

[54] **MAGNETIC MIXER**

[75] Inventor: **Bernard Lichtenstein**, Yorktown Heights, N.Y.

[73] Assignee: **Technicon Instruments Corporation**, Tarrytown, N.Y.

[22] Filed: **Dec. 13, 1971**

[21] Appl. No.: **207,196**

[52] U.S. Cl. **259/1 R, 259/DIG. 46, 356/39, 356/208**

[51] Int. Cl. **G01n 21/24, B01f 13/08**

[58] Field of Search **259/1 R, 99, DIG. 46; 356/39, 208**

[56] **References Cited**

UNITED STATES PATENTS

3,219,318 11/1965 Hershler 259/1 R

Primary Examiner—John Petrakes

Assistant Examiner—Alan I. Cantor

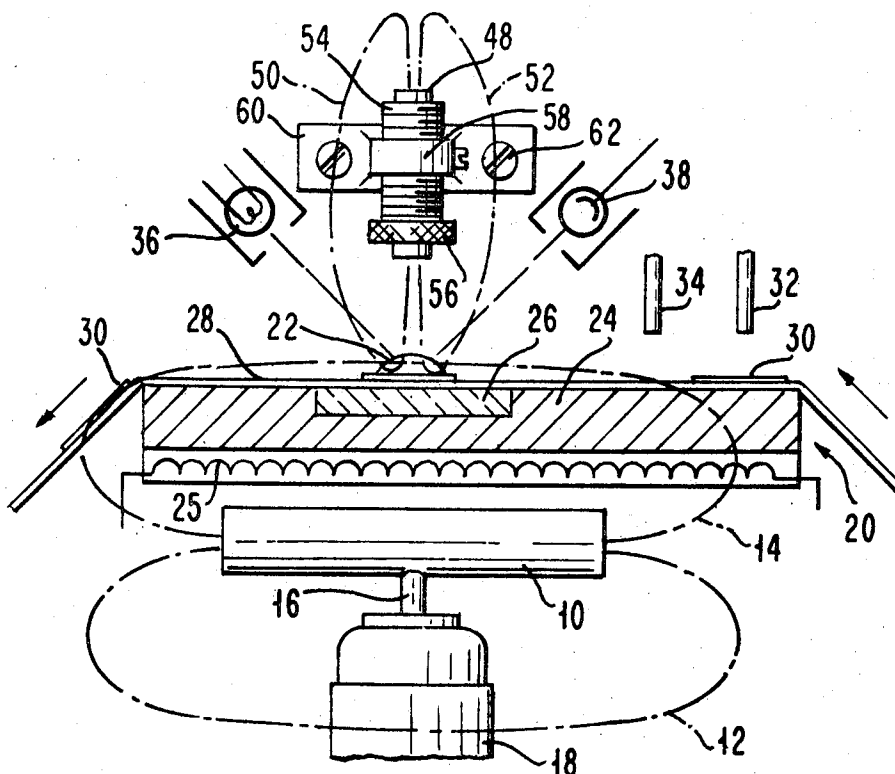
Attorney—Saverio P. Tedesco

[57] **ABSTRACT**

A magnetic mixer for laboratory use which includes a

permanent magnet mounted for rotation and driven on an axis centrally between its poles. A volume of combined liquids, containing in addition a multiplicity of magnetic particles, is supported centrally with reference to the magnet poles for activation of the particles in the rotating magnetic field to mix the liquids to achieve a reaction between them or merely a blending. This rotational force on the mixture has the effect of redistributing the magnetic particles away from the center of the mixture which effect, unless countered, lessens the mixing action. A second permanent magnet is provided having its poles in substantial alignment with the first mentioned axis, and having one of these last-mentioned poles spaced a distance nearer to the mixture than the other pole thereof, the magnetic field of the second magnet being substantially at right angles to the magnetic field of the first magnet. The field of the second magnet effectively counters by attraction the aforementioned redistributing movement of the magnetic particles, and the resultant particle distribution is substantially uniform throughout the combined liquids.

13 Claims, 6 Drawing Figures



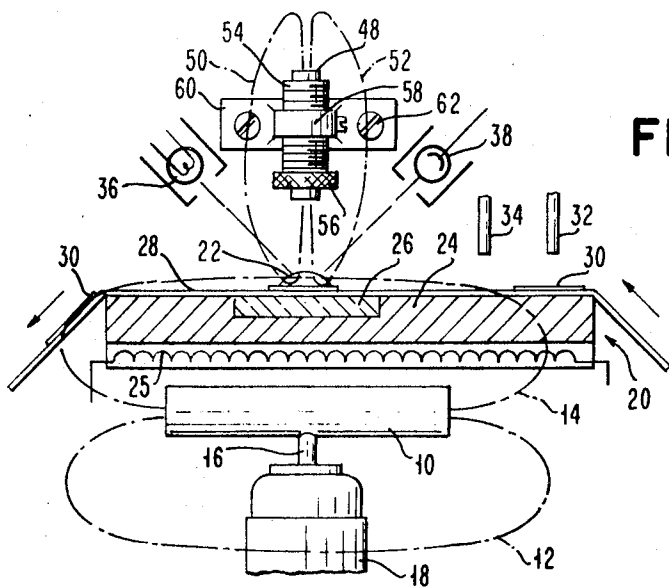


FIG. 1

FIG. 5

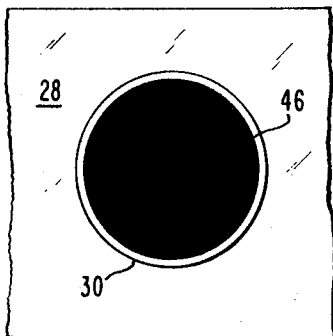


FIG. 6

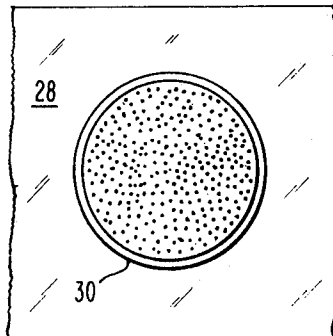


FIG. 2

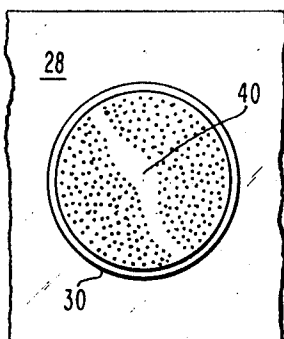


FIG. 3

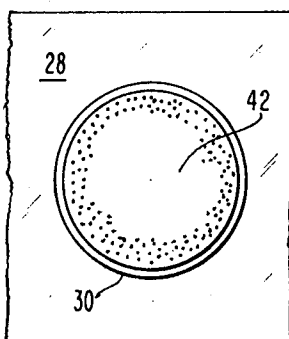
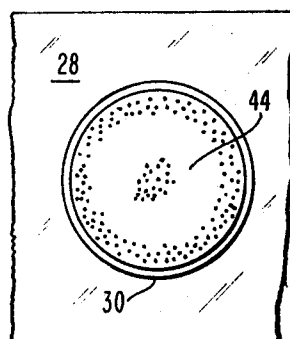


FIG. 4



MAGNETIC MIXER

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a magnetic mixer for mixing together plural combined volumes of liquid in which a volume of magnetic particles have been added for activation and mixing action in the liquid.

2. Prior Art

Especially in clinical laboratories, activated magnetic particles have been used both for mixing together two combined liquids, such as a volume of sample and a volume of reagent, and as a reaction-intensifying agent. These uses may be combined or concomitant as in the coagulation testing of human blood for Prothrombin Time (PT) or Partial Thromboplastin Time (PTT) as illustrated and described in Adler U. S. Pat. No. 3,650,698, issued Mar. 21, 1972, assigned to the assignee of the instant application.

In the last mentioned usage, a movable tape is employed. The tape contains predeposited spots of an iron oxide material in the form of opaque magnetized particles suspended in a water soluble media in thermofomed wells or on a planar tape surface. The testing of the sample blood plasma takes place in each thermofomed well on the clear plastic tape. The plasma and reagents are added at specific points as the tape transports the mixture to the optical detector site. The magnetic particles are resuspended in this solution which is incubated at 37.5° C. for approximately one minute. The plasma and the magnetic particles become mixed by activation of the particles by a rotary permanent magnet. The addition of the final reagent activates an optical detector and a timing device. Constant mixing is achieved by use of the rotating magnetic field of the magnet. The suspension presented to the optical detector should be uniformly opaque. This is a function of the iron particles. Fibrin formation from fibrinogen present in the plasma is recognized when the opaque suspension very abruptly becomes transparent as one or more forming fibrin strands entrap the magnetic iron particles and sweep them together into small localized spots or clumps in the transparent liquid. In other words, the fibrin and all the particles coalesce into a small mass, thus rendering the formerly opaque suspension transparent. The optical detector or monitoring system stops the timer by a signal upon this optical change, and the elapsed time is printed out.

The success of this system depends, among other things, upon the accuracy of the optical detector in detecting the end reaction which is the formation of fibrin. Lack of substantial uniformity of distribution of the magnetic particles in the sample during mixing prior to the formation of fibrin not only lessens the mixing action of the particles but concomitantly renders the sample of nonuniform opaqueness. Such nonuniformity of opaqueness results, in the use of the optical detector, in false or premature cutoffs of the timer.

Such a phenomenon is unlikely to occur if the concentration of the iron oxide in the sample is maintained at a relatively high level or as disclosed in the aforementioned U.S. Pat. No. 3,650,698. However, it has been found that relatively high concentrations of iron oxide have an adverse effect on determinations of PT. In the use of such apparatus with a lower concentration of iron oxide in the sample to avoid such interference with the PT determination, the rotating magnetic field

has redistributed the magnetic particles in solution, as by centrifugal and fluid forces, to render the mixture nonuniform and lacking uniformity of opaqueness prior to the end reaction, so as to cause false or premature cutoffs of the timer by signals generated by the optical detector.

SUMMARY OF THE INVENTION

The invention has for an object the provision of a magnetic mixer which effectively tends to evenly distribute magnetic particles through a liquid medium in which two or more liquids are to be mixed, enhancing the mixing action of such particles. A further object is to provide such a mixer which tends to distribute a relatively low concentration of iron oxide particles in a blood plasma sample in a manner such that the sample is rendered substantially uniformly opaque during coagulation testing, prior to the end reaction to be detected by an optical detector.

There is provided a magnetic mixer which, while not limited thereto, is especially useful in laboratories in carrying out various types of analysis on various types of liquid substances, which mixer includes a permanent magnet mounted for rotation and driven on an axis centrally between its poles. A volume of sample-reagent liquid, containing in addition a multiplicity of magnetic particles, is supported centrally with reference to the magnet poles for activation of the particles in the rotating magnetic field to mix the sample-reagent liquid to achieve a reaction between these constituents or merely for blending them together. To oppose the centrifugal and fluid forces on the mixture by the rotating field, which has the effect of redistributing the magnetic particles away from the center of the mixture, a second permanent magnet is provided having its poles in substantial alignment with the first mentioned axis and having one of these poles spaced a distance nearer to the mixture than the other pole thereof, the magnetic field of the second magnet being substantially at right angles to the magnetic field of the first magnet.

BRIEF DESCRIPTION OF THE DRAWING

In the drawing:

FIG. 1 is a fragmentary view in elevation and partially in section illustrating somewhat diagrammatically mixing apparatus embodying the invention;

FIG. 2 is a fragmentary top plan view illustrating diagrammatically a tape-supported volume of a liquid medium in which there is one type of unequal or nonuniform magnetic particle distribution as influenced by a single magnet (not shown), which generates a rotating magnetic field, in accordance with the prior art;

FIG. 3 is a view similar to FIG. 2, illustrating a second common type of unequal or nonuniform magnetic particle distribution under similar conditions, in accordance with the prior art;

FIG. 4 is a view similar to FIG. 2, illustrating a third common type of unequal or nonuniform magnetic particle distribution under similar conditions, in accordance with the prior art;

FIG. 5 is a view illustrating an opaque condition of the liquid medium resulting from an even or uniform distribution of such particles; and

FIG. 6 is a view similar to FIG. 2 but illustrating diagrammatically the even or uniform particle distribution in the opaque condition of FIG. 5, in accordance with the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Basic elements of the magnetic mixer shown in FIG. 1 include a magnet 10, here illustrated as of the permanent type and as being of bar shape. Magnet 10 may conveniently take the form of an Alnico 5 magnet, having a diameter of approximately one-half inch and a length of $2\frac{3}{8}$ inches. As will be apparent, the poles of the magnet are at the respective ends thereof, and the magnet generates a multiplicity of lines of force or flux, two typical lines of force being indicated at 12 and 14. The magnet 10 is arranged horizontally and is supported for rotation on a vertical shaft 16 angularly fixed thereto, and having its axis as close as possible to the midpoint between the magnet ends or poles. The axis of the magnet is horizontal as previously indicated, and the magnet is driven through the shaft 16, as by any conventional device such as electrical motor 18, to generate a rotary magnetic field.

Spaced a short distance above the magnet 10 is a stationary support for a volume of liquid, the contents of which are to be mixed, and which support is indicated generally at 20. The support 20 may have any desired configuration to support the volume of liquid to be mixed, but is here illustrated as having a flat upper surface portion for the support of the volume of liquid here illustrated as a droplet indicated at 22. The droplet 22, which combines plural liquids to be mixed, contains in suspension a multiplicity of magnetic particles. These particles are magnetized and may be formed of iron oxide and may have a generally acicular configuration with a major dimension in the range of 0.40 to 0.60 microns, for example. Alternatively, such particles may be constituted by cobalt or nickel materials.

The droplet 22 is illustrated as having its center on the axis of rotation of the magnet 10. It is to be noted that the flux or force line 14 is substantially flat in the area thereof passing through the droplet 22. This flatness in this area is desirable to eliminate any significant vertical component of this magnetic field in the droplet 22.

The illustrated apparatus thus far described is in accordance with the teaching of the aforementioned Adler U.S. Pat. No. 3,650,698, the disclosure of which is incorporated by reference, and like the disclosure of the last-mentioned patent, is illustrated as embodied in apparatus for determining the coagulation rate of human blood specimens. More specifically, such coagulation-rate testing is illustrated here and in that patent as involving the determination of Prothrombin Time (PT).

For this use, illustrated by way of example, the support, generally indicated at 20, for the liquid droplet 22 to be analyzed includes a rigid horizontally elongated strip 24 of a nonmagnetic material and mass appropriate for providing a heat sink. An electrical heater coil 25 is conveniently supported and located adjacent to the bottom of the heat sink 24 to generate heat for application to the heat sink which is preferably maintained at the substantially constant temperature of approximately 37.5° C. The heat sink 24 has a flat upper surface, and in the central region thereof has a mirror element 26 recessed therein so as to be substantially flush with the last-mentioned surface. The mirror element 26 extends beyond the periphery of the droplet 22.

The support 20 further includes a strip-like web or tape of transparent flexible material, which may be conveniently formed of Mylar, which directly supports the droplet 22 above the heat sink 24 and mirror element 26 on the upper surface of the tape, the lower surface of the tape being supported directly by the heat sink 24 and, in the area of the droplet 22, the mirror element 26 in the manner shown. The tape 28 may have at spaced intervals along its length thermo-formed wells 30, each of the wells 30 being provided to contain plural liquids to be mixed together. However, the wells 30 may be omitted if desired to improve thermal transfer between the heat sink 24 and the volumes of liquid supported on the tape. In other words, the upper surface of the tape 28 may be flat throughout the entirety of such surface and still afford proper support for the liquid volumes.

In each of the wells 30 there is deposited, in a manner similar to that described and illustrated in the aforementioned Adler U.S. Pat. No. 3,650,698, a spot (not shown) of an iron oxide material or the like which is dried therein during the manufacture of the tape. However, it is to be noted that the amount of such iron oxide particles in each well 30 is significantly lower than that described in the aforesaid Adler U.S. Pat. No. 3,650,698. In that patent, it is indicated that in the manufacture of the tape, the reaction intensifying agent deposited on the tape, may consist of a suspension of approximately 50 grams of magnetic iron oxide particles in 100 ml. of carrier solution. When the magnetic mixer of the present invention is employed in such blood testing, the reaction intensifying agent deposited on the tape in a similar manner, may consist of a suspension of less than 40 grams of magnetic iron oxide particles in 100 ml. of carrier solution.

According to the disclosure of the aforementioned Adler U.S. Pat. No. 3,650,698, with reference to the details of the blood-testing apparatus, which details do not require detailed description or illustration here, the system employed with the magnetic mixer of the present invention for analysis of Prothrombin Time or PT may include an intermittently operated drive mechanism to drive the tape 28 in the direction of the arrows of FIG. 1, a sample discharge probe 32 at a first dispensing station (FIG. 1) over the illustrated tape run, an a reagent discharge probe 34 at a second station over the tape run. The aforementioned system further includes a light source in the form of a lamp 36 over the tape run, light rays from which strike the droplet 22 at a third station over the mirror element 26, and a photo-sensitive device in the form of a photocell 38 over the tape run, which photocell coacts with the droplet 22 and the mirror element 26 below the droplet.

The operation of the apparatus thus far described, detailed in the aforementioned Adler U.S. Pat. No. 3,650,698 with the there recited amounts of the reaction intensifying agent predeposited on the tape, need not be discussed in detail here. It is sufficient here that the tape 28 is advanced to present one of the tape wells 30 at the first station in registry with and below the dispensing probe 32 at which station a precisely measured quantity of a blood plasma sample is added to the aforementioned reaction intensifying or enhancing agent, to rapidly re-suspend the latter, with the effect of the aforementioned rotating magnetic field being to promote initial blood plasma sample-reaction intensifying agent mixing and render the resultant mixture sub-

stantially turbid or opaque. It is to be understood that at this point the mixture is under the influence of the heat sink 24.

After the expiration of a period of time predetermined to provide for sample incubation, the tape 28 is advanced to present the last-mentioned tape well 30 at the second dispensing station at which the well is in registry with and below the dispensing probe 34, at which station a precisely measured quantity of thromboplastin reagent is added to the substantially turbid or opaque mixture to commence the coagulation reaction with the effect of the rotating magnetic field on the magnetic iron oxide agent further promoting mixing of the sample and the thromboplastin reagent. The thromboplastin reagent dispensed by the probe 34 may be diluted at the second station with calcium chloride or calcium chloride may be added to the mixture at a subsequent station not shown. After the addition of the last reagent, the tape 28 is advanced to present the last-mentioned tape well at the third station at which the tape travel is stopped with the last-mentioned well and the liquid mixture therein in the position of the droplet 22 of FIG. 1, and the photocell 38 and the timer are activated.

In the last-mentioned position of the sample mixture, the center of the droplet 22 closely coincides with the center of the rotating magnetic field. As the end point of the PT or coagulation reaction is reached, the substantially turbid or opaque treated sample undergoes a sharp and dramatic change in an optical property due to the collection of the rotating magnetic iron oxide particles by one or more of the fibrin strands generally centrally of the mixture, to thus render the mixture substantially transparent for immediate detection by the photocell 38 which detects the light directed through the droplet 22 to the cell 38 by the mirror element 26. The signal generated by the photocell 38 in this manner effects a printed readout of the Prothrombin Time or PT of the blood plasma sample of interest. Operation of the apparatus is continuous in the manner described until each of the blood plasma samples of a series of such samples from different patients has been determined.

During each such test and before the production of fibrin in the treated sample, the magnetic field of the rotating magnet 10 spins the magnetic particles in the treated sample, substantially about the axis of rotation of the magnet 10, creating a centrifugal force on such magnetic particles such as to tend to move these particles outwardly from the center of the mixture. When the population of the magnetic particles of each treated sample is reduced, as hereinbefore suggested for the reasons given, such a reduction under the aforementioned conditions often results in a lack of uniformity of particle concentrations throughout the treated sample, with concomitant transparency in one or more portions of the treated sample. Such transparency of the treated sample, or lack of uniform opaqueness of such sample, results in sufficient light being received by the photocell 38 to generate a signal which results in a false or early cutoff of the aforementioned timer, resulting in a faulty test.

Such a redistribution of the magnetic particles in the treated sample may be of the type shown diagrammatically in FIG. 2 wherein there appears to be a rivulet 40 of transparent fluid flowing through the center of the treated sample. It is theorized that such a redistribution

may take place through the influence of the rotary magnetic field by a pumping action on the fluid of certain magnetic particles which have agglomerated in the mixture. Another type of unequal redistribution of magnetic particles is indicated diagrammatically in FIG. 3, wherein certain of such magnetic particles, acting under the influence of the rotating magnetic field, have moved outwardly from the center of the treated sample, leaving the entire central portion of the latter transparent, as at 42. In FIG. 4, there is diagrammatically illustrated a further common type of non-uniformity of distribution of the magnetic particles which has been observed in a treated sample under the influence of a rotating magnetic field. Here the magnetic particles have left a transparent ring 44 around the center of the treated sample, giving the sample a bull's-eye effect.

The magnetic particle redistribution of FIGS. 2, 3, and 4, all result in a lack of uniform opaqueness of the treated sample, prior to the end reaction to be detected by the photosensitive device. The desired opaqueness of the treated sample resulting from an even or substantially uniform distribution of magnetic particles is indicated at 46 in FIG. 5, while the substantially even or equal distribution of such particles, which achieves the opaque effect of FIG. 5, is indicated diagrammatically in FIG. 6.

To achieve the desired opaqueness of the treated sample prior to the end reaction by the substantially uniform distribution of FIG. 6, there is provided another magnet 48 illustrated in FIG. 1 as being of the permanent type and of bar shape. The magnet 48 is vertically arranged, its poles being illustrated in vertically spaced relation to one another, which magnet 48 has a vertical magnetic field indicated by typical flux lines or force lines 50, 52.

The magnet 48 may be conveniently formed as an Alnico 5 magnet having 1/4 inch diameter and a length of 1-1/4 inches. The axis of the magnet 48 should closely coincide with the rotational axis of the magnet 10, and the spacing of the lower pole of the magnet 48 from the upper surface of the tape 28 may approximate the spacing of the upper surface of the magnet 10 from the upper surface of the tape. In actual practice, this spacing may approximate 0.4 inch. As clearly shown, the magnetic field of the magnet 48 extends into the treated sample droplet 22 on the support 20, and extends into the magnetic field of the magnet 10, so as to overlap the last-mentioned magnetic field.

The ends of the magnet 48 protrude from the respective ends of a supporting sleeve 54 of non-magnetic material, which is externally threaded as shown in FIG. 1, the magnet 48 being conventionally fixed to the sleeve 54. The sleeve 54 has a knurled radial flange which may be formed as an integral part thereof, the flange being indicated at 56. The threaded sleeve 54 carrying the magnet 48 is threaded into an eye 58 extending horizontally and in fixed relation from a support bracket 60, which may have attachment ears for receipt of suitable fasteners 62.

It will be understood from the foregoing that the magnet 48 may be vertically adjusted to increase or decrease the magnetic gradient of its magnetic field in the area of the supported volume of liquid on the support 20. In other words, the last-mentioned magnet may be adjusted toward and away the last-mentioned support and the volume of liquid supported thereby. It will be

obvious that this adjustment is accomplished by manually turning the knurled portion 56 of the sleeve in one direction or the other. The magnet 48 is preferably vertically adjusted to a position in which the magnetic gradient of its field in the area of the liquids to be mixed is of sufficient strength to generate magnetic centering forces large enough to effectively oppose the tendency of the magnetic particles in the solution under the influence of the rotating field of magnet 10 to move away from the center of the volume of liquid. In practice if it is found for one reason or another that it is desirable to have the central portion of the volume of liquid more opaque than the peripheral region thereof, the magnet 48 may be adjusted so that the vertical component of its field in the area of the volume of liquid produces forces which counter balance the tendency of the rotating magnetic field to redistribute the magnetic particles outwardly, so that the magnetic particles have some tendency to collect toward the center of the volume of liquid.

It will be evident from the foregoing that the construction and arrangement of the magnets 10 and 48 is such that their combined magnetic fields may effect a substantially even or uniform distribution of magnetic particles throughout combined liquids, which liquids are being mixed by the effect of one of the magnets through its rotating field, which combined effect of the magnetic fields enhances mixing and effectively opposes centrifugal force acting on the magnetic particles tending to redistribute such opaque particles from the center of the volume of liquid toward its periphery. It will be further understood that in the combination of the two magnetic fields illustrated and described, a lesser concentration of magnetic particles for mixing may be utilized than heretofore to provide the opaque effect of FIG. 5 of the volume of liquid which is achieved by the substantially even distribution of the magnetic particles in solution.

Although disclosed in the form of a preferred embodiment which is directed toward the automatic successive determination of the respective Prothrombin Times or PT of a plurality of blood plasma samples, it is believed that it has been made clear that the apparatus of the invention has significant utilization for different purposes. More specifically, the apparatus may be utilized, for example, for the determination of Partial Thromboplastin Time of blood plasma samples to enable the use thereof for the more specific isolation of the fact or factors causing deficiencies in the clotting time of a patient's blood. As another example, the apparatus, with suitable modification, may be utilized in the determination of fibrinolysis of coagulated blood plasma samples. In addition, and again with suitable modification, it is believed that it will be apparent to those versed in the art that the apparatus of my invention may be utilized in the determination of the end point of a polymerization-type reaction, the end point of which is evidenced by an abrupt change in viscosity, in a wide variety of liquids other than and different from blood plasma samples. Thus, for example, the apparatus of the invention may be utilized to determine the end point of a flocculation reaction as occurs in pregnancy testing, or in the end point of an agglutination reaction such as occurs in testing for rheumatoid arthritis.

It is to be noted that the support for the tape 28 which in turn supports discrete volumes of liquid

thereon may take other forms. For example, the tape support may take the form of that shown and described in the Bidanset U.S. Pat. No. application, Ser. No. 160,858, filed July 8, 1971, assigned to the assignee of the instant application, which discloses a tape cassette having a platen on which there is a tape run. It is to be understood that the volume of liquid to be mixed in accordance with the present invention, and herein illustrated as a droplet of liquid, need not be supported on a tape or the like, such as the tape 28, but may be supported directly on the upper surface of the mirror element 26.

While there has been shown and described the preferred embodiments of my invention, it will be understood by those versed in the art that the invention may be embodied other than as herein specifically illustrated or described, and that the invention is susceptible of taking other forms, and that changes may be made in details without departing from the principles of the invention.

What is claimed is:

1. Apparatus such as described, comprising: a support for a volume of liquid containing a suspension a multiplicity of magnetic particles, means effecting a rotary movement of said particles relatively to said liquid about an axis, which movement tends to be characterized by redistribution and collection of said particles in one or more localized areas in said liquid, and which rotary movement generates a centrifugal force affecting said particles, and means externally of said liquid generating a magnetic field gradient coaxing with said particles to overcome such redistributing effect thereon and balance said force, for substantial uniformity of distribution of said particles in said liquid.

2. Apparatus as defined in claim 1, wherein: said means effecting a rotary movement of said particles relatively to said liquid comprises a rotating magnetic field gradient generated by a magnet having a rotary axis on which it is driven extending centrally between poles of said magnet.

3. Mixing apparatus comprising: a first magnet having its axis between poles of the magnet disposed in a first plane, means for rotating said magnet on a second axis normal to said plane to generate a rotating first magnetic field, the second axis being located centrally between said magnet poles, support means for fixedly supporting substantially on said second axis a volume of plural combined liquids to be intermixed by a suspension of magnetic particles in said liquid volume, and a second magnet having poles, generating a second magnetic field and having its axis substantially on said second axis, one of said poles of said second magnet being spaced nearer said liquid volume than the other of said last-mentioned poles, said support means supporting said liquid volume in both said first and second magnetic fields so that dislocating movement of said magnetic particles by centrifugal force as the latter move through said liquid volume during mixing of the constituents latter is effectively opposed by said second magnetic field.

4. Mixing apparatus as defined in claim 3, wherein: said second magnet is a permanent magnet.

5. Mixing apparatus as defined in claim 3, wherein: said first and second magnets are permanent magnets.

6. Mixing apparatus as defined in claim 3 further comprising means to adjustably shift said second mag-

net and said support means relatively apart or toward one another.

7. Mixing apparatus as defined in claim 3, further comprising a photosensitive device cooperating with said liquid volume to indicate an optical change in said liquid volume during mixing of its constituents.

8. Mixing apparatus as defined in claim 3, wherein: said first magnetic field is horizontally arranged and said second magnetic field is vertically arranged.

9. Mixing apparatus as defined in claim 3, wherein: said support means comprises a tape for intermittent travel in a direction transverse to said second magnetic field which tape supports said liquid volume in the shape of a droplet on a surface of the tape.

10. Mixing apparatus as defined in claim 9, wherein: said first magnetic field is horizontally disposed and said second magnetic field is vertically disposed, said second magnet being disposed in spaced relation above said first magnet.

11. Mixing apparatus as defined in claim 10, wherein: said support means comprises a tape for intermittent travel in a horizontal direction, which tape supports said liquid volume in the shape of a droplet on an upper surface of the tape.

12. Apparatus such as described, comprising: a sup-

port for a volume of liquid containing in suspension a multiplicity of magnetic particles, means effecting movement of said particles relatively to said liquid volume, which movement tends to be characterized by redistribution and collection of said particles in one or more localized areas in said liquid volume resulting in a non-uniform particle distribution throughout the liquid volume, and means externally of said liquid generating a magnetic field gradient coacting with said particles to overcome such non-uniform distributing effect thereon, to achieve substantial uniformity of distribution of said particles throughout said liquid volume.

13. A method of mixing a volume of plural combined liquids to be intermixed by activation of magnetic particles in suspension in the liquid volume comprising: the step of generating a rotating first magnetic field, generating a second magnetic field substantially at right angles and centrally of said first magnetic field so as to have a portion thereof extending into and overlapping said first magnetic field, and supporting said liquid volume in said overlapping portion of said second magnetic field, so that said magnetic particles are attracted by both magnetic fields.

* * * * *

30

35

40

45

50

55

60

65