Chilworth Technology

A Professional Process Safety Firm

Chilworth Technology, Inc.
250 Plainsboro Rd., Bldg # 7
Plainsboro, NJ 08536
Tel: 609-799-4449
Fax: 609-799-5559
http: www.chilworth.com
email: safety@chilworth.com

CONDUCTIVITY MEASUREMENTS

FOR

NEW ENGINE COMPARTMENT FLUIDS

TO: **R. Rhodes (Rody) Stephenson**
4455 Rockland PL. Unit 10
La Canada, CA 91011

FAO: **Mr. Rody Stephenson**

Prepared by .... **Approved by ....**

William Dey
Laboratory Technician

Don B. Churchwell
Experimental Officer

FOR AND ON BEHALF OF CHILWORTH TECHNOLOGY, INC.

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1. INTRODUCTION

Eight liquid samples were received from **R. Rhodes (Rody) Stephenson** for purposes of conductivity testing. These samples are identified in the following chart; with the addition of four samples in which two are a mixture of hydrocarbons (sample I: regular gasoline and sample J: diesel gasoline) and the other two samples are each mixed with 50% sample and 50% mixture of water (sample K: ethylene glycol and sample L: propylene glycol). Chilworth Technology, Inc. labeled each sample alphabetically for testing purposes only. This report presents the results of testing performed. The report provides: (1) relevant background information; (2) a description of the test method employed; and (3) a discussion of the test results.

SAMPLE #	BRAND	TYPE	LOT #
Motor Oils (Mixture of Hydrocarbons)			
A: # B10FF002	**QUAKER STATE®**	**SAE 5W30**	**3C100898-1338**
Synthetic Motor Oils (Mixture of Hydrocarbons)			
B: # B10FF007	**MOBIL®1**	**SAE 5W30**	**X08B9A2**
Power Steering Fluids (Mixture of Hydrocarbons)			
C: # B10FF014	**VALVOLINE**	**SYNPOWER**	**D298X**
Automatic Transmission Fluids			
D: # B10FF017	**QUAKER STATE®**	**DEXTRONIII/MERCON**	**3C022499-1399**
Brake Fluids (Non-hydrocarbons: Polyglycol Ethers)			
E: # B10FF011	**PRESTONE®**	**DOT 3**	
Antifreeze (Non-hydrocarbons: Ethylene or Propylene Glycol)			
F: # B10FF021	**PRESTONE®**	**ETHYLENE GLYCOL 100%**	**2HA9036**
G: # B10FF022	**SIERRA®**	**PROPYLENE GLYCOL 100%**	**9068**
Windsheild Washing Fluids (Non-hydrocarbons: Methanol-Water)			
H	**ALL WEATHER®**	**WINTER**	
Mixture of Hydrocarbons			
I		**REGULAR GASOLINE**	
J		**DIESEL GASOLINE**	
Antifreeze (Non-hydrocarbons: Ethylene or Propylene Glycol mixed with 50% water)			
K: # B10FF021	**PRESTONE®**	**ETHYLENE GLYCOL 50% / 50% h_2O**	**2HA9036**
L: # B10FF022	**SIERRA®**	**PROPYLENE GLYCOL 50% / 50% H_2O**	**9068**

2. BACKGROUND

When a voltage (V) is applied to a material, charge flows creating an electric current (I). The ratio between the voltage and the current is called the resistance (R). This relationship between voltage, current, and resistance is given by Ohm's Law:

$$V = I \times R \qquad \textbf{[Equation 1]}$$

Resistance provides an indication of the relative ease or difficulty with which charge flows through a material. However, the resistance of a material is dependent on its size and geometry, among other factors. For example, it becomes more difficult for charge to flow through a material as its cross-sectional area decreases or its length increases. Consequently, it was necessary to derive measures that permit comparisons between the resistances of various materials independent of size and geometry. One such measure is conductivity.

The conductivity of a liquid is defined as the reciprocal of the electrical resistance at unit length and unit cross-sectional area through the liquid. This relationship may be expressed as follows:

$$\delta = (1/R) \times k \qquad \textbf{[Equation 2]}$$

where,

δ = conductivity (S/m)
V = test voltage (volts)
I = current between electrodes (amps)
k = measurement cell geometrical constant

Hence,

$$\delta = (I/V) \times k \qquad \textbf{[Equation 3]}$$

Conductivity is a valuable measure as it fulfills the need for a comparative measure of the conductive or insulating character of materials. Since it is based on unit length and unit cross-sectional area, conductivity is independent of sample size and geometry and thus is a property of each material. Conductivity is measured in units of siemens per meter (S/m). However, given the magnitude of the siemen, conductivity is commonly reported in picosiemens per meter (pS/m). [1 pS = 1 x 10^{-12}S]

It is important to know whether a liquid is electrically-insulating or conductive from a materials handling perspective. Insulating liquids are prone to generation and accumulation of electrostatic charge and thus pose special handling problems. When liquids flow or are otherwise processed, they may become charged. In many cases, the charge on conductive liquids can be controlled or eliminated by handling such liquids in grounded vessels, equipment, and conveyances. In contrast, insulating liquids may remain charged even when handled in grounded equipment. Accumulated charge can lead to electrostatic discharges capable of igniting flammable atmospheres.

3. METHOD

Chilworth Technology, Inc., performs liquid conductivity testing in accordance with British Standard 5958, Code of Practice for the Control of Undesirable Static Electricity - Part 1 (1991) and ASTM D2624, Standard Test Method for Electrical Conductivity of Aviation And Distillate Fuels. The method involves the use a liquid conductivity cell. The cell consists of a pair of concentric cylindrical electrodes. The liquid sample to be tested is poured into the annular space between the electrodes and a known voltage is applied. The current through the cell is measured and the conductivity is calculated from the measured current, applied voltage, and cell constant using Equation 3 from above. Trials are repeated until a relatively constant conductivity value is obtained. The test system is checked (validated) before, during, and after testing by measuring the conductivity of heptane (certified grade) -- a known insulating liquid. When the liquid sample is conductive a BM-10 megohmmeter is used to measure the resistance.

4. RESULTS

The results of liquid conductivity testing are on the following pages. The liquid whose conductivity is greater than 10,000 pS/m is generally considered to be conductive. A liquid whose conductivity is within the range of 100 - 10,000 pS/m is generally considered to be medium-conductive. A liquid whose conductivity is less than 100 pS/m is generally considered to be non-conductive.

It is generally accepted that pure or small-phase liquids having conductivities greater than 100 pS/m are incapable of retaining hazardous levels of electrostatic charge when handled in grounded conductive equipment. However, liquids having conductivities as much as 1,000 pS/m may generate and accumulate electrostatic charge under certain flow, processing, or storage conditions. For example, the presence of impurities, immiscibles, and multiple phases can greatly exacerbate electrostatic charging.

LIQUID CONDUCTIVITY: SUMMARY	**pS/m**
Sample A: # **B10FF002 Quaker State® SAE 5W30**	
Liquid Conductivity Average	4.7×10^4
Conductive	
Sample B: # **B10FF007 Mobil® 1 SAE 5W30**	
Liquid Conductivity Average	3.6×10^4
Conductive	

Summary Continued	**pS/m**
Sample C: # **B10FF014 Valvoline® SynPower**	
Liquid Conductivity Average	73
Non-conductive	
Sample D: # **B10FF017 Quaker State® Dextron®III/Mercon® ATF**	
Liquid Conductivity Average	7.1×10^3
Medium-conductive	
Sample E: # **B10FF011 Prestone® Dot 3**	
Liquid Conductivity Average	2.5×10^8
Conductive	
Sample F: # **B10FF021 Prestone® Ethylene Glycol 100%**	
Liquid Conductivity Average	3.1×10^7
Conductive	
Sample G: # **B10FF022 Sierra® Propylene Glycol 100%**	
Liquid Conductivity Average	4.1×10^7
Conductive	
Sample H: **All Weather® Windshield Wash Winter**	
Liquid Conductivity Average	9.3×10^7
Conductive	
Sample I: **Regular Gasoline**	
Liquid Conductivity Average	3.3×10^2
Medium-conductive	
Sample J: **Diesel Gasoline**	
Liquid Conductivity Average	3.3×10^2
Medium-conductive	
Sample K: # **B10FF021 Prestone® Ethylene Glycol 50% / 50% H_2O**	
Liquid Conductivity Average	8.9×10^7
Conductive	
Sample L: # **B10FF022 Sierra® Propylene Glycol 50% / 50% H_2O**	
Liquid Conductivity Average	6.5×10^7
Conductive	

TABLE 1 LIQUID CONDUCTIVITY MEASUREMENT CALIBRATIONS

Sample Information

Test Liquid	:	Heptane 99 + %
Ref. No.	:	Lot # PA 11662MA
Origin of the Sample	:	Aldrich
Comment	:	Transparent liquid

Test Information

Test Purpose	:	To calibrate the liquid conductivity cell with a known insulating liquid.
Apparatus Type	:	Keithley 610C Electrometer Weir 423D Power Supply Liquid Conductivity Cell
Date of Test	:	04.21.04
Operator	:	W. Dey

Results: All Calibrations Passed

Status : Passed (Passing: < 1pS/m)

Calibration of Test Cell With Heptane	Test Voltage (V)	Measured Current (A)	Conductivity (pS/m)
A	10	4.0×10^{-12}	0.4
B	10	5.0×10^{-12}	0.5
C	10	4.0×10^{-12}	0.4
D	10	3.0×10^{-12}	0.3
E	10	4.0×10^{-12}	0.4
F	10	2.0×10^{-12}	0.2
G	10	2.0×10^{-12}	0.2
H	10	5.0×10^{-12}	0.5
I	10	4.0×10^{-12}	0.4
J	10	3.0×10^{-12}	0.3
K	10	4.0×10^{-12}	0.4
L	10	5.0×10^{-12}	0.5

TABLE 2 LIQUID CONDUCTIVITY MEASUREMENTS
A: SAMPLE # B10FF002 QUAKER STATE® SAE 5W30

Sample Information

Company Name : R. Rhodes (Rody) Stephenson
Test Liquid : A: SAMPLE # B10FF002 QUAKER STATE® SAE 5W30
Ref. No. : Lot # 3C100898-1338
Comment : Brown liquid

Test Information

Test Purpose : To measure the conductivity of a liquid sample.
Apparatus Type : Keithley 610C Electrometer
Weir 423D Power Supply
Liquid Conductivity Cell
Date of Test : 04.21.04
Operator : W. Dey

Results

Conductivity = **4.6 x 10^{4} pS/m** **Average = 4.7 x 10^{4} pS/m**
(Minimum of measured values)

Test Voltage (V)	Measured Current (A)	Conductivity (pS/m)
10	4.6 x 10^{-7}	4.6 x 10^{4}
10	4.7 x 10^{-7}	4.7 x 10^{4}
10	4.9 x 10^{-7}	4.9 x 10^{4}

TABLE 3 LIQUID CONDUCTIVITY MEASUREMENTS B: SAMPLE # B10FF007 MOBIL® 1 SAE 5W30

Sample Information

Company Name	:	R. Rhodes (Rody) Stephenson
Test Liquid	:	B: SAMPLE # B10FF007 MOBIL® 1 SAE 5W30
Ref. No.	:	Lot # X08B9A2
Comment	:	Brown liquid

Test Information

Test Purpose	:	To measure the conductivity of a liquid sample.
Apparatus Type	:	Keithley 610C Electrometer Weir 423D Power Supply Liquid Conductivity Cell
Date of Test	:	04.21.04
Operator	:	W. Dey

Results

Conductivity = **3.5×10^{4} pS/m** **Average = 3.6×10^{4} pS/m**
(Minimum of measured values)

Test Voltage (V)	Measured Current (A)	Conductivity (pS/m)
10	3.5×10^{-7}	3.5×10^{4}
10	3.6×10^{-7}	3.6×10^{4}
10	3.7×10^{-7}	3.7×10^{4}

TABLE 4 LIQUID CONDUCTIVITY MEASUREMENTS C: SAMPLE # B10FF014 VALVOLINE® SYNPOWER

Sample Information

Company Name	:	R. Rhodes (Rody) Stephenson
Test Liquid	:	C: SAMPLE # B10FF014 VALVOLINE® SYNPOWER
Ref. No.	:	Lot # D298X
Comment	:	Yellow liquid

Test Information

Test Purpose	:	To measure the conductivity of a liquid sample.
Apparatus Type	:	Keithley 610C Electrometer Weir 423D Power Supply Liquid Conductivity Cell
Date of Test	:	04.21.04
Operator	:	W. Dey

Results

Conductivity = 71 pS/m **Average = 73 pS/m**
(Minimum of measured values)

Test Voltage (V)	Measured Current (A)	Conductivity (pS/m)
10	7.1×10^{-10}	71
10	7.3×10^{-10}	73
10	7.4×10^{-10}	74

TABLE 5 LIQUID CONDUCTIVITY MEASUREMENTS
D: SAMPLE # B10FF017 QUKER STATE® DEXTRON®III/MERCON® ATF

Sample Information

Company Name	:	R. Rhodes (Rody) Stephenson
Test Liquid	:	D: SAMPLE # B10FF017 QUKER STATE® DEXTRON®III/MERCON® ATF
Ref. No.	:	Lot # 3C022499-1399
Comment	:	Red liquid

Test Information

Test Purpose	:	To measure the conductivity of a liquid sample.
Apparatus Type	:	Keithley 610C Electrometer Weir 423D Power Supply Liquid Conductivity Cell
Date of Test	:	04.21.04
Operator	:	W. Dey

Results

Conductivity = 6.9×10^{3} pS/m **Average = 7.1×10^{3} pS/m**
(Minimum of measured values)

Test Voltage (V)	Measured Current (A)	Conductivity (pS/m)
10	6.9×10^{-8}	6.9×10^{3}
10	7.0×10^{-8}	7.0×10^{3}
10	7.3×10^{-8}	7.3×10^{3}

TABLE 6 LIQUID CONDUCTIVITY MEASUREMENTS
E: SAMPLE # B10FF011 PRESTONE® DOT 3

Sample Information

Company Name	:	R. Rhodes (Rody) Stephenson
Test Liquid	:	E: SAMPLE # B10FF011 PRESTONE® DOT 3
Ref. No.	:	n/a
Comment	:	Yellow liquid

Test Information

Test Purpose	:	To measure the conductivity of a liquid sample.
Apparatus Type	:	Megohmmeter BM-10 Liquid Conductivity Cell
Date of Test	:	04.21.04
Operator	:	W. Dey

Results

Conductivity = 2.4×10^8 pS/m **Average = 2.5×10^8 pS/m**
(Minimum of measured values)

Measured Resistance (Ω)	Conductivity (pS/m)
4.1×10^3	2.4×10^8
4.0×10^3	2.5×10^8
3.9×10^3	2.6×10^8

TABLE 7 LIQUID CONDUCTIVITY MEASUREMENTS
F: SAMPLE # B10FF021 PRESTONE® ETHYLENE GLYCOL 100%

Sample Information

Company Name	:	R. Rhodes (Rody) Stephenson
Test Liquid	:	F: SAMPLE # B10FF021 PRESTONE® ETHYLENE GLYCOL 100%
Ref. No.	:	Lot # 2HA9036
Comment	:	Green liquid

Test Information

Test Purpose	:	To measure the conductivity of a liquid sample.
Apparatus Type	:	Megohmmeter BM-10 Liquid Conductivity Cell
Date of Test	:	04.21.04
Operator	:	W. Dey

Results

Conductivity = **2.7×10^7 pS/m** **Average = 3.1×10^7 pS/m**
(Minimum of measured values)

Measured Resistance (Ω)	Conductivity (pS/m)
3.45×10^4	2.9×10^7
2.80×10^4	3.6×10^7
3.69×10^4	2.7×10^7

TABLE 8 LIQUID CONDUCTIVITY MEASUREMENTS G: SAMPLE # B10FF022 SIERRA® PROPYLENE GLYCOL 100%

Sample Information

Company Name	:	R. Rhodes (Rody) Stephenson
Test Liquid	:	G: SAMPLE # B10FF022 SIERRA® PROPYLENE GLYCOL 100%
Ref. No.	:	Lot # 9068
Comment	:	Green liquid

Test Information

Test Purpose	:	To measure the conductivity of a liquid sample.
Apparatus Type	:	Megohmmeter BM-10 Liquid Conductivity Cell
Date of Test	:	04.21.04
Operator	:	W. Dey

Results

Conductivity = **3.9×10^7 pS/m** **Average = 4.1×10^7 pS/m**
(Minimum of measured values)

Measured Resistance (Ω)	Conductivity (pS/m)
2.31×10^4	4.3×10^7
2.57×10^4	3.8×10^7
2.45×10^4	4.1×10^7

TABLE 9 LIQUID CONDUCTIVITY MEASUREMENTS
H: ALL WEATHER® WINTER WINDSHEILD WASH

Sample Information

Company Name	:	R. Rhodes (Rody) Stephenson
Test Liquid	:	H: ALL WEATHER® WINTER WINDSHEILD WASH
Ref. No.	:	n/a
Comment	:	Blue liquid

Test Information

Test Purpose	:	To measure the conductivity of a liquid sample.
Apparatus Type	:	Megohmmeter BM-10 Liquid Conductivity Cell
Date of Test	:	04.21.04
Operator	:	W. Dey

Results

Conductivity = **9.0×10^7 pS/m** **Average = 9.3×10^7 pS/m**
(Minimum of measured values)

Measured Resistance (Ω)	Conductivity (pS/m)
1.10×10^4	9.1×10^7
1.03×10^4	9.7×10^7
1.11×10^4	9.0×10^7

TABLE 10 LIQUID CONDUCTIVITY MEASUREMENTS
I: REGULAR GASOLINE

Sample Information

Company Name	:	R. Rhodes (Rody) Stephenson
Test Liquid	:	I: REGULAR GASOLINE
Ref. No.	:	n/a
Comment	:	Transparent liquid

Test Information

Test Purpose	:	To measure the conductivity of a liquid sample.
Apparatus Type	:	Keithley 610C Electrometer Weir 423D Power Supply Liquid Conductivity Cell
Date of Test	:	04.21.04
Operator	:	W. Dey

Results

Conductivity = 3.1×10^{2} pS/m **Average = 3.3×10^{2} pS/m**
(Minimum of measured values)

Test Voltage (V)	Measured Current (A)	Conductivity (pS/m)
10	3.2×10^{-9}	3.2×10^{2}
10	3.5×10^{-9}	3.5×10^{2}
10	3.1×10^{-9}	3.1×10^{2}

TABLE 11 LIQUID CONDUCTIVITY MEASUREMENTS J: DIESEL GASOLINE

Sample Information

Company Name	:	R. Rhodes (Rody) Stephenson
Test Liquid	:	J: DIESEL GASOLINE
Ref. No.	:	n/a
Comment	:	Yellow liquid

Test Information

Test Purpose	:	To measure the conductivity of a liquid sample.
Apparatus Type	:	Keithley 610C Electrometer Weir 423D Power Supply Liquid Conductivity Cell
Date of Test	:	04.21.04
Operator	:	W. Dey

Results

Conductivity = **3.1×10^2 pS/m** **Average = 3.3×10^2 pS/m**
(Minimum of measured values)

Test Voltage (V)	**Measured Current (A)**	**Conductivity (pS/m)**
10	3.1×10^{-9}	3.1×10^2
10	3.3×10^{-9}	3.3×10^2
10	3.6×10^{-9}	3.6×10^2

TABLE 12 LIQUID CONDUCTIVITY MEASUREMENTS K: SAMPLE # B10FF021 PRESTONE® ETHYLENE GLYCOL 50% / 50% H_2O

Sample Information

Company Name	:	R. Rhodes (Rody) Stephenson
Test Liquid	:	K: SAMPLE # B10FF021 PRESTONE® ETHYLENE GLYCOL 50% / 50% H_2O
Ref. No.	:	Lot # 2HA9036
Comment	:	Green liquid

Test Information

Test Purpose	:	To measure the conductivity of a liquid sample.
Apparatus Type	:	Megohmmeter BM-10 Liquid Conductivity Cell
Date of Test	:	04.21.04
Operator	:	W. Dey

Results

Conductivity = **8.4×10^7 pS/m** **Average = 8.9×10^7 pS/m**
(Minimum of measured values)

Measured Resistance (Ω)	**Conductivity (pS/m)**
11.9×10^4	8.4×10^7
11.3×10^4	8.8×10^7
1.06×10^4	9.4×10^7

TABLE 13 LIQUID CONDUCTIVITY MEASUREMENTS L: SAMPLE # B10FF022 SIERRA® PROPYLENE GLYCOL 50% / 50% H_2O

Sample Information

Company Name	:	R. Rhodes (Rody) Stephenson
Test Liquid	:	L: SAMPLE # B10FF022 SIERRA® PROPYLENE GLYCOL 50% / 50% H_2O
Ref. No.	:	Lot # 9068
Comment	:	Green liquid

Test Information

Test Purpose	:	To measure the conductivity of a liquid sample.
Apparatus Type	:	Megohmmeter BM-10 Liquid Conductivity Cell
Date of Test	:	04.21.04
Operator	:	W. Dey

Results

Conductivity = 6.1×10^7 pS/m **Average = 6.5×10^7 pS/m**
(Minimum of measured values)

Measured Resistance (Ω)	Conductivity (pS/m)
1.65×10^4	6.1×10^7
1.44×10^4	6.9×10^7
1.53×10^4	6.5×10^7