1.0 PURPOSE

This document establishes MSHA's Standard Test Procedure (STP) for the Determining the Viscosity of a Hydraulic Fluid in Saybolt Universal Seconds.

2.0 SCOPE

This document applies to MSHA approved fire-resistant hydraulic fluids (FRHFs), audits of MSHA approved FRHFs, and accident investigations involving MSHA approved FRHFs.

3.0 REFERENCES

3.1. 30 CFR, Part 35, Subpart A, Section 35.6(b)(2)

3.2. The Brookfield Digital Viscometer Operating Instructions (Model DV-I^{+}) filed in the Quality Assurance and Materials Testing Division's (QA&MTD) Instruction & Operation Manuals file cabinet.

3.3. Brookfield publication "More Solutions to Sticky Problems".

3.4. Standard Application Procedure for MSHA Approval of Fire-Resistant Hydraulic Fluids According to the Code of Federal Regulations, Title 30, Part 35 (ASAP5003)

3.5. ASTM D 2161: Standard Practice for Conversion of Kinematic Viscosity to Saybolt Universal Viscosity or to Saybolt Furol Viscosity

3.6. Viscosity Test Report (See Appendix 1)

3.7. ASTM Standard Viscosity Temperature Charts for Liquid Petroleum Products (D 341) Chart A: Saybolt Universal Viscosity (See Appendix 2)

4.0 DEFINITIONS

4.1. Fire-resistant hydraulic fluid - means a fluid of such chemical composition and physical characteristics that it will resist the propagation of flame.

4.2. Viscosity - A property of fluids and slurries that indicates their resistance to flow, defined as the ratio of shear stress to shear rate giving the traditional unit of dyne-sec/cm^2 Poise.

4.3. Centipoise – A unit of measurement for viscosity equivalent to one-hundredth of a "poise" and symbolized by "cP".

5.0 TEST EQUIPMENT

5.1. Viscosity determinations are performed on a Brookfield DV-I$^+$ Viscometer with speed settings ranging from 0 to 100 RPM (See: the DV-I$^+$ Operating Instructions) and a set of four (4) #302 stainless steel spindles. The DV-I$^+$ viscometer has a minimum range of 15 cP and a maximum range of 2,000,000.

5.2. The DV-I$^+$ viscometer is used in conjunction with a Brookfield TC-2-2D 115 digital circulating temperature bath and a RTD temperature probe that is connected to the rear panel of the DV-I$^+$ viscometer. The RTD temperature probe is attached to the LV guard-leg that is immersed in the fluid to be tested.

5.3. The Brookfield TC-2-2D 115 bath is filled with a solution of distilled water mixed with approximately 1 gallon of glycol to prevent rust and provide pump lubrication. Review the specifications for the viscometer and constant temperature bath located in the QA&MTD's Instruction & Operation Manuals file cabinet.

5.4. The DV-I$^+$ Viscometer and Brookfield TC-2-2D 115 bath are to be set up according to the manufacturer's instructions. Note: the viscometer instruction manual requires the use of a 600cc Griffin beaker to make viscosity measurements.

6.0 TEST SAMPLES

See Section 7.0 of this procedure.

7.0 PROCEDURES

7.1. The manufacturer of a hydraulic fluid submitted for MSHA Approval must provide the viscosity of candidate fluid at 100°F, 150°F, and 175°F. The QA&MTD verifies the manufacturer's viscosity values by taking the average of five (5) readings at each of these temperatures.

7.2. Read the Brookfield Digital Viscometer Model DV-I$^+$ Operating Instructions.

7.3. Ensure that the DV-1+ Viscometer calibration is current. The DV-I+ viscometer should be calibrated periodically by running a viscosity determination using Brookfield Viscosity Standards traceable to the National Institute of Standards Technology (NIST). The instrument may also be calibrated and certified to NIST standards by sending it to: Brookfield Engineering Support, 11 Commerce Boulevard, Middleboro, MA 02346.

7.4. Thoroughly mix the fluid to be tested. The fluid should be at room temperature for at least 24 hours before pouring it into the Griffin beaker.

7.5. Mount the guard-leg on the DV-I+ Viscometer. Attach the spindle to the lower shaft. Lift the shaft slightly, holding it firmly with one hand while screwing the spindle on with the other (note: left-hand thread). Avoid putting side thrust on the shaft. Spindles #1 and 2 are generally used because of the range of viscosities that are usually found in hydraulic fluids.

7.6. Pour the fluid to be tested into the beaker to the proper height and place the beaker in the bath. Set the desired temperature on the dial and turn the unit on. Note: when determining viscosities at temperatures near or below room temperature, the cooling water described in the instruction manual should be attached and used.

7.7. Insert and center the spindle in the test material until the fluid's level is at the immersion groove in the spindle's shaft. Care must be taken when placing the spindle in the fluid to insure: (1) that no air bubbles are trapped underneath the spindle, (2) that the fluid height comes to the notch on the spindle, and (3) the fluid is free of air bubbles.

7.8. Enter the "two" digit Spindle Code Number and desired speed setting into the key pad of the DV-I+ and turn the motor on. Allow time for the indicated reading to stabilize before recording the viscosity measurement. The time required for stabilization will depend on the speed at which the viscometer is running and the characteristics of the sample fluid.

7.9. When the fluid has stabilized at the desired temperature, record the % torque and viscosity (cP) on the Viscosity Test Report. The average of five readings is used to determine the final value.

7.10. Centipoises are then converted to centistokes (cSt) using the following equation:

7.11. Kinematic viscosity in Centistokes = Centipoises

7.12. Specific gravity (at temperature)

7.13. Centistokes can than be converted into the viscosity in Saybolt Universal Seconds (SUS) using the ASTM D 2161 Viscosity Table (See page 8, Example 1).

7.14. The kinematic viscosity may also be converted to SUS_t at temperatures other than 100°F and 210°F when the kinematic viscosity is 75 centistokes or less using the ASTM D 2161 Viscosity Tables 1 and 2, and the following method (See page 9, Example 2, at 150°F [65.5°C]).

7.15. Convert Centistokes to $SUS_{100°F}$ using Table 1

7.16. $SUS_t = SUS_{100°F}$ x Factor A (Table 2)

7.17.

7.18. For kinematic viscosities greater then 75 Centistokes, SUS_t can be determined by multiplying centistokes by Factor B (See page 9, Example 2 at 71°F [21.7°C] and 100°F [37.7°C]).

7.19. SUS_t = cSt x Factor B (Table 2)

7.20.

7.21. When determining the viscosity of a fluid at various temperatures, one of the temperatures should be 100F since it is a common reference value for many oils and fluids. It is also a temperature that may be conveniently converted to Saybolt Universal Seconds from the centistoke value by using the ASTM Viscosity Tables for Kinematic Viscosity Conversions and Viscosity Index Calculations (ASTM D 2161).

7.22. The viscosity should also be determined at room temperature and at 150F. The 150F temperature is used because it is the spray temperature for the temperature-pressure spray-ignition test described in 30 CFR 35.21. It is also the oven temperature used in the wick test to determine the effect of evaporation on flammability of hydraulic fluids described in 30 CFR 35.22.

7.23. These three temperatures, when converted to SUS, may be plotted on an ASTM Standard Viscosity Temperature Chart (D 341), extrapolated, and compared graphically to submitted data at similar and/or other temperatures.

7.24. Since a great deal of information is available on viscosity, the users should familiarize themselves with the principles involved in viscosity determinations by reading the Brookfield publication "More Solutions to Sticky Problems".

7.25. Since all possible materials, products, compositions, physical properties, and applicable methods cannot be foreseen, MSHA reserves the right to modify the above test procedures.

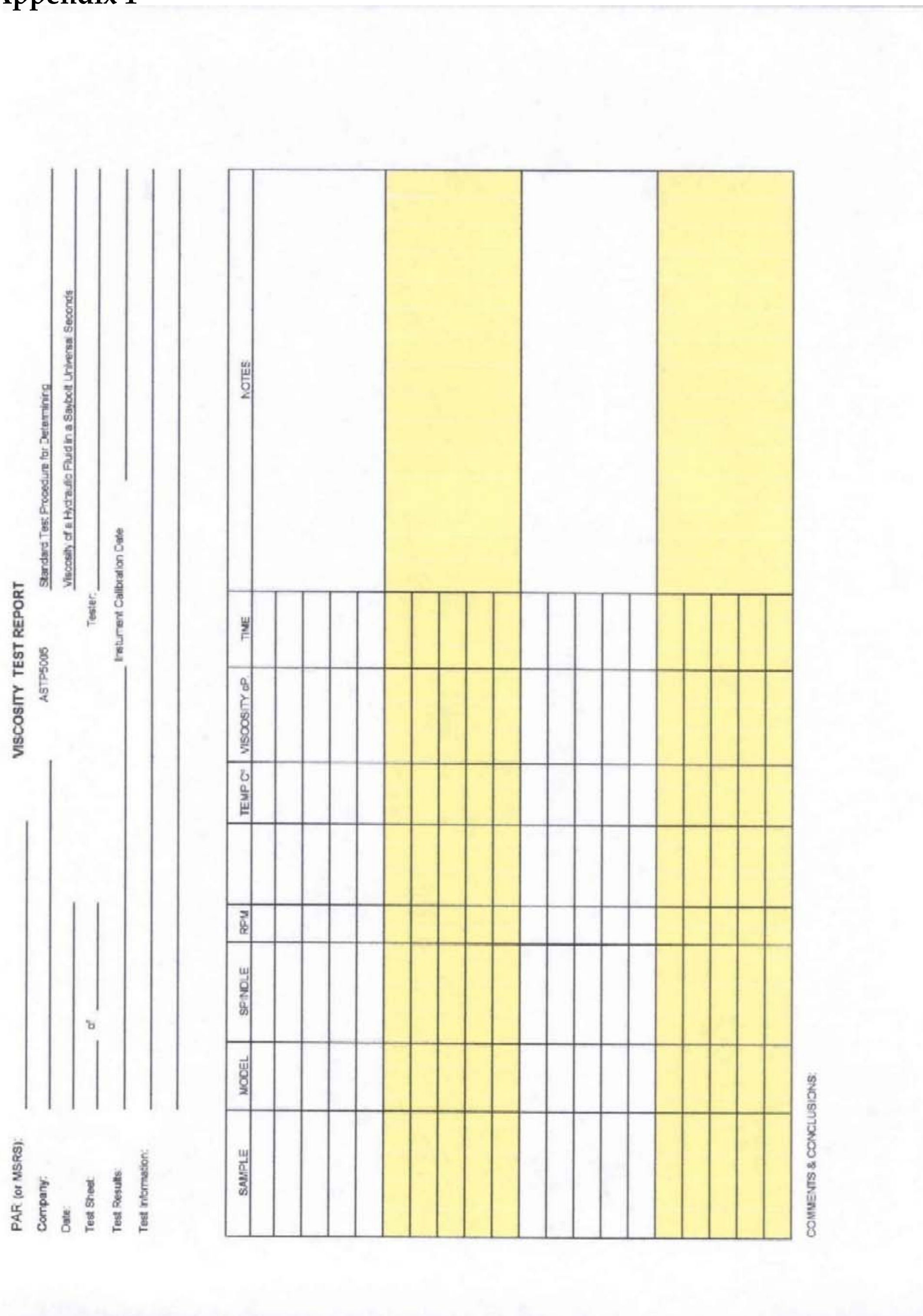
8.0 TEST DATA

Test results are summarized in MSHA's approval and audit documentation files of Fire Resistant Hydraulic Fluids. Accident and other investigations requiring viscosity determinations of products other than hydraulic fluids will also summarize test results where appropriate.

9.0 PASS/FAIL CRITERIA

Not Applicable

Appendix 1



VISCOSITY TEST REPORT

PAR (or MSRS): ____________________

Company: ____________________ ASTP5005 Standard Test Procedure for Determining Viscosity of a Hydraulic Fluid in a Saybolt Universal Seconds

Date: ____________________

Test Sheet: ________ of ________ Tester: ____________________

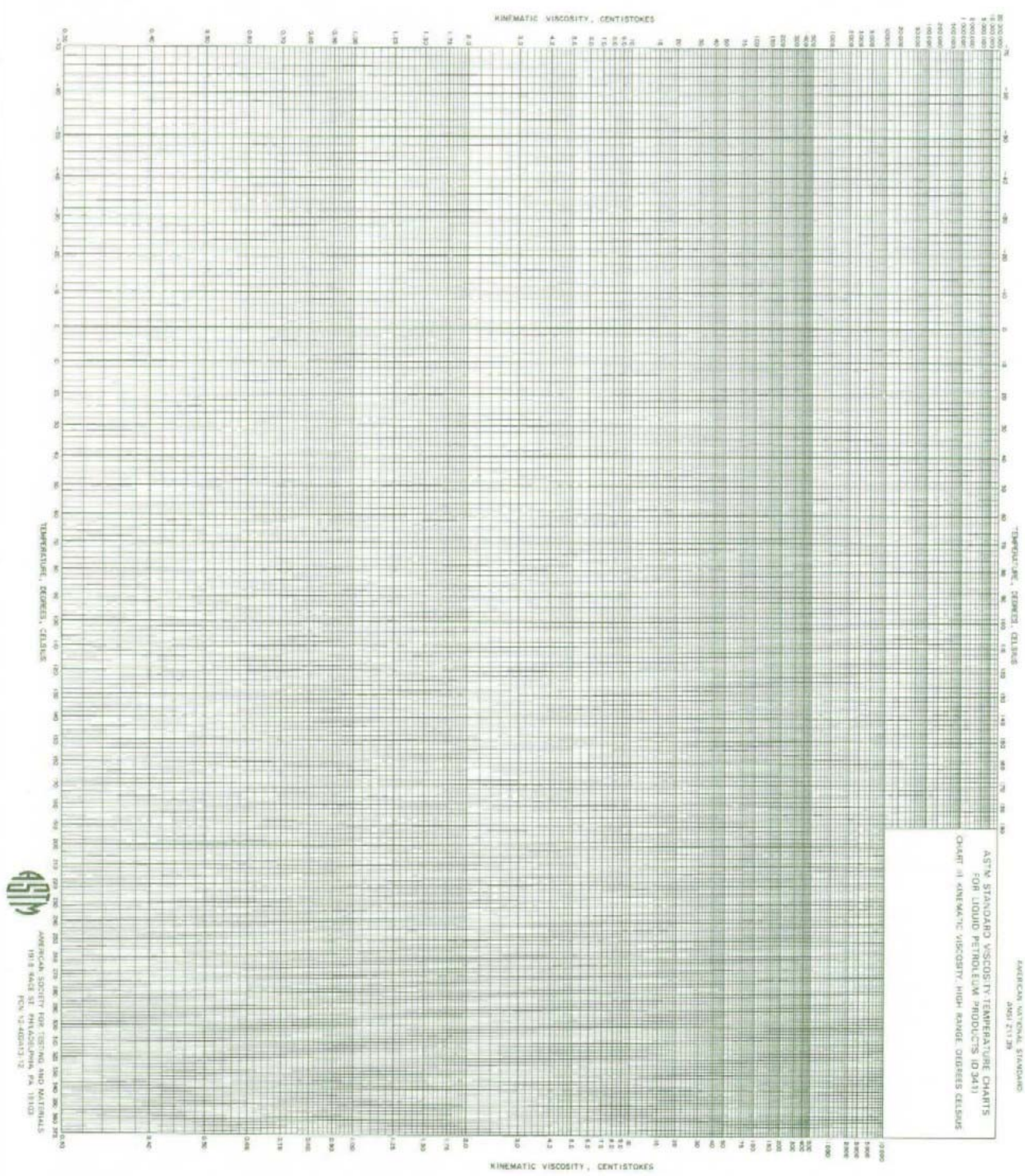
Test Results: ____________________ Instrument Calibration Date ____________________

Test Information: ____________________

SAMPLE	MODEL	SPINDLE	RPM		TEMP C°	VISCOSITY cP.	TIME	NOTES

COMMENTS & CONCLUSIONS:

Appendix 2


KINEMATIC VISCOSITY, CENTISTOKES
TEMPERATURE, DEGREES, CELSIUS
ASTM STANDARD VISCOSITY-TEMPERATURE CHARTS
FOR LIQUID PETROLEUM PRODUCTS (D 341)
CHART III KINEMATIC VISCOSITY, HIGH RANGE DEGREES CELSIUS
AMERICAN NATIONAL STANDARD
ANSI Z11.39

Example 1

Example 1: Determination of SUS using ASTM Table 1.

VISCOSITY TEST REPORT

PAR (or MSRS): ____________

Company: XYZ Lubricants Co. ASTP5005 Standard Test Procedure for Determining Viscosity of a Hydraulic Fluid in a Saybolt Universal Seconds

Date: Jan. 19, 2007

Test Sheet: 1 of 1 Tester: ____________

Test Results: ____________ Instument Calibration Date Sept. 10, 2006

Test Information: Viscosity Determination on XYZ 4899 Invert Emulsion Hydraulic Fluid □

Tested on the Brookfield DV-1+ Viscometerand the Brookfield EX200 Temperature Bath.

SAMPLE	MODEL	SPINDLE	RPM		TEMP C°	VISCOSITY cP	TIME	NOTES
XYZ 4899	DV-1+	#1	30		21.7°	197.4	9:05	Avg. = 197.4 cP
			30		21.7°	197.4	9:06	21.7°C = 71°F SG = 0.9298
			30		21.7°	197.4	9:07	197.4/0.9298 = 212.3 cSt
			30		21.7°	197.4	9:08	212.3 cSt = 983 $SUS_{100°F}$ (Table 1)
			30		21.7°	197.4	9:09	
XYZ 4899	DV-1+	#1	30		37.7	101.2	9:05	Avg. = 101.2 = cP
			30		37.7	101.4	9:06	37.7°C = 100°F SG = 0.9197
			30		37.7	101.2	9:07	101.2/0.9197 = 110 cSt
			30		37.7	101.2	9:08	110.0 cSt = 510 $SUS_{100°F}$ (Table 1)
			30		37.7	101	9:09	
XYZ 4899	DV-1+	#1	12		37.9	97.5	9:05	Avg. = 98.0 = cP
			12		37.9	98	9:06	37.9°C = 100°F SG = 0.9197
			12		37.9	98	9:07	98.0/0.9197 = 106.6 cSt
			12		37.9	97.5	9:08	106.6 cSt = 494 $SUS_{100°F}$ (Table 1)
			12		37.9	98	9:09	
XYZ 4899	DV-1+	#1	60		65.5	41	9:05	Avg. = 40.9 = cP
			60		65.5	40.8	9:06	65.6°C = 150°F SG = 0.9024
			60		65.6	40.9	9:07	40.9/0.9024 = 45.3 cSt
			60		65.6	41.1	9:08	45.3 cSt = 211 $SUS_{100°F}$ (Table 1)
			60		65.6	40.7	9:09	

COMMENTS & CONCLUSIONS:

Example 2

Example 2: Determination of SUS using equation & ASTM Tables 1 & 2.

VISCOSITY TEST REPORT

PAR (or MSRS): ______

Company: XYZ Lubricants Co — ASTP5005 — Standard Test Procedure for Determining Viscosity of a Hydraulic Fluid in a Saybolt Universal Seconds

Date: Jan. 19, 2007

Test Sheet: 1 of 1 — Tester: ______

Test Results: ______ Instrument Calibration Date: Sept 10, 2006

Test Information: Viscosity Determination on XYZ 4899 Invert Emulsion Hydraulic Fluid I7 Tested on the Brookfield DV-1+ Viscometerand the Brookfield EX200 Temperature Bath.

SAMPLE	MODEL	SPINDLE	RPM		TEMP C°	VISCOSITY cP	TIME	NOTES
XYZ 4899	DV-1+	#1	30		21.7°	197.4	9:05	Avg. = 197.4 cP
			30		21.7°	197.4	9:06	21.7°C = 71°F SG = 0.9298
			30		21.7°	197.4	9:07	197.4/0.9298 = 212.3 cSt
			30		21.7°	197.4	9:08	981.7 $SUS_{71°F}$ = 212.3 cSt x 4.624 (Table 2, Factor B)
			30		21.7°	197.4	9:09	
XYZ 4899	DV-1+	#1	30		37.7	101.2	9:05	Avg. = 101.2 = cP
			30		37.7	101.4	9:06	37.7°C = 100°F SG = 0.9197
			30		37.7	101.2	9:07	101.2/0.9197 = 110 cSt
			30		37.7	101.2	9:08	509.5 $SUS_{100°F}$ = 110.0 cSt x 4.632 (Table 2, Factor B)
			30		37.7	101	9:09	
XYZ 4899	DV-1+	#1	12		37.9	97.5	9:05	Avg. = 98.0 = cP
			12		37.9	98	9:06	37.9°C = 100°F SG = 0.9197
			12		37.9	98	9:07	98.0/0.9197 = 106.6 cSt
			12		37.9	97.5	9:08	498.6 $SUS_{100°F}$ = 106.6 cSt x 4.632 (Table 2, Factor B)
			12		37.9	98	9:09	
XYZ 4899	DV-1+	#1	60		65.5	41	9:05	Avg. = 40.9 = cP
			60		65.5	40.8	9:06	65.6°C = 150°F SG = 0.9024
			60		65.6	40.9	9:07	40.9/0.9024 = 45.3 cSt
			60		65.6	41.1	9:08	45.3 cSt = 211 $SUS_{100°F}$ (Table 1)
			60		65.6	40.7	9:09	211.6 $SUS_{150°F}$ = 211 $SUS_{100°F}$ x 1.003 (Table 2, Factor A)

COMMENTS & CONCLUSIONS: