Standard Test Method for Fuel Injector Shear Stability Test (FISST) for Polymer Containing Fluids[1]

This standard is issued under the fixed designation D 5275; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method measures the percent viscosity loss at 100°C of polymer-containing fluids using fuel injector shear stability test (FISST) equipment. The viscosity loss reflects polymer degradation due to shear at the nozzle.

NOTE 1—Test Method D 2603 has been used for similar evaluation of this property. It has many of the same limitations as indicated in the significance statement. No detailed attempt has been undertaken to correlate the results by the sonic and the diesel injector methods. Equipment and replacement parts are no longer available for Test Method D 2603 as it is currently written. The test method is currently under revision.

NOTE 2—This test method was originally published as Procedure B of Test Methods D 3945. The FISST method was made a separate test method after tests of a series of polymer-containing fluids showed that Procedures A and B of Test Methods D 3945 often give different results.

1.2 The values given in SI units are to be regarded as the standard. The inch-pound units given in parentheses are for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary statements are given in Section 7.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)

D 2603 Test Method for Sonic Shear Stability of Polymer-Containing Oils

D 3945 Test Methods for Shear Stability of Polymer-Containing Fluids Using a Diesel Injector Nozzle[3]

3. Summary of Test Method

3.1 The polymer-containing fluid is passed through a diesel injector nozzle at a shear rate that causes the less shear stable polymer molecules to degrade. The resultant degradation reduces the kinematic viscosity of the fluid under test. The reduction in kinematic viscosity, reported as percent loss of the initial kinematic viscosity, is a measure of the shear stability of the polymer-containing fluid.

4. Significance and Use

4.1 This test method evaluates the percent viscosity loss for polymer-containing fluids resulting from polymer degradation in the high shear nozzle device. Minimum interference from thermal or oxidative effects are anticipated.

4.2 This test method is not intended to predict viscosity loss in field service for different polymer classes or for different field equipment. Some correlation for a specific polymer type in specific field equipment can be possible.

5. Apparatus

5.1 The apparatus consists of two fluid reservoirs, a single-plunger diesel fuel injection pump with an electric motor drive, a pintle-type fuel injection nozzle installed in a nozzle holder, and instrumentation for automatic operation. Annex A1 contains a more complete description of the apparatus.[4,5]

6. Reference Fluids

6.1 Diesel fuel is required for adjusting the nozzle valve assembly to the prescribed valve opening pressure.

6.2 Calibration fluid TL-11074[5,6] is used to verify that the shearing severity of the apparatus is within the prescribed limits.

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.07 on Flow Properties.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn.

[4] The sole source of supply of the entire apparatus and spare parts (injectors) known to the committee at this time is Falex Corporation, 1020 Airpark Dr., Sugar Grove, IL 60554.

[5] If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee [1], which you may attend.

[6] The sole source of supply of the apparatus known to the committee at this time is Tannas Co., 4800 James Savage Rd., Midland, MI 48642.

***A Summary of Changes section appears at the end of this standard.**

7. Precautions

7.1 During operation, the line between the pump and the nozzle holder is under high pressure. The safety shield should be in place when the apparatus is running. Stop the apparatus before tightening any fitting that is not properly sealed.

7.2 During operation and during the setting of the valve opening pressure, the fluid is discharged from the nozzle at high velocity and can inflict a serious wound if it strikes a part of the human body. Therefore, secure the nozzle assembly in position before the test apparatus is started. Similarly, take care to shield the operator from the nozzle discharge during the pressure-setting step.

8. Sampling

8.1 The test fluid shall be at room temperature, uniform in appearance and free of any visible insoluble material prior to placing in the test equipment.

8.2 After the test fluid has completed its twentieth cycle through the apparatus, drain it into a bottle for transfer to the kinematic viscosity measurement.

9. Calibration

9.1 Set the valve opening pressure of the diesel injector nozzle assembly to 20.7 ± 0.35 MPa (3000 ± 50 psi) by means of a hand-actuated pump[5,7] and diesel fuel.

9.2 Set the delivery rate of the pump to 534 ± 12 cm^3/min by the procedure described in Annex A1.

9.3 Verify the shearing severity of the apparatus by running the standard test procedure, described in 9.3.1, with reference oil. Make this check every twentieth run when the apparatus is used frequently. Make this check before any other samples are tested if the apparatus has been idle for a week or more. The kinematic viscosity at 100°C for the sheared reference oil is to be within the limits prescribed for the specific batch of the reference oil in use. For oil TL-11074,[5,6] the limits are 9.64 and 9.94 mm^2/s (cSt) at 100°C.

9.3.1 If the viscosity of the sheared oil does not fall within the above limits, make another shear test of the reference oil by the standard procedure. If the viscosity of the sheared oil still does not fall within the limits, take steps to correct the rating level of the test. Either mechanical difficulty or test technique is at fault.

10. Procedure

10.1 Shearing is accomplished by pumping the entire 100 cm^3 test oil charge through the nozzle in successive passes or cycles. One cycle consists of pumping the oil from the lower reservoir (*8*) in Fig. A1.1, through the nozzle (*5*), and into the upper reservoir (*6*). At the end of each cycle, when the entire test oil charge has been collected in the upper reservoir (*6*), the pump (*2*) stops and the solenoid-operated drain valve (*7*) opens, draining the oil into the lower reservoir (*8*). The pump then restarts automatically for the next cycle. This process repeats for the number of cycles that have been set on the cycle counter. At the end of the last cycle, both solenoid-operated drain valves, (*7*) and (*9*) in Fig. A1.1, open and the test oil drains into the sample collection bottle (*10*).

10.2 Flush the apparatus with three separate 100 cm^3 portions of the test oil as described in 10.2.1 and drain. Do not use solvent as part of the flush at any time because it could cause contamination.

10.2.1 Pour the first 100 cm^3 charge of test oil into the lower reservoir, (*8*) in Fig. A1.1, through the funnel (*14*). Set the cycle counter for three cycles of the fluid through the nozzle, the pump timer for 15 s and the valve time for 20 s.

NOTE 3—These timer settings have been found satisfactory for all oils normally tested. The pump time should be sufficient for all oil to be pumped through the nozzle and into the upper reservoir, (*6*) in Fig. A1.1. The valve time should be sufficient for the oil to drain completely from the upper reservoir to the lower reservoir.

10.2.2 Start the pump, (*2*) in Fig. A1.1, and run until three cycles have been completed. Drain and discard the sheared oil.

10.2.3 Similarly, run the second 100 cm^3 for two cycles and the third 100 cm^3 flush for one cycle, draining and discarding each flush.

10.3 Pour 100 cm^3 of the test oil into the lower reservoir through the funnel. Set the cycle counter for 20 cycles. Set a clean 120 cm^3(4 oz) bottle, (*10*) in Fig. A1.1, under the drain tube of the lower reservoir to receive the sheared sample. Start the pump and run until the 20 cycles have been completed. At the end of the twentieth cycle, both drain valves, (*7*) and (*9*) in Fig. A1.1, open automatically and the sample drains into the collection bottle, (*10*).

10.4 Measure the kinematic viscosity of the sheared oil and a sample of the unsheared oil at 100°C by Test Method D 445.

11. Calculation

11.1 Calculate the percentage loss of viscosity of the sheared oil as follows:

$$VL = 100 \times (V_u - V_s)/V_u \quad (1)$$

where:

VL = viscosity loss, %,
V_u = kinematic viscosity of unsheared oil at 100°C, mm^2/s (cSt), and
V_s = kinematic viscosity of sheared oil at 100°C, mm^2/s (cSt).

12. Report

12.1 Report the following information:

12.1.1 Percentage viscosity loss as calculated in 11.1,

12.1.2 Kinematic viscosity of the unsheared oil at 100°C,

12.1.3 Kinematic viscosity of the sheared oil at 100°C,

12.1.4 Number of cycles,

12.1.5 For reference oil runs, the batch number of the reference oil, and

12.1.6 Specify this test method (ASTM D5275).

[7] The sole source of supply of the apparatus known to the committee at this time is Waukesha Engine Div., 1000 W. St. Paul Ave., Waukesha, WI 53188. Part No. G-818–7.

13. Precision and Bias [8]

13.1 The following criteria should be used for judging the acceptability of results:

13.1.1 *Repeatability*—The difference between successive test results, obtained by the same operator with the same apparatus under constant operating conditions on identical test material would, in the long run, and in the normal and correct operation of the test method, exceed the following value only in one case in twenty: 1.19 %.

13.1.2 *Reproducibility*—The difference between two single and independent results, obtained by different operators working in different laboratories on identical test material would, in the long run, and in the normal and correct operation of the test method, exceed the following value only in one case in twenty: 5.22 %.

NOTE 4—The indicated repeatability and reproducibility values represent the subtractive difference between the reported percentage viscosity loss values for the two determinations being compared.

13.1.3 *Bias*—All test results are relative to those of Calibration Fluid TL-11074.[5,6] Therefore no estimate of bias can be justified.

14. Keywords

14.1 fuel injector; polymer containing fluids; VII; shear stability

[8] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02–1131. This test method was formerly Procedure B of Test Method D 3945.

ANNEXES

(Mandatory Information)

A1. DETAILS OF FUEL INJECTOR SHEAR STABILITY TEST (FISST)

A1.1 *Apparatus:*

A1.1.1 Fig. A1.1 shows the test schematically. A cycle counter, pump timer, valve timer, main power switch, and drain valve switch are mounted on an instrument panel not shown in Fig. A1.1.

A1.1.2 *Specifications for the Fuel Injection Parts*:

NOTE A1.1—The parts have not changed; only the parts supplier and part number have changed. Previous parts may be used until supply is exhausted.

A1.1.2.1 *Diesel Fuel Injection Pump ((2) in* Fig. A1.1*)*, Waukesha pump 106712G that contains: Plunger and barrel assembly, 8.0 mm, PPK 1/2ZG ((*17*) in Fig. A1.2), camshaft, 6/1, PAC 26/1X ((*34)* in Fig. A1.2), delivery valve assembly, 6.0 mm cuffless, PVE 67/1Z ((*16*) in Fig. A1.2), plunger spring SP 769 CA ((*31*) in Fig. A1.1), and tappet assembly TP 7615-1A ((*19*) in Fig. A1.1).

A1.1.2.2 *Nozzle Holder*, ((4) in Fig. A1.1), Waukesha P/N 110743.

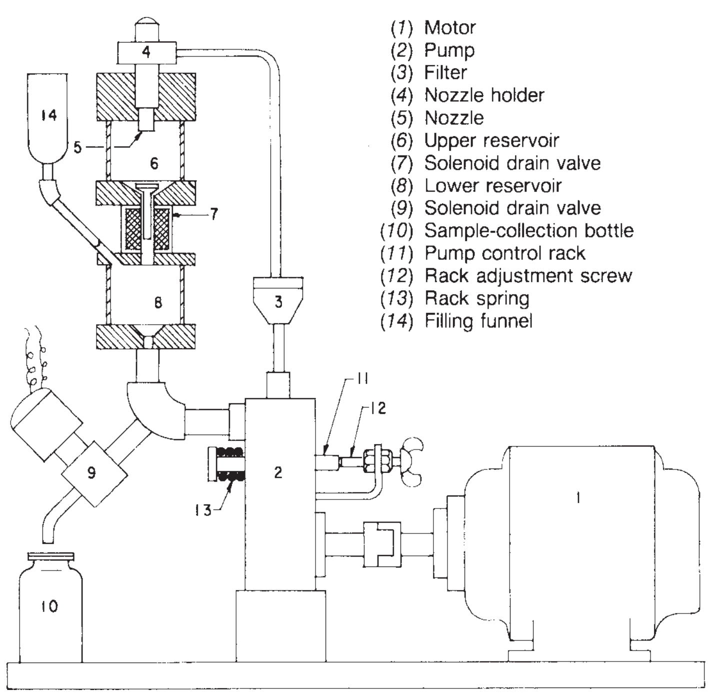

FIG. A1.1 Fuel Injector Shear Stability Test (FISST) (Schematic)

(1) Housing
(2) Petcock, bleeder
(3) Screw, barrel locating
(4) Plug, breather
(5) Cover, inspection
(6) Screw, fastening
(7) Stud, fuel supply pump
(8) Cover, pad-fuel supply pump
(9) Plug, drain
(10) Nut, delivery union
(11) Washer
(12) Holder, delivery valve
(13) Spring, delivery valve
(14) Plate, name
(15) Gasket, delivery valve
(16) Delivery valve assembly
(17) Plunger and barrel assembly
(18) Screw, control rack
(19) Tappet assembly
(20) Shell, tappet
(21) Roller, tappet
(22) Bushing
(23) Pin
(24) Petcock, overflow
(25) Plug, closing
(26) Plug, fuel inlet
(27) Rack, control
(28) Gear, segment
(29) Sleeve, control
(30) Seat, upper—plunger spring
(31) Spring, plunger
(32) Seat, lower—plunger spring
(33) Cam
(34) Camshaft
(35) Seal, oil
(36) Bearing, ball
(37) Pad, felt
(38) Plug
(39) Screw, segment gear

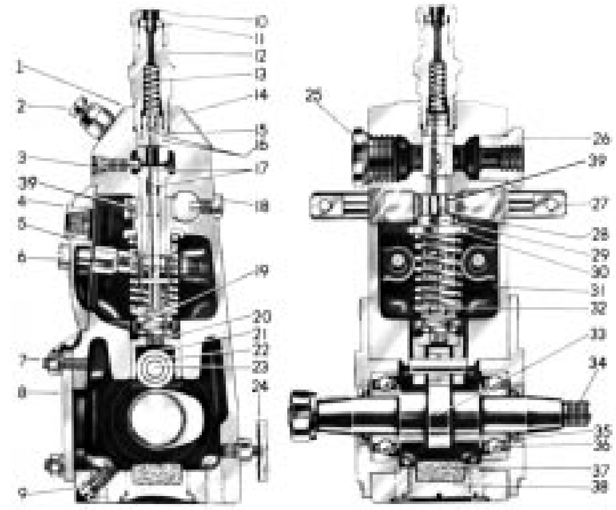

FIG. A1.2 Injection Pump of Fuel Injector Shear Stability Test (FISST)

A1.1.2.3 *Nozzle Valve*, ((5) in Fig. A1.1), Waukesha P/N 110700.

NOTE A1.2—Take great care to avoid damage to the precision parts of the fuel injection equipment, namely the pump plunger and barrel ((*17*) in Fig. A1.2) and the nozzle valve assembly ((*5*) in Fig. A1.1). Service work on the injection equipment should be performed by a diesel fuel injection pump specialist or with reference to the manufacturer's service manual.

A1.1.2.4 *Nozzle Holder/Valve Assembly*, ((4 and 5) in Fig. A1.1), Waukesha P/N A75067E.

A1.1.3 *Motor*, 2.25 kW (3 hp), 1725 rpm, 230 V, 60 Hz, 182T frame ((*1*) in Fig. A1.1).

A1.2 *Method for Setting Injection Pump Rack:*

A1.2.1 *Preparation*:

A1.2.1.1 Remove delivery valve holder (*12*) (numbers in parentheses refer to Fig. A1.2). Leave the body of the delivery valve (*16*) in place, but remove the internal check. Leave the delivery valve gasket (*15*) in place. The top of the pump plunger will be visible through the bore of the delivery valve body.

A1.2.1.2 Turn pump shaft (*34*), watching the top of the plunger (*17*) through the bore of the delivery valve body, until the plunger is at the bottom of its stroke.

A1.2.1.3 Insert a rod 4 mm (0.158 in.) in diameter by 40 mm (1.575 in.) or longer down through the open delivery valve body (*16*) and measure how high it stands above the top of the pump housing (*1*) to the nearest 0.50 mm (0.020 in.).

A1.2.1.4 Rotate the pump shaft until the rod moves upward 5 mm (0.197 in.). Mark the pump shaft or coupling so that it can be reset to this position again later.

A1.2.1.5 Taper one end of a length of stiff plastic translucent tubing (for example, 6.4 mm (0.252 in.) in diameter by 130 mm (5.118 in.) long nylon). Force the tapered end into the body of the delivery valve (*16*). Attach to it a 200-mm (7.874 in.) length of 8 mm (0.315 in.) diameter flexible tubing.

A1.2.1.6 Put sufficient light oil (such as a 4 to 5 mm^2/s (cSt) at 100°C neutral oil) in the reservoir to cover the inlet to the pump (*26*). Turn the pump shaft as necessary to let oil rise in the nylon tube at the delivery valve.

A1.2.1.7 Set the control rack (*27*) at about two-thirds full open position (rack moved away from coupling).

A1.2.1.8 Set pump shaft or coupling at the position established in A1.2.1.4.

A1.2.1.9 Blow into or apply light air pressure to the tube attached to the delivery valve. The oil level in the translucent tube should not change.

A1.2.2 *Adjustment*:

A1.2.2.1 Open the rack ((*27*) in Fig. A1.2) slowly until the oil level in the nylon tube begins to drop. This rack position will correspond to the uncovering of the fill port by the vertical portion of the plunger grooving. It may be necessary to reset the position of the segment gear ((*28*) in Fig. A1.2) relative to the control sleeve ((*29*) in Fig. A1.2) to allow the pump plunger to rotate far enough to uncover the fill port. The segment gear

((*28*) in Fig. A1.2) is mounted concentrically on the control sleeve ((*29*) in Fig. A1.2) and is locked in place by a clamping screw ((*39*) in Fig. A1.2). Loosening the clamping screw allows the segment gear to be rotated to the desired position on the control sleeve.

A1.2.2.2 Note the position on the rack adjusting screw where the fill port becomes uncovered.

A1.2.2.3 Return the rack ((*27*) in Fig. A1.2) 4.4 mm (0.175 in.) toward its closed position (move 3½ turns of SAE ¼-20 screw or 3½ turns of 1.25-pitch metric screw). This position should leave about 1.77-mm (0.07-in.) distance between the edge of the fill port and edge of the vertical groove on the pump plunger.

A1.2.2.4 Lock the pump control rack ((*11*) in Fig. A1.1) in this position by means of the rack adjustment screw ((*12*) in Fig. A1.1) and its two lock nuts. The rack spring ((*13*) in Fig. A1.1) will hold the rack against the adjustment screw.

A1.2.2.5 Remove standpipe and drain fluid from pump gallery.

A1.2.2.6 Reassemble delivery valve and connect pintle nozzle.

A1.2.3 *Flow Rate Check*:

A1.2.3.1 Flush the system three times with 100 cm^3 of reference oil, as in 10.2.

A1.2.3.2 Charge 400 cm^3 of reference oil to the reservoir.

A1.2.3.3 Set cycle counter at five cycles and the pump timer at 50 s.

A1.2.3.4 Start the pump, and with a stopwatch measure the time required to pump the 400-cm^3 charge. Clock the time from the instant the pump starts until the sound indicates that the pump has taken in air. This time should be 44 to 46 s.

A1.2.3.5 If the pumping time does not fall between 44 to 46 s for a 400-cm^3 charge, adjustments of the rack setting should be made up to 0.63 mm (0.025 in.) of the adjusting screw (½ turn of SAE 1/4-20 or 1.25 mm pitch metric screw).

A1.2.3.6 If a pumping time of 44 to 46 s cannot be obtained without turning the adjusting screw ½ turn or less, suspect either an error in establishing fill port uncovering (see A1.2.2.1) or the condition of the pump.

A2. PRECISION

A2.1 The data used to develop the precision statement given in Section 13 were based on test work carried out by ASTM Subcommittee D02 RDD VIIB (presently designated Subcommittee D02.07.B0), Task Force on Shear Test Methods. United States and European cooperators supplied the data used. A report dated June 7, 1979, “ASTM Subcommittee D-2 RDD VIIB, Task Force on Shear Test Methods” defined the test oils, cooperators, test results, and statistical treatment of data. Ten engine oils and six hydraulic fluids were evaluated by five U.S. laboratories and one European laboratory. All of the test fluids used in this study contained one of two types of polymer.

A2.2 At the time of the precision study, two distinct test procedures were used. Data was developed using the European Diesel Injector Test in Test Method D 3945 (formerly Procedure A of Test Methods D 3945) and this test method (FISST method) (formerly Procedure B in Test Method D 3945).

A2.3 The precision indicated in Section 13 for this test method represents the largest data block, ten polymer containing engine oils tested by six laboratories after correction for outliers at a 1 % significance screening level.

A2.4 The precision for this test method of 1.19 % viscosity loss repeatability and 5.22 % viscosity loss reproducibility compares to European Diesel Injector Test precision of 1.43 % and 4.57 % respectively in Test Method D 3945. In either test method, precision for hydraulic type fluids is lower than indicated in the precision statement.

A2.5 Analysis of variance calculations for the two test methods with the combined ten engine oils and six hydraulic fluids was carried out on viscosity loss data at 100°C to compare test severity of the two test methods. They were found to be equivalent, with a correlation coefficient of 0.982. With X as Test Method D 3945 and Y as this test method, the correlation equation was $Y = 0.15 + 0.987X$.

A2.6 Subsequent investigation[9] has shown that the two test methods give different results with certain polymers or when the number of test cycles are significantly increased. Under these conditions, European Diesel Injector Test in Test Method D 3945 tends to be more severe.

A2.7 The significance statement clearly indicates that it is not intended that this test method serve to predict the performance of polymer-containing fluids in service. This conclusion is based on regression analysis of data by the European Diesel Injector Test in Test Method D 3945 compared to available (limited statistical basis) field data for the test oils. Although a specific correlation between this test method and the field data was not attempted, the correlation between the two test methods shown in A2.5 would support a statement that this test method does not correlate with field data for the test oils.

[9] Alexander, D. and Rein, S. “Relationship Between Engine Oil Bench Shear Stability Tests,” *SAE Paper 872047*, Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

SUMMARY OF CHANGES

Subcommittee D02.07 has identified the location of selected changes to this standard since the last issue (D 5275–92 (1998)$^{\epsilon 1}$) that may impact the use of this standard.

(1) Modified Footnote 6 and Paragraph 6.2 to reflect a different supplier of the reference oil.