



REPORT

Testing of coated sample panels with COT sample number 8-5-20/0232
according to AWWA C210-15
"Liquid-Epoxy Coatings and Linings for Steel Water Pipe and Fittings" section 5

Consultancy Laboratory

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Haarlem, August 11th, 2020

Client :



Project number : 20200123

Report number : LAB20-0297-REP

Handled by : Mr. A.R. van Marion

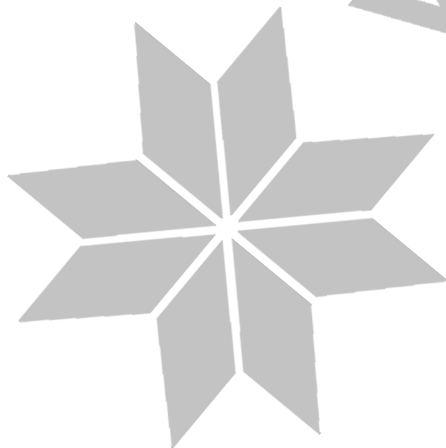
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1 INTRODUCTION

1.1 Commission

By order of [REDACTED], hence referred to as the client, the Centrum voor Onderzoek en Technisch advies (COT bv) in Haarlem, the Netherlands, has tested the sample with COT sample number 8-5-20/0232 as supplied according to AWWA C210-15.

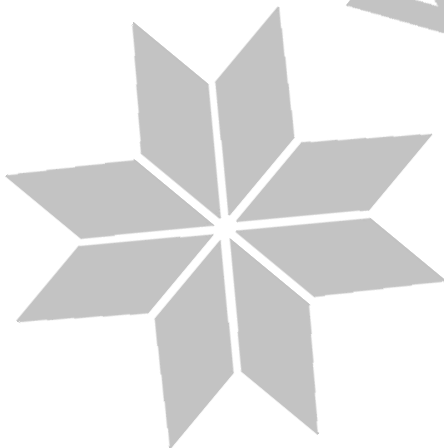
The test has been carried out in accordance with the COT quotation by e-mail dated February 25th 2020 15:28. The order has been confirmed by e-mail as well as the sending of the sample materials by the client.

1.2 Information

Table 1: Sample materials.

| COT sample number | Sample | Dimensions panels | Received |
|-------------------|---|-------------------|----------|
| 8-5-20/0232 | 3x fully coated steel panels, No. 19-21 | 100 x 300 x 5 mm | 8-5-2020 |
| | 18x fully coated steel panels, No. 1-18 | 75 x 150 x 5 mm | |

The coating system on the panels has been applied by the client.



2 PROCEDURE

The tests have been performed according to AWWA C210-15 "Liquid-Epoxy Coatings and Linings for Steel Water Pipe and Fittings", section 5 "Verification".

In table 2 prequalification tests are listed with their normative references and AWWA- specific adaptations and requirements. As well quality control requirements are listed, which are used here to qualify the applied coating sample for prequalification testing.

Table 2: Normative references of AWWA C210-15

| Test | Reference | Specifics | Requirements |
|-------------------------|--|---|---|
| Visual appearance * | Sec. 5.5.1 | -- | ≤ 10% of area minor defects * |
| Cure * | ASTM D5402 | 25 doublerubs; MEK, xylene, white spirit | Full cure * |
| Electrical continuity * | NACE RP0188 | Minimum 100 V/mil | No holidays * |
| Adhesion reference * | ASTM D4541 | 24 hours acclimation | ≥ 5.5 MPa * |
| Dry film thickness * | SSPC-PA2 | ISO 2178, substrate medium rough, n = 5 | ≥ 16 mil (406 µm) * |
| Immersion 50% | Sec 5.2.1.1 | 30 days at 23 °C in: - Demineralised water - 1 % NaOH - 1 % H ₂ SO ₄ | No blistering No peeling No disbondment |
| Cathodic disbondment | ASTM G 8 Holiday facing away from anode | 30 days immersed, Ambient temperature, - 1.41 V (Ag/AgCl ref.) | ≤ 9.53 mm radius of disbondment from holiday |
| Dielectric Strength | ASTM D149 | Dry film DFT < 50% nDFT | > 250 V/mil (at 16 mils) |

* Methods required for quality control by constructor of field applied coating (sec. 5.3, 5.5), included in laboratory testing for reference and quality control of prequalification testing samples.

Dry film thickness

The dry film thickness measurements have been carried out by magnetic flux (digital) dry film thickness meter (COT E004) before testing according to ISO 19840(12), which is technically equivalent to ISO 2178. Reported are per specimen, corrected for substrate roughness, the five individual readings, the range of values and the mean value including standard deviation.

Electrical continuity

Electrical continuity (or rather the lack thereof) is determined of CD panels after electrical connections have been made, but before machining artificial holidays. According to NACE SP0188 the requirement is 100 V/mil without failure of the coating.



3 RESULTS

3.1 Quality control sample

Visual appearance: Upon receipt of sample, all test panels appear smooth and glossy, no gross defects are observed.

On 13-5-2020 the dry film thickness of the entire sample is measured, the average DFT is 642 ± 80 microns (25 mils), the specified application dry film thickness is 16 mils.

Table 3a: Dry film thickness measurements, panel size 150x75x5mm.

| Dry film thickness ISO 19840 (C = 25 μm) | COT sample number 13-5-20/0232 | | | | |
|--|-----------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| | Panel 1 | Panel 2 | Panel 3 | Panel 4 | Panel 5 |
| Readings (n=5) | 737 699 711 692 661 | 606 526 500 561 500 | 738 721 738 737 702 | 678 655 711 682 699 | 540 582 611 665 670 |
| Min. - Max. (μm) Average, SD (μm) | 661 - 737 700 \pm 28 | 500 - 606 539 \pm 45 | 702 - 738 727 \pm 16 | 655 - 711 685 \pm 21 | 540 - 670 614 \pm 55 |
| | Panel 6 | Panel 7 | Panel 8 | Panel 9 | Panel 10 |
| Readings (n=5) | 548 535 587 562 557 | 699 620 672 653 666 | 529 582 591 620 647 | 604 510 585 530 534 | 687 701 643 618 621 |
| Min. - Max. (μm) Average, SD (μm) | 535 - 587 558 \pm 19 | 620 - 699 662 \pm 29 | 529 - 647 594 \pm 44 | 510 - 604 553 \pm 40 | 618 - 701 654 \pm 38 |
| | Panel 11 | Panel 12 | Panel 13 | Panel 14 | Panel 15 |
| Readings (n=5) | 698 702 723 730 724 | 662 650 655 652 722 | 563 531 590 673 647 | 728 624 696 748 667 | 665 770 692 689 759 |
| Min. - Max. (μm) Average, SD (μm) | 698 - 730 715 \pm 14 | 650 - 722 668 \pm 30 | 531 - 673 601 \pm 59 | 624 - 748 693 \pm 49 | 665 - 770 715 \pm 47 |
| | Panel 16 | Panel 17 | Panel 18 | | |
| Readings (n=5) | 746 695 730 707 693 | 742 665 740 701 650 | 754 772 755 675 796 | | |
| Min. - Max. (μm) Average, SD (μm) | 693 - 746 714 \pm 23 | 650 - 742 700 \pm 42 | 675 - 796 750 \pm 45 | | |

Table 3b: Dry film thickness measurements, panel size 300x75x5mm

| Dry film thickness ISO 19840 (C = 25 μm) | COT sample number 13-5-20/0232 | | |
|--|-----------------------------------|---------------------------------|---------------------------------|
| | Panel 19 | Panel 20 | Panel 21 |
| Readings (n=5) | 601 512 594 598 596 | 540 518 514 483 488 | 495 539 541 596 561 |
| Min. - Max. (μm) Average, SD (μm) | 512 - 601 580 \pm 38 | 483 - 540 509 \pm 23 | 495 - 596 546 \pm 37 |

3.2 Solvent rub cure test

Table 4: Solvent rub cure test
 Performed: May 18th 2020

| COT Sample number | | 8-5-20/0232 |
|-------------------|---------------------------|--|
| | | Panel 1 |
| ASTM D5402 | MethylEthylKetone 25 rubs | Temporary softening, loss of gloss, pass |
| | Xylene 25 rubs | No effect, pass |
| | White spirit 25 rubs | No effect, pass |

3.3 Reference adhesion

Table 5: Adhesion unexposed panels
 Performed: June 5th 2020

| COT Sample number | | 8-5-20/0232 | | |
|-------------------|--------------------------------------|---|---------------------------------|---------------------------------|
| | | Panel 1 | Panel 2 | Panel 3 |
| ASTM D4145 | Adhesion Readings (MPa) Break (%) | 11.0 25% A/B, 35% B, 30% C, 10% Y | 12.9 40% B, 50% C, 10% Y | 11.2 50% B, 25% C, 25% Y |
| | | 12.6 40% B, 40% C, 20% Y | 12.1 30% B, 10% C, 60% Y | 9.6 50% A/B, 25% B, 25% C |
| | | 12.2 40% A/B, 20% B, 20% C, 20% Y | 8.3 30% A/B, 30% C, 40% Y | 8.8 30% B, 30% C, 40% Y |
| | Average | 11.0 ± 1.7 MPa | | |

3.4 Immersion tests

Table 6a: Immersion testing 30 days in demineralised water
 Performed: 18-05-2020 to 17-06-2020.

| COT Sample number | | 8-5-20/0232 | | |
|-------------------|-------------|-------------|---------|---------|
| | | Panel 4 | Panel 5 | Panel 6 |
| Vapour phase | | | | |
| Visual defects | Blistering | None | None | None |
| ASTM D714 | Peeling | None | None | None |
| ASTM D3359-A | Disbondment | 5A | 3A-4A | 4A-5A |
| Liquid phase | | | | |
| Visual defects | Blistering | None | None | None |
| ASTM D714 | Peeling | None | None | None |
| ASTM D3359-A | Disbondment | 4A | 2A | 4A-5A |

Table 6b: Immersion testing 30 days in 1% NaOH.
 Performed: 18-05-2020 to 17-06-2020

| COT Sample number | | 8-5-20/0232 | | |
|-------------------|-------------|-------------|---------|---------|
| | | Panel 7 | Panel 8 | Panel 9 |
| Vapour phase | | | | |
| Visual defects | Blistering | None | None | None |
| ASTM D714 | Peeling | None | None | None |
| ASTM D3359-A | Disbondment | 4A | 4A | 4A |
| Liquid phase | | | | |
| Visual defects | Blistering | None | None | None |
| ASTM D714 | Peeling | None | None | None |
| ASTM D3359-A | Disbondment | 4A | 4A | 4A |

Table 6c: Immersion testing 30 days in 1% H₂SO₄.
 Performed: 18-05-2020 to 17-06-2020.

| COT Sample number | | 8-5-20/0232 | | |
|-------------------|-------------|---------------------|---------------------|---------------------|
| | | Panel 10 | Panel 11 | Panel 12 |
| Vapour phase | | | | |
| Visual defects | Blistering | None | None | None |
| ASTM D714 | Peeling | None | None | None |
| ASTM D3359-A | Disbondment | 4A | 3A-4A | 3A-4A |
| Liquid phase | | | | |
| Visual defects | Blistering | None, loss of gloss | None, loss of gloss | None, loss of gloss |
| ASTM D714 | Peeling | None | None | None |
| ASTM D3359-A | Disbondment | 4A | 4A | 4A |

3.5 Cathodic disbondment

Table 7: Cathodic disbondment test
 Performed: 8-06-2020 to 7-07-2020

| COT Sample number | | 8-5-20/0232 | | | | | |
|-------------------------------|------------------------|-------------|------------------------|-------------|------------------------|-------------|--|
| | | Panel 19 | | Panel 20 | | Panel 21 | |
| Immersed area (mm x mm) | | 100 x 150 | | 100 x 150 | | 100 x 150 | |
| Continuity of coating (2.5kV) | | Pass | | Pass | | Pass | |
| Electrical readings | $\Delta E_{(2-1)}$ (V) | - log I (A) | $\Delta E_{(2-1)}$ (V) | - log I (A) | $\Delta E_{(2-1)}$ (V) | - log I (A) | |
| Start | -0.52 | 2.66 | -0.44 | 2.34 | -0.50 | 2.60 | |
| Intermediate | -0.46 | 2.77 | -0.40 | 2.42 | -0.44 | 2.66 | |
| End | -0.42 | 2.68 | -0.41 | 2.43 | -0.41 | 2.71 | |
| Change (start - end) | +0.10 | +0.02 | +0.03 | +0.09 | +0.09 | +0.11 | |
| Disbondment readings | | | | | | | |
| Disbondment diameter (mm) | 14.7 | 13.9 | 12.5 | 12.7 | 11.9 | 13.6 | |
| | 13.9 | 13.5 | 11.6 | 12.9 | 12.9 | 12.4 | |
| Radius disbondment (mm) | 3.8 | | 3.0 | | 3.2 | | |
| Average radius disbondment | 3.3 ± 0.4 mm | | | | | | |

3.6 Dielectric strength

Table 8: Dielectric strength test, outsourced to Intertek
Performed: 17-07-2020

| COT sample number | | 8-5-20/0232 | | |
|--------------------------|---------|----------------|----------------|----------------|
| | | 16 | 17 | 18 |
| Total DFT (double sided) | (um) | 1428 | 1400 | 1500 |
| | (mil) | 56.2 | 55.1 | 59.1 |
| Breakdown voltage | (kV) | 33.7 | 33.8 | 30.9 |
| Failure location | | Center | Center | Center |
| Dielectric strength | (V/mil) | 599 | 613 | 523 |
| Breakdown voltage | (kV) | 33.2 | 37.9 | 34.1 |
| Failure location | | Center | Center | Center |
| Dielectric strength | (V/mil) | 591 | 688 | 577 |
| Breakdown voltage | (kV) | 35.9 | 36.3 | 35.5 |
| Failure location | | Center | Center | Center |
| Dielectric strength | (V/mil) | 639 | 659 | 601 |
| Breakdown voltage | (kV) | 35.6 | 32.4 | 35.3 |
| Failure location | | Center | Center | Center |
| Dielectric strength | (V/mil) | 633 | 588 | 598 |
| Breakdown voltage | (kV) | 34.7 | 32.2 | 35.7 |
| Failure location | | Center | Center | Center |
| Dielectric strength | (V/mil) | 617 | 584 | 605 |
| Average DES | (V/mil) | 616 ± 21 V/mil | 626 ± 45 V/mil | 581 ± 34 V/mil |



4 SUMMARY OF TEST RESULTS

In the table below average results are listed with the requirements of AWWA C210-15.

Table 9: Overview of averaged results

| Test | | Results | Requirement | Pass/Fail |
|-------------------------------|-----------------------------------|---|--|---------------|
| Dry film thickness (averaged) | | 642 ± 80 µm (25 mils) | ≥ 16 mils | For reference |
| Visual assessment | | Smooth and continuous | Surface area defects ≤ 10% | For reference |
| Adhesion | | 11.0 ± 1.7 MPa | ≥ 5.515 MPa | For reference |
| Cure | | Fully cured | Full cure | Pass |
| Immersion | Demineralised water | No blistering, no peeling nor disbondment | No blistering, no peeling and no disbondment | Pass |
| | 1% NaOH | | | Pass |
| | 1% H ₂ SO ₄ | | | Pass |
| Cathodic Disbondment | | 3.3 ± 0.4 mm radius | ≤ 9.53 mm radius | Pass |
| Dielectric Strength | | 608 ± 38 V/mil | 250V/mil | Pass |

5 CONCLUSION

The tested coating system with COT sample number 5-8-20/0232, meet all the requirements of AWWA C210-15.

CENTRUM VOOR ONDERZOEK
EN TECHNISCH ADVIES (COT bv)

Ing. A. R. van Marion
Laboratory Technician

J.R.S. Brakenhoff
Technical Manager Laboratory

ANNEX I

Photographs



Photo 1: Solvent rub (MEK), (xylene) and (white spirit), panel 1.

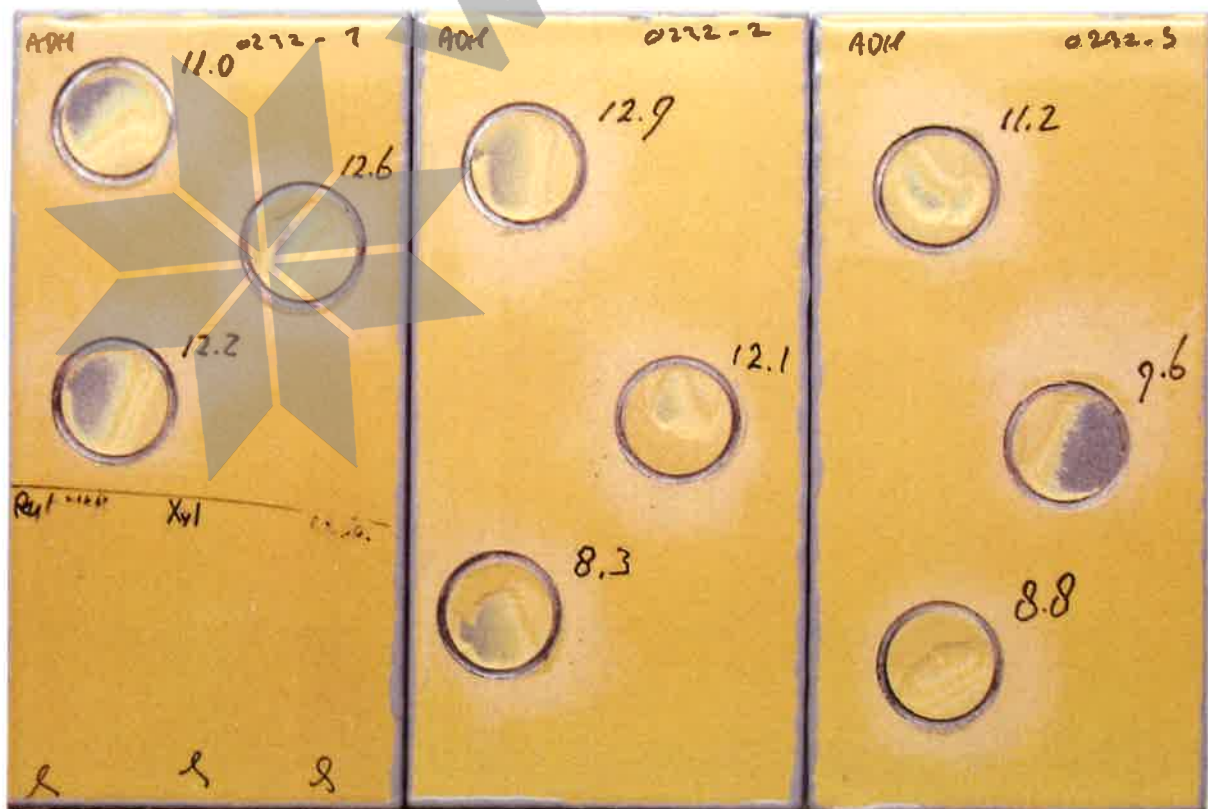


Photo 2: Adhesion, panels 1, 2 and 3



Photo 3: Immersion in demineralised water, panels 4, 5 and 6.

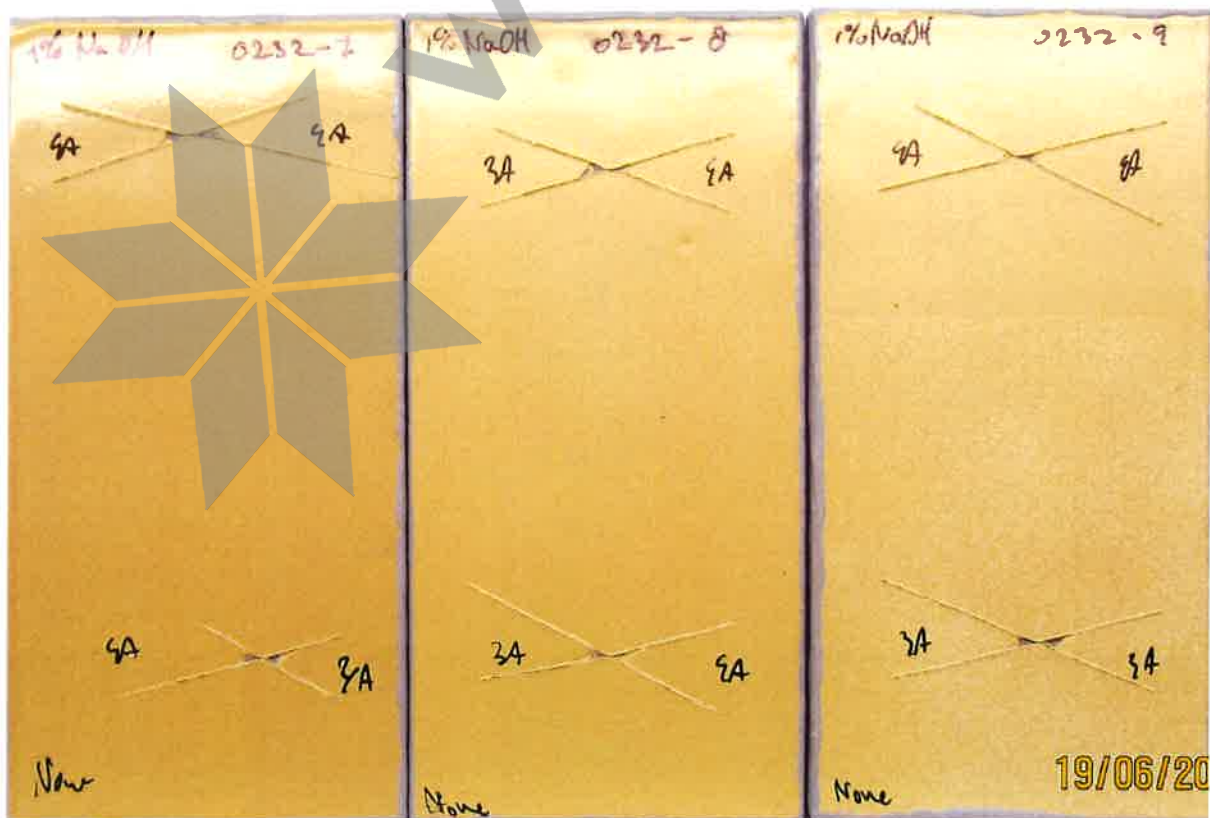


Photo 4: Immersion in NaOH 1%, panels 7, 8 and 9.



Photo 5: Immersion in H₂SO₄ 1%, panels 10, 11 and 12.

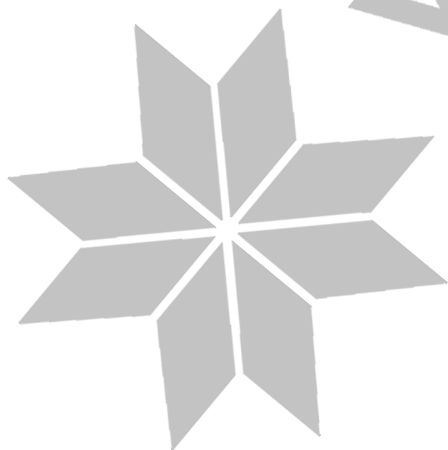


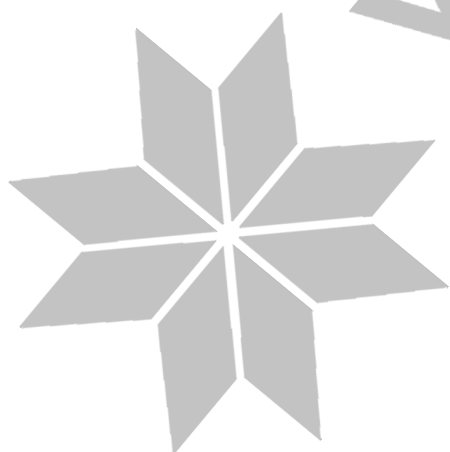


Photo 6, 7, 8: Cathodic disbondment, panels 19, 20 and 21.



ANNEX II

Intertek report RE32879: Dielectric Strength testing



welesgard

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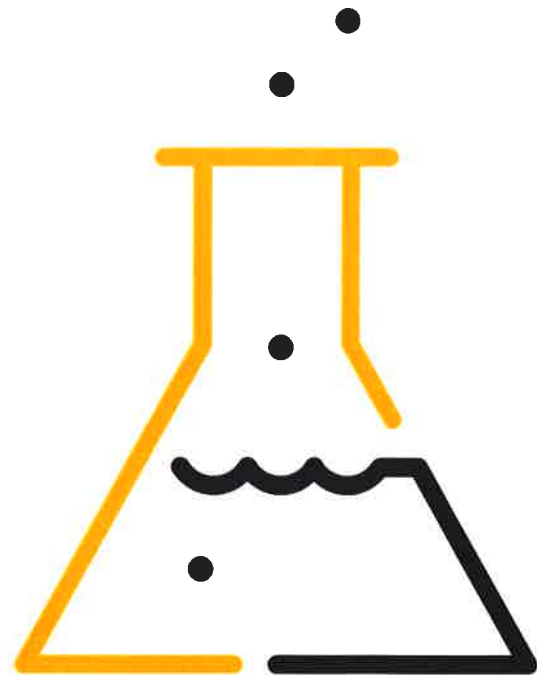
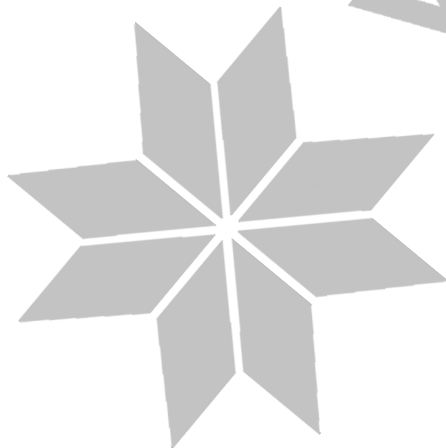
TEST REPORT – RE32879

DIELECTRIC STRENGTH PER ASTM D149

CLIENT NAME

COT BV

Attn. Mr. Arnoud van Marion
Jan Tademaweg 40
2031 CV Haarlem
Netherlands



DATE

July 17, 2020

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RE32879

July 17, 2020

Dear Mr. van Marion,

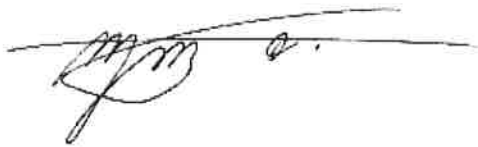
Hereby we present to you the results of the laboratory study, which was carried out by your request (ref. SO32879).

The general conditions of delivery of Intertek Polychemlab B.V., located in Geleen, the Netherlands, are applicable. These conditions are an integral part of all research carried out and the services and consultations provided; where appropriate, expanded upon by agreements specific to the client.

This report applies only to the sample(s) tested. If information about the measurement uncertainty of a method is required, this can be provided on request.

We trust that this information will meet your approval.

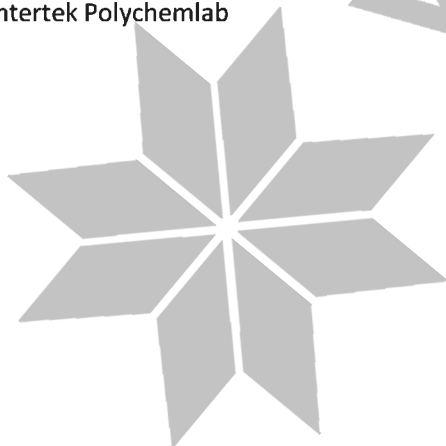
Yours sincerely,



Marc Triepels

Application Specialist – Polymers

Intertek Polychemlab



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RE32879

July 17, 2020

1 SAMPLES

The following samples are received:



The samples were also coded by Intertek with a unique Intertek LIMS number.

Table 1 Sample description

| NO. | CUSTOMER SAMPLE DESCRIPTION | DATE RECEIVED | INTERTEK LIMS NUMBER |
|-----|-----------------------------|---------------|----------------------|
| 1 | Weleforce PW No.16 | 24-06-2020 | 23052637 |
| 2 | Weleforce PW No.17 | 24-06-2020 | 23052638 |
| 3 | Weleforce PW No.18 | 24-06-2020 | 23052639 |

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RE32879

July 17, 2020

2 METHODS APPLIED AND RESULTS

Dielectric Strength per ASTM D149, Method A (Short Time Test) at 23°C.

| | |
|--------------------------|---|
| Rate of Rise (Volts/sec) | : 2000 |
| Voltage Type | : AC |
| Sample Preparation | : Tested as received. (Sticker removed prior to testing). |
| Sample Conditioning | : 40+ hours at 23°C ± 2°C / 50%RH ± 10% |
| Electrode Size | : 0.25" diameter (cylindrical) |
| Surrounding Medium | : Transformer - Mineral Oil |
| Test Specimen Type | : 3" x 6" Coated Plaque |
| Test Conditions | : 23°C ± 2°C |

| Sample ID | Test Number | Failure Location On Electrode | Customer Supplied Total Coating Thickness (mm) | Breakdown Voltage (kV) | Time To Failure (sec) | Dielectric Strength (kV/mm) |
|--|-------------|-------------------------------|--|------------------------|-----------------------|-----------------------------|
| Weleforce PW No. 16 23052637 714 µm Thick Coating | 1 | Center | 1.428 | 33.7 | 17 | 23.6 |
| | 2 | Center | 1.428 | 33.2 | 17 | 23.2 |
| | 3 | Center | 1.428 | 35.9 | 18 | 25.1 |
| | 4 | Center | 1.428 | 35.6 | 18 | 24.9 |
| | 5 | Center | 1.428 | 34.7 | 17 | 24.3 |
| | Average | | 1.428 | 34.6 | 17 | 24.2 |
| | Std.Dev. | | 0.000 | 1.2 | 1 | 0.8 |
| Weleforce PW No. 17 23052638 700 µm Thick Coating | 1 | Center | 1.400 | 33.8 | 17 | 24.1 |
| | 2 | Center | 1.400 | 37.9 | 19 | 27.1 |
| | 3 | Center | 1.400 | 36.3 | 18 | 25.9 |
| | 4 | Center | 1.400 | 32.4 | 16 | 23.1 |
| | 5 | Center | 1.400 | 32.2 | 16 | 23.0 |
| | Average | | 1.400 | 34.5 | 17 | 24.6 |
| | Std.Dev. | | 0.000 | 2.5 | 1 | 1.8 |

Note: Samples were coated on both sides. Total coating thickness used to calculate dielectric strength.

| Sample ID | Test Number | Failure Location On Electrode | Customer Supplied Total Coating Thickness (mm) | Breakdown Voltage (kV) | Time To Failure (sec) | Dielectric Strength (kV/mm) |
|--|-------------|-------------------------------|--|------------------------|-----------------------|-----------------------------|
| Weleforce PW No. 18 23052639 750 µm Thick Coating | 1 | Center | 1.500 | 30.9 | 15 | 20.6 |
| | 2 | Center | 1.500 | 34.1 | 17 | 22.7 |
| | 3 | Center | 1.500 | 35.5 | 18 | 23.7 |
| | 4 | Center | 1.500 | 35.3 | 18 | 23.5 |
| | 5 | Center | 1.500 | 35.7 | 18 | 23.8 |
| | Average | | 1.500 | 34.3 | 17 | 22.9 |
| | Std.Dev. | | 0.000 | 2.0 | 1 | 1.3 |

Note: Samples were coated on both sides. Total coating thickness used to calculate dielectric strength.

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