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DEVICE FOR TIMING A CHEMICAL REACTION

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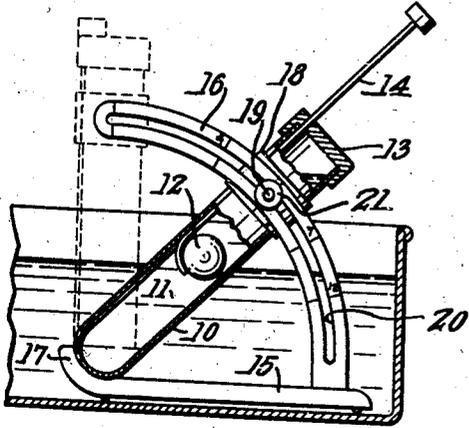


Fig. 1.

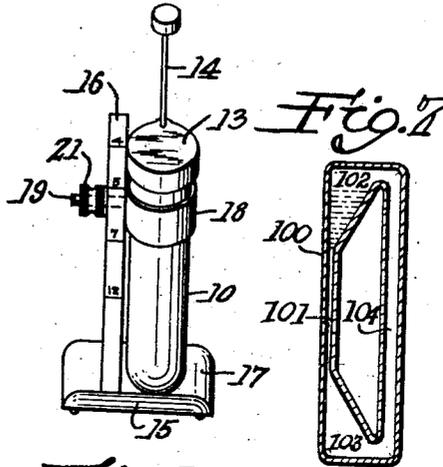


Fig. 2.

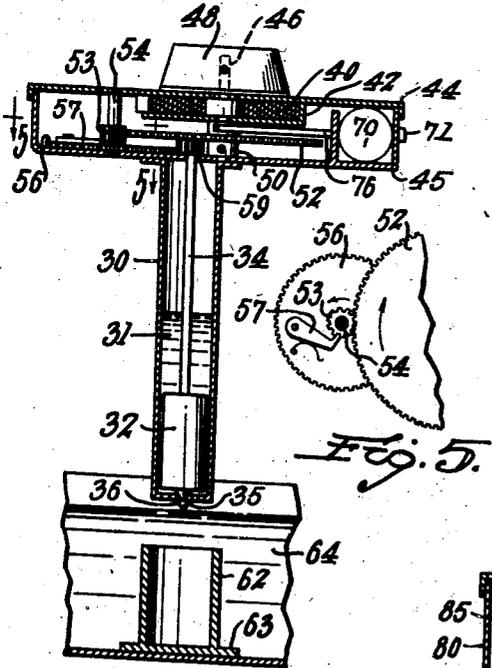


Fig. 3.

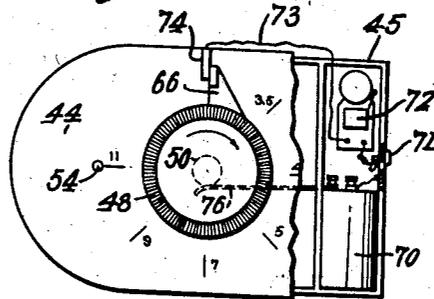


Fig. 4.

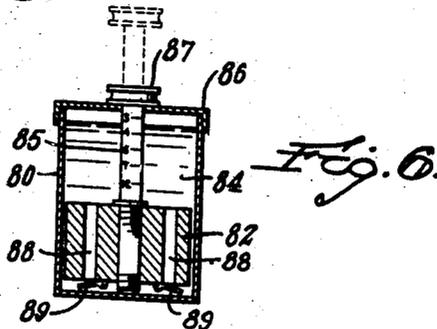


Fig. 6.

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DEVICE FOR TIMING A CHEMICAL REACTION

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19 Claims. (Cl. 161—15)

This invention relates to a timing apparatus and it particularly applies to the timing of processes in which the time required for completion of the process decreases with rising temperature.

It is well known that the rate of a chemical reaction varies with the temperature, the rate being faster at high than at low temperatures. For example, the rate of development of a photographic image increases rapidly with the temperature, and for the best results it is necessary to accurately judge the end point. This may be done by watching the formation of the image in a dim light of suitable color and judging by experience when the image is of satisfactory quality. This method is fraught with numerous disadvantages among which may be listed the difficulty of obtaining a satisfactory light for viewing panchromatic film, the difficulty of judging contrast in such a dim light, the exposure of the developer solution in shallow trays to excessive oxidation and the impossibility of the operator carrying, over any extended period of time, a quantitative memory of density and contrast. The preferred method involves accurately compounding the developer solution, and immersing the sensitive photographic material to be developed for a definite time at a constant temperature. With uniform photographic materials this method gives excellent results, provided the temperature is held constant. But, since the rate of development of the image increases rapidly with a rise in temperature, this method involves a degree of control of both time and temperature that is difficult to attain; and that represents a source of error very common with amateurs and not at all uncommon with professionals who have much better equipment for controlling the process. This same problem is found in many chemical industries where the temperature of a reagent is important and it is necessary to control the rate of reaction or the end point.

A primary object of this invention is, therefore, to provide a device which will time a chemical reaction and determine when the desired end point has been reached.

A further object of the invention is to provide a timing apparatus which will not only time the reaction for a given temperature but will correctly compensate for changes in temperature and determine the end point irrespective of the temperature conditions.

Another object is to provide apparatus for use in the photographic field which will determine the required end point for development of a photographic image whether the temperature of the

developer solution remains constant or changes during the operation.

A still further object is to provide apparatus of this type which will give an aural or a visual signal to the operator when the end point of a chemical reaction has been reached and thus make it possible to prevent the reaction from going beyond that desired point. Further objects will be apparent in the following disclosure.

It is well known that the time of development of a photographic image can be represented with high accuracy by the equation

$$\log D = \frac{A}{T} + B \quad (1)$$

where D represents the time required for development, T is the temperature on the absolute scale, and A and B are constants. It is customary for the manufacturer to state the correct developing time at 65° F. for a given developer and photographic material. One may calculate the correct time for another temperature by means of the above formula, by subtracting from that equation the further equation:

$$\log D_{65} = \frac{A}{525} + B$$

which results in the equation:

$$\log D_T = \frac{A}{T} - \frac{A}{525} + \log D_{65} \quad (2)$$

wherein 525 is the absolute temperature at 65° F., D_T represents the developing time at the absolute temperature T, or $460^\circ + t$, where t is the temperature Fahrenheit, and D_{65} represents the time at 65° F. The results of much experience indicate that A has a value of 5500.

It is also known that the viscosity of a liquid can be represented with very good approximation over a limited temperature range by the equation:

$$\log U = \frac{C}{T} + E \quad (3)$$

where U is viscosity, T the temperature on the absolute scale and C and E are constants. The similarity between Equations 1 and 3 will be immediately apparent. We can, therefore, relate the viscosity at any given temperature to that of 65° F. in the same way that we relate the developing time at a given temperature and thus obtain the following equation:

$$\log U_T = \frac{C}{T} - \frac{C}{525} + \log U_{65} \quad (4)$$

In accordance with my invention, I propose to

choose a liquid with the proper viscosity-temperature relationship so as to make C in Equation No. 4 equal to A in Equation No. 2, i. e. equal to 5500. Hence, after inserting these values for A and C the last equation may be subtracted from Equation No. 2 and we obtain

$$\log \frac{D_T}{U_T} = \log \frac{D_{05}}{U_{05}}$$

10 or

$$\frac{D_T}{D_{05}} = \frac{U_T}{U_{05}} \quad (5)$$

15 If, therefore, a small quantity of this liquid is brought to the temperature of the developing solution during the reaction, it is only necessary to measure the viscosity of the liquid in order to find the correct time for development, if one knows the viscosity for a standard temperature, such as 65° F.

20 A fundamental principle of the mechanics of fluids is that the velocity of an object moving under a constant force through a viscous medium is inversely proportional to the viscosity of the medium, provided the velocity is not high enough to produce turbulence. It, therefore, follows that the time required for such an object to move through a stated distance is a measure of the viscosity of the liquid.

30 In accordance with the above principles, I therefore propose to make an apparatus in which the movement in a suitable viscous medium of a chosen body moved by an appropriate force may be so employed that a time interval measured thereby is identical with the time interval required for a given chemical reaction, such as the development of a photographic image. Examples of such are a falling body, a positively rotated disk, cylinder or paddle, and an ascending bubble of gas, which are retarded in movement by the chosen viscous fluid. Similarly, the capillary flow of the viscous fluid may serve to time the reaction and provide an equivalent construction.

45 In the drawing I have illustrated various types of apparatus in which the reaction of chemical reagents is timed by a body movable under an impelling force within a viscous liquid and which is so constructed and arranged that the movement thereof varies with the temperature of the reaction, the end point of which is to be determined, and wherein the viscosity of the fluid is so selected that the rate of movement of the body is proportional to the rate of reaction at the given temperature. Other forms of apparatus will be apparent in view of this disclosure.

In the drawing:

Fig. 1 is a front elevation, partly in section, of one form of timing apparatus;

Fig. 2 is an end elevation of the same;

60 Fig. 3 is a section of a modified form as used in a chemical bath;

Fig. 4 is a top plan view of the same, partly broken away;

65 Fig. 5 is a detail of the ratchet drive taken on the line 5-5 of Fig. 3;

Fig. 6 is a vertical section of a still further form; and

Fig. 7 is a section of a capillary tube to be used in an apparatus of the type shown in Fig. 1.

70 In Fig. 1 I have shown an apparatus comprising a tube 10 containing the selected viscous liquid 11 and a ball 12 or other properly shaped weight which fits loosely in the tube and is only slightly smaller than the diameter of the tube, 75 so that the frictional drag of the liquid will

properly retard the falling or rolling movement of the body. Since the viscous liquid permits the weight to fall more rapidly at a higher temperature than at a lower one, it is now feasible to immerse the tube containing a chosen viscous liquid and ball in the chemical solution during the reaction thereof, and if the ball is released at the same instant as the chemical reaction starts; then the ball will reach a given and predetermined point, such as the bottom of the tube, when the chemical reaction has proceeded to a correct end point. Hence, it is not necessary to take the temperature of the bath and from this to calculate by means of tables the proper reacting time, but one may neglect the temperature and need only observe the movement of the ball.

That arrangement comprising a tube fixed vertically or at a chosen angle would be satisfactory if only one class of chemical material were being handled and wherein the reaction time at a given temperature would always be the same. However, in the photographic field, it is necessary to change the developing time with the different photographic materials and different developers employed, and this would require a large assortment of different pieces of apparatus with different viscous liquids therein. I overcome this difficulty by so constructing the apparatus that the tube may be inclined at different angles and thus vary the rate of movement of the weight therein. In this case, the ball will roll down the tube in a time varying directly as the viscosity, the same as in a vertical tube; but the time at a given temperature will vary inversely as the sine of the angle that the tube makes with the horizontal. Hence, one may vary the time of ball movement through wide limits by varying the angle of inclination of the tube and yet retain the advantages of automatic compensation for temperature fluctuation.

The apparatus shown in Fig. 1 will, therefore, satisfy these requirements, and in this figure the tube 10 made of suitable material, such as glass, metal or a resinoid, may contain a chosen viscous liquid 11 and a ball or other shaped weight 12 of metal or other material loosely fitted in the tube. This tube may have a removable cover 13 at its top to prevent escape of the liquid. A rod 14 having a lower hooked end slides through the cover and serves to adjust the position of the ball. The tube may, if desired, be provided with a groove in its wall to receive the rod and the parts may be so shaped that the rod and wall form a substantially cylindrical surface which will permit proper movement of the ball. In operation, the rod is pulled up and its hooked end raises the ball to a desired height and holds it there. When the reaction is to be started, the rod is thrust quickly downwardly to the bottom of the tube and the freed ball starts its travel unhampered except by the viscous fluid.

In order that the tube may be arranged at various angles, I provide as a simple construction the base 15 having an arcuate metal piece 16 connected thereto. This arcuate piece is suitably graduated to provide a scale for indicating either the time of chemical reaction or merely the angle of inclination of the tube. The tube may be held in position at its bottom by the hooked end 17 of the base. The tube may be held at a desired angle by a suitable clamping device which may comprise a ring 18 fitted around the tube and having a projecting post 19 threaded at its outer end which passes through a

slot 20 in the arcuate member 16. A binding nut 21 serves to draw the clamping ring 18 tightly against one side of the scale arm and thereby hold it in a desired position indicated by the scale and to a suitable mark on the clamping ring or other part of the device.

If a given chemical reaction is to consume a time, for example, of 7 minutes at a specified temperature, then the tube will be swung to that position indicated by the 7 minutes mark on the scale, and the ball after having been pulled to the top of the tube or to an indicated point will then take the 7 minutes in rolling down through the viscous medium if the temperature is normal. The ball will travel faster, if the temperature is higher, or slower if the temperature is lower than the normal requirement. For timing another chemical reaction taking 4 minutes, the tube will be tilted to the point indicated by the numeral 4 on the scale, and the ball 12 will then reach the bottom in the 4 minutes under normal temperature conditions. Hence, by this mechanism, one may adjust the tube to take care of various reaction periods.

The viscous liquid employed is to have the same temperature coefficient as that of the photographic material or other chemical reagent to be timed. The following table gives the time for development of a photographic image and the corresponding angle of inclination of the tube which will correctly time the development, where several different photographic materials, A, B, C and D requiring different developing times at 65° F. are to be processed:

| Material | Development time | | Angle | |
|----------|------------------|---------|---------|----|
| | Minutes | Degrees | Minutes | |
| A..... | 4 | 62 | | 7 |
| B..... | 5 | 45 | | |
| C..... | 7 | 30 | | 20 |
| D..... | 12 | 17 | | 8 |

If the tube is filled with the correct viscous medium and then set at the indicated angle, such as 45°, which calls for a development time of 5 minutes at 65° F., then if the temperature of the photographic developer is above that temperature, the ball will reach the bottom of the tube in less than 5 minutes, or if the temperature is too low the ball will take more than 5 minutes, but the development of the photographic image will be completed and correct at that moment when the ball reaches the bottom of the tube, irrespective of the temperature. Hence, the operator may completely ignore the temperature conditions and the time of development and merely watch the movement of that ball from the top of the tube to the bottom and remove the photographic film or plate from the solution when that visual signal has been given.

It will now be appreciated that other types of instruments may be employed for this purpose, wherein the time interval required for completion of a chemical reaction is proportional to the movement of a body in a fluid whose viscosity-temperature curve is adjusted or selected to give a time interval dependent on the temperature in the same way that the time interval of the process being controlled is dependent upon the temperature.

In Fig. 3 I have shown another type of apparatus in which the frictional drag of a viscous liquid on a rotating body is employed to determine the time interval. This construction will serve to give both a visual signal as well as an aural

signal by means of an electric cell. This particular device comprises a tube 30 arranged to hold the viscous medium 31 and within which is rotated a positively driven paddle, cylinder or other suitable body. The form shown is a cylindrical body 32 which fits loosely within the tube but near enough to the walls thereof so that the frictional drag of the viscous fluid will tend to retard its movement. This body 32 is mounted on a rod 34 which has a lower pointed end 35 pivoted 10 is a V-shaped depression 36 in the bottom of the tube. The cylinder 32 may be rotated by suitable mechanism, such as a driving spring 40. One end of the spring is fastened to a fixed angle plate 42 secured to the underside of the cover 44 15 of the casing 45. The other end of the spring is suitably secured to the shaft 46 so as to rotate therewith, and this shaft may be the hub of a driving gear 52. That gear meshes with a further gear 53 fixed on a shaft 54 likewise mounted 20 in bearing holes in the cover and bottom of the casing. The small gear 53 is arranged to drive another gear 56 through a pawl 57 pivotally mounted on the gear 56. The pawl is so shaped and arranged that the teeth of the gear 53 will 25 serve as a ratchet and drive the gear 56, while the spring is unwinding. When the spring is being wound by means of the knob 48, the gear 53 will turn idly and the pawl 57 will slip thereover without moving the gear 56 on which it is mounted. 30 The gear 56 is loosely mounted on the shaft 54 which carries the gear 53, and it in turn meshes with a small gear 59 on the top of the shaft 34 carrying the body 32. The shaft 34 has a suitable bearing in the lower wall of the casing 45. 35

The tube 30 is immersed directly in the developing or other chemical liquid or conduction of the heat thereof through the wall of the tube to the viscous fluid 31. If desired, a standard may be used to support the device, which may consist of a hollow tube 62, which may have perforated or slotted sides, and this tube is mounted on a base 63 which has a sufficiently extensive surface to stand in the solution and hold the 45 mechanism upright. The tube 62 of the standard may make a tight fit with the tube 30 so as to conduct heat readily thereto, or if the tube 62 is perforated, the chemical solution 64 may contact directly with the tube 30. The top 44 of the 50 casing may be provided with a scale, as shown in Fig. 4, which is suitably graduated to show time intervals, angles or other desired indicia, and the edge of a pointer 66 on the knob 48 may serve to indicate the movement of that knob from a 55 definite point on the scale to the zero point.

Having selected a suitable fluid medium 31 for the type of chemical reaction to be timed and having suitably marked the scale in accordance with the time temperature relationship, then it 60 is merely necessary in the use of the apparatus to wind the spring 40 through a part of a turn until the mark line of the pointer 66 is opposite that numeral on the scale indicating the time desired for the reaction. The spring will have been 65 previously wound to a medium degree of tightness so that one more turn of the spring will not greatly change its driving force. Then the knob 48 is released the moment that the chemical reaction begins and the paddle of cylinder 32 will 70 be revolved at a speed determined by the viscosity of the fluid medium 31, and that rate will vary in accordance with the temperature, as above explained. If the temperature is standard, the pointer 66 will reach the zero point at the exact 75

time set for the reaction, but if the temperature of the chemical solution 54 is too high then that pointer will return more quickly, but in any case, when the pointer 56 has reached the zero mark on the scale the chemical reaction will have proceeded to the correct end point.

In order to give an aural indication as to when this end point has been reached, I may provide various types of apparatus. A simple form shown diagrammatically in the drawings comprises an electric battery 70 suitably connected through a switch 71 with an electric bell 72. One terminal of the bell is connected through a wire 73 with a contact block 74 which is positioned on the cover 44 at the zero point of the scale. The other terminal of the battery 70 is connected with a spring arm 75 which makes a wiping contact with the metal hub 30 of the pivot 46, so that electrical connection will be made through that post and the metal knob 48 to the arm 58. This arm is made of metal and arranged so that its forward edge will strike the other contact member 74. The electrical circuit may also be connected to control various electrical mechanisms of use in connection with the timing device. The various electrical parts are to be adequately insulated to prevent any short circuit. It will also be understood that the showing of electrical arrangements in Figs. 3 and 4 is purely diagrammatic and not drawn to scale, and that battery and bell may be located apart from the timing device and constructed as needed. The device may be used for timing various solutions. To that end, the tube 30, which is suitably attached to the casing 55, may be removed and a different viscous fluid substituted for the one used.

A very simple form of device suitable for use in developing a photographic image in a given type of solution is shown in Fig. 6. This comprises a casing 80 of metal, or any material which conducts heat readily, which carries a massive weight or plunger 82 therein. The plunger makes a loose fit in the casing 80 so that the viscous fluid 84 within the casing may pass slowly between the plunger and the casing wall. The plunger is attached to a rod 85 by means of screw threads, and that rod 85 makes a sliding fit in an opening through the cover 86 of the casing. The parts are so arranged that the plunger 82 may be pulled upwardly by the knob 87 on the rod 85 to a given scale point marked on the rod. Then when released, the plunger will gradually sink to the bottom of the casing under the impelling force of gravity. The scale may be marked in minutes so that the plunger may be set to move through the number of minutes required for a given chemical reaction, such as the photographic development of an image. If desired, the weighted plunger 82 may have channels 88 there-through, and flap valves 89 may be pivotally mounted on the bottom of the plunger and so located and arranged that when the plunger is passing downwardly these passages 88 will be closed, but when the plunger is pulled upwardly by means of the handle 87 the flaps will open and allow the viscous fluid to pass easily and thus avoid any time delay or effort in resetting the device.

The above described types of apparatus involve the use of a body which is movable through a viscous liquid. It will be appreciated that this motion may be relative, wherein either the viscous liquid or an associated body moves. For example, the associated body having a wall which

is in frictional and dragging relationship to the viscous fluid may be a capillary tube through which the liquid is caused to flow under the impelling force of gravity or a positively applied hydraulic pressure. The frictional drag of the viscous medium on the wall of the tube depends upon the viscosity of the fluid which is in turn dependent on the temperature. Hence, the above discussed relationships apply equally well to devices wherein the fluid moves and the body having a frictional wall or surface is stationary.

Fig. 7 shows a capillary tube which illustrates this aspect of the above described invention, but the specific details thereof are not herein claimed. The capillary tube 100 of this construction is adapted to be substituted for the tube 10 and mounted in the clamping ring 18 of Figs. 1 and 2, and it is used in the manner above described. This tube is shaped to provide a finely drawn capillary passage 101 connecting the enlarged reservoirs 102 and 103 in the opposite ends of the device. These reservoirs are also connected by a second tube 104 parallel with the capillary tube 101, and the tube 104 has a bore of large diameter so as to permit an easy return flow of fluid therethrough. The device may be made of glass so that the flow of fluid through the capillary tube may be visually noted, and the proper measurements may be made by providing the glass with suitable scale lines. The capillary device may have an outlet through which different types of fluid may be introduced, or the fluid may be placed therein initially and the ends then sealed as shown. The tube is mounted in the clamping ring 18 in such a position that the fluid will flow from the upper reservoir to the lower one when the capillary device is mounted in either a vertical position or at angle, as illustrated in Fig. 1. The passage 104 serves for a quick return of the fluid from one reservoir to the other when the device is reversed. It will be appreciated that the flow of the fluid through the capillary tube depends upon the viscosity of that fluid, and the fluid will be selected as herein explained so that it will move at a rate which is proportional to the rate of the chemical reaction when that reaction is carried on at the temperature to which the viscous fluid is exposed. The rate of flow of the fluid will also depend upon the angle at which the capillary tube is tilted, hence by utilizing the holder shown in Figs. 1 and 2, one may control the rate of movement of the fluid through the capillary passage and thereby adjust the mechanism to take care of various reaction periods.

Numerous other modifications will be readily apparent to one skilled in the art. It will also be readily apparent that the viscous fluid and the chemical reagents need not be at exactly the same temperatures, just so long as the temperatures are in a definite relationship as regards the viscosity of the fluid. For example, there may be a lag in the heat transfer between the chemical reagents and the viscous fluid and due compensation may be made for that lag. Hence, the claims are to be interpreted as covering these equivalent constructions.

The viscous liquid employed in this apparatus is selected not only from the viewpoint of having the proper viscosity-temperature gradient, but it should also show Newtonian flow whereby its viscosity should be the same at all rates of shear. The material should not be volatile, and it should be stable in air over long periods of time. Few single compounds have all of these properties and

it is ordinarily desirable to mix liquids or to dissolve a solid in a liquid so as to obtain the combination of properties desired.

One mixture which meets all of the above requirements is made by thoroughly mixing 17 parts by volume of viscous oil # 23497-R, obtained from the Standard Oil Company of California, with 83 parts of medicinal white oil, sold by the United Drug Co. under the trade-mark "Puretest." Both oils are highly refined and therefore resistant to oxidation and change with storage. To illustrate the applicability of this oil mixture, a glass tube was filled with the oil except for a small bubble of air. It was then placed in an inclined clamp in a waterbath held at a constant temperature of 65° F. After sufficient time was allowed for the tube and contents to come to the temperature of the bath, the tube was quickly inverted and placed in the clamp so that the bubble was at the lower end. The time required for the bubble to move between two marks on the wall of the tube was measured with a stop-watch and found to be 174 seconds. The temperature of the water-bath was now raised to 80° F. and the observations repeated. This time the bubble required 89 seconds to traverse the distance between the two marks. Fitting these values into Equation No. 4 and solving for C, the value of 5500 is obtained, which is the value of A in Equation No. 2; hence Equation No. 5 is valid.

Another suitable viscous fluid consists of solutions of different amounts of FF wood rosin, furnished by the Hercules Powder Company, dissolved in tricresyl phosphate. Both substances are stable and meet the requirements if they are used in a sealed container to avoid oxidation. This time an inclined tube containing a steel ball was used and the time required for the ball to roll between two marks taken as a measure of the viscosity. When the mixture contained 10.7% by weight of rosin and 89.3% of tricresyl phosphate, it required 112 seconds for the traverse at 65° F. and 57 seconds at 80° F., which again is the same temperature coefficient as for photographic material.

Another pair of liquids that is eminently suitable for sealed apparatus is glycerine and water. A mixture of 95.5% of glycerine and 4.5% water shows the above viscosity-temperature coefficient.

Still another mixture that is extremely resistant to change due to oxidation or evaporation is obtained by dissolving one of the many coumarone resins commercially available in tricresyl phosphate.

Other combinations of liquids or liquids and solids can be readily found that will fulfill the requirements, so that while I have given the above four combinations for illustration, it is to be understood that I am not limited to them, but may choose any of a great number that would readily come to the mind of a skilled chemist.

While the above description of my invention has been specifically applied to the development of photographic images, it applies to other types of chemical reactions. For example, it is applicable in the ageing of alkali cellulose in the manufacture of viscose for rayon or cellophane. This process is dependent upon temperature and time in a very similar manner to the photographic process. The cellulose, moist with a strong caustic solution, is customarily stored in large cans with loose covers in a room whose temperature is very accurately regulated. The

time of storage decreases rapidly as the temperature rises, and therefore, if there are temperature fluctuations, it is very difficult, to determine when the alkali cellulose has aged to the desired extent. My timing device is eminently suited to this situation, since it can conveniently be thrust into the center of the mass of alkali cellulose and therefore will make allowance for any spontaneous heating of the mass or for a temperature lag between the room and the interior of the mass.

Still another process of industrial importance that can be better controlled by my timing device than by any existing method is the vulcanization of rubber. It has long been recognized that the rate of vulcanization increases rapidly with an increase in temperature, and numerous expedients, no one of which is entirely satisfactory, have been devised in an attempt to determine accurately when vulcanization is complete. It is especially necessary to make allowance for small fluctuations in the temperature of vulcanization when the modern ultra-accelerators are used, since optimum properties are obtained only over a narrow range of vulcanization. At present, it involves a laborious calculation to determine the actual cure that a rubber article has received, since much of the time it is in the vulcanizer, the temperature is either rising or falling. My viscous timer is especially well suited to the determination of extent of cure of rubber goods due to the fact that it is an integrating device and therefore makes allowance for all changes of temperature during process.

Although the rubber vulcanization process takes place usually at a much higher temperature than that of the photographic process or the ageing of alkali cellulose, there are numerous substances available that have proper viscosity-temperature relationships at these temperatures from which a suitable combination can be chosen. In fact, neither high nor low temperature is a limitation to my invention. For very low temperatures there are petroleum hydrocarbons, alcohols, etc., that are suitable. For medium temperatures the number of suitable substances is very large, and for moderately high temperatures the fusible synthetic or natural resins serve; while for very high temperatures, the inorganic glasses are available.

It is also to be understood that while I have attempted to explain this invention in the terms of mathematical equations and certain theories, yet the invention is not to be limited by any such consideration. Moreover, the apparatus above described, is to be considered as merely illustrative of the invention and not as limitations thereon, and the claims are to be interpreted as covering all equivalent constructional features and all combinations of apparatus which will satisfy the desired end herein described, and which comprise the use of a viscous liquid arranged to retard the movement of a body under a given impelling force, and wherein the viscous liquid is so selected for the timing device that its viscosity-temperature relationship is substantially the same as the time-temperature relationship of a process that it is desired to time and control.

I claim:

1. A device for timing the reaction of chemical reagents comprising a viscous medium and an associated body which are relatively movable under an impelling force and in frictional relationship, said fluid being so constituted that the relative movement of fluid and body is propor-

tional to the rate of the chemical reaction at different temperatures when the fluid and the reagents are held at related temperatures.

2. A device for timing the reaction of chemical reagents comprising a body movable under an impelling force and a viscous fluid retarding the same, wherein the fluid is so constituted that the rate of movement of the body is proportional to the rate of a chemical reaction at different temperatures when the fluid and the chemical reagents are held at related temperatures.

3. A device for timing the reaction of chemical reagents comprising a body and a viscous fluid which are relatively movable under an impelling force in a frictional relationship, the fluid being so constituted as to its viscosity that the rate of movement is proportional to the rate of the chemical reaction at different temperatures when the fluid and reagents are held at related temperatures, and means for varying the impelling force and the relative rate of movement.

4. A device for timing a chemical reaction comprising a container, a viscous fluid therein and a body which are relatively movable under an impelling force but retarded by the frictional drag of said fluid, said device being so constructed that the movement may be started at a predetermined but variable starting point so as to time chemical reactions of different time intervals, and said fluid having a viscosity-temperature relationship of the reaction over a moderate temperature range near the standard temperature for the reaction.

5. A device for timing a chemical reaction comprising a container, a viscous fluid therein, a body movable in the fluid and retarded thereby, means for causing movement of said body, said fluid being so constituted that the body moves at a rate which is proportional to the rate of the chemical reaction within a limited temperature range when the temperatures of the viscous fluid and the reaction are held in a definite relationship.

6. A device for timing a chemical reaction comprising a container, a viscous fluid therein, a body movable under an impelling force within the fluid but frictionally retarded thereby and means for varying the rate of movement of the body, said fluid being so constituted that the body moves at a rate which is proportional to the rate of the chemical reaction within a limited temperature range when the temperatures of the viscous fluid and the reaction are held in a definite relationship.

7. A device for timing a chemical reaction comprising a tube, a viscous fluid therein, a body movable under the impelling force of gravity within the fluid but frictionally retarded thereby, means for varying the inclination of the tube, said fluid being such that the rate of movement of the body is proportional to the rate of the chemical reaction within a limited temperature range when the temperatures of the viscous fluid and the reaction are held in a definite relationship.

8. A device for timing a chemical reaction comprising a tube, a viscous fluid therein, a body movable under the impelling force of gravity within the fluid but frictionally retarded thereby, and means providing a scale whereby the tube may be inclined to predetermined positions for timing chemical reactions of various time intervals, said fluid being so constituted

that the body moves at a rate which is proportional to the rate of the chemical reaction within a limited temperature range when the temperatures of the viscous fluid and the reaction are held in a definite relationship.

9. A device for timing a chemical reaction comprising a container, a viscous fluid therein, a body movable in but frictionally retarded by the fluid, mechanism for moving the body under a substantially uniform force, said fluid having a viscosity-temperature relationship which is substantially the same as the time temperature relationship of the chemical reaction.

10. A device for timing a chemical reaction comprising a container, a viscous fluid therein, a body movable in but frictionally retarded by the fluid, and mechanism for moving the body under a substantially uniform force, and an electrical mechanism, which is rendered operable by completion of a predetermined movement of the body, said fluid having a viscosity-temperature relationship which is substantially the same as the time temperature relationship of the chemical reaction.

11. A device for timing a chemical reaction comprising a container, a viscous fluid therein, a body movable in but frictionally retarded by the fluid, and mechanism for moving the body under a substantially uniform force, and an electrical signalling mechanism which is rendered operable by completion of a predetermined movement of the body, said fluid having a viscosity-temperature relationship which is substantially the same as the time temperature relationship of the chemical reaction.

12. A device for timing a chemical reaction comprising a container, a viscous fluid therein, a body movable in but frictionally retarded by the fluid, mechanism for moving the body and means for varying the extent of movement of the body, said fluid having a viscosity-temperature relationship which is substantially the same as the time temperature relationship of the chemical reaction.

13. A device for timing a chemical reaction comprising a container, a viscous fluid therein, a body movable under an impelling force within the fluid but retarded thereby, said fluid having a viscosity-temperature relationship which is substantially the same as the time-temperature relationship of a chemical reaction, and means for varying the time required for the body to travel through a predetermined extent.

14. A device for timing the reaction of a chemical solution comprising a container immersible in said solution and made of material capable of exchanging heat readily, a viscous fluid therein, a body movable under the impelling force of gravity within the fluid but frictionally retarded thereby and means for raising the body to a predetermined position and releasing it for movement through the fluid at the beginning of a chemical reaction, said fluid having a viscosity-temperature relationship which is substantially the same as the time-temperature relationship of a chemical reaction, and means for varying the time required for the body to travel through a predetermined extent.

15. A device for timing a temperature dependent process comprising a relatively movable viscous fluid and a body providing a surface in contact therewith, said fluid being so constituted that the relative movement of fluid and body is proportional to the rate of the process under related temperature conditions, and means

whereby an impelling force may cause said relative movement.

16. A device for timing a temperature dependent process comprising a relatively movable viscous fluid and a body providing a surface in contact therewith, said fluid being so constituted that the relative movement of fluid and body is proportional to the rate of the process under related temperature conditions, means whereby an impelling force may cause said relative movement and means for indicating when said relative movement has reached a predetermined magnitude.

17. A device for timing a temperature dependent process comprising a relatively movable viscous fluid and body providing a surface in contact therewith, said fluid being so constituted that the relative movement of fluid and body is proportional to the rate of the process under related temperature conditions, means whereby an impelling force may cause said relative movement and means for giving a signal which is rendered operable when said relative movement has reached a predetermined magnitude.

18. A device for timing a temperature dependent process comprising walls forming a reservoir and a capillary tube, a viscous fluid therein and means whereby the fluid may be caused to flow through said tube under an impelling force, said fluid being so constituted that it will flow through the tube at a rate which is proportional to the rate of the process under related temperature conditions.

19. The method of timing and controlling a temperature dependent process comprising the steps of causing relative movement between a viscous medium and a body in frictional relationship by an impelling force, wherein the fluid is so constituted that the relative movement of fluid and body is proportional to the rate of the process under related temperature conditions, and stopping the temperature dependent process when said relative movement has reached a predetermined magnitude.

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