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MAGNETIC MERCURY

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This invention relates in general to a process for preparing and stabilizing a magnetically sensitive fluid and to the product.

It is an object of this invention to provide a process for the preparation of a stable fluid which is sensitive to a magnetic field.

It is a further object of this invention to provide a fluid which is sensitive to a magnetic field and which exhibits unusual stability.

Another object of this invention is to provide a magnetically sensitive fluid of low viscosity, i.e. a viscosity approaching that of pure mercury.

Other objects and advantages of this invention, if not specifically set forth, will become apparent during the course of the description which follows:

It has been found that a superior mercury product which is sensitive to a magnetic field may be prepared by incorporating iron in mercury either by a chemical replacement reaction, utilizing a sodium or potassium and mercury amalgam, or by an electrolytic process using mercury as the cathode and that the product is stable, especially after it has been washed with hydrochloric acid to remove the largest iron crystals, provided that it is maintained in a system such that continued volatilization of mercury cannot occur. If volatilization of mercury is permitted, as by storing or using the mercury in open air with no protective film on the surface thereof, mercury is lost and the iron amalgamated therewith is released to form a black or brown coating on the surface thereof and, in addition, a portion of the mercury remaining loses its magnetic susceptibility.

A convenient method for preventing volatilization of mercury is to utilize it in a closed system which may contain a large gas-filled space which is in equilibrium with respect to mercury vapor so that no further mercury can be evaporated from the surface of the magnetically sensitive fluid. Pure mercury may be introduced into the system at the outset and a state of equilibrium established before introduction of the magnetically sensitive fluid or, in the alternative, a small amount of another liquid having a greater vapor pressure than mercury may be introduced into the system together with the mercury, such fluid being present in sufficient quantity that equilibrium conditions will be established in the system before all of the added liquid has volatilized.

The product prepared chemically or electrolytically and so treated, especially if first shaken with concentrated HCl to dissolve any abnormally large iron grains which may be present in the mercury, will be stable for an indefinite time period.

In the chemical replacement reaction, sodium or potassium is first incorporated in the mercury by direct union (preferably in the presence of a small amount of water) and the sodium-mercury or potassium-mercury amalgam is contacted with an iron salt which may be in the hydrated form, thus applying sufficient water for the reaction) or may be in the form of a concentrated aqueous solution. In the electrolytic process, iron is electrolytically deposited from a dissociated iron salt in solution ($FeCl_2$, $FeSO_4$, etc.) an iron or carbon rod conveniently serving as the anode and the mercury serving as the cathode. The method described in co-pending application Serial No. 80,736, filed January 5, 1961, now abandoned, may also be used to form the amalgam, though this method is not preferred since it results in a highly granular product of somewhat reduced stability.

Preferably, the mercury is subjected to the electrolysis only for a sufficient period of time to cause the mercury to exhibit enough magnetic susceptibility to be attracted to a small permanent magnet dipped into the mercury, such as a small horseshoe magnet having pole pieces about ¼" in cross section. Removal of the magnetically susceptible fraction immediately after formation by immersing the magnet in the mercury yields a product of low viscosity and limits the formation of large iron crystals in the mercury which tend to grow preferentially, thus yielding a grainy product which deteriorates rapidly. Also, strong agitation of the mercury or a flowing action during the period that the current is passing is desirable since this also tends to limit the formation of the large iron crystals within the mercury. A current density per square decimeter not in excess of 20 amps is recommended with an E.M.F. not in excess of 6 volts. Lower current densities and voltages reduce the iron grain sizes.

Vigorous agitation of the mercury is desirable also where the chemical replacement reaction is utilized or the process described in the aforementioned co-pending patent application is used, such agitation tending to reduce the grain size and increase the stability of the product.

The appearance of the product is improved considerably and a bright, silvery-appearing product lacking black or brown iron deposits is assured if the product is agitated with concentrated or dilute HCl after it is removed from the reaction vessel.

Whether the product is so washed with HCl or not, it is absolutely essential that it then be stored in a closed system wherein litle or no mercury is permitted to evaporate. As mercury evaporates, iron is released from the amalgam and oxidizes, appearing on the surface of the fluid product in the form of a black or reddish-brown powder or scum. A further important effect of permitting volatilization of the mercury over any extended period of time is that the entire sample tends to lose its magnetic susceptibility. After several days in the open air, a sample which is initially entirely magnetically susceptible will be found to be less than one-half magnetically susceptible with the remainder of the mercury in the vessel being completely insensitive to the presence of a magnet. As noted earlier, there are several methods for preventing such volatilization of the mercury, the preferred being the use of a non-oxidizing fluid which is inert to mercury and iron as a "cover" liquid. Thus, even if the system is heated, the second fluid will vaporize more readily than the mercury, quickly establishing a state of equilibrium in the system and preventing further vaporization of the mercury. Preferred "cover" liquids are concentrated HCl or H_3PO_4; aqueous solutions of HCl, H_2SO_4, H_3BO_3, H_3PO_4 or H_2CO_3; concentrated solutions of alkali metal or alkaline earth metal salts (especially the halides) or hydroxides; the various borate esters and anhydrides, both aliphatic and aromatic, and salts thereof, in an aqueous solution if necessary; alcohols; vegetable oils and mineral oils; as well as any of the commerical anti-oxidants of which examples are Shell "Ionel" and various of the amines; and various buffer solutions such as an 0.1 N solution of phosphoric, phenylacetic and boric acids, for use where a non-corrosive cover liquid is required.

In addition to utilizing a small amount of the fluid or a sealed, gas-filled vessel as means of preventing volatilization of mercury, deposit of iron on the surface thereof, and rusting of the iron, it is also possible to use a sealed vessel containing an inert gas such as argon or nitrogen. If the gas is present in sufficient quantity at the outset, little if any volatilization of mercury will result and, in any case, any iron deposited out of the mercury will not oxidize. This, however, is a less preferred embodiment

of the invention since a fluid acts as a lubricant for the mercury in the system and since various of the "cover" liquids named (especially concentrated HCl) act to reduce the viscosity of magnetically susceptible mercury with which they are in contact.

Another important feature of this invention is the incorporation of at least one of the metals bismuth, aluminum, chromium, magnesium, antimony, cadmium, tin, or titanium in the amalgam of iron and mercury. Bismuth, magnesium and aluminum have a dramatic effect upon the viscosity and magnetic susceptibility of the mercury-iron amalgam and on the stability thereof. Antimony, cadmium, tin and titanium so affect the amalgam also, but to a significantly lesser degree, the first three of these metals yielding a product which "wets" glass.

These metals may also be used in admixture with one another or other metals than those listed may be added. Bismuth and tin mixtures, bismuth and aluminum mixtures, and bismuth, tin and lead mixtures have all been added to mercury-iron amalgams. Such metals as cobalt, nickel, and zinc may also be added to the mercury; however, nickel, cobalt, lead, and zinc do not beneficially affect the viscosity of the mercury. It is desired that between 90% and 98% by weight of the product constitute mercury, with the remainder constituting the iron, where a two-component amalgam is prepared. However, where an additional metal is added, as in the preferred embodiment of this invention, the mercury may constitute between 50% and 96% by weight, with 2% to 40% representing the third metal(s) and the remaining 2% to 10% representing the iron. A preferred product contains, by weight, 65–93% mercury, 2–10% iron, and 5–25% bismuth, magnesium, aluminum, chromium, or antimony.

Examples are set forth below for illustrative purposes but these are not to be construed as imposing limitations on the scope of the invention other than as set forth in the appended claims.

Example 1

A quantity of 7.3 grams mercury was placed in an electrolytic cell containing a saturated aqueous solution of ferrous chloride. An insulated copper wire was immersed in the cell with the bottom ¼" left bare and completely immersed in the mercury. Six volts D.C. were impressed upon a soft low-carbon iron anode (a nail), this anode resting in the cell in such a manner that it did not contact the mercury. The current density was 10 amps/square decimeter and the aqueous solution temperature was about 90–120° F. After ten minutes, during which time the mercury became somewhat more viscous, a portion of the mercury was removed from the cell with a small Alnico V magnet, washed twice by being vigorously agitated with several volumes of tap water, and dried with soft, adsorbent paper. This product was divided into two fractions, both of which were shaken with distilled water over a three-day period. One portion was then allowed to stand under distilled water while the second portion was placed in the test tube under ½ gram soluble oil. Both samples remained shiny, sensitive to magnetic fields, and showed no signs of deterioration when stored in the open test tube for an extended period of time.

Example 2

About 3.3 grams mercury was placed in the cell containing a concentrated lithium chloride electrolyte and provided with the same iron anode and current source described in Example 1. After a period of about ten minutes, during which time bubbles were evolved at the cathode, the lithium chloride was removed and replaced with ferrous chloride in saturated aqueous solution. Current was impressed on the anode for an additional ten minutes, and the product became noticeably more viscous. A portion of the mercury was removed from the cell, washed, and quickly dried and placed in a test tube under a layer of "Three-in-One" oil, where the product was stored without detectable deterioration. A portion of this product was stored in the absence of added oil and in the open air, and it was found that the lithium in the mercury attracted moisture, forming lithium hydroxide in water solution.

Example 3

A quantity of 5 grams mercury was placed in a vessel containing stainless steel which had been dissolved in concentrated 20° Bé. hydrochloric acid. The mercury lay at the bottom of the cell and an insulated copper wire was placed in the cell with the bottom ¼" left bare and completely immersed in the mercury. A stainless steel rod was used as the anode and it was placed in the cell in such a manner that it did not contact the mercury but merely dipped into the ferrous chloride solution so formed. A six volt automobile battery was connected to the anode and current supplied for a period of about ten minutes. The magnetically susceptible fraction was shaken with a saturated aqueous solution of $CaCl_2$ and dried. The magnetic fraction was divided into two aliquot portions, and one was placed under a layer of a saturated solution of calcium chloride and the other was covered with solid (powdered) calcium chloride which, because of its deliquescent properties, subsequently formed an aqueous solution. Both samples maintained their susceptibility to magnetic fields. However, the appearance of the product deteriorated somewhat, sufficient free iron material being formed over two weeks' time to cause the cover liquid to turn reddish-black. In additional runs where the product was washed immediately after preparation with concentrated (20° Bé) HCl, this deterioration in appearance was not encountered.

Example 4

A small piece of copper-containing Alnico magnet (Alnico V) was crushed and dissolved in concentrated hydrochloric acid to yield about 3 cc. of solution. Utilizing an anode consisting of another piece of Alnico V magnet, a mercury product was obtained electrolytically (as in Example 3) incorporating the Alnico magnet material. The magnetically susceptible portion of the product was washed and dried and a saturated aqueous solution of $CaCl_2$ in a quantity volumetrically equivalent to that of the mercury product was added and the mercury stored for an extended period of time without apparent deterioration in appearance or in susceptibility to a magnetic field.

Example 5

Using a low-carbon iron nail anode, 2.6 g. of mercury, a ferrous ammonium sulfate electrolyte and the aforementioned six volt battery, a small quantity of magnetically susceptible product was prepared, shaken with concentrated (20° Bé) HCl daily over a period of three days, and then stored with a layer of 20° Bé. HCl thereover. There was no detectable deterioration in the appearance or the magnetic susceptibility of the product. It remained mobile, though slightly less mobile than pure mercury, and shiny throughout the storage period.

Example 6

An electrolyte was prepared by pouring concentrated HCl over nails and the solution which formed after the reaction had been completed was decanted; 5 grams of mercury cathode contained in a glass jar was agitated by dipping a steel rod into it at 3 cps. Using a low-carbon iron nail as an anode, a product weighing about 5.2 grams was prepared which was washed and dried. The product was smooth, mobile and magnetically susceptible and was stored open to the air in contact with powdered $CaCl_2$, which eventually formed an aqueous solution due to exposure to moist air. The product maintained its magnetic susceptibility throughout the storage period, but the appearance deteriorated somewhat, a small amount of black powder clouding the $CaCl_2$ solution after about two weeks' time.

Example 7

A quantity of 8 grams of mercury and 0.1 gram sodium formed an amalgam, the sodium being cut into small pieces (1/16") and impressed beneath the surface of the mercury piece by piece. A grinding action resulted in a reaction, sparks, and vaporization of mercury. The mercury became progressively more viscous as the sodium was added. A large excess of $FeCl_2 \cdot 4H_2O$ was added to the reaction vessel and the entirety vigorously agitated with a stirring rod, the hydrated ferrous chloride providing most of the water for the exchange reaction, with a few drops of additional water being added. There was a vigorous exothermic reaction. Following washing, the product was found to be magnetically susceptible and capable of supporting itself when it was placed tightly against a piece of paper surrounding a pole piece of a small permanent magnet. The sample was divided into two parts, one of which was treated with an additional .1 gram sodium, resulting in the formation of a solid amalgam. To this was added a saturated solution of $SnCl_2$. A reaction ensued and the product was washed with 2 N HCl, followed by water, and stored under a 1/32" layer of 2 N HCl without any apparent deterioration either in magnetic susceptibility or appearance. The resultant product had a somewhat lower viscosity than the iron and mercury amalgam prepared initially. The second portion of the iron-mercury amalgam was simply shaken with stannous chloride solution, no sodium having been added thereto. There was no effect on the viscosity or appearance of the product and it was apparent that none of the tin had found its way into the amalgam. Similar results were obtained when a chromous chloride solution was contacted with a sodium-iron-mercury amalgam, on the one hand, and an iron-mercury amalgam on the other. Further, the samples having no tin or chromium therein showed considerably less stability than the products into which tin and chromium had been incorporated by the sodium replacement reaction.

Example 8

A quantity of 165 grams of mercury and 2.2 grams sodium were triturated together to form an amalgam and the amalgam allowed to stand overnight. To the resultant amalgam was added an excess of $FeCl_2 \cdot 4H_2O$ crystals and a few drops of water to initiate a reaction. A dark green viscous mass formed and hydrogen evolution was apparent; at one point, it burst into flame. On cessation of the exothermic reaction, the product was washed and dried and to it was added an additional 2.2 grams sodium which was ground beneath the surface of the mercury, a similar violent reaction ensuing, and an amalgam containing quantities of solids being formed. An excess of crystalline $FeCl_2 \cdot 4H_2O$ was added together with several drops of water and again there was a strong exothermic reaction. Sufficient metallic sodium was added to form a solid amalgam and the entire mass was divided into a series of samples:

(*a*) To a first portion was added an excess of stannous chloride crystals together with a drop of water. A gray fluid formed. The product was washed with water and then concentrated HCl, being shaken therewith six times over three days. No further deposition of iron occurred and the product exhibited excellent magnetic susceptibility and was only slightly duller in color than pure mercury. Also, its viscosity was only slightly greater than that of pure mercury. It was stored with several drops of concentrated (20° Bé.) HCl in a closed bottle and showed no tendency to deteriorate, either in appearance, magnetic susceptibility, or viscosity over a period of several weeks.

(*b*) To a second portion of the sample was added an excess of $MgCl_2 \cdot 6H_2O$ crystals. A mildly exothermic reaction ensued. After six washings over three days with concentrated (20° Bé.) HCl, the product was stored under the HCl in a capped vial. A point of stability had been reached after the aforementioned several washings with concentrated HCl and a product exhibiting a viscosity approaching that of pure mercury, a very shiny appearance, and high magnetic susceptibility, was obtained.

(*c*) To a third portion of the sample was added $CrCl_3 \cdot 6H_2O$ crystals in excess; a strongly exothermic reaction ensued and a dark green solution formed. The product was shaken with HCl six times over a period of three days, a small amount of HCl added and the product placed in a sealed vial. No deterioration in appearance, magnetic susceptibility or viscosity was apparent over several weeks.

(*d*) To a fourth portion of the sample was added $AlCl_3 \cdot 6H_2O$ crystals in excess; a mild reaction ensued with a gray precipitate being formed. The product was shaken with 20° Bé. HCl six times over three days and the HCl wash was replaced with a few drops of fresh HCl (a sufficient quantity to form small droplets on the surface of the mercury). As in the other tests aforementioned, the top was placed on the bottle so that the mercury could not volatilize. The viscosity of the product approached that of pure mercury and no precipitation of ferrous or ferric oxides appeared on the surface over several weeks. The magnetic susceptibility of the product also appeared to be unchanged following the aforementioned storage period.

(*e*) To a fifth portion of the sample was added $CdCl_2 \cdot 2\frac{1}{2}H_2O$ crystals in excess. A strong exothermic reaction ensued, with a gray precipitate forming. The product was treated with HCl as in (*d*) above, a product being obtained which wetted glass slightly and was unusually bright and shiny, but exhibited somewhat less magnetic susceptibility than the aluminum, chromium, and magnesium samples described above. Its magnetic susceptibility was about that of the sample containing tin.

(*f*) Antimony metal was filed into small particles and treated with 20° Bé. HCl to form a solution thereof. This was then added to a sixth portion of the aforementioned iron- and sodium-containing amalgam and a reaction ensued yielding hydrogen. The product felt somewhat granular, as particles of the antimony had found their way into the amalgam in addition to the antimony which was dissolved in the HCl. The solid particles tended to appear at the surface of the amalgam in time and eventually a smooth antimony-containing amalgam was secured. The amalgam was washed with water and shaken six times with 20° Bé. HCl over the next three days and then stored in a closed bottle in contact with a small amount of concentrated HCl. There was no further noticeable deterioration. The product exhibited excellent magnetic susceptibility, its appearance closely resembling pure mercury, and a very low viscosity which also approached that of pure mercury.

(*g*) To a seventh portion of the aforementioned batch of mercury-iron-sodium amalgam was added an excess of $Bi(NO_3)_3 \cdot 5H_2O$ crystals and a drop of water to initiate the reaction. Quantities of red nitrous oxide gas were evolved. The product was washed with water and shaken six times with the concentrated HCl over the next three days. The product was then stored in a closed bottle in the presence of only sufficient concentrated HCl to wet the surface of the product. The viscosity of this material was the lowest of all samples reported above, the viscosity very closely approaching that of pure mercury. This sample also remained bright and shiny, closely resembling pure mercury, and exhibited very high magnetic susceptibility. This bismuth-containing product was superior to the others described above in magnetic susceptibility and mobility.

A portion of the sample discussed in sub-section (*g*) above was separated from the main portion of the sample after the three days' washing with HCl had been completed. This material was in turn separated into two aliquot portions and these stored in sealed vessels in an

atmosphere of argon and nitrogen, respectively. The total volume of each bottle was about three times that of the mercury therein. No deterioration in the samples after three weeks' storage was apparent. Each remained shiny, mobile, and magnetically susceptible.

(*h*) To an eighth portion of the batch was added an excess of liquid $TiCl_4$. A strong reaction ensued; the mercury product was washed with water, shaken six times over three days with 20° Bé. HCl, and stored in a closed bottle in contact with the HCl, as previously described. The product exhibited good stability and fair mobility and magnetic susceptibility.

(*i*) The last portion was treated, as aforementioned, with water to remove the sodium, no additional metal being added. The product was washed with additional water and concentrated HCl as were the products above and stored in a closed bottle under enough of the aforementioned HCl to slightly wet the product surface. The product exhibited excellent stability, but its magnetic susceptibility was lower than the bismuth, aluminum, magnesium, and chromium samples described above and about the same as the magnetic susceptibility of the tin and cadmium samples, though the viscosity of the sample containing no additional metal was somewhat higher than either of the last two mentioned as well as of the others.

When any of the aforementioned products were left uncapped for a sufficient period of time for the small amount of acid in the bottle to evaporate, a black powder (ferrous oxide) or a rust (ferric oxide) began to form on the surface. To prevent the deterioration of the product; therefore, it is important that it be stored either under a layer of a suitable fluid or that the vessel containing the product be sealed so as to prevent the loss of mercury through volatilization. Preferably, both precautions should be taken.

In various additional tests, amalgams containing mixtures of metals in addition to mercury, iron and one of the preferred additive metals mentioned above were prepared by the sodium replacement reaction using the chlorides of the metals incorporated. For example, an amalgam containing both tin and lead was formed; an amalgam containing both bismuth and cobalt was formed; and an amalgam containing cobalt and aluminum was formed.

Example 9

A quantity of 16 grams of mercury was placed under an approximately 1 inch saturated solution of ferrous chloride in a large test tube. A soft iron nail was used as the anode and a six volt battery connected thereto with a wire, insulated to a point beneath the surface of the mercury, dipped thereinto to provide a cathode. The current was allowed to flow for approximately 15 minutes, throughout which time the mercury and ferrous chloride were vigorously agitated. The entire 16 grams became somewhat more viscous and was attracted to a magnet. The ferrous chloride was then drained off and aluminum chloride in the form of a super-saturated solution of about ¾" height was substituted. An aluminum anode was used and the current permitted to flow for about 5 minutes during which time the solution boiled. Thereafter, 8 grams of mercury which adhered to a magnet was withdrawn. Two aliquot portions were vigorously agitated with a saturated calcium chloride solution on the one hand and concentrated (20° Bé.) HCl on the other; each was placed under a layer of the same liquid and shaken therewith daily for three days. This assisted in the removal of the largest grains of iron within the amalgam. The cover liquid, in the case of the calcium chloride, formed a faint green color immediately after being added to the mercury, indicating the formation of ferrous chloride. After the three day period, the cover liquids were decanted and the $CaCl_2$ solution replaced. The sample treated with HCl was divided into three portions, one of which was again placed under concentrated HCl, one under 1 N HCl and another in a dry vial having twice the volume of the mercury. The samples all exhibited viscosities approaching that of pure mercury and were stored in sealed vessels for four weeks without any apparent deterioration, except for the sample lacking a cover liquid, which sample became slightly reddish on the surface thereof. This deterioration in appearance did not continue after the first few days and the sample remained mobile and magnetically susceptible throughout the storage period. All had a magnetic susceptibility substantially superior to that of pure mercury-iron amalgam prepared without the addition of the aluminum.

Example 10

An amalgam consisting of about 7 grams of mercury and about 1 gram of iron, prepared electrolytically, was treated to incorporate cadmium from a cadmium chloride solution using an iron nail for the anode and a six volt D.C. battery over a period of about 10 minutes. The circuit resistance was about .8 ohm. The product wetted glass, thus indicating that cadmium had gone into the mercury. The viscosity of the product was somewhat less than that of an amalgam containing no metal other than iron and mercury. The product was stored in a bottle of about twenty times the volume of the mercury and sufficient saturated $CaCl_2$ solution was added to just wet the mercury surface. No deterioration was apparent after three weeks.

Example 11

An additional electrolytic run was made utilizing a saturated solution of stannous chloride and a product was obtained which was also stored under a saturated solution of calcium chloride.

Example 12

A dish was filled to about a one inch depth with mercury, providing a surface area of about 12 square inches and current passed from the aforementioned six volt battery into a saturated ferrous chloride solution which had been poured over the mercury to a depth of about three inches. A small Alnico horseshoe magnet having about ¼" pole pieces was dipped into the mercury as the current flowed and the magnetically susceptible fraction removed. About 25 grams were collected and divided into a series of samples. All were shaken vigorously with concentrated HCl four times over two days and then placed under about ¼" of various cover liquids. The samples placed under a saturated aqueous solution of boric acid; ethyl alcohol; light machine oil; saturated aqueous solutions of $CaCl_2$, $MgCl_2$, NH_4Cl and NaOH; olive oil; 3 N HCl; 2 N HCl; 1 N HCl; 20° Bé. HCl; 1 N H_2SO_4; concentrated H_3PO_4; Shell "Ionel"; distilled water; and pyridine remained shiny, magnetically susceptible, and of low viscosity throughout the test period. The samples under the H_3PO_4 and 20° Bé. HCl appeared superior in that their viscosities remained lowest of any of the samples. Samples of the mercury product placed under concentrated HNO_3, CCl_4, kerosene, acetone and $NaHClO_4$ rusted within several days, as the cover liquids either attacked the mercury or promoted oxidation of the iron component.

When one of the aforementioned metals Bi, Cr, Al, Mg, Sb, Cd, Sn, and Ti is added to an amalgam containing mercury and iron, unusual stability is contributed to the product. These magnetic mercury products, in addition to having the improved viscosity characteristics, magnetic susceptibility, etc. described above, may also be used out of a sealed vessel for extended periods of time (especially at temperatures of less than 30° C.) without there occurring sufficient volatilization of the mercury to result in an iron material appearing on the surface as a contaminant. However, it is preferred to maintain all magnetic mercury products in sealed vessels except when it is necessary that they be exposed to open air temporarily, since mercury has relatively high vapor pres-

sure and will volatilize, thus freeing a certain amount of the iron.

The additional metals just mentioned may also be incorporated in the mercury through electrolytic means. All except bismuth may be electrolyzed from their chloride or other salt solutions under conditions similar to those described above as applied to ferrous chloride.

Bismuth may be electrolyzed from an aqueous solution of $Bi(NO_3)_3$ in dilute HNO_3 or from an aqueous solution of Bi_2O_3 and $HClO_4$. In any case, the conditions recommended for plating these various elements onto solid surfaces are satisfactory as applied to incorporating them into mercury.

As aforementioned, the use of one of the aforementioned or a similar non-oxidizing fluid which is inert to mercury and iron (though possibly a solvent therefor, to some extent) reduces or completely eliminates the deterioration of the amalgam, almost or completely preventing the formation of a scum of black powder or reddish-brown material on the surface thereof. The product exhibiting the best appearance and stability is obtained where both a sealed vessel and a small amount (sufficient to wet the mercury surface after equilibrium is reached) of relatively concentrated HCl is placed within the vessel in contact with the mercury. Only enough to provide most of the vapor molecules to fill the system is required and this may even be insufficient entirely to cover the surface of the amalgam if low temperatures (room temperature) of use are contemplated. Larger quantities are required at higher temperatures where there is a greater opportunity for volatilization of mercury and release of the iron component.

In addition to use in magnetic clutches, the magnetic fluid of this invention finds particular utility in mercury switches which need not be tilted or have any moving parts excepting the mercury contained within. The contacts enter the chamber partially filled with the mercury at some point near the top thereof, which point is adjacent an electromagnet. When the magnet is energized, the mercury bridges the gap between the contacts, permitting the circuit to be completed.

Application Serial No. 80,737, filed January 5, 1961, describes a similar product prepared by adding iron filings to a mercury-sodium amalgam. The product of this co-pending application may also be beneficially affected with respect to stability when stored as described and claimed herein.

Obviously, many modifications and variations may be made without departing from the spirit and scope of this invention, and therefore only such limitations should be imposed as are indicated in the appended claims.

This is a continuation-in-part of application Serial No. 80,737, filed January 5, 1961, now abandoned.

I claim:

1. A fluid sensitive to a magnetic field consisting essentially of an amalgam of between about 2 and 40 weight percent of a metal selected from the group consisting of bismuth, aluminum, chromium, magnesium, antimony, cadmium, tin and titanium and between about 2 and 10 weight percent iron, with the remainder being mercury.

2. A fluid sensitive to a magnetic field consisting essentially of an amalgam of between about 2 and 40 weight percent bismuth and between about 2 and 10 weight percent iron, with the remainder being mercury.

3. A fluid sensitive to a magnetic field consisting essentially of an amalgam of between about 2 and 40 weight percent magnesium and between about 2 and 10 weight percent iron, with the remainder being mercury.

4. A fluid sensitive to a magnetic field consisting essentially of an amalgam of between about 2 and 40 weight percent aluminum and between about 2 and 10 weight percent iron, with the remainder being mercury.

5. A fluid sensitive to a magnetic field consisting essentially of an amalgam of between about 2 and 40 weight percent chromium and between 2 and 10 weight percent iron, with the remainder being mercury.

6. A fluid sensitive to a magnetic field consisting essentially of an amalgam of between about 2 and 40 weight percent tin and between about 2 and 10 weight percent iron, with the remainder being mercury.

7. A process for preparing a fluid sensitive to a magnetic field consisting essentially of forming a sodium-mercury amalgam; contacting said amalgam with an iron-containing material and permitting a reaction to ensue whereby to replace said sodium of said amalgam with the said iron; and amalgamating therewith a third metal selected from the group consisting of bismuth, aluminum, chromium, magnesium, antimony, cadmium, tin and titanium whereby to form a product containing between about 2 and 40 weight percent of the said third metal, and between about 2 and 10 weight percent iron, with the remainder being mercury.

8. A process for preparing a fluid sensitive to a magnetic field consisting essentially of depositing by electrolysis iron into mercury utilizing iron as the anode and said mercury as the cathode; and amalgamating a third metal therewith selected from the group consisting of bismuth, aluminum, chromium, magnesium, antimony, cadmium, tin and titanium whereby to form a product containing between 2 and 40 weight percent of the said third metal, and between about 2 and 10 weight percent iron, with the remainder being mercury.

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