodes **28** and **29** are embedded in a portion of the light control element **7**, e.g., at one side thereof.

Assume now that a switch **16** is closed, a current flows through the electromagnetic coil **17** causing the magnetic field of the permanent magnet **8** to be cancelled. Thus upon actuation of the electromagnetic coil **17**, the magnetic fluid **2** is moved to both sides in the light control element **7** as shown in FIG. **8**, and at the same time the opening is formed in the light control element **7** which permits light to pass to the light-sensing material, e.g., a film **6**. Since the electrodes **28** and **29** are located in one side of the light control element **7** and since the both electrodes **28** and **29** are now submerged in the electrically conductive magnetic fluid **2**, the electrodes **28** and **29** are electrically shortcircuited.

Accordingly, if a time-constant circuit shown at **27** in FIG. **8** comprises a known type of time-constant circuit for photographic cameras which comprises a resistor and a capacitor and if the time-constant circuit **27** is designed to begin its operation from the time of shortcircuiting of the electrodes **28** and **29** and the electromagnetic coil **17** is deenergized after the expiration of a predetermined time determined by the values of the resistor and capacitor in the time-constant circuit **27**, the light transmission time (shutter speed) of the light control device can be varied at any time in accordance with the time constant of the time-constant circuit **27**. The switch **16** may be constructed to cooperate with, e.g., a shutter button of a camera. More specifically, operation of the time-constant circuit **27** is initiated by the decrease in the electrical resistance between the electrodes **28** and **29** which occurs when they become submerged in the low resistance electrically conductive magnetic fluid **2**. In a conventional time-constant circuit of the type used in conjunction with the shutter timing mechanism of a camera, as shown for example in U.S. Pat. No. 3,326,103 granted Dec. 9, 1964, the reduction in resistance causes a capacitor to be charged through a resistor. When the voltage across the capacitor reaches a predetermined value, a switch is opened causing the coil **17** to be de-energized and the magnetic fluid **2** is returned to its initial state thereby completing the exposure of the film **6** to light.

FIG. **9** illustrates still another embodiment of the present invention in which the exposure time of the light control element **7** is also associated with the time-constant circuit **27** of a photographic camera. Referring to FIG. **9**, as compared with FIG. **8**, a portion of the light control element **7** at one side thereof is provided with a pickup coil **30** wound about that portion of the light control element **7**. In this embodiment, the magnetic property of the magnetic fluid **2** is utilized instead of electrical conductivity thereof in contrast to the device of FIG. **8**. When a switch **16** is closed, the magnetic fluid **2** flows into the portion of the light control element **7** around which portion the pickup coil **30** is wound in the same manner as described in connection with FIG. **8**.

A magnetization conversion circuit **31** is designed to detect the movement of the magnetic fluid **2** and actuate the time-constant circuit **27**. Specifically, the magnetization conversion circuit **31** may comprise a resonance circuit including the pickup coil **30** and a capacitor, and a switching element to actuate the time-constant circuit **27**. When the magnetic fluid **2** which has a relatively high permeability, flows into the pickup coil **30**, the inductance of the coil varies and the resonance circuit of the magnetization conversion circuit **31** becomes resonant and produces a pickup signal. Then, the switching element of the magnetization conversion circuit **31** in response to the pickup signal actuates the time-constant circuit **27**. Circuits of this type are well-known, an example being shown in publication "Electronics", Vol. 35, No. 23, page 113 (1965). The operation and function of the time-constant circuit **27** are the same as in the device of FIG. **8**. In these embodiments illustrated in FIGS. **8** and **9**, the movement of the magnetic fluid **2** not only controls directly the passage of light through the light control element **7**, but also functions as a switching means when associated with the suitable pickup coil **30** or electrodes **28** and **29**. The switching means in turn actuates another circuit such as time-constant circuit **27**.

In an ordinary photographic camera employing a lens shutter, in the normal conditions the interception of incident light is effected by the closing of a mechanical shutter disposed at the front or back of the lens to prevent the passage of incident light to a light-sensitive material such as a film.

On the other hand, in a photographic camera employing a focal plane shutter, the incident light transmitted through the lens is intercepted by means of rubberized curtains, metal plates or metal foils placed in front of a light-sensitive material such as a film.

Consequently, when these shutters are closed, their relatively rigid mechanical structures ensure a positive interception of the incident light in the normal conditions of the camera.

Considering the time of the opening operation in either of these types of shutter, however, the lens shutter mainly employs a mechanical structure so that a plurality of the metal plates are gradually opened with time, while the focal plane shutter has a mechanical structure comprising front and rear curtains so that the gap between the curtains is adjusted.

With these constructions, all of the known shutters are based on the use of mechanical elements and therefore their shutter speed is inevitably limited by the spring pressure, mechanical friction and resistance, etc. With the presently available techniques, the shutter speed is limited to 1/**1000** – 1/**2000** of a second.

On the contrary, the basic operating principle of the present invention is based on the use of a magnetic fluid suspended in a medium and therefore the device of this invention is practically unrestricted by purely mechanical factors. Moreover, while the viscosities of the liquids have mutual influence on them, the magnetic fluid prepared according to the previously described method is particularly of low viscosity and therefore in contrast to the mechanical shutters, the device of this invention is practically unrestricted with respect to the shutter speed and moreover very high-speed opening and closing operations are possible by increasing the starting current of the electromagnet for actuating the magnetic fluid.

I claim:

1. A light exposure control device comprising:

a hermetically sealed container having a front surface and a back surface with respect to the passage of incident light and containing an immiscible fluid transparent to light and a non light transmitting magnetic colloidal fluid including an activiated magnetic material,

means for locating, a light-sensitive member adjacent the back surface of said container, and

means for generating a magnetic field in close proximity to said container to shift the position of said magnetic fluid out of the light passage in said container, said light-sensitive member being exposed to light through said immiscible fluid or shielded therefrom by said colloidal fluid in accordance with whether said magnetic field is being generated.

2. A light exposure control device according to claim 1, wherein said magnetic field generating means comprises a permanent magnet.

3. A light exposure control device according to claim 1, wherein said magnetic field generating means comprises an electromagnetic coil.

4. A light control device according to claim 1, wherein said magnetic field generating means comprises a plurality of small magnets set in array in the vicinity of said hermetically sealed container.

5. A light exposure control device according to claim 1, further including a time-constant circuit for controlling the time of energy supply to said electromagnetic coil.

6. A light exposure control device according to claim 5, further including a plurality of electrodes disposed in said hermetically sealed container for actuating said time-constant circuit.

7. A light exposure control device according to claim 5, further including magnetic detecting means for detecting a magnetic variation caused by the movement of said magnetic fluid in said hermetically sealed container.

8. A light exposure control device according to claim 1 further comprising a light shielding plate disposed on the front surface side of said container and in the vicinity thereof for intercepting said light, said light shielding plate being operable. to allow light to reach the front surface of said container, immediately before the actuation of said magnetic field generating means and shield the front surface of said container after termination of generation of said magnetic field.

* * * * *