Client	Corrosion Resistant Products Ltd
Contact	Mr C Bullock
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Carbon Loaded PTFE Pipe

Electrostatic Analysis

Checked by Gavin Rogers	Reviewed by Stephen Rowe
Team Leader - IEH Laboratory	Process Safety Specialist
For and on behalf of Chilworth Technology Limited	

Quote / Job Numbers: 107616 / 306344

Report prepared by Christine Simmons

Chilworth Technology Limited
Beta House Southampton Science Park
Southampton SO16 7NS
United Kingdom

T +44 (0)23 8076 0722
F +44 (0)23 8076 7866
E info@chilworthglobal.com
W www.chilworth.co.uk

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1. Introduction

This report contains test data for Corrosion Resistant Products Ltd regarding the electrostatic properties of Carbon Loaded PTFE Pipe. Specifically, the following work has been undertaken:

- Surface Resistivity Determination (at two relative humidities)
- Volume Resistivity Determination (at two relative humidities)

This work is in response to quotation number 107616. A formal hazard assessment of the process / plant has not been conducted by Chilworth Technology and the consequences of specific process deviations have not been examined[1].

Detailed characterisation of the material tested in this study is provided in Section 2 of this report (with results summarised in the conclusions section)[2,3]. The following are the key dates for the work reported here:

Study initiation date*	:	11/01/2013
Start date of the experimental work	:	22/01/2013
Completion date of the experimental work	:	24/01/2013

* Sample, purchase order or last information receipt date, whichever is the latter.

The materials used in this assessment were supplied by Corrosion Resistant Products Ltd.

Name and address of client:
Corrosion Resistant Products Ltd
Todmordon Road
Littleborough
Lancashire
OL15 9EG
United Kingdom

[1] Process safety requires that all possible explosion, thermal stability and chemical reaction hazards are evaluated and that a suitable basis for safe operation is determined and implemented. Should the materials or processing conditions change then consideration should be given to re-assessment.
[2] A description of the test procedures together with full test results and information on their interpretation is given in the test sections of this report. The appendices provide background information on the subject matter. Chilworth Technology's Laboratories are GLP (Good Laboratory Practice) compliant and this study was carried out to the principles of GLP.
[3] This report has been issued in digital format. In order to ensure that the integrity of the data is maintained, the signed hard copy (in the CTL archive) will be considered the source document and digital versions will be considered copies. All original test records are kept in a locked archive for a minimum of 10 years after the date of this report. Any remaining material will be stored for a minimum of 1 month after the issue date of this report.

2. Sample Information

Product name	Carbon Loaded PTFE Pipe
CTL sample reference	6713
Appearance	As received, the sample is observed to be a non-cylindrical, black pipe
Preparation	Sample tested as received
Internal Circumference (m)	0.231
External Circumference (m)	0.254
Wall Thickness (mm)	11.5

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3. Surface Resistivity (BS EN 61340-2-3)

Test Objective and Information

The units of Surface Resistivity are Ω or Ω/☐. It describes the ability of a material to conduct electric charge across its surface and is the reciprocal of the electrical conductivity. For historical reasons the surface resistivity is generally used for solids and the Conductivity for liquids.

Method of Measurement

Due to the geometry of the test specimen it was not possible to use the standard test cell detailed within BSEN 61340-2-3 and thus the given formula for resistance and resistivity. Therefore the standard test cell was substituted for a bespoke test cell arrangement and modified resistivity formula (see below):

The Surface Resistivity, (in Ω/□), is calculated using the following formula

$$\rho_s = \frac{R\,C}{l}$$

Where:

P_s	= Surface Resistivity (Ω/□)
R	= Resistance (Ω)
l	= Length of sample tested (m)
C	= Circumference tested (m)

The measurement cells used comprised of two opposing, metal, band electrodes that were securely tightened around the pipes outer circumference and spaced 10 mm apart. One a current / resistance measuring electrode, the other a voltage application electrode.

The electrode assemblies described above are positioned onto the approximate centre of the specimen or at least 10mm away from the edges and connected to the test instrumentation.

The equipment is energised at 10 V, if the calculated resistance is less than 1.0×10^6 Ω then this result is recorded and the procedure repeated at various areas of the specimen or on fresh material if available. If the calculated resistance is equal to or greater than 1.0×10^6 then the procedure is repeated using 100 V.

The measured or calculated resistance (applied voltage / measured current) is then substituted into the above formula to present a surface resistivity value, the average of all areas tested shall be given as the final value of resistivity.

Most materials also adsorb atmospheric water to a lesser or greater extent, which for many materials has a dramatic effect on the surface resistivity. The test is therefore carried out at ambient relative humidity (RH 50 ± 5 %) and in dry conditions (RH 15 ± 2 %), in both cases the sample is conditioned at the stated relative humidity for 24 hours prior to testing.

Interpretation of results

By definition as stated in CENELEC CLC/TR 50404:2003 a material would no longer be regarded as static dissipative when the surface resistivity is found to be greater than $10^{11}\Omega/\square$.

It is good practice to minimise the use of non-conductive materials in hazardous areas. Materials may be grouped by their resistivity as follows:

Definition	Surface Resistivity ($\Omega/\square$)	Volume Resistivity (Ωm)	Examples
Conducting	-	$< 10^4$	Metal
Dissipative	$< 10^{11}$	$10^4 - 10^9$	some organic materials
Insulating	$>10^{11}$	$> 10^9$	synthetic polymers

3.1 Test Results for Carbon Loaded PTFE Pipe

Date	:	22/01/2013 – 24/01/2013
Operator	:	G. Rogers
Preparation	:	Sample tested as received

RH (%)	Temperature (°C)	Surface resistivity ($\Omega/\square$)
50	20	3.3×10^7
15	20	3.8×10^7

Table 3.1 : Full Test Results

Voltage (V)	@ 50% RH			@ 15% RH		
	Current (A)	Resistance (Ω)	Resistivity ($\Omega/\square$)	Current (A)	Resistance (Ω)	Resistivity ($\Omega/\square$)
10	9.0×10^{-7}	1.1×10^7	$> 1.0 \times 10^6$	Resistivity assumed to be $> 1.0 \times 10^6$		
100	-	1.3×10^6	3.3×10^7	-	1.4×10^6	3.6×10^7
100	-	1.5×10^6	3.8×10^7	-	1.5×10^6	3.8×10^7
100	-	1.1×10^6	2.8×10^7	-	1.6×10^6	4.1×10^7

An insulation tester was used measuring direct resistance when using 100 V.

The results obtained above indicate that the sample of Carbon Loaded PTFE Pipe is static dissipative

4. Volume Resistivity (BS EN 61340-2-3)

Test Objective and Information

The ratio of a d.c. field strength (V/m) and the steady-state current density (A/m^2) within the material. In practice, it is equivalent to the volume resistance of a cube with unit length, having the electrodes at two opposite surfaces.

The units of Volume Resistivity are Ωm. It describes the ability of a material to conduct electric charge and is the reciprocal of the electrical conductivity. For historical reasons the Volume Resistivity is generally used for solids and the Conductivity for liquids.

Method of Measurement

Due to the geometry of the test specimen it was not possible to use the standard test cell detailed within BSEN 61340-2-3 and thus the given formula for resistance and resistivity. Therefore the standard test cell was substituted for a bespoke test cell arrangement and modified resistivity formula (see below):

The Volume Resistivity, (in Ωm), is calculated using the following formula

$$P_V \approx R \, \frac{C_i + C_o}{2} \, \frac{w}{d} = RK_V$$

Where:

- P_v = Volume Resistivity (Ωm)
- R = Resistance (Ω)
- d = Thickness of sample tested (m)
- C_i = Inner circumference (m)
- C_o = Outer circumference (m)
- w = Width of narrowest electrode (m)
- K_v = Cell Constant

The measurement cells used comprised of a metal, band electrode that was securely tightened around the pipes outer circumference and an internal sprung electrode that was inserted into the pipes void, making good contact with the pipes internal surface apart and directly below he outer metal electrode. One used as a current / resistance measuring electrode, the other a voltage application electrode.

The electrode assemblies described above are positioned onto the approximate centre of the specimen or at least 10mm away from the edges and connected to the test instrumentation.

The equipment is energised at 10 V, if the calculated resistance is less than 1.0 x 10^6 Ω then this result is recorded and the procedure repeated at various areas of the specimen. If the calculated resistance is equal to or greater than 1.0 x 10^6 then the procedure is repeated using 100 V.

The calculated resistance (applied voltage / measured current) is then substituted into the above formula to present a volume resistance value, the average of all areas tested shall be given as the final value of resistivity.

Most materials also adsorb atmospheric water to a lesser or greater extent, which for many materials has a dramatic effect on the surface resistivity. The test is therefore carried out at ambient relative humidity (RH 50 ± 5 %) and in dry conditions (RH 15 ± 2 %), in both cases the sample is conditioned at the stated relative humidity for 24 hours prior to testing.

Interpretation of results

By definition as stated in CENELEC CLC/TR 50404:2003 a material would no longer be regarded as static dissipative when the volume resistivity is found to be greater than 10^9 Ωm.

It is good practice to minimise the use of non-conductive materials in hazardous areas. Materials may be grouped by their resistivity as follows:

Definition	Surface Resistivity (Ω/☐)	Volume Resistivity (Ωm)	Examples
Conducting	-	$< 10^4$	Metal
Dissipative	$< 10^{11}$	10^4 - 10^9	some organic materials
Insulating	$>10^{11}$	$> 10^9$	synthetic polymers

4.1 Test Results for Carbon Loaded PTFE Pipe

Date : 22/01/2013 – 24/01/2013
Operator : G. Rogers
Preparation : Sample tested as received

RH (%)	Temperature (°C)	Volume resistivity (Ωm)
50	20	2.5×10^7
15	20	3.0×10^7

Table 4.1 : Full Test Results

Voltage (V)	@ 50% RH			@ 15% RH		
	Current (A)	Resistance (Ω)	Resistivity (Ωm)	Current (A)	Resistance (Ω)	Resistivity (Ωm)
10	1.5×10^{-8}	6.7×10^8	$> 1.0 \times 10^6$	Resistivity assumed to be $> 1.0 \times 10^6$		
100	-	3.1×10^7	2.7×10^7	-	3.5×10^7	3.0×10^7
100	-	2.6×10^7	2.3×10^7	-	3.1×10^7	2.7×10^7
100	-	2.8×10^7	2.4×10^7	-	3.8×10^7	3.3×10^7

An insulation tester was used measuring direct resistance when using 100 V.

The results obtained above indicate that the sample of Carbon Loaded PTFE Pipe is static dissipative.

5. Summary of Test Results and Recommendations

5.1 Summary of Test Data Obtained

The results of testing completed on Carbon Loaded PTFE Pipe are summarised in Table 5.1.

Table 5.1: Summary of Results

Parameter	Test Results
Electrostatic Properties	
Surface Resistivity Determination (Ω/☐)	
50% RH	3.3×10^7
15% RH	3.8×10^7
Volume Resistivity Determination (Ωm)	
50% RH	2.5×10^7
15% RH	3.0×10^7

The results of testing are highly dependent on the composition and physical nature of the sample. For this reason, any change in manufacturing / handling procedures or composition should be accompanied by a review of the relevant data.

Chilworth Technology Ltd would be pleased to provide specific advice, including interpretation and application of experimental data. Site visits to discuss operational safety or to perform plant inspections and measurements can be arranged on request.

5.2 Interpretation of Results and Recommendations

Both surface and volume resistivity show that this pipe should be considered to be static dissipative.

This guidance is based purely upon the data collected from the current study and therefore may not encompass all factors which are necessary in order to fully support your chosen Basis of Safety for processing the material. The test work should be supplemented with a detailed hazard and risk assessment (incorporating a hazardous area classification study), definition and implementation of a Basis of Safety and control measures, and continuing auditing to ensure that places where the material is processed remain safe. If further clarification, or support in any of these activities, is required, Chilworth Technology would be pleased to assist.