

[54] MAGNETICALLY COUPLED VISCOMETER

[72] Inventor: Austin S. Norcross, Newton, Mass.
[73] Assignee: Norcross Corporation, Newton, Mass.
[22] Filed: Dec. 28, 1970
[21] Appl. No.: 101,862

[52] U.S. Cl. 73/57
[51] Int. Cl. G11n 11/12
[58] Field of Search 73/57

[56] References Cited

UNITED STATES PATENTS

2,778,220 1/1957 Kuhlmann et al. 73/57
3,277,916 10/1966 Deming 73/57 X

FOREIGN PATENTS OR APPLICATIONS

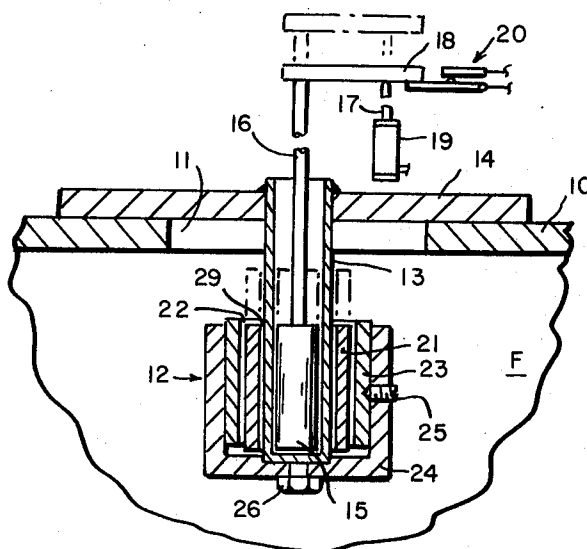
54,510 3/1967 Germany 73/57

Primary Examiner—Louis R. Prince
Assistant Examiner—Joseph W. Roskos
Attorney—Dike, Bronstein, Roberts & Cushman

[57] ABSTRACT

A viscosity measuring apparatus of the type in which a movable body element is caused to move within the fluid to be measured, the time period required to move the body a predetermined distance representing an index of the viscosity. A movable driven body element, at least partially made of a magnetic material, has a second movable magnetic driver element magnetically coupled thereto but isolated from the fluid. The driver element is actuated by appropriate means, such as a pneumatic actuation system, which places such elements in a predetermined position at which point they are released and caused to move to a second predetermined position under a substantially constant force, the time required to move between such positions thereby representing a measure of the viscosity of the fluid in which the drive element moves.

17 Claims, 8 Drawing Figures



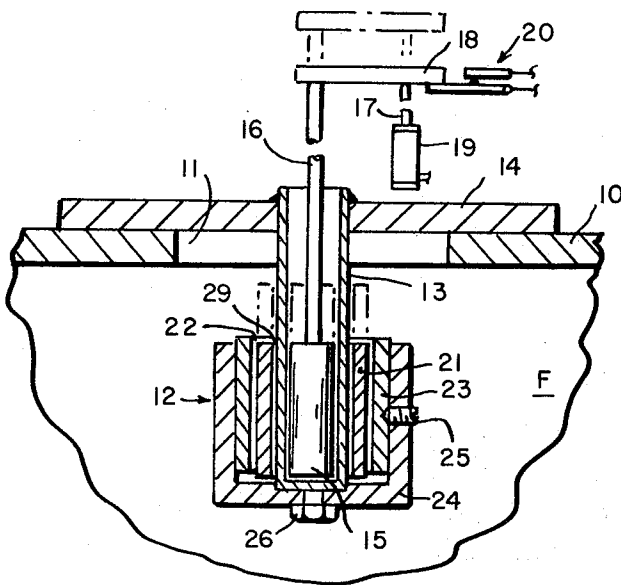


FIG. 1

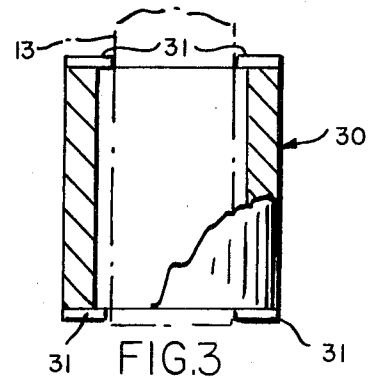


FIG. 3

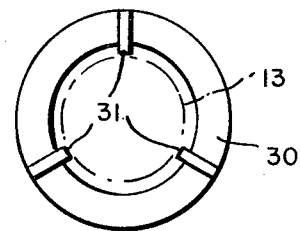


FIG. 3A

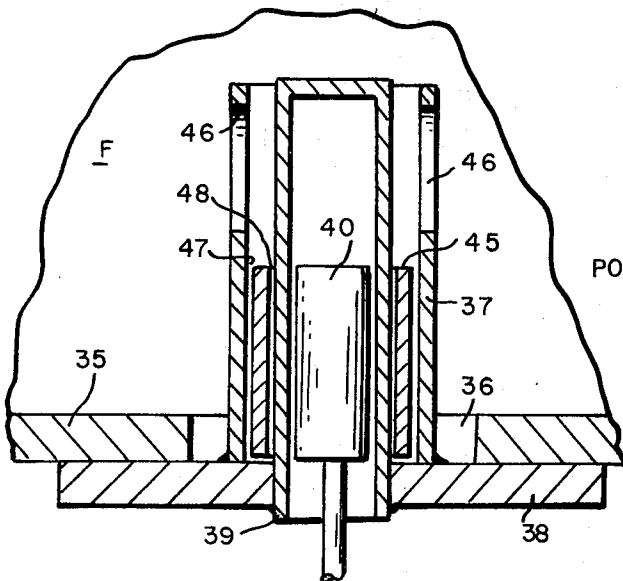


FIG. 4

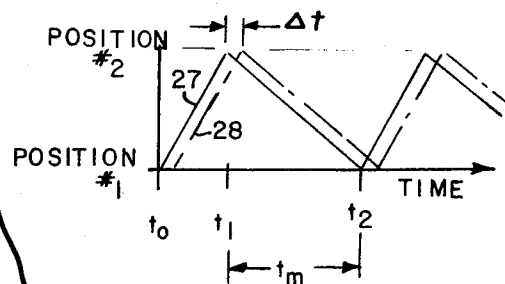


FIG. 2

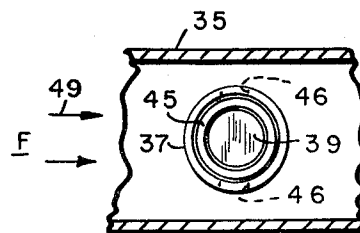


FIG. 4A

INVENTOR
AUSTIN S. NORCROSS
BY *Roberts, Anderson & Jones*
ATTYS

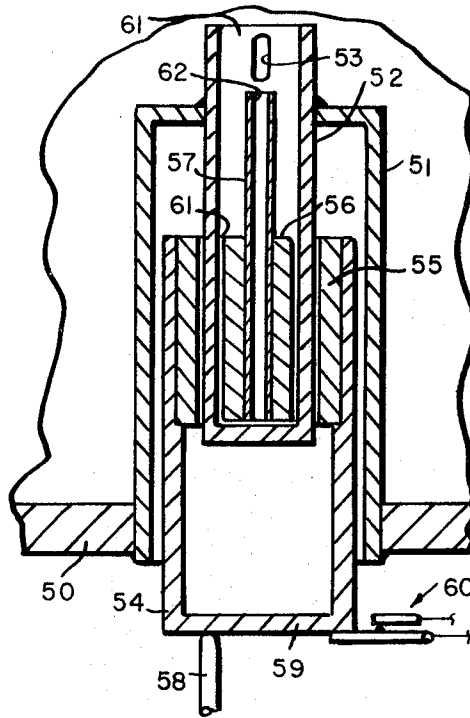


FIG. 5

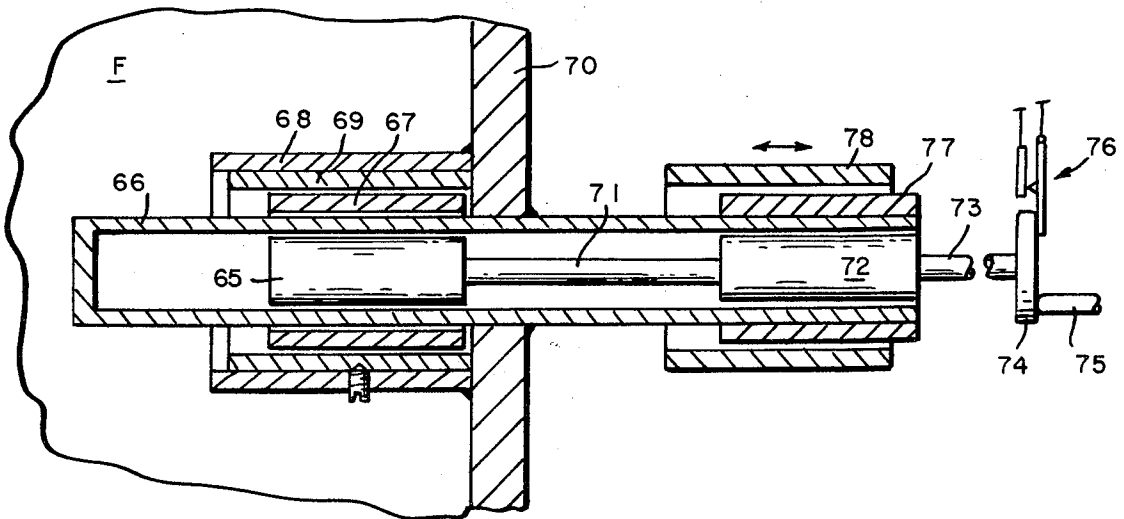


FIG. 6

MAGNETICALLY COUPLED VISCOMETER

This invention relates generally to the measurement of the viscosity of a fluid and, more particularly, to a viscosity measuring device wherein the fluid is forced through one or more restricted orifices defined with respect to two relatively movable bodies. The measured duration of a predetermined relative movement of said bodies represents an index of the viscosity of the fluid and the duration of such movement is detected and applied to suitable indicating means in a cyclical fashion so as to periodically and controllably repeat the viscosity measurement.

Viscosity measuring devices of this general class are described in my U.S. Pat. Nos. 2,491,389 of Dec. 13, 1949; 3,290,923 of Dec. 13, 1966; 3,304,765 of Feb. 21, 1967; 3,368,390 of Feb. 13, 1968; and 3,371,522 of Mar. 5, 1968. Further, the use of such viscosity measuring principles in a system for effectively providing a continuous measurement of the viscosity of a fluid which is moving in a duct is described in my co-pending application, Ser. No. 10799, filed Feb. 12, 1970.

Systems of this type should impede as little as possible the flow of fluid the viscosity of which is to be measured, even if such fluid is very heavy. Moreover, such systems should be installed by way of appropriate and relatively standard flange connections for dependable and reliable operation. While my previous viscometer systems have proved generally satisfactory, it is necessary in some applications thereof to be able to move the movable body by the use of an appropriate shaft which is coupled to and actuated by an externally controlled means, such as an electropneumatic control system. In order to insert the shaft into the region of the fluid to be measured, a suitable, and relatively conventional, stuffing box is used to couple the shaft from the external actuation system to the internally located body within the fluid. Appropriate packing material is used in the stuffing box so as to provide a suitable seal so that motion of the actuator rod can be obtained without leakage of the fluid.

It has been found that, after such devices have been in use over relatively extended periods of time, the effectiveness of the stuffing box is somewhat reduced since the packing material often tends to deteriorate in the presence of many fluids and the repeated mechanical action of the shaft within the box causes undesirable wear and, hence, a decreased operating effectiveness of the mechanical elements within the stuffing box. Moreover, operation under severe temperature and pressure conditions tends to aggravate the situation even more. It is desirable, therefore, to utilize means for externally actuating the movable body of such a viscometer system without the need for a stuffing box structure at all. Such a system is achieved as a result of the present invention described in more detail below.

SUMMARY OF THE INVENTION

In the invention the body to be moved through the fluid for providing the viscosity measurement is formed, at least partially, of a magnetic material. A second driver element, also formed of magnetic material, is maintained adjacent said first magnetic body but isolated from the fluid in which the first body is immersed. The second, or driver, magnet element is appropriately connected mechanically to a suitable externally located actuating system, such as electropneumatic actuator, the placement of the magnetic bodies being such as to provide a magnetic coupling action between the driver magnet element and the driven magnet element (i.e., the body to be moved within the fluid) so that motion of the former causes a corresponding motion of the latter. The actuation mechanism for the driver magnet element can be isolated from any contact with the fluid without the use of a stuffing box and an appropriate motion of the driven magnet element obtained.

The magnetically coupled structure can be suitably arranged to be driven from a point above a container in which the fluid is placed or a duct in which the fluid is flowing or, alternatively, from a point below such container, or duct, de-

pending on the specific desired application. Such structures are particularly adaptable to applications where the motion of the driven body within the fluid during the measurement period results substantially from gravitational force with the structure oriented in a vertical position.

In a modification of the invention, the structure also can be adapted to be moved appropriately during the measurement period by other than gravitational force so that the structure can be oriented in a position other than a substantially vertical one.

Thus, the use of magnetic coupling action to provide for the motion of the movable body within the fluid, whereby its predetermined measurement motion is obtained, results in an improved apparatus which avoids the problems encountered when using conventional stuffing boxes, reduces the maintenance problems associated therewith, and extends the useful life of the viscometer device.

DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a view in cross-section of an installation in accordance with the invention for actuation from the top of a vertically mounted structure;

FIG. 2 shows graphically the relationship between the motions of the driver and driven magnet elements in the embodiment of FIG. 1;

FIG. 3 is a view partially in side elevation and partially in cross-section of a modified driven magnet element useful in the embodiment of FIG. 1;

FIG. 3A is a plan view from the top of the element shown in FIG. 3;

FIG. 4 is a view in cross-section of an installation in accordance with the invention for actuation from the bottom of a vertically mounted structure;

FIG. 4A shows a plan view of a portion of the embodiment of FIG. 4;

FIG. 5 is a view in cross-section of a modification of the bottom mounted installation of FIG. 4; and

FIG. 6 is a view in cross-section of an installation in accordance with the invention for mounting in other than a vertical direction.

DESCRIPTION OF PREFERRED EMBODIMENTS

With reference to FIG. 1 a container 10 holds a stationary fluid F the viscosity of which is to be measured and has an opening 11 for the insertion of a viscosity measuring device 12. Device 12 comprises a first elongated cylindrical tube 13 having a flange 14 welded thereto, which flange is in turn suitably connected by any conventional and appropriate means (not shown) to container 10. A first driver magnet element 15 is mounted for movement in such apparatus by means of an operating shaft, or lift rod, 16 which is lifted by an appropriate push rod 17 via operating head 18. Push rod 17 is part of an externally mounted pneumatic system 19 of conventional structure for moving said push rod 17 in a vertical direction whereby operating head 18, shaft 16 and magnetic body 15 are moved upward to the position shown in phantom in FIG. 1 and are then released so as to permit such components to fall as a result of gravitational force, the overall apparatus being mounted in a substantially vertical orientation. As particularly described with reference to my U.S. Pat. No. 3,371,522, the operating head 18 opens switch 20 when the magnetic body 15 has reached a specified position at the bottom of cylindrical tube 13.

The connections to switch 20 as well as the actuation of pneumatic system 19 are appropriately cyclically controlled for indicating the viscosity measurement and such indicating and cycle controlling apparatus may be of the form described in my above-mentioned U.S. Pat. Nos., 3,304,765 and 3,371,522 which need not be further described herein.

An annular driven magnetic element 21 encircles cylindrical tube 13 and is freely movable thereon. Element 21 is magnetically coupled to driver magnet element 15. A first annular

gap, or orifice, 29 exists between the inner surface of magnet element 21 and the outer surface of tube 13. A non-magnetic sleeve element 23 is fixedly mounted to an exterior housing structure 24 by means of a set screw 25 so as to encircle magnetic element 21. A second annular gap, or orifice, 22 exists between the outer surface of magnet element 21 and the inner surface of sleeve 23. Cylindrical tube 13 is attached to housing 24 by means of screw 26 and element 15 and shaft 16, accordingly, are isolated from the fluid F within container 10.

The actuation of push rod 17 upwardly causes driver magnet element 15 to be moved upwardly within cylindrical tube 13 and, because of the magnetic coupling action between driver magnet element 15 and driven magnet element 21, the latter element is also moved upwardly within fluid F adjacent the outer periphery of tube 13 in a corresponding manner. When the elements reach a predetermined position, shown by the phantom lines, push rod 17 is rapidly withdrawn downwardly so as to release the sub-assembly consisting of operating head 18, shaft 16, driver magnet 15 and driven magnet 21. Such elements thereby fall downwardly as a result of gravitational force, the driven magnet 21 being subject both to the gravitational force and to the magnetic attractive force due to the downward motion of driver magnet 15. The sub-assembly reaches a predetermined position substantially at the bottom of cylindrical tube 13 at which point the operating head 18 opens switch 20.

The position of the driven magnet 21 with respect to the driver magnet 15 during their upward and downward motions is such that the position of the driven magnet 21 lags the driver magnet by a substantially fixed amount depending on the magnetic coupling therebetween. Thus, during such motions there is a phase difference between their positions as a function of time as shown in FIG. 2. In that figure, the position of driver magnet 15 is represented graphically by solid line 27 such that position No. 1 represents a predetermined position at or near the bottom of tube 13 and Position No. 2 represents a predetermined position at or near the top of the stroke as shown by the phantom lines. The time t_m represents the measurement time period and its duration depends on the viscosity of the fluid F and accordingly represents an index of such viscosity, as desired.

Dashed line 28 represents the position of the driven magnet as a function of time and, as can be seen in FIG. 2, the motion of driven magnet 21 lags that of driver magnet 27 by a substantially fixed amount Δt which represents a substantially fixed distance between the two magnets during their motion upward and downward throughout any one period. It is desirable to maintain the phase lag (Δt) as small as possible and to this end the weight of the driver magnet 15, shaft 16 and operating head 18 is maintained at a sufficiently small value that such time lag is minimized. At the same time it is desirable that such weight be at least sufficient to actuate mechanical switch 20. It has been found in one successfully used embodiment that if the overall weight of operating head 18, shaft 16 and driver magnet 15 is one pound, for example, and the weight of driven magnet 21 is approximately 3-4 ounces, a suitable compromise is reached between the value necessary to operate switch 20 and that desired to minimize the phase lag between the magnet motions. If the mechanical switch 20 is replaced by an appropriate proximity switch of the type described in my previous patents, the weight of the operating head, shaft and driver-magnet combination can be reduced even further so as to further minimize the phase lag.

As shown in FIG. 1, during the upward stroke of driver magnet 15, fluid enters the region of housing 24 below the driven magnet 21 via orifices 22 and 29, primarily the former. During the downward stroke such fluid as has been effectively trapped in the region below driven magnet 21 is then forced outwardly from housing 24 via the same orifices during the measurement portion of the operation.

The size of orifice 22 can be effectively adjusted by adjusting the thickness of the non-magnetic sleeve element 23, as by inserting sleeves of various thickness therein. Such sleeves are

held by set screw 25 and, accordingly, can be readily replaced. If the viscosity of the fluid to be measured is relatively high, it may be desirable to permit the driven magnet to move more freely within the fluid by increasing the size of orifice 22 as much as possible. For extremely high viscosities, the sleeve 23 and housing 24 may be removed altogether and the driven magnet left free to move within the fluid with no confining orifice between its outer surface and a sleeve element. Such a driven magnet element 30 is shown in FIGS. 3 and 3A, such magnet element 30 being utilized to encircle cylindrical tube 13. A plurality of guide members 31 are mounted on the upper and lower surfaces of magnet element 30 as shown to permit the element 30 to maintain its inner surface parallel to the outer surface of tube 13.

FIG. 4 shows an installation in which the magnet elements are driven from the bottom of a substantially vertically mounted structure and in this particular embodiment are shown as inserted within a duct 35 through which the fluid to be measured is continuously flowing. In this instance, the device is inserted through an opening 36 therein and outer housing element 37 of the device is welded to a flange 38 which is in turn suitably attached to duct 35 and has welded to it a cylindrical tube 39 into which is inserted the driver magnet element 40 attached to shaft 41 and operating head 42. The driver magnet assembly is actuated by push rod 44 which can be appropriately connected to a pneumatic actuator in the manner discussed with reference to FIG. 1 and operating head 42 is used to actuate a switch 43 as before, when driver element 40 is in a predetermined position near the bottom of cylindrical tube 39. A driven magnet element 45 encircles tube 39 and for simplicity is shown as merely enclosed by housing 37 which extends upwardly to a region adjacent the top of cylindrical tube 39. Housing 37 has one or more sample openings 46 through which the fluid is drawn into the interior of housing 37 to the region below driven magnet 45 during its upward stroke. It is clear that provision can be made for an adjustable sleeve element such as is shown in FIG. 1 to provide an appropriately adjustable orifice. During the upward stroke, fluid enters openings 46 and to some extent through the opening between housing 37 and the top of tube 39 and is drawn down to the region below driven magnet 45 via orifices 47 and 48. Openings 46 are oriented so as to be substantially perpendicular to the direction of fluid flow so that the least interference with the motion of driven magnet 45 by fluid flow occurs. Such orientation is shown in the plan view of FIG. 4A, wherein the arrows 49 show the direction of fluid flow within duct 35.

The structure of FIG. 4 operates substantially in a similar manner to that shown with reference to FIG. 1, the push rod 44 moving driver magnet 40 upwardly through cylindrical tube 39 to a predetermined position at the upper end thereof. Push rod 44 is then rapidly withdrawn so as to release the overall assembly of driver magnet 40, shaft 41, operating head 42, and driven magnet 45 so that the latter moves downwardly through the fluid as a result of gravitational force and the magnetic attractive force between the magnets. When driver magnet 40 reaches a predetermined position near the lower end of tube 39, operating head 42 opens switch 43 at the end of the measurement period, as before.

FIG. 5 represent still another embodiment of the invention wherein the relative positions of the driver and driven magnet elements are, in effect, interchanged. For example in FIG. 5 which depicts a bottom mounted installation within a duct 50, a cylindrical housing 51 is welded to duct 50 and has welded to its upper end a cylindrical tube 52, the upper end of which extends into the fluid and has one or more openings 53 for permitting fluid to enter into the interior thereof. A movable cylindrical member 54 has attached thereto a driver magnet element 55 which encircles cylindrical tube 52. A driven magnet element 56 is inserted within tube 52 and is fixedly attached to a centrally located cylindrical tube 57 forming an effective centrally located orifice 62. Driven magnet 56 is free to move within tube 52 and is magnetically coupled to driver

magnet 55, the latter being free to move within cylindrical housing 51 in isolation from the fluid F within duct 50.

The movement of driver magnet 55 is obtained through the actuation of push rod 58 which is appropriately attached to a pneumatic control system (not shown) in a manner such as shown in FIG. 1. The bottom end 59 of movable member 54 is arranged to open switch 60 when driver magnet 55 is in a predetermined position at or near the lower end of tube 52, as shown in FIG. 5. Push rod 58 causes driver magnet 55 to move upwardly to a predetermined position near the upper end of tube 51. Because of the magnetic coupling action between driven magnet 56 and driver magnet 55, the former moves in a corresponding manner through tube 52 so that fluid entering tube 52 via openings 53 and over the open end 61 at the top of tube 52 is drawn downwardly through centrally located orifice 62 of tube 57 to the region below driven magnet 56. A portion of the fluid is also drawn downwardly to such region via orifice 61 between the outer surface of driven magnet 56 and the inner surface of tube 52.

When push rod 58 is rapidly withdrawn, the sub-assembly comprising movable member 54, driver magnet 55, driven magnet 56, and centrally located tube 57 moves downwardly due to gravitational force, the driven magnet 56 also being drawn downwardly by its magnetic coupling action with respect to driver magnet 55. During the downward stroke fluid is forced upwardly out the top of centrally located tube 57 and, hence, outwardly via openings 53 and open end 61 so that a new sample can be drawn in during the next upward stroke. As before, the viscosity is measured in terms of the duration of time for the driver magnet 55 to move from a predetermined position near the upper end of tube 51 to a predetermined position shown in FIG. 5 at which latter point the switch 60 is caused to open as before.

FIG. 6 shows still another modification of the invention which is useful in installations where the device at times must operate in a non-vertical position or where it cannot be mounted in a vertical orientation but must be fixedly mounted horizontally or at some other angle off the vertical. For convenience, the embodiment of FIG. 6 is shown as horizontally mounted although it is understood that the orientation is not limited thereto. In such embodiment the driver magnet element 65 is shown as movable within cylindrical tube 66 with the driven magnet element 67 encircling tube 66 and being in turn effectively enclosed within a housing 68 and non-magnetic sleeve element 69 in a manner similar to that shown with reference to FIG. 1. Housing 68 is welded to the container 70 in which the fluid F is contained and cylindrical tube 66 is also appropriately welded thereto for permanent installation. Alternatively the latter tube may be attached to container 70 by an appropriate flange as in FIG. 1.

In this embodiment, inasmuch as gravitational force cannot be used to provide the necessary motion of the driver magnet-driven magnet sub-assembly as in the previous embodiments, it is necessary to provide an appropriate reciprocal motion of the driver magnet in some other manner so that the viscosity measurement can be made. In the particular embodiment shown the driver magnet 65 is fixedly attached to a shaft 71 which is in turn fixedly attached to an auxiliary movable inner magnet element 72. Magnet element 72 is in turn fixedly attached to a shaft 73 which has attached thereto an operating head 74 for actuation by push rod 75 in a manner similar to that discussed with reference to the previous embodiments. Operating head 74 is also arranged to open switch 76 in the position shown in FIG. 6. An auxiliary outer magnet element 77 is fixedly attached to one end of cylindrical tube 66 and is magnetically coupled to inner magnet element 72 in a manner similar to that discussed with reference to driver element 65 and driven element 67. An auxiliary adjusting magnet element 78 is movably mounted with reference to fixed magnet element 77 for purposes discussed below.

In the operation of the embodiment shown in FIG. 6, push rod 75 moves the sub-assembly comprising operating head 74, shaft 73, inner magnet 72, shaft 71, driver magnet 65, and

driven magnet 67 to the left in the orientation shown therein. In doing so, the force provided by push rod 75 must be sufficient to overcome the magnetic coupling force that exists between movable inner magnet 72 and fixed outer magnet 77. When driver magnet 65 reaches a predetermined position at the left end of cylindrical tube 66, push rod 75 is rapidly withdrawn to the right and the magnetic coupling force between fixed outer magnet 77 and inner magnet 72 provides a substantially constant force for moving the sub-assembly to the right until driver magnet 65 reaches a predetermined position as shown in FIG. 6 at which point switch 76 is opened.

In this manner the overall apparatus may be oriented in any position and does not depend on the presence of a gravitational force to produce the substantially constant force for moving the sub-assembly during the measurement period. Auxiliary magnet 78 is used to adjust the magnetic force between inner magnet 72 and outer magnet 77 so as to provide the desired relationship between such forces. It is preferable that the magnetic coupling force between magnets 72 and 77 be somewhat less than that between driver magnet 65 and driven magnet 67 for best operation. Such force can be adjusted by moving the position of auxiliary magnet 78 with reference to fixed magnet 77 so that the overall magnetic field between magnets 72 and 77 is suitably varied.

Alternatively, the substantially constant force required in this embodiment may be supplied by a suitable mechanical means, such as a spring, for example, positioned between the container 70 and operating head 74 as a substitute for the auxiliary magnetic elements shown in FIG. 6. So long as the spring is made sufficiently long to provide a substantially constant force over the distance through which the measuring elements move during the measurement period, such a mechanical force can be used with success in many applications. Other means for providing a substantially constant force also may be devised for use by those in the art within the scope of the invention.

Further, a spring, or other force means, may be used in the above embodiments to provide an additional force to the forces present therein. Thus, a spring may be used to aid or oppose the gravitational force as used in the gravity driver embodiments discussed above with reference to FIGS. 1-5 or such a spring may be used to aid or oppose the force provided by an auxiliary magnetic driving means, such as discussed with reference to the embodiment of FIG. 6, for example.

What is claimed is:

1. A viscosity measuring apparatus wherein a movable means moves within a fluid the viscosity of which is to be measured and wherein the time period required to move said movable means a predetermined distance in a predetermined direction through said fluid represents an index of said viscosity, said apparatus comprising

a first movable magnetic driver means;

a second movable driven means at least partially made of a magnetic material mounted adjacent and magnetically coupled to said first movable magnetic means so as to be moved within said fluid in response to the motion of said first movable magnetic means;

means for moving said first and second movable means to first predetermined positions; and

means for releasing said first and second movable means to permit both said means to move a predetermined distance under a substantially constant force, said first and second movable means being arranged to remain magnetically coupled during the movement thereof through said predetermined distance.

2. A viscosity measuring apparatus in accordance with claim 1 wherein said apparatus is substantially vertically mounted and said substantially constant force is supplied by gravity.

3. A viscosity measuring apparatus in accordance with claim 1 wherein said first movable magnetic driver means is mounted in isolation from said fluid.

4. A viscosity measuring apparatus in accordance with claim 3 and further including

a cylindrical tube inserted within said fluid;

said first movable magnetic driver means being mounted for movement within said tube in isolation from said fluid; said second movable driven means encircling said cylindrical tube and being freely movable with respect thereto within said fluid.

5 5. A viscosity measuring apparatus in accordance with claim 4 and further including a housing means for housing said cylindrical tube and said first and second movable driven means.

10 6. A viscosity measuring apparatus in accordance with claim 5 and further including non-magnetic sleeve means attached to said housing means and encircling said second movable driven means; whereby orifices are formed between said cylindrical tube and said second movable driven means and between said non-magnetic sleeve and said second movable driven means for permitting the flow of fluid therethrough during the movement of said second movable driven means within said fluid.

15 7. A viscosity measuring apparatus in accordance with claim 5 wherein said non-magnetic sleeve is adapted to be removable whereby sleeves of different thicknesses can be used for adjusting the dimension of said orifice between said second movable driven means and said sleeve.

20 8. A viscosity measuring apparatus in accordance with claim 5 wherein said second movable driven means is the sole element encircling said cylindrical tube and further includes a plurality of guide elements mounted on said second movable driven means to guide said means during its motion with respect to said tube within the fluid.

25 9. A viscosity measuring apparatus in accordance with claim 5 wherein said apparatus is adapted for mounting within a duct containing a substantially continuously flowing fluid, said housing having one or more openings therein oriented so as to be substantially removed from the direct line of flow of said fluid for permitting entry of fluid therein, whereby the viscosity of said fluid can be measured while said fluid is substantially in continuous motion.

30 10. A viscosity measuring apparatus in accordance with claim 3 wherein said fluid is contained in a containing means, said apparatus further including means for mounting said apparatus in a substantially vertical orientation at the top of said containing means.

35 11. A viscosity measuring apparatus in accordance with claim 3 wherein said fluid is contained in a containing means, said apparatus further including means for mounting said apparatus in a substantially vertical orientation at the bottom of said containing means.

40 12. A viscosity measuring apparatus in accordance with claim 1 and further including a housing means inserted within said fluid; a cylindrical tube means fixedly attached to said housing means and having a portion thereof within said housing means and a portion thereof extending into said fluid;

said first movable driver means including a first movable member having a magnetic driver means fixedly attached thereto and inserted within said housing for movement therein, said magnetic driver means encircling said cylindrical tube means and being isolated from said fluid;

said second movable driven means being freely movable within said cylindrical tube and magnetically coupled to said magnetic driver means so as to be moved within said cylindrical tube means in response to the motion of said magnetic driver means;

means for moving said first movable member and said second movable driven means to first predetermined positions; and

means for releasing said first movable member and said second movable driven means to permit both said member and said means to move a predetermined distance under a substantially constant force.

13. A viscosity measuring apparatus in accordance with claim 12 and further including a centrally located orifice for permitting movement of said fluid therethrough during the motion of said first movable member and said second movable driven means.

14. A viscosity measuring apparatus in accordance with claim 12 wherein said apparatus is mounted within a containing means in which said fluid is substantially continuously moving;

said cylindrical tube including

one or more openings therein oriented so as to be substantially removed from the direct line of flow of said fluid for permitting entry of fluid therein whereby the viscosity of said fluid can be measured when said fluid is substantially in continuous motion.

15. A viscosity measuring apparatus in accordance with claim 1 and further including

auxiliary magnetic means for providing said substantially constant force for moving said first and said second movable means said predetermined distance.

16. A viscosity measuring apparatus in accordance with claim 15 wherein said auxiliary magnetic means includes a first auxiliary magnetic means fixedly attached to said first movable magnetic driver means for movement therewith; a second auxiliary magnetic means fixedly mounted with respect to said apparatus and magnetically coupled to said first auxiliary magnetic means, whereby said magnetic coupling provides a substantially constant force to move said first auxiliary magnetic means and said first and second movable driver and driven magnetic means said predetermined distance.

17. A viscosity measuring apparatus in accordance with claim 16 and further including

a third auxiliary magnetic means movably mounted adjacent said second fixed auxiliary magnetic means and adapted to be moved so as to adjust the magnetic coupling between said first movable auxiliary magnetic means and said second fixed auxiliary magnetic means.

* * * * *

60

65

70

75