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ELECTROVISCOUSLY CONTROLLED RECORDER

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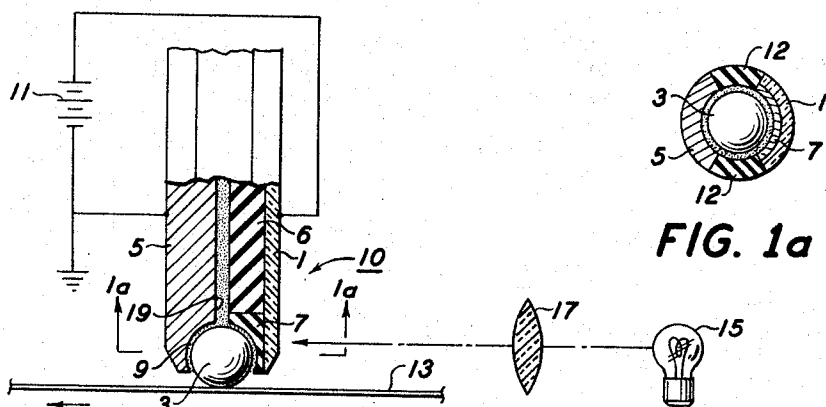


FIG. 1

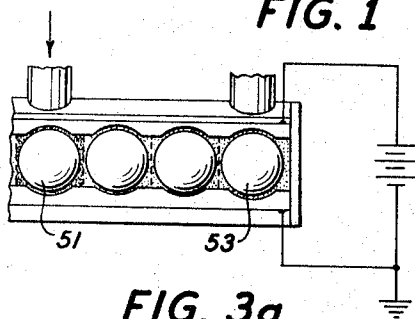


FIG. 3a

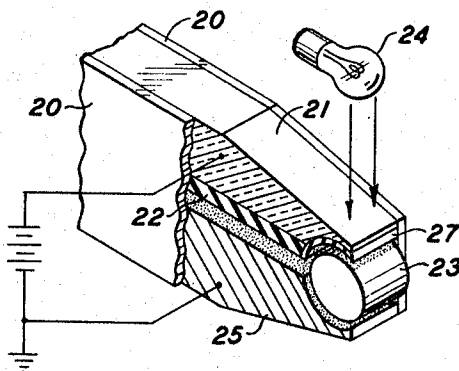


FIG. 2

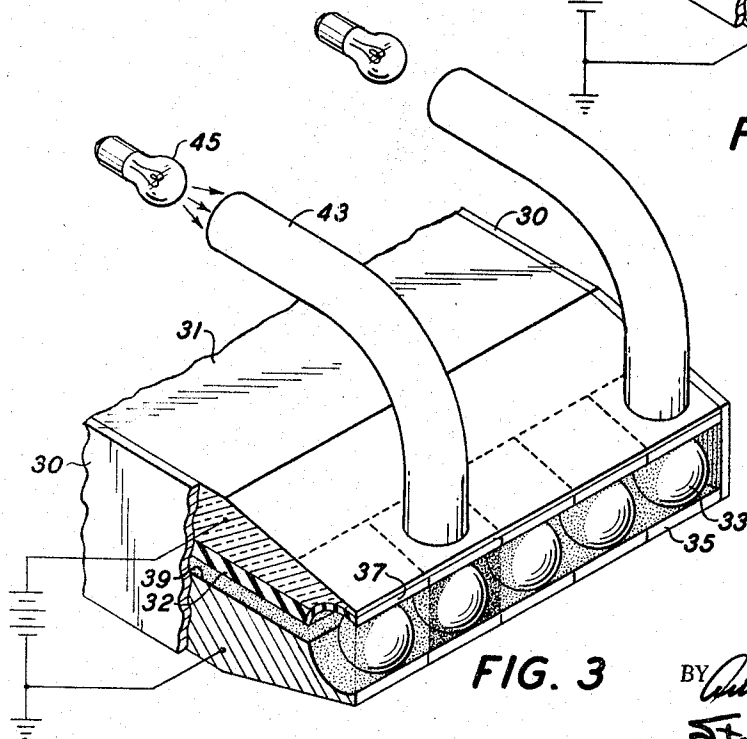


FIG. 3

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ELECTROVISCOUSLY CONTROLLED RECORDER
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This invention relates generally to ink scribing recorders and more particularly to such recorders wherein ink flow is controlled or modulated by the so-called electroviscous effect.

It has been shown by Willis M. Winslow that the apparent viscosity of certain liquids can be markedly altered by the application of an electric field. (Journal of Applied Physics, vol. 20, 137 (1949). U.S. Patent Nos. 2,417,850; 2,661,825; 2,661,596; 2,663,809; and 3,047,507.) Generally speaking, these liquids comprise a suspension of micron size solid particles in a liquid carrier. The Winslow patents and publications, supra, include numerous specific formulas for electroviscous liquids, any of which may be modified, as will be described below, for use with the present invention.

The present invention may be considered basically as an improvement upon an invention recently disclosed in the patent application of Harold E. Clark entitled "Electroviscous Recording," Ser. No. 313,675, filed Oct. 3, 1963, now Patent No. 3,270,637, and assigned to the assignee of the present invention. In the Clark application, methods and apparatus are for the first time disclosed for effectively utilizing the electroviscous effect for recording purposes. The embodiment of the Clark invention, that is of principal interest for present purposes, utilizes electric fields adjacent to an aperture to selectively inhibit the flow of marking liquid therethrough. Specifically, in Clark, the application of the electric field produces an increase in the apparent viscosity of the liquid to a point where flow through the aperture ceases. Thus, if the aperture is considered as an orifice for recording ink intended to subsequently mark a suitable surface, the application of electric field across the orifice serves to modulate the flow from the recording instrument.

While the Clark invention as described above operates satisfactorily for low rates of modulation yet it has been found that alternate stopping and starting of liquid flow cannot be achieved with sufficiently great rapidity, because of a residual inertia that remains within the viscosity-altered liquid upon removal of the electric field. That is to say that although the liquid can be made to gel almost simultaneously with application of the field, yet upon the removal of such field, there is a slight time lag before the apparent viscosity changes back to its original value.

It is accordingly, the principal object of the present invention to provide an electroviscously controlled ink scribe, incorporating means to facilitate the reintroduction of ink flow upon removal of the electric field.

It is an additional object of the present invention to provide an electroviscously controlled ink scribe in which stopping and starting of ink flow can be achieved more rapidly than in instruments previously known.

It is a further object of the present invention to provide electroviscously controlled recording apparatus capable of scribing multiple, parallel, independently modulated lines at a time.

It is yet a further object of the invention to provide electroviscously controlled scribing instruments having reliability of operation exceeding those previously known.

Briefly, these and other objects are achieved in the present invention by utilizing a rolling ball or cylinder as the ink scribing point of the electroviscously controlled system. A tiny ball bearing or cylinder is positioned at the

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writing tip of the instrument much as in a conventional ball-point pen. A controlled electric field is applied across the volume of scribing fluid surrounding the minute rolling surface, and under the influence of such field the viscosity of the fluid is raised to a point where it effectively gels and freezes the rolling surface. Yet, as the rolling surface continues in contact with the recording media in normal use, sufficient frictional torque is present to immediately reactivate flow of the fluid—and marking of the media—upon removal of the electric field.

The invention is diagrammatically illustrated by way of example in the accompanying drawings, in which:

FIGURES 1 and 1a are cross sectional views through an elementary preferred embodiment of the present invention;

FIGURE 2 is an isometric sectional view of an embodiment of the invention utilizing a minute rotating cylinder as a scribing point;

FIGURE 3 is an isometric view of an embodiment of the invention adapted for scribing multiple parallel independently modulated lines at a time;

FIGURE 3a is a diagrammatic partial view of the open scribing end of the instrument depicted in FIGURE 3 and illustrates the manner in which independent control of the several scribing points is achieved.

In FIGURE 1, a longitudinal cross section through a simple preferred embodiment of the present invention is depicted. The instrument there shown superficially resembles a ball point pen. The scribing point 3 in the preferred embodiment comprises a hard steel ballbearing and is mounted at the extremity of barrel 10 with a sufficient area of the bearing protruding beyond the barrel to act as an ink-bearing contact surface with the recording media 13. Point 3 may also comprise an insulating material such as for example hardened nylon. The barrel 10 comprises the split conductive sections 1 and 5 which, as seen in the transverse sectional view of FIGURE 1a are separated by insulating section 12. An insulating sleeve is provided at 6 to prevent establishment of a field within the channel 19. The section 5 is comprised of an uncritical conductive material as for example, aluminum. Section 1, however, must be transparent to incident light and accordingly, comprises an electrically conductive glass, such as, for example, NESA glass (a product commercially available from the Corning Glass Works, in Corning, New York). In the portion of barrel 10 adjacent to the scribing point, an inset 7 is carried. This inset comprises a photoconductive insulator such as vitreous selenium. An electroviscous scribing fluid 9 is carried within channel 19 and by gravity flow bathes the scribing point 3 in a manner similar to that of a conventional ball point pen. In normal use sufficient fluid 9 is always present between the scribing point and the depression of the barrel in which it is positioned to provide electrical insulation even where 3 is conductive, but in any event the photoconductive material comprising inset 7 never becomes highly enough conductive to cause a general electric breakdown.

The operation of the device illustrated in FIGURE 1 is as follows: A D.C. potential from source 11 is applied across the conductive sections 1 and 5. Provided no light is incident upon the photoconductive inset 7, the electroviscous scribing fluid 9 will act much like a conventional ink, and by virtue of relative motion provided between the recording surface 13 and the scribing instrument, the rotating point 3 will scribe a continuous line. If now, however, light source 15 is activated, the light will be focused through lens 17 and made incident upon section 1, and in particular, upon the photoconductive inlet 7. As a result, the potential of source 11 is applied across the volume of electroviscous fluid 9 surrounding the scribe-

ing point 3. The viscosity of the fluid, reacting to the electric field changes, and the fluid becomes a gel-like consistency. This, in turn freezes the rotating sphere 3 in place and the scribing action upon surface 13 ceases. It will be appreciated at this point, however, that in the present invention by virtue of the normal writing pressure between the scribing instrument and the recording medium 13, plus the continuing relative movement of the recording medium 13, a degree of residual torque continues to be applied to the frozen spherical point 3. Thus, it is that upon extinction of the light source 15, immediate reactivation of the scribing action occurs. That is to say, that immediately upon return of the fluid viscosity to its former value, the residual torque ever present at the surface of the point 3 acts to immediately reinstate flow of the scribing fluid.

As has been previously indicated, the electroviscous scribing fluid 9 may basically be prepared in accordance with formulations enumerated in the referenced Winslow patents and publications. Modification is necessary to the extent that coloring agents must be added in the event a particular formulation is not initially dark enough to serve as a marking or a recording fluid. This is generally accomplished by modifying the Winslow liquids in either or both of two ways: carbon black may be employed as a solid component of the liquid, or a soluble dye may be added to the liquid. Other pigments may be used instead of carbon black, but carbon black has a desirably high visual density and has been found to promote a large electroviscous effect.

Other types of homogeneous liquids also exhibit an electroviscous effect and are useful in the present invention. These include solutions of metal soaps and non-polar hydrocarbons; mixtures of mutually soluble substances which can exist as solid or liquid solutions at different temperatures and which exist in a liquid crystalline state in liquid solutions; solutions of paraffin sulfates which form micelles; and, liquid crystals, i.e., elongated molecules which contain one or more polar groups and which form nematic, smetic, or cholesteric phases. Further information on non-particulate electroviscous materials may be found in the literature, e.g., Bjornstahl and Snellman, *Kolloid Zeitschrift* 78, 258 (1937); Bjornstahl and Snellman, *Kolloid Zeitschrift* 86, 223 (1939); Michailoff and Zwetkoff, *Acta Physicochimica U.S.S.R.* 10, 415 (1939).

In FIGURE 2, an isometric sectional view is shown through an embodiment of the present invention that is quite similar to the basic embodiment of FIGURE 1, except that the rolling spherical point 3 of FIGURE 1 is now replaced by a rotating cylindrical scribing surface 23. Again here, 25 represents a non-critical electrically conductive material such as for example, aluminum. End pieces 20 and liner 22 are comprised of non-critical insulators. Section 21 is a transparent conductive glass member as for example, the NESA glass previously alluded to. The photoconductive inset 27 may suitably comprise a mixture of an organic photoconductor such as, for example, TO 1920 available from Kalle and Company and a polyvinyl chloride-acetate copolymer resin such as, for example Vinylite VYNS (Union Carbide).

The operation of the FIGURE 2 embodiment is completely analogous to the FIGURE 1 device except it will be appreciated that since a cylindrical rotating surface now comprises the ink depositing surface, the width of the line laid down by the instrument is limited only by the designed length of the cylinder. Again here it is emphasized that by utilizing a rotating scribing point exceedingly rapid stopping and starting of the line being scribed is possible. In use of the instrument shown in FIGURE 2, for example, the cylindrical scribing point 23 is placed in contact with a recording medium and relative motion is provided between the instrument and the medium. This might be brought about in a typical case by the continual movement of a recording tape beneath

the instrument. Upon application of incident light from light source 24 to the photoconductive inset 27, the electric field established within the volume of fluid surrounding the scribing point causes such fluid to gel and effectively freeze rotation of the scribing surface 23. The scribing action thus ceases. While prior devices have been designed that utilize the electroviscous effect to stop the fluid flow across for example, an exit orifice, and thereby achieve the same cessation of scribing as is shown in the present invention, yet the advantage of the present design becomes clear upon consideration of the action that takes place upon subsequent extinction of the incident light. Upon such extinction, the immediate result is a change in viscosity of the gelled liquid to its former value. In the prior art, such a reversion did not automatically reinitiate writing of the instrument for the reason that considerable inertia remained in the fluid with a resulting reluctance to reflow. But by means of the present apparatus, this difficulty is overcome. Since the scribing surface 23 will be in continuous contact with the moving recording media even while in a frozen condition, there is always sufficient torque present about the axis of rotation of the cylindrical scribing surface to immediately reinitiate its rotation upon releasing it from its locked state. The release is, of course, accomplished by extinction of the incident light. Thus, the net result of such extinction is that the scribing fluid reverts to its low viscosity state and immediately begins to flow from the rotating scribing surface.

Using representative electroviscous inks and maintaining potentials of the order of 1,000 to 2,000 volts, it is found that cessation of the scribing action of the instruments depicted in FIGURE 1 or FIGURE 2 occurs at light intensity levels of the order of 2,000 ft. candles. It will be understood, however, that the level of light necessary to disrupt the electroviscous fluid flow will in general be a function of the particular fluid used as well as of the dimensions of the instrument orifice and scribing point, and of the pressure and degree of relative motion between the instrument and the underlying recording medium.

FIGURE 3 is an isometric view of an embodiment of the invention adapted for scribing multiple parallel lines. Here, a plurality of spherical scribing points 33 are positioned in a device somewhat similar to that described in FIGURE 2. The insulating end sections 30 enclose the sections 31 and 35 which are separated by the ink channel 39. As in previous embodiments 35 comprises a non-critical conductive material such as, for example, aluminum; and 31 comprises generally a conductive glass, such as NESA glass previously alluded to, which is lined by an insulating section 32. An insulating photoconductive inset 37 is carried at the extremity of the section 31 and partially encloses the spherical scribing points 33. As previously indicated, this inset may comprise vitreous selenium, or by way of example, may be formed from a mixture of the components previously alluded to, i.e., from an organic photoconductor such as the Kalle composition TO 1920 and Vinylite VYNS (Union Carbide). In the embodiment shown, individual and separate control of the several scribing points is achieved by utilizing discrete illumination means for each particular scribing point 33. These illumination means comprise a series of light sources 45 arranged to illuminate light conductive pipes 43. One such light pipe is associated with each of the several spherical scribing points. It thus becomes possible to separately and independently control the writing action of the several scribing points by selectively illuminating or darkening the photoconductive area adjacent to the particular point.

This action is best shown in FIGURE 3a which is a diagrammatic partial view of the open scribing end of the instrument depicted in FIGURE 3. It may be assumed there that illumination is projected through the

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light pipe associated with the scribing point 51, but not through the pipe associated with the scribing point 53. As a result, in accordance with the principles previously discussed gelling of the electroviscous ink occurs in the immediate vicinity of the point 51 but not in the vicinity of the point 53. Accordingly, as long as light is conducted to the vicinity of the point 51, no scribing action will occur from this source, but the remainder of the scribing points, including 53, will continue to function completely independent of the frozen point 51. It will be clear then that in this manner separate and distinct modulation of the writing action of any or all of the individual scribing points can be accomplished. Thus, for example, the instrument depicted in FIGURE 3 may readily be adapted to reproduction of complex graphic representations, facsimile applications, and the like.

Having thus described the present invention, it will now become possible for those skilled in the art to devise numerous variations thereof and modifications therefrom; yet, it will be clear that such variations and modifications will yet be within the province of the present invention. Accordingly, the invention described herein is to be construed broadly and limited only by the scope and spirit of the claims appended hereto.

What is claimed is:

1. An electroviscously controlled recording instrument comprising: liquid containing means for electroviscous liquid having an opening at one end thereof from which said liquid may flow, said opening being defined by surfaces formed for frictionally holding at least one rotatable writing body mounted therein; at least one pair of electrodes positioned at the formed surfaces; and, circuit means connected to said electrodes to establish an electric field across said opening, said circuit means including means to selectively control the establishment of said electric field.

2. Apparatus according to claim 1 in which said rotatable writing body comprises a sphere.

3. Apparatus according to claim 1 in which said rotatable writing body comprises a right cylinder.

4. An electroviscously controlled recording instrument comprising: containing means for electroviscous liquid; at least one spherical writing point rotatably mounted in an enclosing socket connected to said containing means by a channel adapted for gravitational flow-through of said electroviscous liquid; a pair of electrodes positioned at the surface of said enclosing socket to establish an electric field within the said liquid present in the volume of said socket in response to an electrical voltage applied thereto; and circuit means to selectively apply said voltage.

5. An electroviscously controlled recording instrument comprising: liquid containing means for electroviscous liquid having an aperture gravitationally fed by said liquid, said aperture having a rectangular cross section in the plane perpendicular to the feed of said liquid; rotatable spherical writing points co-linearly mounted in said aperture and held therein by spherical sectioned depressions formed on the interior surfaces of the walls defining said aperture, so that said points protrude beyond the aperture sufficiently to make rotatable contact with a writing surface; a pair of electrodes positioned at said aperture to establish an electric field across said aperture in response to an electrical voltage applied thereto; and circuit means to selectively apply said voltage.

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6. Apparatus according to claim 5 in which said electrodes define said aperture.

7. Apparatus according to claim 6 in which one of said electrodes is transparent and carries a photoconductive insulating layer in the portion thereof defining said aperture; and said circuit means comprises a source of constant potential connected to said electrodes and a source of light adapted to selectively illuminate portions of said photoconductive layer.

8. An electroviscously controlled recording instrument comprising: a generally cylindrical body having a central channel therein adapted for gravity flow-through of electroviscous marking fluid and having a spherical sectioned depression at one end open to said channel; a spherical rotatable writing body mounted within said depression and frictionally held therein with a portion of said body protruding beyond said depression perimeter; and a pair of electrodes separably positioned upon the spherical sides of said depression so that an electric field may be established in the vicinity of said writing body by application of an electrical potential to said electrodes.

9. Apparatus according to claim 8 in which said electrodes are formed integrally with said depression.

10. Apparatus according to claim 9 in which one of said pair of electrodes is covered with a layer of photoconductive material.

11. An electroviscously controlled recording instrument comprising: liquid containing means for electroviscous liquid having an aperture at one end thereof of bounded by surfaces formed for frictionally holding rotatable writing spheres mounted therein, which spheres are continuously bathed by said liquid; a pair of electrodes positioned at said aperture; and, means to selectively apply a voltage between said electrodes to inhibit the flow of said electroviscous liquid to said spheres.

12. Apparatus according to claim 11 in which said electrodes define said aperture.

13. Apparatus according to claim 12 in which said rotatable writing spheres are multiple and in which one of said electrodes is transparent and is covered by a layer of photoconductive material in at least the portion thereof defining said aperture.

14. Apparatus according to claim 13 in which said means to selectively apply a voltage between said electrodes includes a source of constant potential to said electrodes and a series of light conductive pipes, one each of said pipes being associated with but one of said writing spheres, and said pipes being positioned to selectively illuminate that area of said electrode having said photoconductive layer, which is adjacent to the writing sphere associated with the particular light conductive pipe, so that inhibition of flow of said electroviscous liquid may be controlled in the immediate vicinity of a given writing sphere by application of a light signal to the light conductive pipe associated therewith.

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J. W. HARTARY, *Assistant Examiner*.