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DAE SIK KIM ETAL
ENGINE VISCOSITY SIMULATOR

3,350,922

Filed May 17, 1965

2 Sheets-Sheet 1

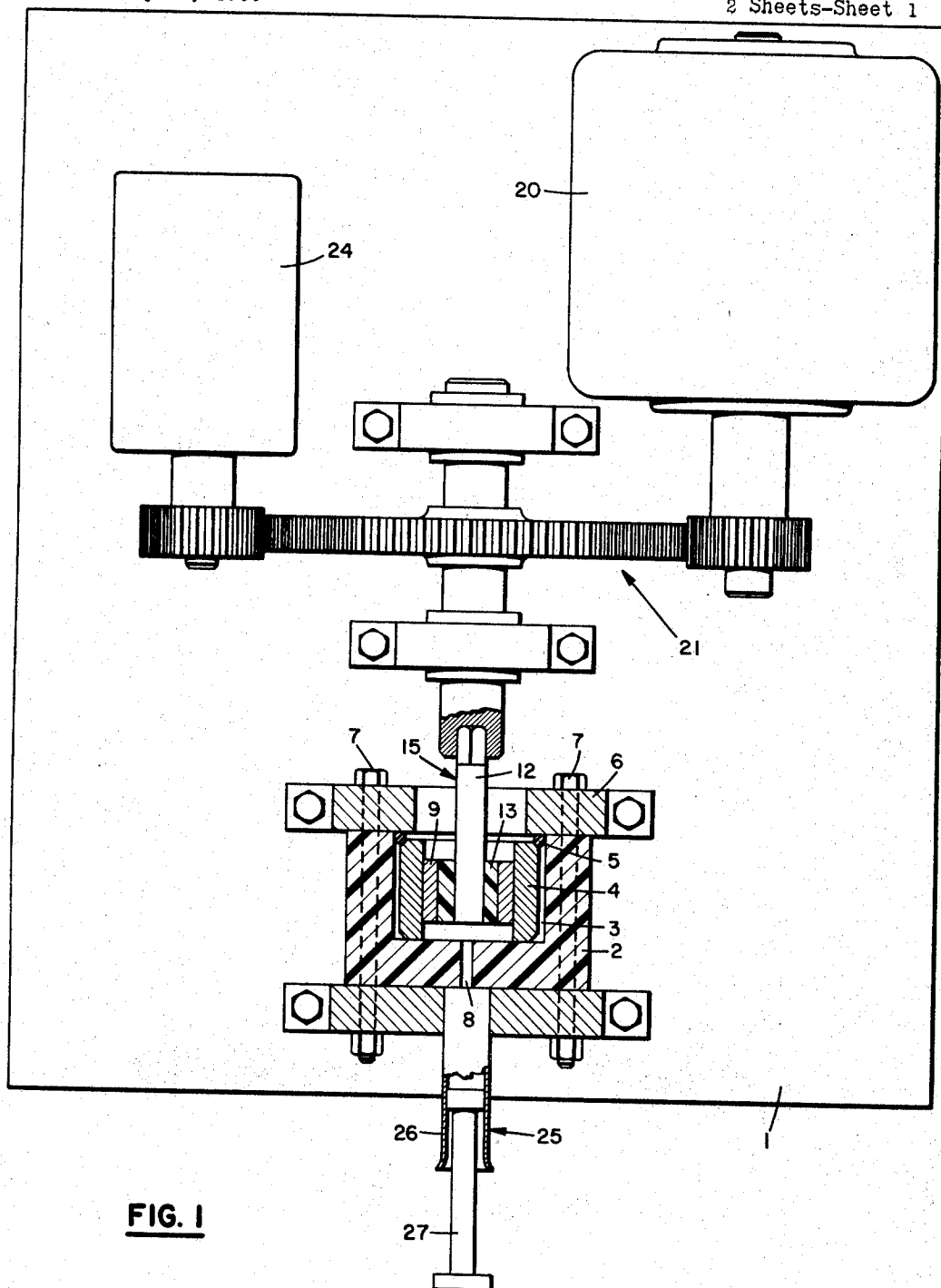


FIG. 1

DAE SIK KIM
GERALD K. VICK

INVENTORS

BY

Frank T. Johnson

PATENT ATTORNEY

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FIG. 2

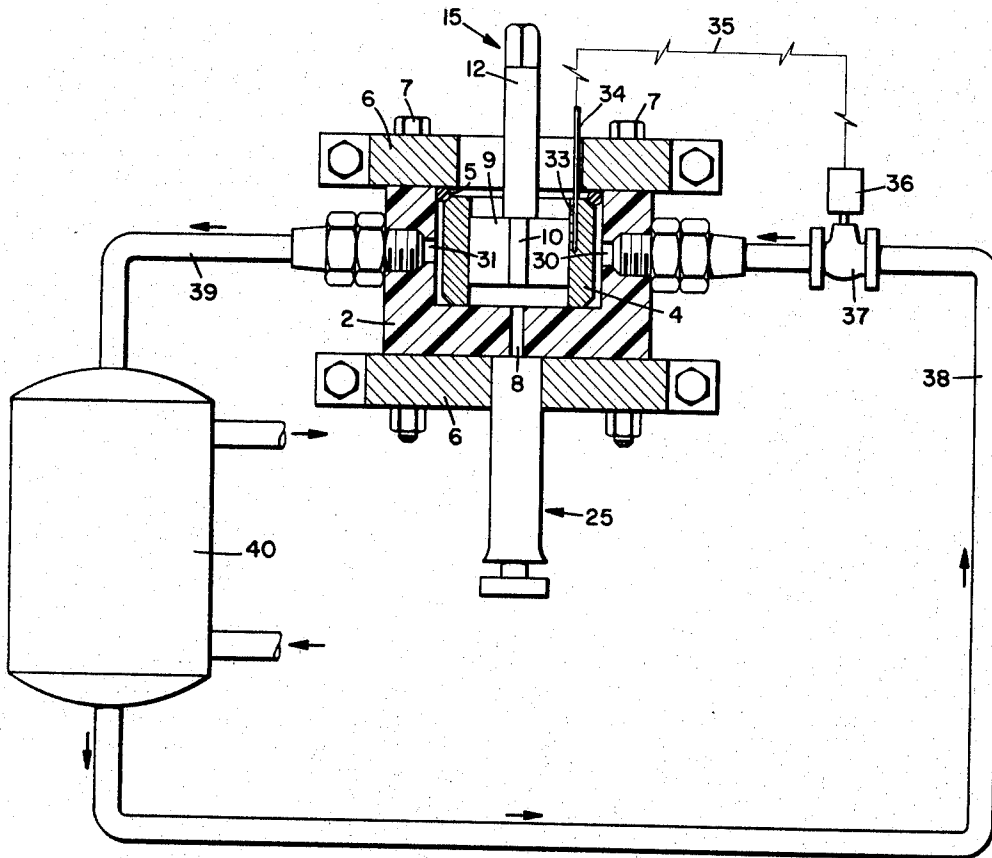
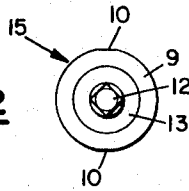


FIG. 3

DAE SIK KIM
GERALD K. VICK

INVENTORS

BY

Frank T. Johnson

PATENT ATTORNEY

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3,350,922

ENGINE VISCOSITY SIMULATOR

Dae Sik Kim, Jersey City, and Gerald K. Vick, Plainfield, N.J., assignors to Esso Research and Engineering Company, a corporation of Delaware

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6 Claims. (Cl. 73—60)

ABSTRACT OF THE DISCLOSURE

A viscosity measurement device employing a sample container having a sleeve therein and a spindle rotatable within said sleeve. The spindle is connected to its supporting shaft through an insulator and is provided with flattened surface portions to continuously vary the shear rate between the spindle and the sleeve. A temperature control system is also included to maintain the sample at a uniform temperature during the viscosity test.

The present invention relates, in general, to an apparatus for measuring the viscosities of oils. In particular, the invention provides a means for accurately predicting the engine cold cranking characteristics (i.e., "engine viscosity") of a crankcase oil.

The problem of accurately predicting the cranking characteristics of a crankcase oil (i.e. an engine oil) in an engine operating at low temperatures (e.g. below about 0° F.) is well known. It is further known that the viscosity of such an oil influences the force (torque) required to crank an engine and the engine cranking speed; and that the viscosity of any oil is temperature dependent. Thus, the viscosity of a crankcase oil influences the ease of starting the engine at low temperatures. As is known in the art, "engine viscosity" of a crankcase oil will determine the ease of engine cranking.

Engine manufacturers, oil processors, and automobile owners, among others, are vitally interested in being able to determine the engine viscosity of a crankcase oil without having to crank the oil under controlled conditions in an actual engine. The cranking characteristics of the so called "straight mineral" oils can, in general, be predicted adequately (i.e., without actual cranking) by using the viscosity at the temperature of interest, e.g. 0° to -20° F. The "straight mineral" oil viscosity is obtained by extrapolating low-shear viscosities obtained at 100° and 210° F. on the ASTM viscosity-temperature chart. This procedure, however, is not satisfactory to non-Newtonian oils, as has been amply pointed out in the literature. Most crankcase oils used at the present time are non-Newtonian oils, containing polymeric additives called viscosity index improvers. The complex viscosity-temperature relationships which these present day crankcase oils exhibit preclude the use of the extrapolated viscosity technique employed to predict the engine cranking characteristics of a straight mineral crankcase oil. That is, the extrapolated viscosity technique is not applicable to polymer-containing crankcase oils or other non-Newtonian oils.

Accordingly, it is an object of the present invention to provide apparatus for predicting the engine cranking performance of a crankcase oil. It is a further object to provide an engine viscosity simulator of improved characteristics. It is still a further object to provide an apparatus for predicting the relative distribution of the viscous forces and the hydrodynamic forces in a liquid system particularly, a non-Newtonian liquid system. Still further objects of the present invention will become apparent from the description that follows.

The above objects and others are accomplished by an improved engine viscosity simulator. The invention will

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be better understood by reference to a detailed description, including a preferred embodiment thereof. Hence, reference will next be made to the attached drawing wherein FIGURE 1 is a vertical view, in partial cross section, of an engine viscosity simulator of the present invention; FIGURE 2 is a top view of a spindle adapted for use in the apparatus of the present invention; and FIGURE 3 is a vertical view, in partial cross section, of a preferred embodiment of the present invention wherein the simulator is further adapted with a temperature control system.

Referring to FIGURE 1, the elements of the engine viscosity simulator of the present invention are suitably supported in any appropriate manner such as by structural or frame element 1. A sample holder 2 made of a durable, strong plastic resin, such as "Teflon" (or other fluorinated hydrocarbon polymer) is provided with a cylindrical bore or cavity 3. The cavity 3 is of sufficient size (diameter and depth) so as to receive cylinder or sleeve 4. Sleeve 4 is made, for example, from a .75 inch length of solid brass bearing material having a .25 inch wall thickness and a .75 inch inside diameter. Sleeve 4 is fixed, for example, by means of O-rings 5, end-plates 6 and bolts 7, to prevent its movement. Sample holder 2 is further provided with a hole or channel 8 for insertion of the sample of oil to be tested. Sleeve 4 is adapted to receive a snugly fitting rotatable drum 9. Drum 9 is made, for example, from a .50 inch length of stainless steel cylindrical material having an outside diameter of about 0.75 inch. Drum 9 is fixed to a shaft 12 but insulated from the shaft 12 by a suitable insulator 13, such as a plastic sleeve of phenol-formaldehyde resin. The insulator 13 substantially insulates the drum 9 from temperature changes in the shaft 12 but is so adapted as to impart any motion from shaft 12 to drum 9. Together, drum 9, insulator 13, and shaft 12, comprise spindle 15. Spindle 15 is coupled to and driven by motor 20 by means of gear train 21. The motor 20 is a series wound DC or AC universal motor, of the type in which torque varies with speed at constant voltage. For example, motor 20 may be of the type commonly designed for stirring operations, such as an "Eclipse" Air Brush Company's universal 1/50 H.P., 130 max. line voltage, model. Gear train 21 also drives a tachometer 24 or other suitable device for measuring r.p.m. For example, tachometer 24 can be "Servo-Tek" type SA 740B-1.

The oil to be tested is inserted into sample holder 2 through channel 8, by means of sample injector 25. The injector is made, for example, from a glass or plastic tube 26, fitted with a plunger 27. The injector 25 holds, for example, about a 2 cc. sample of oil and allows injection of the oil in a manner so that air bubbles will not remain in the oil. Thus, any suitable means for inserting the oil sample without introducing air bubbles may be employed.

With a constant voltage source of current (e.g. 90 volts) for the electric motor 20, the speed (r.p.m.) at which the motor 20 can turn the spindle 15 inside the sleeve 4 will depend upon the characteristics of the oil sample. The simulator is calibrated with oils of known viscosity. Using oils of different, but known viscosity (e.g. "REO" oils) a plot of viscosity (or log viscosity) versus r.p.m. at constant voltage can be made. The engine viscosity of an unknown oil sample is then obtained by reading the r.p.m. at the same voltage and then obtaining the engine viscosity from the plot. The viscosities so obtained agree with engine viscosities for the same oils in actual cranking tests, as described hereinafter.

Referring to FIGURE 2, it is seen that the drum 9 employed in a preferred embodiment is provided with a pair of symmetrical flats 10. These flats 10 are one important aspect of the present invention, in that they

serve several purposes. First, and most importantly, these flats 10 create a continuously varying shear rate which simulates, to a degree heretofore unattainable, engine viscosity. In addition, the flats 10 provide a stable film of sample oil with the result that the data does not fluctuate. Finally, the flats facilitate cleaning and assembly of the simulator. The flats 10 are symmetrical so as to prevent spindle fluctuation. The size of the flats 10 may vary depending upon the particular application. In an application wherein the simulator of the present invention is used to simulate the cold cranking characteristics of a crankcase oil, flats having a total surface area of about 10% of the total cylindrical surface area of the drum 9 are suitable. For example, if the total cylindrical surface area of the drum 9 is about 1.2 square inches

$$(\pi D \times h = 3.14 \times .75 \times .5)$$

the total area of the two flats is about .12 square inch, or each flat is about 0.06 square inch. Although it is not intended that the following theoretical explanation limit the present invention in any respect, it is believed that the flats dictate the relative distribution of viscous force and hydrodynamic force, which are the two controlling forces encountered in systems such as these. By "system," is meant any application wherein a liquid, particularly a non-Newtonian liquid, is used to lubricate an element driven by a rotational force. Thus, the higher the relative distribution of hydrodynamic force in a given system the larger the surface area of the flats need be, in order to simulate the characteristics of the system by means of the simulator of the present invention.

Referring to FIGURE 3, there is shown the preferred embodiment of the present invention, wherein the simulator is further adapted with temperature controlling means. Sample holder 2 is provided with two holes or conduits 30 and 31. Conduit 30 is an inlet for a temperature control fluid (e.g. Varsol solvent). Conduit 31 is an outlet for said fluid. Said fluid comes in contact with and flows around sleeve 4, maintaining sleeve 4 a predetermined temperature. In cold cranking studies this temperature is usually 0° F. Sleeve 4 is provided with a small hole 33 close to the inner wall of sleeve 4, to receive a thermocouple 34. This thermocouple 34 transmits the temperature of the inner wall of sleeve 4 through line 35 to a temperature recorder-controller 36. Said controller 36 is of conventional type and per se forms no part of the invention. Controller 36 controls a valve 37 (e.g. an electrically operated valve) by means of which flow of the temperature control fluid is regulated. Heat exchanger 40, of conventional type, controls the temperature of the control fluid. In cold cranking applications, heat exchanger 40 is a cooler. Inlet lines 38 and outlet line 39 transport the control fluid to and from the sample holder, respectively.

The engine viscosity simulator of the present invention is superior to prior art devices in several respects. Instruments used heretofore include capillary, forced ball and rotational viscometers for low-shear rates and viscometers such as the Mason Crystal viscometer, the Haake viscometer and the Ferranti-Shirley cone-plate viscometer for high shear rates. These instruments are expensive and are complex to operate. In addition, many of these instruments are objectional in that they have limited r.p.m. range, exhibit sample loss, require considerable data evaluation, etc. In contrast, the engine viscosity simulator of the present invention is inexpensive, rugged, easily cleaned, and relatively simple to operate. It is operable over a wide r.p.m. range and is eminently suitable for high shear operation; requires no data evaluation after initial correlation; and the sample may be easily injected and maintained. In addition, the simulator may be readily adapted with a temperature control system for excellent and stable temperature control. Further, it may be further adapted for use in liquid systems, particularly non-Newtonian, other than in simulating engine cold cranking

characteristics. For example, the simulator has utility in high temperature cranking studies, in evaluating gear oils, and in any other system where there is present the compounded effect of viscous and hydrodynamic forces. Most importantly, none of the prior art instruments predict engine cold cranking characteristics with the degree of accuracy obtainable with the engine viscosity simulator of the present invention.

In order to demonstrate the superiority of the engine viscosity simulator of the present invention in predicting "engine viscosity", comparative tests were run. In these tests, Coordinating Research Council, Inc. (CRC) reference oils were used. These oils are known in the art as "REO" oils and are described, for example, in SAE publication 805A, "Development of Research Technique for Determining the Low-Temperature Cranking Characteristics of Engine Oils," presented at the Automotive Engineering Congress, Detroit, Mich., Jan. 13-17, 1964.

As a basis of comparison the viscosities obtained using (a) the simulator of the present invention (designated E.V.S.), (b) a Ferranti-Shirley viscometer (designated F-S) and (c) the Haake viscometer used by Rohm & Haas Co. (designated Haake R&H) were compared with the art recognized standard (designated CRC Avg. E.V.). The Ferranti-Shirley viscometer was modified with a temperature control system (as described in U.S. Ser. No. 416,092, filed Dec. 4, 1964, now Patent No. 3,307,619) in order to achieve uniform 0° F. temperatures. The art recognized standard is described in CRC Report 381, and briefly, is based upon the average engine viscosities of eight different engines. Thus, the target in these tests was to obtain viscosity data identical with or closely approximating the standard (i.e. "CRC Avg. E.V."). The test data is shown in Table I.

TABLE I.—COMPARATIVE ENGINE VISCOSITY¹

REO Oil#	CRC Av. E.V.	E.C.S.	F-S	Haake R & H
155	14.7	15.5	17.8	18.8
156	18.3	18.0	20.6	20.0
157	27.0	27.0	25.6	27.8
158	18.0	17.8	17.3	19.8
159	25.9	26.5	29.7	30.5
160	31.1	32.0	35.2	35.0
161	10.0	10.0	10.7	10.0
162	27.6	26.5	31.7	29.5
171	17.0	17.0	20.0	18.5
172	6.0	6.4	7.6	7.4
173	8.9	9.0	9.6	9.4
175	50.4	50.5	55.7	48.5

¹ Viscosity in poise at 0° F.

The data in Table I clearly demonstrate the superiority of the engine viscosity simulator of the present invention.

It will be obvious that various changes and modifications may be made in the apparatus described above. It is intended by the claims which follow to cover such modifications as would suggest themselves to those skilled in the art.

What is claimed is:

1. An engine viscosity simulator comprising a sample holder provided with a cavity; a sleeve, fixed within said cavity; a spindle adapted to rotate within said sleeve, said spindle including in combination a shaft, an insulator, and a drum, said drum being provided with a pair of substantially symmetrical flats; a series wound motor; a tachometer; and a gear train responsive to said motor, said gear train being adapted to drive said spindle and said tachometer.

2. A simulator as defined by claim 1 wherein said sample holder is further provided with temperature controlling means.

3. A simulator as defined by claim 1 wherein said sample holder is further provided with sample injecting means.

4. A simulator as defined by claim 1 wherein said series wound motor is a direct current motor.

5. A simulator as defined by claim 1 wherein said

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series wound motor is an alternating current universal motor.

6. A viscosity measurement device comprising, a sample holder provided with a cavity; a spindle adapted to rotate within said cavity, said spindle including a drive shaft, a drum having a pair of substantially symmetrical flat portions on an exterior surface thereof, and a thermal insulator connecting said drive shaft to said drum; a drive motor, a tachometer, and drive connection means responsive to said motor, said connection means being adapted to drive said spindle and said tachometer.

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10 DAVID SCHONBERG, *Primary Examiner.*