



Department of Environmental Protection

2600 Blair Stone Road ♦ Tallahassee, Florida 32399-2400

DEP Form: 62-761.900(9)

Form Title: Storage Tank Equipment

Registration Form

Effective Date: July 2019

Incorporated in Rule 62-761.850, F.A.C.

Storage Tank System Equipment Registration Form

Fill out completely

General Information

Company Name: Carbontech Americas Contact Name: David Banks
Company Address: 1912 N Willow Ave Unit B City, State: Broken Arrow Zip: 74012
E-mail: david.banks@carbontech-americas.com Contact Number: 918-361-6513
Product Name: Revowrap
Model Number(s): Revowrap110™, Revowrap185™, Revowra Product Type: Composite Repair
Rule(s) citation that registration is being requested within Chapter 62-761 (UST), and/or 62-762 (AST), 62-761.700, 62-762.7

F.A.C.: Write a brief description of equipment registration request including product limitations:

We would like to register our composite repair products for repair of wall loss, through wall defects, and other similar damage, with our Revowrap Carbon Fiber Composite Repair Systems. Products are limited by maximum allowable temperatures per the epoxy. Physical limitations apply to the total amount installed. Allowable pressure and stress are a function of the repair thickness as defined in ASME PCC2 Article 401.

Information Checklist (Choose Yes, No, or N/A - Not Applicable):

	Yes	No	N/A
1. Third-party Certification by a Nationally Recognized Testing Laboratory? (Required)	☒	☐	☐
2. Documentation of third-party evaluation that the equipment meets DEP Rules?	☒	☐	☐
3. Documents included about the qualifications of the Nationally Recognized Testing Laboratory?	☒	☐	☐
4. Technical information and drawings included?	☒	☐	☐
5. Installation instructions included?	☒	☐	☐
6. Annual Operability Testing Requirements (Rules 62-761.500, 62-762.501, & 62-762.502 F.A.C.)?	☐	☐	☒
7. Integrity Testing Requirements (Rules 62-761.700, 62-762.701, & 62-762.702, F.A.C.)?	☐	☐	☒
8. Compatible with fuel blends containing >10% ethanol or >20% biodiesel?	☒	☐	☐
9. Has the product been approved or registered in other countries or states? (If so provide list)	☒	☐	☐
10. Any requirements for company-certified installers or trainers?	☒	☐	☐
11. Was this product(s) previously approved or registered by the Department? If yes, EQ- _____	☐	☒	☐
12. Any changes or modifications to the equipment since the last submittal to DEP?	☐	☒	☐

Document Information: Provide supporting documents indicated as "Yes" above including this form via email to Tanknotify@floridadep.gov, or documents can be sent to FDEP, Division of Waste Management, 2600 Blair Stone Road, MS 4560, Tallahassee, FL 32399.

Write a brief description of equipment installation and performance in the U.S.:

Composite repairs are installed by hand by trained installers. The installer will apply a coat of epoxy to the damaged section with a brush as a primer. Then, the installer will saturate the carbon fiber cloth with epoxy. The saturated cloth is then placed onto the primed section. More fabric is installed until the required repair thickness is achieved. The repair is then allowed to cure per a set period. Once the repair is fully cured and inspected, the asset may be returned to service.

Equipment Registration Certification:

To the best of my knowledge and belief, all information submitted on this form is true, accurate and complete.

David Banks, Engineering Director

Printed Name and Title

Signature (right click to sign)

2/21/23

Date

For Department Use Only:

Date Application Received: 02/21/2023 Application complete: Yes: ☒ No: ☐

EQ- 992 Date of complete or incomplete letter sent: 02/28/2023 Date Equipment Requires Renewal: 02/28/2028

Storage tank system equipment requires renewal every 5 years in accordance with subsection 62-761.850(2), F.A.C.

Revowrap 110

PRODUCT SHEET



PRODUCT OVERVIEW

REVOWRAP 110

-58°F to 228°F (-50°C to 109°C) with no pressure limitations!

Revowrap is an engineered composite solution used to restore damaged critical assets back to the original design specification of the equipment. Each repair is engineered using ASME PCC2 or ISO TS 24817 engineering codes for High risk non-metallic repairs. Carbontech engineers have the technology to perform FEA (Finite element analysis) on both the damaged piping systems and the Revowrap composite repair system. Revowrap provides re-enforcement of the piping in both the axial and hoop directions, and delivers uniform loading throughout the repair. The "Revowrap110 ®" composite systems are engineered to operate in working temperatures from -58°F to 228°F (-50°C to 109°C) and bares no pressure limitations. Our composite systems can be applied by hand lamination or by infusion methods and may be applied to live piping systems without shutting down for the repair. Revowrap may be applied to any pipe size, most substrates and almost any piping configuration including tanks, vessels, flanges, and other compromised structural assets.



PRODUCT PERFORMANCE INDICATORS	
ASME PCC2 Compliant	Fully Compliant
ISO T- 24817 Compliant	Fully Compliant
Minimum Application Temperature	46°F (8°C)
Maximum Application Temperature	212°F (100°C)
Minimum Allowable Operating Temperature	-58°F (-50°C)
Maximum Allowable Operating Temperature	228°F (109°C) for non Leaking Defects
Maximum Allowable Operating Pressure	No Limitations
Shelf Life	2 Years – Extendable
Set Time @ 84°F (29°C)	4 Hours
Minimum Pipe Diameter	No Limitations
Maximum Pipe Diameter	No Limitations
Repair Lifespan	Up to 20 Years
Through Wall Defects	Permissible

REVOWRAP 110

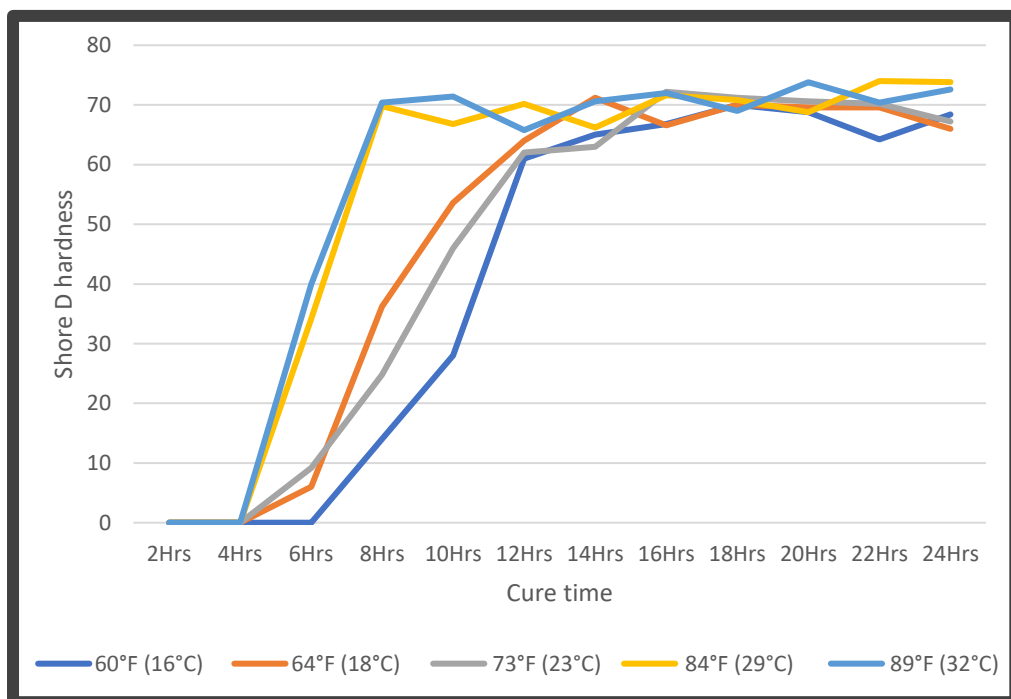


PRODUCT ISO TS-24817 & ASME PCC2 QUALIFICATION DATA

REVOWRAP 110	TEST	Test Code	Metric	Imperial
	Ply Thickness	N/A	.45mm	0,02inch
	Tensile Modulus Hoop	ASTM D3039	48,8GPa	7077,8ksi
	Tensile Modulus Axial	ASTM D3039	20,5GPa	2973,3ksi
	Tensile Strength	ASTM D3039	568,2GPa	82410,4psi
	Tensile Strain to Failure	ASTM D3039/D638	1.1%	1.1%
	Shear Strength	ASTM D5379	73,6MPa	10674,8psi
	Poisson's Ratio	ASTM D3039	0,33	0,33
	Lap Shear Strength To Steel (SA2.5)	ASTM D3165	10,04MPa	1456,18psi
	Lap Shear Strength To Steel (ST2)	ASTM D3165	7,35MPa	1066,03psi
	Lap Shear Strength To Steel (ST3)	ASTM D3165/D1002	5,86MPa	849,92psi
	Barcol/Shore D Hardness	ISO 868	75 Minimum	75 Minimum
	Thermal Expansion Coefficient	ISO 11369-2	1,45E-6°C ⁻¹	8,06E-7°F ⁻¹
	HDT (Heat Distortion Temperature)	ASTM D648	124,08°C	255,34°F



Revowrap 110 cure time VS Shore D Hardness



ADVANTAGES

- Fast, Non-invasive repair - does not require hot work
- Repairs done live – no unplanned downtime
- Can Handle complex geometries
- Resistant to Harsh chemicals

INDUSTRIES

- Oil and Gas facilities
- Petrochemical plants
- Chemical plants
- Transmission Pipelines
- Potable water

USES

- Internal Corrosion
- External corrosion
- Mechanical damages
- Weld Anomalies



CARBONTECH

The place chemistry, engineering and global expertise are brought together to drive progressive innovation in advanced composite technologies for the emergency repair of critical assets
"There is nothing generic about us" we don't just sell pipe wraps; we provide accurate engineering backing to deliver tailored solutions

Sound and responsible engineering is the basis on which we build our company, products and services. It is the core to our success and it is the foundation on which we have engineered and manufactured our innovative and bespoke products

We strive by a zero-failure philosophy and warrant our engineered composite solutions are tested, proven and validated. We vow to provide dependable, responsible and accurate information regarding the capabilities of our systems

www.revowrap.com

PROGRESSIVE COMPOSITE ENGINEERING



Revowrap 185

PRODUCT SHEET



PRODUCT OVERVIEW

REVOWRAP 185

-40°F to 406°F (-40°C to 208 °C) with no pressure limitations!

Revowrap is an engineered composite solution used to restore damaged critical assets back to the original design specification of the equipment. Each repair is engineered using ASME PCC2 or ISO TS 24817 engineering codes for High risk non-metallic repairs. Carbontech engineers have the technology to perform FEA (Finite element analysis) on both the damaged piping systems and the Revowrap composite repair system. Revowrap provides reinforcement of the piping in both the axial and hoop directions, and delivers uniform loading throughout the repair. The "Revowrap185®" composite systems are engineered to operate in working temperatures from -40°F to 406°F (-40°C to 208°C) and bares no pressure limitations. Our composite systems can be applied by hand lamination or by infusion methods and may be applied to live piping systems without shutting down for the repair. Revowrap may be applied to any pipe size, most substrates and almost any piping configuration including tanks, vessels, flanges, and other compromised structural assets.



PRODUCT PERFORMANCE INDICATORS	
ASME PCC2 Compliant	Fully Compliant
ISO T- 24817 Compliant	Fully Compliant
Minimum Application Temperature	65°F (18°C)
Maximum Application Temperature	248°F (120°C)
Minimum Allowable Operating Temperature	-58°F (-50°C)
Maximum Allowable Operating Temperature	413°F (211.8°C for non Leaking Defects)
Maximum Allowable Operating Pressure	No Limitations
Shelf Life	1 Year – Extendable
Set Time @ 84°F (29°C)	12 Hours
Minimum Pipe Diameter	No Limitations
Maximum Pipe Diameter	No Limitations
Repair Lifespan	Up to 20 Years
Through Wall Defects	Permissible

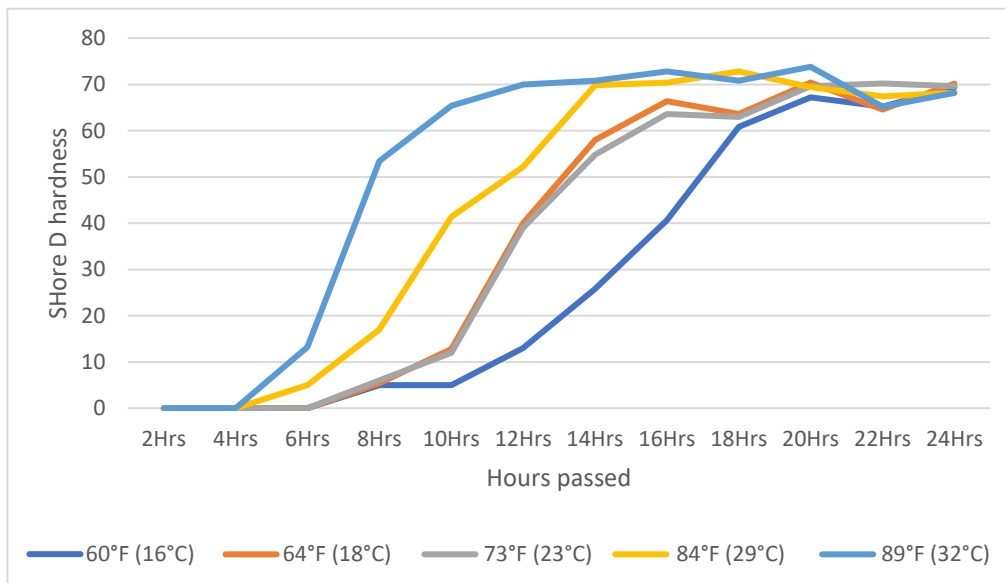


PRODUCT ISO TS-24817 & ASME PCC2 QUALIFICATION DATA

REVOWRAP 185	TEST	Test Code	Metric	Imperial
	Ply Thickness	N/A	0,52mm	0,02inch
	Tensile Modulus Hoop	ASTM D3039	37,6GPa	5453,42ksi
	Tensile Modulus Axial	ASTM D3039	19,6GPa	2842,74ksi
	Tensile Strength	ASTM D3039	453,1MPa	65716,6psi
	Tensile Strain to Failure	ASTM D3039/D638	1.3%	1.3%
	Shear Strength	ASTM D5379	82,1MPa	11907,6psi
	Poisson's Ratio	ASTM D3039	0.37	0,37
	Lap Shear Strength To Steel (SA2.5)	ASTM D3165	9,2MPa	1334,3psi
	Lap Shear Strength To Steel (ST2)	ASTM D3165	4,8MPa	696,2psi
	Lap Shear Strength To Steel (ST3)	ASTM D3165/D1002	4,7MPa	681,7psi
	Barcol/Shore D Hardness	ISO 868	75 Minimum	75 Minimum
	Thermal Expansion Coefficient	ISO 11369-2	1,88E-6°C ⁻¹	1,04E-6°F ⁻¹
	HDT (Heat Distortion Temperature)	ASTM D648	226,8°C	440,2°F



Revowrap 185 cure time VS Shore D Hardness



ADVANTAGES

- Fast, Non-invasive repair - does not require hot work
- Repairs done live – no unplanned downtime
- Can Handle complex geometries
- Resistant to Harsh chemicals

INDUSTRIES

- Oil and Gas facilities
- Petrochemical plants
- Chemical plants
- Transmission Pipelines
- Potable water

USES

- Internal Corrosion
- External corrosion
- Mechanical damages
- Weld Anomalies



CARBONTECH

The place chemistry, engineering and global expertise are brought together to drive progressive innovation in advanced composite technologies for the emergency repair of critical assets
"There is nothing generic about us" we don't just sell pipe wraps; we provide accurate engineering backing to deliver tailored solutions

Sound and responsible engineering is the basis on which we build our company, products and services. It is the core to our success and it is the foundation on which we have engineered and manufactured our innovative and bespoke products

We strive by a zero-failure philosophy and warrant our engineered composite solutions are tested, proven and validated. We vow to provide dependable, responsible and accurate information regarding the capabilities of our systems

www.revowrap.com

PROGRESSIVE COMPOSITE ENGINEERING



Revowrap 225

PRODUCT SHEET



PRODUCT OVERVIEW

REVOWRAP 225

-58°F to 451°F (50°C to 233 °C) with no pressure limitations!

Revowrap is an engineered composite solution used to restore damaged critical assets back to the original design specification of the equipment. Each repair is using ASME PCC2 or ISO TS 24817 engineering codes for High risk non-metallic repairs. Carbontech engineers have the technology to perform FEA (Finite element analysis) on both the damaged piping systems and the Revowrap composite repair system. Revowrap provides re-enforcement of the piping in both the axial and hoop directions, and delivers uniform loading throughout the repair. The "Revowrap110 ®" composite systems are engineered to operate in working temperatures from -50°C to 109°C and bares no pressure limitations. Our composite systems can be applied by hand lamination or by infusion methods and may be applied to live piping systems without shutting down for the repair. Revowrap may be applied to any pipe size, most substrates and almost any piping configuration including tanks, vessels, flanges, and other compromised structural assets.



PRODUCT PERFORMANCE INDICATORS	
ASME PCC2 Compliant	Fully Compliant
ISO T- 24817 Compliant	Fully Compliant
Minimum Application Temperature	73°F (23°C)
Maximum Application Temperature	248°F (120°C)
Minimum Allowable Operating Temperature	-58°F (-50°C)
Maximum Allowable Operating Temperature	451°F (233°C) for non Leaking Defects
Maximum Allowable Operating Pressure	No Limitations
Shelf Life	1 Year – Extendable
Set Time @ 84°F (29°C)	20 Hours
Minimum Pipe Diameter	No Limitations
Maximum Pipe Diameter	No Limitations
Repair Lifespan	Up to 20 Years
Through Wall Defects	Permissible

REVOWRAP 225

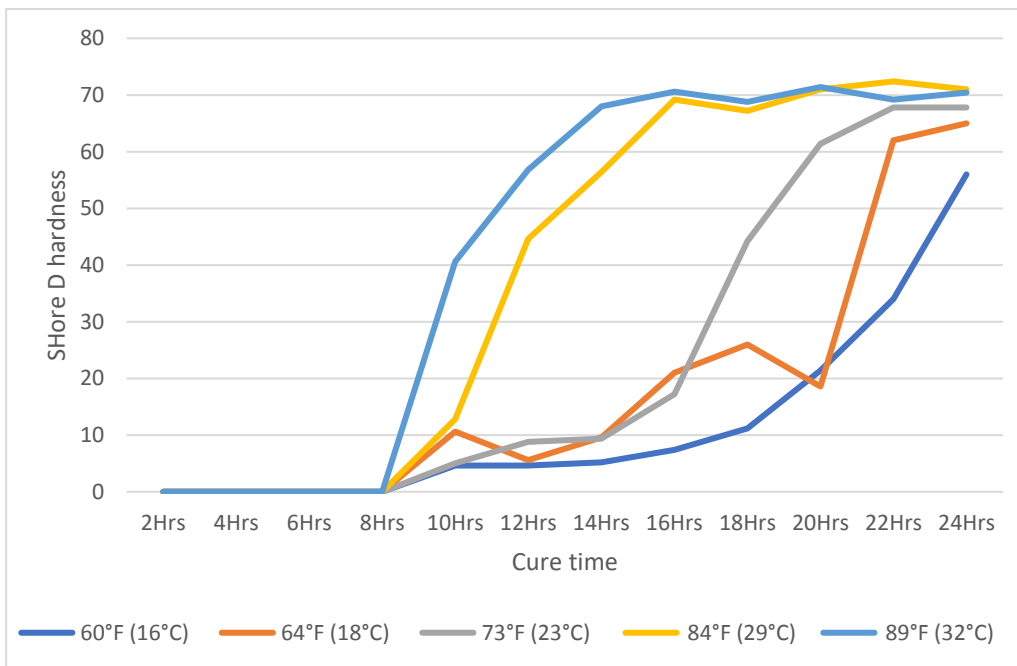


PRODUCT ISO TS-24817 & ASME PCC2 QUALIFICATION DATA

REVOWRAP 225	TEST	Test Code	Metric	Imperial
	Ply Thickness	N/A	0,52mm	0,02inch
	Tensile Modulus Hoop	ASTM D3039	30,7GPa	4452,7ksi
	Tensile Modulus Axial	ASTM D3039	20,5GPa	2973,3ksi
	Tensile Strength	ASTM D3039	454,1MPa	65861,6psi
	Tensile Strain to Failure	ASTM D3039/D638	1.1%	1.1%
	Shear Strength	ASTM D5379	106,8MPa	15490psi
	Poisson's Ratio	ASTM D3039	0.38	0,38
	Lap Shear Strength To Steel (SA2.5)	ASTM D3165	9,58MPa	1389,46psi
	Lap Shear Strength To Steel (ST2)	ASTM D3165	5,45MPa	790,46psi
	Lap Shear Strength To Steel (ST3)	ASTM D3165/D1002	4,2MPa	609,16psi
	Barcol/Shore D Hardness	ISO 868	75 Minimum	75 Minimum
	Thermal Expansion Coefficient	ISO 11369-2	1,86E-6°C ⁻¹	1,03E-6°F ⁻¹
	HDT (Heat Distortion Temperature)	ASTM D648	247°C	476,6°F



Revowrap 225 cure time VS Shore D Hardness



ADVANTAGES

- Fast, Non-invasive repair - does not require hot work
- Repairs done live – no unplanned downtime
- Can Handle complex geometries
- Resistant to Harsh chemicals

INDUSTRIES

- Oil and Gas facilities
- Petrochemical plants
- Chemical plants
- Transmission Pipelines
- Potable water

USES

- Internal Corrosion
- External corrosion
- Mechanical damages
- Weld Anomalies



CARBONTECH

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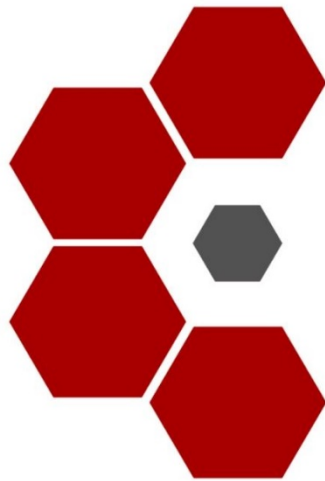
We strive by a zero-failure philosophy and warrant our engineered composite solutions are tested, proven and validated. We vow to provide dependable, responsible and accurate information regarding the capabilities of our systems

www.revowrap.com

PROGRESSIVE COMPOSITE ENGINEERING



SYSTEM:	EQUIPMENT/LINE TAG NO:	DESCRIPTION:	UNIT/ AREA:
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CARBONBTECH COMPOSITE SYSTEMS

CTA016 – Rev 01

MS (Method Statement) for general Revowrap installations



SYSTEM:	EQUIPMENT/LINE TAG NO:	DESCRIPTION:	UNIT/ AREA:
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1. PURPOSE

The purpose of this Method statement is to cover the Pre-works Inspection and Installation of 'Revowrap Wrap' Composite repair systems as well as the QA/QC Inspection. This works is to be carried out in compliance with ISO TS 24817 and ASME PCC2. Design life span to be calculated by Carbontech engineering department for both internal and external corrosion. Due to Internal corrosion works, cannot be guaranteed due the inability to halt the corrosion. Historic corrosion rates may help to better design for specific repair lifetimes. Should a through-wall defect be present an arrest method is to be selected and approved prior to 'Revowrap' installation. Arrest method and size will be taking into consideration when Design Calculations for the Revowrap are carried out.

2. APPLICABILITY

This MS is applicable to the General installation of Revowrap composite repair on piping systems

3. RESPONSIBILITIES

3.1. Site Supervisor: The Site Supervisors shall ensure that the requirements of this Method Statement and associated customer control procedure(s), codes of practice, risk assessments, PPHA and JSA discipline work instructions are complied with fully during all project works.

3.2. Revowrap Installer: It is the duty of each installer to execute his or her individual work assignments in accordance with recognized policies, rules and procedures. If there is any doubt regarding proper methods of executing work, consult with your supervisor or Carbontech composite systems Pty Ltd for specific instructions.

4. GENERAL REQUIREMENTS

This Method Statement outlines the minimum requirements and acceptable procedures required for the installation of Revowrap Composite repair systems.

5. TRAINING AND AWARENESS

All Technicians are trained and certified to Revowrap ® Level one in accordance with ASME PCC2 regulations

6. PROCEDURES

6.1. Pre-Works required Inspection and Documentation

Prior to works commencing it is to be determined if external heating is required for lines that are out of service and an applicable method selected. This is to be done at the Calculation review stage.

Prior to works commencing it is to be determined which risk level is applicable ASME PCC-2 Articles 4.1 (high risk) and 4.2 (low risk)

ASME PCC2 Calculations to be requested from CCS (Carbontech Composite Systems) Engineering, Calculations to be reviewed and approved by the Client.

Should a through wall defect be present, a suitable arrest procedure is to be selected and approved by CCS Engineering

6.2. Surface preparation

Tel: +1.918.813.7882 ● Email: sales@carbontech-americas.com ● www.carbontech-composites.com

7136 S Yale Ave, Suite 300 ● Tulsa ● Oklahoma ● 74136 ● USA



SYSTEM:	EQUIPMENT/LINE TAG NO:	DESCRIPTION:	UNIT/ AREA:
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Carbontech offers a wide variety of composite repair systems that utilize two-part, 100% solid epoxies as well as pre-impregnated systems. In order for the proper bond strengths and adhesion to be achieved, surface preparation is a vital component of the application process.

The recommendations outlined below are required for the proper and advertised bond strengths to be achieved with Revowrap systems. The desired result of the surface preparation, by any of the recommended manners below, is a clean, bare surface with a minimum anchor profile of 3 mills (0.003" or 0.076 mm). Any deviation from the recommended standards may result in a less than advertised bond strength and may have other adverse effects on the performance of the composite system. Surface preparation area to be marked off 50mm wider than the required length of repair. Surface preparation required standards:

6.2.1 Recommended Surface Preparation Standards:

a) NACE 2 or equivalent (e.g. SSPC-SP-10 or SA-2 ½)

Description: Near-White Blast Cleaning – Removal of nearly all mill scale, rust, rust scale, paint, or foreign matter by the use of abrasives propelled through nozzles or by centrifugal wheels, to the degree hereafter specified. A Near-White Blast Cleaned Surface Finish is defined as one from which all oil, grease, dirt, mill scale, rust, corrosion products, oxides, paint or other foreign matter have been completely removed from the surface except for very light shadows, very slight streaks or slight discolorations caused by rust stain, mill scale oxides, or light, tight residues of paint or coating that may remain. At least 95 percent of each square inch of surface area shall be free of all visible residues, and the remainder shall be limited to the light discoloration mentioned above

b) St 3 or equivalent (e.g. SSPC –SP-3)

Description: Power Tool Cleaning – Removal of all rust scale, mill scale, loose paint, and loose rust to the degree specified by power wire brushes, power impact tools, power grinders, power sanders or by a combination of these methods. The substrate should have a pronounced metallic sheen and also be free of oil, grease, dirt, soil, salts and other contaminants. Surface should not be buffed or polished smooth. Substrate to be wiped after surface preparation is completed using SSPC-SP-1 procedure

c) St 2 or equivalent (e.g. SSPC-SP-2)

Description: Hand tool Cleaning - Tool Cleaning – Removal of all rust scale, mill scale, loose rust and loose paint to the degree specified by hand wire brushing, hand sanding, hand scraping, hand chipping or other hand impact tools or by a combination of these methods. The substrate should have a faint metallic sheen and also be free of oil, grease, dust, soil, salts and other contaminants. Surface should not be buffed or polished smooth.

Acronym Glossary:

- ◆ NACE – National Association of Corrosion Engineers
- ◆ St/Sa – Swedish Standard
- ◆ SSPC – Steel Structures Painting Council

References:



SYSTEM:	EQUIPMENT/LINE TAG NO:	DESCRIPTION:	UNIT/ AREA:
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Descriptions obtained from the website: <http://www.corrosion.com/prep.asp#NACE%201>.

6.2.2 Surface Preparation Approval

Once surface preparation has been completed to the applicable standard installation is to be placed on a hold point. Client or independent inspection QA/QC is to approve the surface preparation and record data on the Carbontech CTA017 rev1 document.

*NOTE: Flapper disks are not to be used for surface preparation

6.3 Revowrap Site Environmental Parameters

Revowrap Site Environmental Parameters- 'Revowrap site Environmental parameters are to be measured and recorded steel surface to be >3°C above dew point. Record parameters in Carbontech CTA017 rev1 document.

6.4 Revowrap Installation

Prior to 'Revowrap installation 'Revowrap material Data to be recorded Carbontech CTA017 rev1 document. Repair may only be completed by a level 1 Technician

6.4.1 Priming the pipe

The primer acts as an insulator between the carbon and the host pipe, evens out pits and rough spots for even load transfer, and insures good adhesion. Pour the Primer Hardener B into Resin, Container A.

Mix thoroughly using the stir stick or mixer provided attached. Do not use power drill to mix resins as this causes excessive aeration/Bubbling in the resin. Mix for a minimum of 3 minutes or until the colour is even and no marbling is present. Make sure that all hardener is mixed thoroughly into the resin.

Using one of the brushes supplied, apply a thin layer of primer evenly over the area that has been prepared (approximately 20 to 40 mils thick).

Use this material to fill voids, cracks and other surface irregularities so that there will be no voids between the carbon cloth and the host substrate. For severe pitting where wall loss is significant, use Revowrap Filler Putty to fill the pits. Do not apply thicker than necessary on smooth areas. Doing so may cause the cloth to slip and misalignment during wrapping.

6.4.2 Wetting the Carbon Fabric

Lay out the carbon cloth on a clean, non-porous surface such as visqueen or a non-stick surface. Pour the Wetout Hardener B into the Wetout Resin, Container A.

Mix thoroughly using the stir stick or mixer provided attached. Do not use power drill to mix resins as this causes excessive aeration/Bubbling in the resin. Mix for a minimum of 3



SYSTEM:	EQUIPMENT/LINE TAG NO:	DESCRIPTION:	UNIT/ AREA:
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minutes or until the colour is even and no marbling is present. Make sure that all hardener is mixed thoroughly into the resin.

Pour equal amounts of the mixed Wetout epoxy over the piece(s) of carbon cloth. Using the roller or brush provided, distribute the resin evenly over the entire carbon cloth insuring that all areas are wetted. Finger massage may be used to accelerate the wet-out procedure (*Be sure to wear solvent resistant medical or chemical gloves at all times)

Flip the cloth over and brush again on the opposite side. Fold the carbon like you would book wallpaper. This will insure that the carbon is completely and evenly wetted. You may also roll the carbon onto a cardboard core to use as you unroll the carbon onto the pipe.

6.4.3 Wrapping a Spiral Wrap

Begin by making one complete wrap around the pipe with the carbon fabric at the end point of the repair section. With the next wrap, begin spiralling the fabric by overlapping the previous wrap by 50% of the width of the fabric. Continue in this manner until you reach the end of the repair section. Once at the end of the repair section, repeat the procedure by starting on the end you finished at and going back over your first layer of wrap

6.4.4 Wrapping a Tee wrap

Tee Kits have specially cut pieces to fit a size of Tee. Begin with the wider piece of cloth (diaper) that is about 3 to 4 times as long as the pipe is wide. Centre this cloth on the straight side of the Tee and the wrap both ends around the body of the Tee and up the sides of the side outlet of the Tee. (You should notch the cloth at the base of the side outlet, so that this section can be laid smooth.)

Next you will be making a spiral wrap on each leg of the Tee working toward the middle. Begin by spiral wrapping as you would in the instructions for a spiral wrap above. When you reach the Tee, the last wrap should allow you to make one wrap around the opposite side of the Tee. At this time, there should be no bare pipe showing. Repeat procedure starting with "diaper" then spiral wrap each leg.

7. Force Curing Wrap

Force curing of composite materials are required in certain scenarios where the available heat transmission from ambient and piping temperatures do not meet the required minimum curing temperature of the composite material.

- High temp Pipelines that are wrapped out of service
- Cold ambient temperatures
- Low temperature operating pipelines with high design temperatures

I. For Revowrap 110:

Tel: +1.918.813.7882 ● Email: sales@carbontech-americas.com ● www.carbontech-composites.com
7136 S Yale Ave, Suite 300 ● Tulsa ● Oklahoma ● 74136 ● USA



SYSTEM:	EQUIPMENT/LINE TAG NO:	DESCRIPTION:	UNIT/ AREA:
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110 is an ambient cure system but requires a minimum cure temperature of 4°C please refer to the Revowrap Cure Graph for more

II. For Revowrap 185:

Revoshrink needs to be applied in both low and elevated temperatures, (the Revoshrink consolidates the resin systems from migrating to the bottom and protects external heating equipment i.e Revomat from resin damage)

Place the Revomat over the wrapped pipe in either a spiral or circumferential layout

Revowrap 185 requires 140°C at 8 hours

After 8 hours a hardness test needs to be performed and the wrap needs to have achieved a minimum of 74 Shore D hardness.

If the hardness is not achieved a further 4 hours of exposure is required until the hardness is achieved.

At all times during the force curing process there needs to be a level 1 'Revowrap' technician present

III. For Revowrap 225:

Needs to be applied in both low and elevated temperatures, (the Revoshrink consolidates the resin systems from migrating to the bottom and protects external heating equipment i.e Revomat from resin damage)

Place the Revomat over the wrapped pipe in either a spiral or circumferential layout

Revowrap 225 requires 140°C at 8 hours

After 8 hours a hardness test needs to be performed and the wrap needs to have achieved a minimum of 74 Shore D hardness.

If the hardness is not achieved a further 4 hours of exposure is required until the hardness is achieved.

At all times during the force curing process there needs to be a level 1 'Revowrap technician present

8. Post Cure inspection

Approved Curing procedure to be selected for Revowrap 110,185, and 225 Resin systems.

Post cure inspection to be carried out to conform Shore D Hardness.

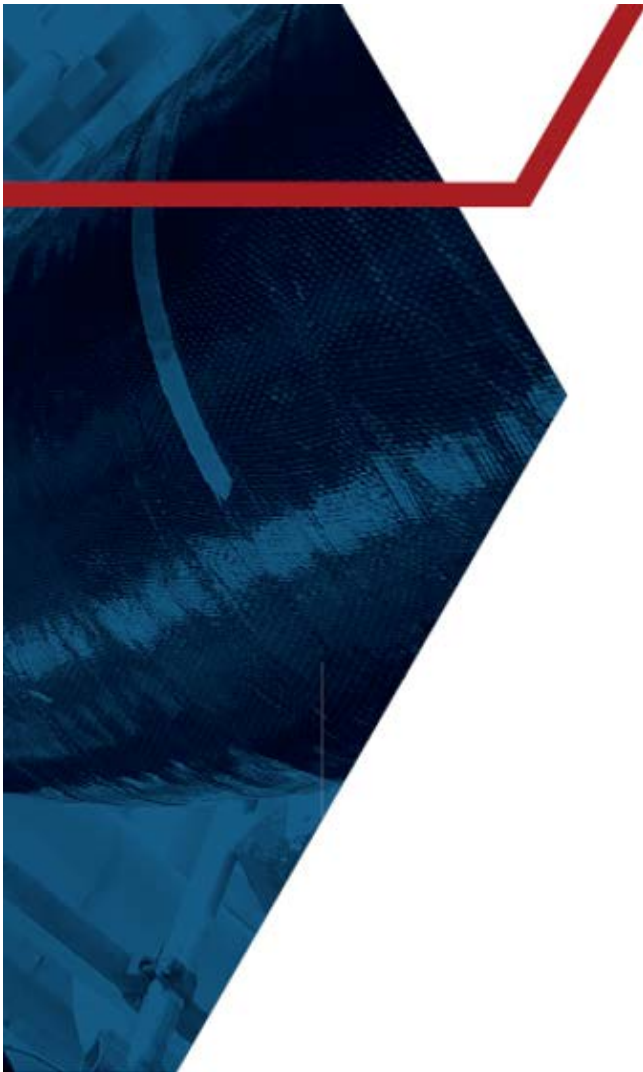
Minimum hardness for all 'Revowrap'® systems is 74 Shore D. Once this is reached, the repair has completed a sufficient cure cycle is a hold point for inspection to witness final Hardness test, data is to be recorded on Carbontech CTA017rev1 document.





#	End User	Country
1	Petamamina EP aAsset 3	INDONESIA
2	NSL	SINGAPORE
3	Total Petrochemical	SINGAPORE
4	Lubrizol Singapore	SINGAPORE
8	PTT	THAILAND
14	Petamina Hulu	INDONESIA
15	Singapore Refinery Corp	SINGAPORE
16	SEPL (Brunei)	SINGAPORE
33	OSF Pertamina	INDONESIA
37	Petamina	INDONESIA
47	Pupuk Sriwijaya	INDONESIA
48	Medco	INDONESIA
49	Petamina Hulu Rokan	INDONESIA
50	Petronas	MALAYSIA
54	Shell - SAPREF	South Africa
55	Salalah Methanol Oman	Oman
56	ORPIC Oman	Oman
57	KPC Kurdistan	Iraq-Kurdistan
58	BP Oman	Oman
60	Petrobel/GASCO (Shell)	Egypt
61	OPCO	Sudan
63	BAPCO	Bahrain
64	Tatweer	Bahrain
65	Akakus Oil	Libya
66	CCED	Oman
67	Pharonic PHPC	Egypt
68	Torishima	UAE
1	PetroEnergy	Sudan
2	KPC	Iraq-Kurdistan
3	KAR	Iraq-Kurdistan
4	OQ Oman	Oman
5	UMGENI PMB	SA
6	ESKOM GROOTVLEI	SA
7	UMGENI HOWICK	SA
8	UMGENI	SA
9	CORROCOAT SA	SA
10	Exxon Mobil	SINGAPORE
11	KANSAI PLASCON	SA
12	SAPREF IVS	SA
13	SAPPI	SA
14	NAE	NIGERIA
15	SAB	SOUTH AFRICA
16	SASOL	KAZ
17	ESKOM	SOUTH AFRICA
18	UDT - national technical inspection authority	Poland
19	GAZ SYSTEM, national operator of natural gas transmission	Poland
20	Refinery BAZAN	Israel
21	TSO UA - national operator of natural gas in Ukraine	Ukraine

22	TANAP - Trans Anatolian Natural gas Pipeline	Turkey
23	TRANS GAZ Romania - national operator of natural gas	Romania
24	MERO - operator of crude oil pipelines	Czech Republic
25	BAZAN refinery	Israel
26	Namtvædt - Equinor Refinery / Off-shore	Norway
27	Scanseal - Preem Refinery	Sweden
28	HSOS - AlcoEnergy Bioplant	Netherlands
29	HSOS - Off-shore TAQA / Wintershall	Netherlands
30	HSOS - Refineries Shell / ExxonMobil	Netherlands
31	HSOS - Petrochemical LyondellBasell / Hexion / Air Liquide / DOW / Shin-Etsu	Netherlands
32	HSOS - Shell	Germany
33	Repco - Total	France
34	HSOS - Tank farm	Portugal
35	Bunge	Canada
36	Delaware City Refining Wastewater Complex	USA
37	Delaware City Refining	USA
38	ADM Cedar Rapids	USA
39	Citgo	USA
40	DCR	USA
41	Imperial Oil	Canada
42	Delaware City Refinery	USA
43	CF Industries	Canada
44	Holly Frontier	USA
45	ADM	USA
46	BP	Trinidad and Tobago
47	CNRL	Canada
48	ONEOK NGL – Medford Fractionator	USA
49	Monroe	USA
50	Nutrien	Canada
51	HF Sinclair	USA
52	0	Venezuela
53	Afton Chemical	USA
54	HollyFrontier	USA
55	Repsol	Ecuador
56	Monroe Energy	USA
57	Georgia Pacific	USA
58	Emerald Energy	Colombia



	Revowrap 110 Qualification Test Report	Ref: Edition: Date:
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	Name	Date	Signature
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Contents

Carbontech Composite Systems – Revowrap 110 Qualification Test Report	2
INTRODUCTION:	2
SUMMARY OF REVOWRAP 110 QUALIFICATION TEST RESULTS:	3
DESCRIPTION OF COMPOSITE REPAIR SYSTEM:	3
QUALIFICATION TEST METHOD MATRIX:	4
SECTION 1 - DATA FOR REPAIR LAMINATES:	4
1.1 LAMINATE TENSILE TEST DATA	4
1.2 HARDNESS OF REPAIR LAMINATE	5
1.3 IN-PLANE SHEAR MODULUS TEST DATA	6
1.4 COMPRESSIVE MODULUS TEST DATA FOR FILLER PUTTY	6
SECTION 2 - THERMAL CHARACTERISTICS OF THE REPAIR SYSTEMS:	7
2.1 THERMAL EXPANSION COEFFICIENT	7
2.2 HEAT DISTORTION TEMPERATURE	7
NOTES REGARDING CURING OF THE REPAIR SYSTEM	7
SECTION 3 - INTERFACE ADHESION STRENGTH:	8
SECTION 4 - SHORT-TERM SURVIVAL TESTING:	10
SECTION 5 – TESTING FOR THROUGH WALL DEFECTS:	11
5.1 TOUGHNESS PARAMETER (ENERGY RELEASE RATE) TESTING	11
5.2 IMPACT PERFORMANCE TESTING	13
CONCLUSIONS:	13
References	14
APPENDICES	16
APPENDIX 1 – Reinforcement Fabric TDS:	16
APPENDIX 2 – Resin System TDS:	17
APPENDIX 3 – Tensile Test Data:	20
APPENDIX 4 – In Plane Shear Modulus Test Data:	24
APPENDIX 5 – Compressive Modulus of Filler Putty:	25
APPENDIX 6 – HDT Test Data:	33
APPENDIX 7 – Interface Adhesion Test Report:	36
APPENDIX 8 – Short Term Survival Test Details and Test Data	45
APPENDIX 9 – Toughness Parameter Testing Report	47



Carbontech Composite Systems – Revowrap 110 Qualification Test Report.

INTRODUCTION:

The purpose of this document is to report the methodology used and qualification test data obtained by Carbontech Composite Systems when their carbon fibre reinforced epoxy composite repair systems were tested according to the qualification requirements of the standards ASME PCC2-2015 [1] and ISO 24817-2015 [2]. The report details full qualification test data for the company's Revowrap 110 repair system as well as presenting thermal test data for the complimentary repair systems Revowrap 185 and Revowrap 225 that are designed for elevated operating temperatures.

Following the presentation of a summary of all the test data, the composite repair systems are briefly described and a matrix is presented showing the test standards selected according to the requirements of the ASME and ISO standards referenced above. Testing was then divided into the following sections, following the order typically used by the ASME and ISO standards referenced above.

- **SECTION 1 – DATA FOR THE REPAIR LAMINATES** – The repair system tensile properties were examined in circumferential and axial directions. In plane shear modulus, compressive modulus of the filler putty (load transfer material) and Poisson's ration were also defined.
- **SECTION 2 – THERMAL CHARACTERISTICS OF THE REPAIR SYSTEMS** – The heat distortion temperatures (HDT) of the 3 Revowrap repair system resins Revowrap 110, 185 and 225 were examined and the coefficient of thermal expansion (CTE) of the Revowrap 110 repair system was determined.
- **SECTION 3 – INTERFACE ADHESION STRENGTH** – Lap shear testing was carried out to demonstrate that an adhesive bond of adequate strength and durability for a Revowrap 110 repair system laminate can be achieved. Testing was carried out on carbon steel substrates with sandblasting, Bristle Blaster® and hand tool surface preparations examined.
- **SECTION 4 – SHORT TERM SURVIVAL TESTING** - A performance test described as the short-term pipe spool survival test was carried out to determine the maximum % wall loss for a non through wall defect that can be repaired with the Revowrap 110 repair system. An 85% wall loss defect was successfully repaired, and pressure tested to 21 MPa.
- **SECTION 5 – TESTING FOR THROUGH WALL DEFECTS** – In this section multiple through wall defects were repaired and pressure tested to establish a toughness parameter (energy release rate) and to establish that the Revowrap 110 repair system could withstand a 5J impact.



SUMMARY OF REVOWRAP 110 QUALIFICATION TEST RESULTS:

ISO TS24817 and ASME PCC2 REPAIR SYSTEM QUALIFICATION DATA			
Property	Revowrap 110		Test Method
	SI	Imperial	
Ply Thickness (mm, inches)	0.4	0.01575	ASTM D3039
Tensile Modulus – Hoop (GPa, ksi)	48.8	7078	ASTM D3039
Tensile Modulus – Axial (GPa, ksi)	41.0	5947	ASTM D3039
Tensile Strength – Hoop (MPa, ksi)	568	82.4	ASTM D3039
Tensile Strength – Axial (MPa, ksi)	229	33.2	ASTM D3039
Tensile Strain to Failure	1.1%		ASTM D3039
In Plane Shear Modulus (GPa, ksi)	1.6	232	ASTM D5379
Compressive Modulus – Filler Putty (GPa, ksi)	2.55	369.8	ASTM D695
Poisson's Ratio	0.33		ASTM D3039
CTE (mm/mm/°C, in/in/°F)	1.45x10 ⁻⁶	8.06x10 ⁻⁷	ASTM E831
Heat Distortion Temperature (°C, °F)	124	255	ASTM D648-07
Shore D Hardness	92		ASTM D2583
Lap Shear Strength - SA2.5 (MPa, ksi)	14.1	2.05	ASTM D3165
Lap Shear Strength - Bristle Blaster® (MPa, ksi)	7.71	1.12	ASTM D3165
Lap Shear Strength - Hand Sanded (MPa, ksi)	5.86	0.85	ASTM D3165
Short Term Survival Test	Pass – pressure tested to 21MPa		ASME PCC2 – III, ISO 24817 Annex C
Toughness Parameter (J/m ² , in-lb/in ²)	194.7	1.11	ASME PCC2 – IV, ISO 24817 Annex D
Impact Performance Test	Pass		ASME PCC2 – VI, ISO 24817 Annex F

Table 1: Summary table detailing repair system qualification data required by ISO 24817 and ASME PCC2.

DESCRIPTION OF COMPOSITE REPAIR SYSTEM:

The Revowrap composite repair systems consist of a plain weave 3K carbon fibre reinforcement tape that is saturated with a two-component epoxy resin matrix. The reinforcement tape is available in several product widths from 50mm to 330mm. Additional details can be found in Appendix 1 – Fabric TDS. Revowrap repair systems use different epoxy matrix systems – each system being formulated for a specific working temperature range. Revowrap 110 is the core repair system product, with Revowrap 185 and Revowrap 225 available for elevated operating temperatures. Additional resin system details can be found in Appendix 2 – Resin System TDS.

DESCRIPTION OF COMPOSITE REPAIR SYSTEM						
Property	Revowrap 110		Revowrap 185		Revowrap 225	
	SI	Imperial	SI	Imperial	SI	Imperial
Epoxy Colour After Mixing	Orange		Blue		Red	
Max Service Temperature – Non-leaking Defects (°C, °F)	109	228.2	211	411.8	233	451.4
Minimum Application Temperature	9	48.2	18	64.4	23	73.4
Cure Time at 30°C (86°F)	8 hours		Requires post curing		Requires post curing	

Table 2: Description of the composite repair system appearances and service temperatures

QUALIFICATION TEST METHOD MATRIX:

ASME PCC2-2015 and ISO TS 24817-2015 standards were reviewed and test methods applicable to both standards were selected. Test methods selected by Carbontech are described in the table below. All composite laminate samples and sample pipe wraps required for testing were prepared by Carbontech engineers and technicians using the same processes and curing conditions that will be used on site or following the specific methodology described in the composite repair standards themselves.

Laminate testing, HDT testing, lap shear testing and toughness parameter testing from sections 1, 2, 3 and 5 was carried out by Aerosud of Pretoria, South Africa. One Eighty Materials (PTY) Ltd of Cape Town, South Africa (a nationally accredited test laboratory, the most widely scoped lab in Africa and holder of SANAS accreditation) were responsible for Shore hardness testing, CTE measurements and pressure testing the short term survival test and impact test spools from section 4 and 5.

QUALIFICATION TEST METHOD MATRIX			
	ASME PCC2-2015	ISO TS 24817-2015	Selected Test Method
Ply Thickness, Tensile Strength/Modulus & Poisson's Ratio	ASTM D3039	ISO527-1, 527-4 or ASTM D3039	ASTM D3039 [3]
In Plane Shear Modulus	ASTM D5379	ASTM D5379	ASTM D5379 [4]
Compressive Modulus	ASTM D695	N/A	ASTM D695
Shore D Hardness	ASTM D2583	ASTM D2583	ASTM D2583
Thermal Expansion Coefficient	ASTM E831	ASTM E831	ASTM E831
Heat Distortion Temperature	ASTM D648-07	ASTM D648-07	ASTM D648-07
Lap Shear Adhesion Strength	ASTM D3165	ASTM D3165	ASTM D3165 [5]
Short Term Survival Test	APPENDIX III [7]	ANNEX C [8]	IDENTICAL METHOD
Toughness Parameter, Energy Release Rate	APPENDIX IV [9]	ANNEX D [10]	IDENTICAL METHOD
Impact Performance	APPENDIX VI [11]	ANNEX F [12]	IDENTICAL METHOD

Table 3: Comparison of the test standards required by PCC2 and TS 24817 standards, and details of the test standards selected by Carbontech

SECTION 1 - DATA FOR REPAIR LAMINATES:

1.1 LAMINATE TENSILE TEST DATA

An internal Carbontech Product Qualification Procedure for tensile testing was defined to confirm the testing required and deliverables to be provided by the test laboratory. Samples were prepared according to ASTM D3039 and tested by Aerosud of Pretoria, South Africa. Laminate tensile testing results are summarized below with additional details in Appendix 3.

PLY THICKNESS AND LAMINATE TENSILE TEST DATA

Property	Revowrap 110		Test Method
	SI	Imperial	
Ply Thickness (mm, inches)	0.4	0.01575	ASTM D3039
Tensile Modulus – Hoop (GPa, ksi)	48.8	7078	ASTM D3039
Tensile Modulus – Axial (GPa, ksi)	41	5947	ASTM D3039
Tensile Strength – Hoop (MPa, ksi)	568	82.4	ASTM D3039
Tensile Strength – Axial (MPa, ksi)	229	33.2	ASTM D3039
Tensile Strain to Failure	1.1%		ASTM D3039
Poisson's Ratio	0.33		ASTM D3039

Table 4: Summary of the Revowrap 110 laminate test data

1.2 HARDNESS OF REPAIR LAMINATE

Test laminates of 5mm thickness and size 100mm long by 100mm wide were prepared for Shore D hardness testing in accordance with ASTM D2583. Five measurements were taken from across the surface of the sample laminate.

SHORE D HARDNESS TEST DATA

Sample number	Revowrap 110		Test Method
	Measured hardness	Unit	
1	92	°D	ASTM D2583
2	92	°D	ASTM D2583
3	93	°D	ASTM D2583
4	92	°D	ASTM D2583
5	93	°D	ASTM D2583
Mean hardness	92	°D	

Table 5: Shore D hardness test results

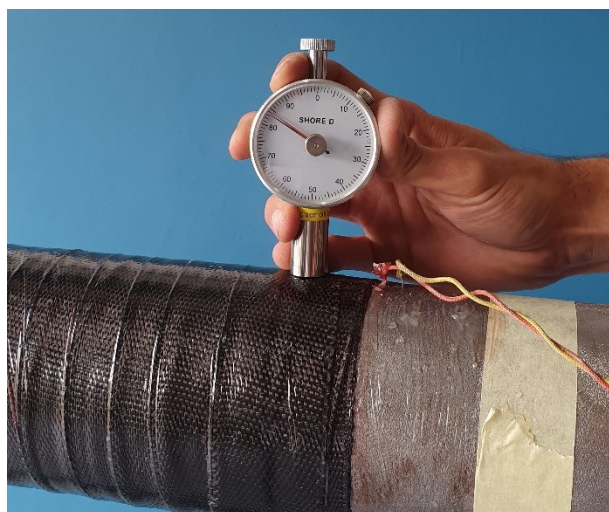


Figure 1 showing a sample hardness test

1.3 IN-PLANE SHEAR MODULUS TEST DATA

Test laminates were produced according to the specifications of the ASTM D5379 test standard. The samples were made up in a silicone mould specifically cast for this purpose. The mould has a matching counter mould that is placed over the samples and closed with pressure to ensure good compaction of the test laminate. The use of this matched mould method ensures a clean and consistent laminate section in the shear area. Once fully cured, the samples were demoulded, installed in a shear testing jig and tested.

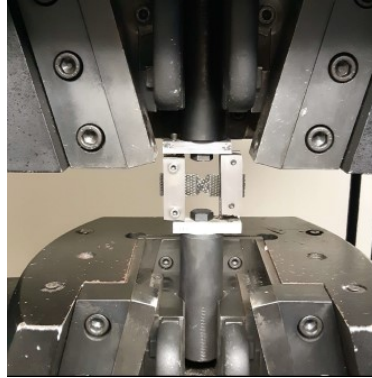


Figure 2: In plane shear modulus test set up

IN PLANE SHEAR MODULUS TEST DATA			
	Revowrap 110		
Property	SI	Imperial	Test Method
In Plane Shear Modulus (GPa, ksi)	1.6	232	ASTM D5379

Table 6: Summary of in plane shear modulus results

1.4 COMPRESSIVE MODULUS TEST DATA FOR FILLER PUTTY

The ASME PCC2-2015 standard requires that the compressive modulus of any filler putty (load transfer materials used to profile the pipe surface before a composite repair system is added as in the case of the short term survival test defect in section 4) is recorded as part of the qualification testing. No minimum value is specified

To ensure the production of identical test samples, Carbontech machined and aluminium pattern to cast a silicon elastomer mould for the compression test samples defined in ASTM D695. Samples were moulded, cured, and then tested by Aerosud. Test results are summarised below with the detailed test report included in Appendix 5.

FILLER PUTTY COMPRESSIVE MODULUS TEST DATA			
	Revowrap 110		
Property	SI	Imperial	Test Method

Compressive Modulus – Filler Putty (GPa, ksi)	2.55	369.8	ASTM D695
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SECTION 2 - THERMAL CHARACTERISTICS OF THE REPAIR SYSTEMS:

2.1 THERMAL EXPANSION COEFFICIENT

The thermal expansion coefficient (CTE) of the Revowrap 110 repair system was tested according to ASTM E831. Small samples of cured repair laminated were analysed with testing carried out in both the circumferential and axial directions. As expected for a carbon fibre reinforced epoxy composite, the measured values for CTE were extremely small with similar results recorded in both directions. The CTE value determined is shown in the table below.

2.2 HEAT DISTORTION TEMPERATURE

Heat distortion temperature (HDT) testing was also carried out by Aerosud to determine the temperature at which the repair laminate can no longer support a specified load. HDT values for 3 different Revowrap resin systems are shown in the table below. Graphs detailing test datapoints are attached to this report in Appendix 6.

THERMAL TEST DATA							
	Revowrap 110		Revowrap 185		Revowrap 225		
Property	SI	Imperial	SI	Imperial	SI	Imperial	Test Method
CTE (mm/mm/°C, in/in/°F)	1.45x10 ⁻⁶	8.06x10 ⁻⁷	1.88x10 ⁻⁶	1.04x10 ⁻⁶	1.86x10 ⁻⁶	1.03x10 ⁻⁶	ASTM E381
HDT (°C, °F)	124	255	226	438	247	476	ASTM D648-07

Table 7: Summary of thermal test data

NOTES REGARDING CURING OF THE REPAIR SYSTEM

Recognising that field applied composite repair failures often occur due to inadequate curing of the resin matrix, Carbontech have also developed the Revomat system to provide an intelligent post curing system for composite pipe repairs.

Comprising durable, light weight, flexible, temperature controlled silicone blankets and an intelligent recording system, Revomat unlocks the best mechanical properties & chemical resistance performance of the laminate by delivering the specific cure cycles necessary in order to fully complete the cross-linking of the epoxy matrix.

Revomat solutions are available on request and are typically used in very low ambient temperatures or to provide the optimum curing of Carbontech's elevated temperature repair systems Revowrap 185 and Revowrap 225 if the pipe process temperature is not sufficient for full curing. In the case where the time to execute is limited, the Revomat is programmed to force cure the Revowrap 110 system in a significantly shorter time.

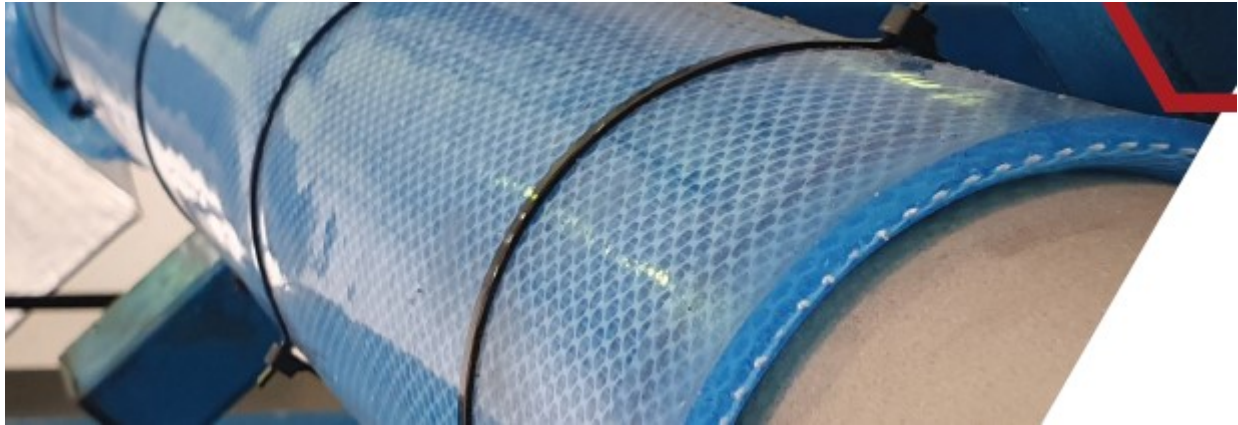


Figure 3: Revomat temperature-controlled silicon blanket installed on composite repair for intelligent post curing

SECTION 3 - INTERFACE ADHESION STRENGTH:

The following test section details the testing carried out to demonstrate that an adhesive bond of adequate strength and durability for a Revowrap 110 repair system laminate can be achieved. An internal Carbontech Product Qualification Procedure for lap shear testing was defined to confirm the testing required and deliverables to be provided by the test laboratory. Samples were prepared according to ASTM D3165 and tested by Aerosud of Pretoria, South Africa.

To ensure the correct size of the bond area and alignment of the steel tabs used for the test samples a machined aluminium pattern was used to cast a silicon elastomer alignment jig. The samples were produced as per the geometry illustrated below.

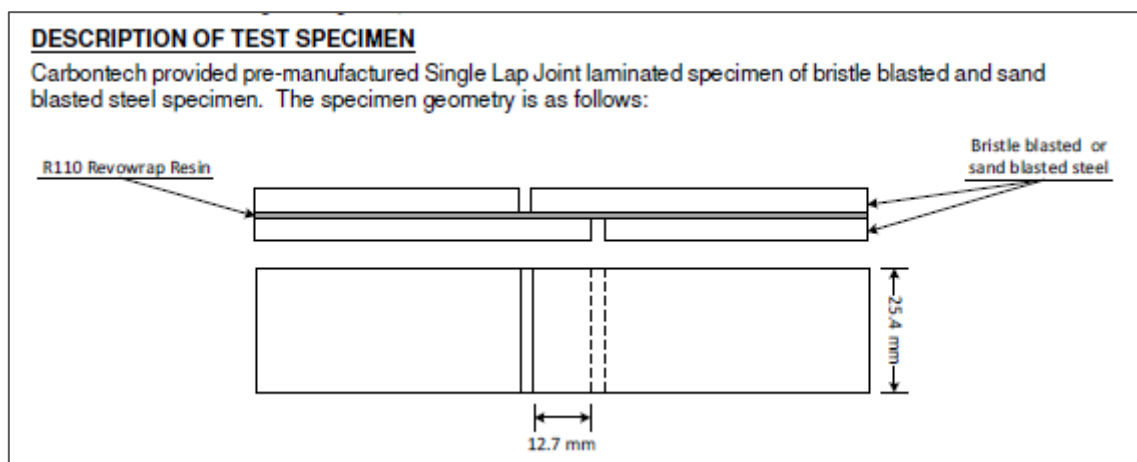


Figure 4: lap shear sample format and geometry

Carbon steel substrates were used for the lap shear testing with two different surface preparations applied to the steel substrate tabs. One set of test samples was prepared by sandblasting to produce a minimum surface roughness profile of 80 micrometers and a Sa 2.5 surface, whilst the second set of samples was prepared using a Monti Bristle Blaster® to clean the surface and provide a minimum 75 micrometer surface profile (i.e. SSPC-SP3 (St-3) surface preparation). Lap shear testing results are summarized in the table below with further details in Appendix 7.

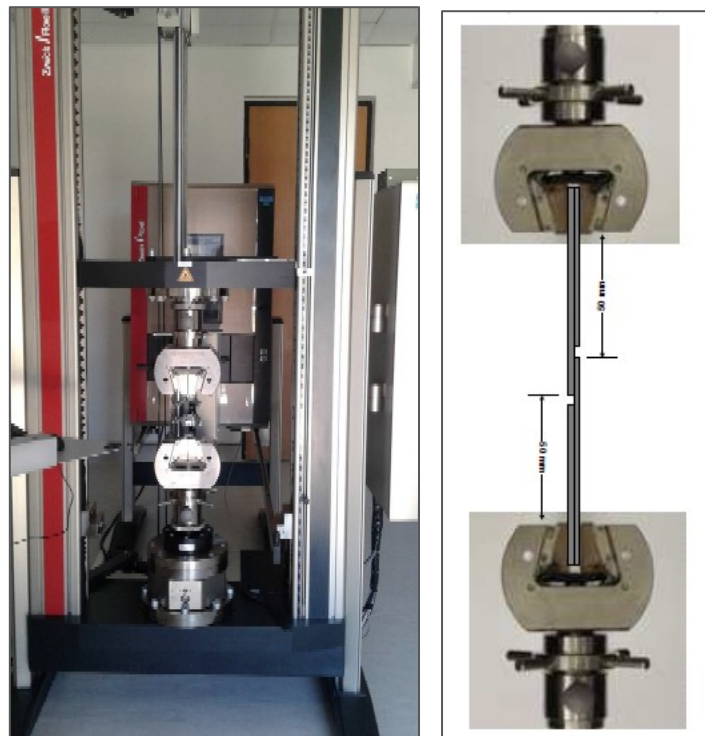


Figure 5: Revowrap 110 lap shear sample under test and sample set up illustration

INTERFACE ADHESION STRENGTH TEST DATA			
	Revowrap 110		
Property	SI	Imperial	Test Method
Lap shear strength – Sandblasted steel (MPa, ksi)	14.1	2.05	ASTM D3165
Lap shear strength – Bristle Blast steel (MPa, ksi)	7.71	1.12	ASTM D3165

Table 8: Summary of lap shear test data

In both cases, the Revowrap 110 repair system demonstrated an adhesive bond stronger than the 5 MPa value prescribed in the ISO TS 24917-2015 standard.

Carbontech recognizes the value of long term and elevated temperature lap shear test results in providing additional input to design calculations, particularly for higher temperature repairs. The company is currently preparing to carry out additional testing in this regard.

SECTION 4 - SHORT-TERM SURVIVAL TESTING:

To determine the maximum percentage of wall loss that can safely be repaired by the composite repair system in a non-through wall defect scenario, a performance test described as the short-term pipe spool survival test was carried out. The test method described by both ASME PCC2-2015 and ISO 24817-2015 is identical.

A test pressure and repair thickness were defined based on the calculations in the standards, an 85% wall loss defect was machined into the 6" SCH40 pipe based on recommended dimensions in the standards. Further details of the test spool and the calculations used are included in Appendix 8.

The pipe test spool was then sandblasted to produce a Sa 2.5 surface and a surface profile of at least 80 microns before an Revofill putty was used to profile the defect and a Revowrap 110 repair was applied.

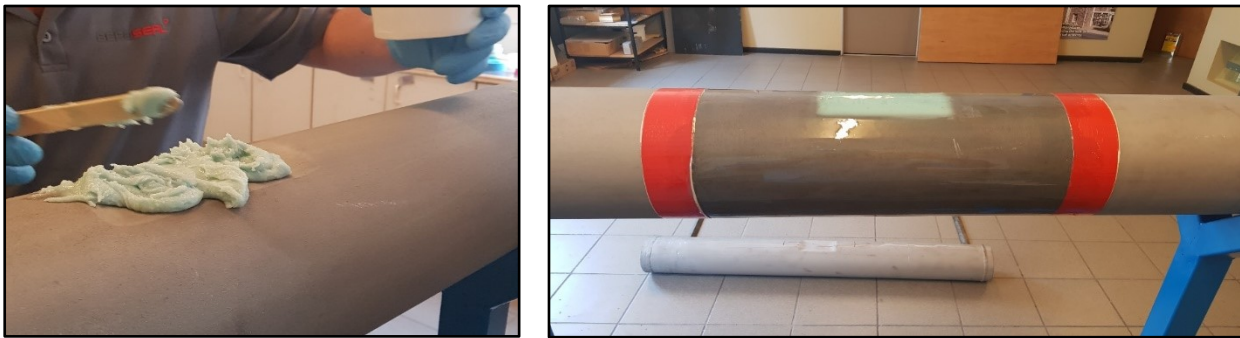


Figure and 7: Epoxy profiling putty being applied and then profiled in the defect section of the short-term survival test pipe spool



Figure 8: 85% wall loss defect repaired with 10 layers of Revowrap 110 ready for short term survival test

SHORT-TERM SURVIVAL TEST RESULTS		
	Revowrap 110	
Property	SI	Imperial
Outer diameter of test pipe spool (mm, inches)	168.3	6.625
Original wall thickness of test pipe spool (mm, inches)	7.11	0.2795
% wall loss in machined defect section	85	
Yield strength of the test pipe spool (MPa, ksi)	241	34.95
Number of layers of Revowrap 110 used for test	10 layers	
Test pressure required (MPa, ksi)	20.3	2.94
Maximum test pressure (MPa, ksi)	21.0	3.05

Table 9: Summary of short-term survival test parameters and results

The 10 layer Revowrap 110 repair system was successfully pressure tested as above, validating the performance of the repair system for non-through wall defects with wall loss up to a maximum of 85% of the original pipe wall thickness.

SECTION 5 – TESTING FOR THROUGH WALL DEFECTS:

5.1 TOUGHNESS PARAMETER (ENERGY RELEASE RATE) TESTING

Using the test methodology described in Appendix IV and Annex D of the PCC2 and 24817 standards, Carbontech defined an internal Product Qualification Criteria for Toughness Parameter testing. 10 test pipes were prepared with a range of different sized circular through wall defects for testing by Aerosud.

All the test pipes, 4" diameter standard spools of ASTM 106 Grade B carbon steel, were repaired using an identical repair process and four layers of the Revowrap 110 repair system, before the pipe repairs were cured, and pressure testing with water was carried out. All 10 of the pipes tested exhibited an identical repair failure mechanism, delamination of the composite repair and leakage of the test fluid at the repair edge after 1-3 minutes.



Figures 9,10 and 11: 25mm and 15mm defects before repair, testing of repaired spool

Test pipe details and leakage pressures are recorded below along with a summary of the Toughness Parameter (Energy Release Rate – Y_{LCL}) calculation. Further details of the testing carried out are included in the report in Appendix 9

TOUGHNESS PARAMETER TEST RESULTS							
Revowrap 110							
Test No.	Pipe ID	Defect dia (mm)	Failure pressure (MPa)	$A(d_i)$	Y_{Mean}	Variance	Y_{LCL} (J/m ²)
1	R110-10TW-101	10	9.31	0.677	337.03	1.96	194.7
2	R110-15TW-105	15	8.92	0.420			
3	R110-15TW-106	15	11.06	0.420			
4	R110-15TW-107	15	8.95	0.420			
5	R110-20TW-108	20	2.96	0.289			
6	R110-20TW-109	20	5.58	0.289			
7	R110-20TW-110	20	5.01	0.289			
8	R110-25TW-100	25	4.36	0.209			
9	R110-25TW-102	25	4.71	0.209			
10	R110-25TW-104	25	4.22	0.209			

Table 10: Summary of pipe IDs, defect sizes and test results for Revowrap 110 toughness parameter testing

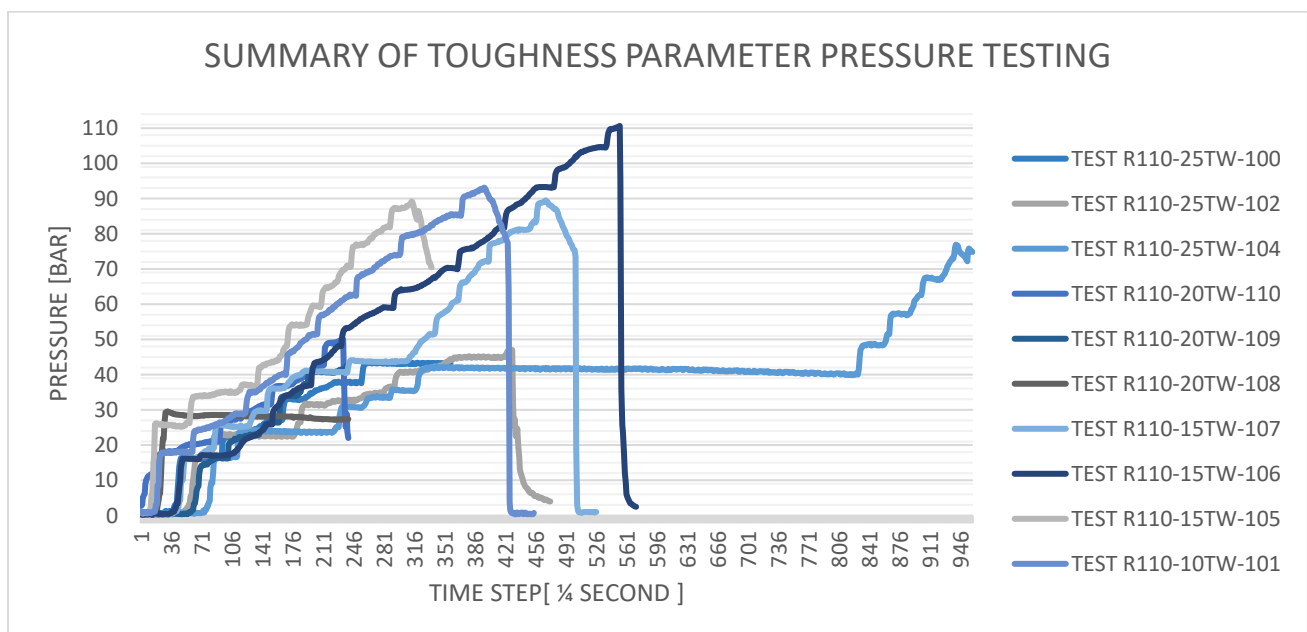


Figure 12 showing the results of pressure testing

Pressure testing of the tubes repaired with the Revowrap 110 repair system demonstrated relatively low variance in the failure pressures and a toughness parameter value – Y_{LCL} – of 194.7 J/m² was calculated.

5.2 IMPACT PERFORMANCE TESTING

The testing carried out for this section was intended to ensure that repair performance is not adversely impacted by, and that the repair system is capable of withstanding, a low velocity (5J) impact from such an event as a dropped hand tool.

In line with the methodologies described in PCC2 and 24817, Carbontech prepared a test specimen and repair identical to one of those used for toughness parameter testing. In this case a 20mm circular defect was used and a 4 layer Revowrap 110 repair.

The empty and dry test pipe was positioned with the defect at the 12 o'clock position and a 0.5kg mass with a 12.5mm hemispherical indenter was dropped from a height of 1m so as to strike the repair directly over the circular 20mm defect.

The test pipe was then pressurized with water using the same process as used for toughness parameter testing and the pressure at which delamination of the repair and leakage of the test fluid occurred was recorded.

The pressure test result below confirms that the repair system Revowrap 110 is capable of withstanding the test impact defined by the ASME PCC2-2015 and ISO 24917-2015 standards.

IMPACT PERFORMANCE TEST RESULTS		
	Revowrap 110	
Property	SI	Imperial
Size of circular defect (mm, inches)	20	0.787
Failure pressure required – $A(d_i)\sqrt{Y_{LCL}}$ – (MPa, ksi)	4.0	0.58
Failure pressure recorded (MPa, ksi)	9.9	1.44

Table 11: Results of the impact testing of the Revowrap 110 repair system

CONCLUSIONS:

The testing carried out and detailed in this qualification report confirms that the Revowrap 110 composite repair system meets and exceeds the requirements of ASME PCC2-2015 and ISO TS 24817-2015 and can be used for the repair of carbon steel pipes and piping systems. Non through wall defects have been qualified up to 85% wall loss and the repair system has also been demonstrated to meet the requirements for through wall leaking defects with the impact performance verified and a repair toughness parameter defined.

Carbontech recognises the importance of extended lifetime testing and continues its test program to develop additional longer term test data that will be used to update this report in due course.

References

- [1] ASME PCC-2 - 2015, ASME PCC-2 - 2015 Repair of Pressure Equipment and Piping Part 4 Nonmetallic Bonded Repairs, The American Society of Mechanical Engineers, 2015.
- [2] ISO 24817:2015(E), ISO 24817:2015(E) Petroleum, petrochemical and natural gas industries- Composite repairs for pipework- Qualification and design, installation, testing and inspection, International Organization for Standardization, 2015.
- [3] ASTM D3039/D3039M - 17, *ASTM D3039/D3039M - 17 Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials*, ASTM International, 2017.
- [4] ASTM D5370/D5379M-19, *ASTM D5379/D5379M-19 Standard Test Method for Shear Properties of Composite Materials by V-Notched Beam Method*, ASTM International, 2019.
- [5] ASTM D3165-07(2014), *ASTM D3165-07(2014)*, ASTM International, 2014.
- [6] ASTM D3039/D3039M - 00, *ASTM D3039/D3039M - 00 Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials*, ASTM International, 2000.
- [7] ASME PCC-2 -2015, "Article 4.1, Mandatory Appendix III Short-Term Pipe Spool Survival Test," in ASME PCC-2 - 2015 Repair of Pressure Equipment and Piping Part 4 Nonmetallic and Bonded Repairs, The American Society of Mechanical Engineers, 2015, p. 165.
- [8] ISO 24817:2015(E), "Annex C (normative) Short-term pipe spool survival test," in ISO 24817:2015(E) Petroleum, petrochemical and natural gas industries - Composite repairs for pipework - Qualification and design, installation, testing and inspection, International Organization for Standardization, 2015, pp. 57-58.
- [9] ASME PCC-2 - 2015, "Article 4.1, Mandatory Appendix IV Measurement of Gamma for Leaking Defect Calculation," in ASME PCC-2 - 2015 Repair of Pressure Equipment and Piping Part 4 Nonmetallic and Bonded Repairs, The American Society of Mechanical Engineers, 2015, pp. 166-167
- [10] ISO 24817:2015(E), "Annex D (normative) Measurement of Gamma_LCL for through-wall defect calculation," in ISO 24817:2015(E) Petroleum, petrochemical and natural gas industries - Composite repairs for pipework - Qualification and design, installation, testing and inspection, International Organization for Standardization, 2015, pp. 59-61.
- [11] ASME PCC-2 - 2015, "Article 4.1, Mandatory Appendix VI Measurement of Impact Performance," in ASME PCC-2 Repair of Pressure Equipment and Piping Part 4 Nonmetallic and Bonded Repairs, The American Society of Mechanical Engineers, 2015, p. 170.
- [12] ISO 24817:2015(E), "Annex F (normative) Measurement of impact performance," in ISO 24817:2015(E) Petroleum, petrochemical and natural gas industries - Composite repairs for pipework - Qualification and design, installation, testing and inspection, International Organization for Standardization, 2015, p. 65.





APPENDICES

APPENDIX 1 – Reinforcement Fabric TDS:

GENERAL INFORMATION:

ⁱCarbontech provides a 320gsm 3K-3K carbon fibre tape in a series of dimensions for use with the Revowrap resin systems.

CARBON TAPE PLAIN 320GSM

Product code	Description
RCT-50-10	Carbon Cloth: T-0.44mm-W-50mm x L-100m
RCT-80-10	Carbon Cloth: T-0.44mm-W-80mm x L-100m
RCT-100-10	Carbon Cloth: T-0.44mm-W-100mm x L-100m
RCT-150-10	Carbon Cloth: T-0.44mm-W-150mm x L-100m
RCT-250-9	Carbon Cloth: T-0.44mm-W-250mm x L-50m
RCT-333-9	Carbon Cloth: T-0.44mm-W-330mm x L-50m

CARBON TAPE PLAIN 320GSM TECHNICAL SPECIFICATIONS

ⁱⁱSpecifications

Warp type	Carbon yarn 3K
Weft type	Carbon yarn 3K
Weave style	Plain
Weight	320 g/m ² ± 5%
Thickness	0.4mm

Dimensions

Roll width	Roll length
50mm	100 lm
80mm	100 lm
100mm	100 lm
150mm	100 lm
250mm	50 lm
330mm	50 lm

Packaging

Packaging form	Tape is provided rolled up on cardboard tube and packed under polyethylene plastic.
Packaging label and product identification	Rolls are individually labelled with the following details: Product reference Product nomination Manufacture series number and number of rolls Quantity

ⁱ The Revowrap resin system and carbon fibre tape together form a complete composite pipe repair system. MSDS's and TDS's for the Revowrap resin systems can be made available on request.

ⁱⁱ An MSDS for the carbon fibre tape can be provided on request.

APPENDIX 2 – Resin System TDS:



GENERAL PROPERTIES:

The REVOWRAP 110 epoxy resin system is specifically designed for the impregnation of glass, carbon and aramid engineering fabric for pipe repair. This system can be applied by hand lamination, filament winding or by infusion methods. REVOWRAP 110 is designed to operate up to temperatures of 110°C. It has excellent workability at ambient temperatures and 60minute pot life. It provides excellent mechanical, thermal and chemical resistant properties.

PHYSICAL PROPERTIES:

COMPOSITION	RESIN	HARDENER	MIXED
Mix Ratio by Weight	100	25	
Aspect	Liquid	Liquid	Liquid
Colour	Clear	Orange	
Viscosity at 25°C (mPa.s) {BROOKFIELD LVT}	900	950	2,000
Specific gravity at 25°C (ISO 1675 : 1985)			-
Specific gravity of cured product at 23°C (ISO 2781 : 1996)	-	-	
Pot life at 25°C on 500g (min)			65

MECHANICAL PROPERTIES:

Final Hardness	ISO 527 : 1993	MPa	87
Tensile Strength	ISO 527 : 1993	MPa	65 ± 5
Elongation at break	ISO 527 : 1993	%	5.0
Flexural Modulus	ISO 178 : 1993	MPa	131 ± 5
Flexural Modulus of Elasticity (MPa)	ISO 178 : 1993	Mpa	3500 ± 200

THERMAL TREATMENT:

There is no thermal treatment required for Revowrap110, it is designed to cure in ambient conditions. In the event that ambient temperatures are below 9DegC it is recommended to post cure the epoxy for 8 hours at 80 degrees Celsius.

STORAGE AND STABILITY:

Shelf life is 9 months for Resin and 24 months for the Hardener in a dry place and in original unopened containers at a temperature between 10°C and 25°C. Any open can must be tightly closed under dry nitrogen blanket.

GENERAL PROPERTIES:

The REVOWRAP 185 epoxy resin system is specifically designed for the impregnation of glass, carbon and aramid engineering fabric for pipe repair. This system can be applied by hand lamination, or by infusion. REVOWRAP 185 is designed to operate up to temperatures of 185°C. It can be applied by hand at room temperature but does require a post curing to achieve its maximum temperature resistance, It offers excellent wetting properties, high temperature resistance and excellent chemical resistance.

PHYSICAL PROPERTIES:

Laminating: After mixing according to the indicated ratio, carry out impregnation of the reinforcements. Let it polymerise for 24 hours at room temperature. Then cure for 24 hours at 45°C.

Then demould and cure (see § Thermal Treatment). Laminating thickness must not exceed 10mm. In the case of a laminating recovery a peel-ply fabric is recommended.

COMPOSITION	RESIN	HARDENER	MIXED
Mix Ratio by Weight	100	37	
Mix Ratio by volume at 25°C	100	47	
Aspect	Liquid	Liquid	Liquid
Colour	Amber	Blue	Dark Amber
Viscosity at 25°C (mPa.s) {BROOKFIELD LVT}	4,000	200	2,000
Specific gravity at 25°C (ISO 1675 : 1985)	1.16	1.02	-
Specific gravity of cured product at 23°C (ISO 2781 : 1996)	-	-	1.12
Pot life at 25°C on 500g (min)			150

MECHANICAL PROPERTIES:

Final Hardness	ISO 868 : 2003	Shore D15	90
Tensile Strength	ISO 527 : 1993	MPa	40
Glass Temperature Transition (Tg)	ISO 11359 : 2002	°C	190
Flexural Modulus	ISO 178 : 2001	MPa	2,800
Flexural Strength	ISO 178 : 2001	Mpa	62

THERMAL TREATMENT:

It is important to follow the post curing requirements to achieve maximum performance. Once the product has set at room temperature, the recommended curing cycle is as follows.

2 hours at 120°C.

4 hours at 160°C.

GENERAL PROPERTIES:

The REVOWRAP 225 epoxy resin system is a very high temperature resin system designed for the impregnation of glass and carbon fabrics for pipe repair. This system can be applied by hand lamination, or by infusion methods. REVOWRAP 225 is designed to operate up to temperatures of 225°C. It can be applied ambient temperature but does require a post curing to achieve its maximum temperature resistance. It has an extremely long pot life of 400 minutes and excellent wetting of fibres due to its low viscosity.

PHYSICAL PROPERTIES:

After mixing according to the indicated ratio, carry out impregnation of the reinforcements. To ensure an optimal use and a good impregnation, please use packaging stored at temperatures above 15°C. The physical properties are guaranteed between 18°C and 25°C. Outside this range, variations in viscosity and reactivity will be observed.

COMPOSITION	RESIN	HARDENER	MIXED
Mix Ratio by Weight	100	50	
Mix Ratio by volume at 25°C	100	63	
Aspect	Liquid	Liquid	Liquid
Colour	Amber	RED	Dark Amber
Viscosity at 25°C (mPa.s) {BROOKFIELD LVT}	1,600	100	550
Specific gravity at 25°C (g/cm ³) (ISO 1675 : 1985)	1.20	0.95	-
Specific gravity of cured product at 23°C (ISO 2781 : 1996)	-	-	1.15
Pot life at 25°C on 500g (min)			400
Time to reach 1,00 MPa's on 500g at 25°C. (min)			230

MECHANICAL PROPERTIES:

Tensile Modulus	ISO 527 : 1993	MPa	4,600
Tensile Strength	ISO 527 : 1993	MPa	26
Elongation at break	ISO 527 : 1993	%	1.0
Flexural Modulus	ISO 178 : 1993	MPa	2,900
Maximum Flexural Strength	ISO 178 : 2001	MPa	73

THERMAL TREATMENT:

It is important to follow the post curing requirements to achieve maximum performance. Once the product has set at room temperature, the following curing cycle is recommended:

- 3 hours at 120°C.
- 3 hours at 180°C.

APPENDIX 3 – Tensile Test Data: Circumferential direction

Zwick / Roell

26.11.19

Test report

Customer : CARBON TECH COMPOSITE SYSTEM
 Job no. : ATS-LAB-033
 Test standard : ASTM D 3039
 Type and designation :
 Material : CARBON COMPOSITE WOVEN WITH TABS
 Specimen removal :
 Specimen type :
 Pre-treatment :
 Strain measurement :
 Test climate :
 Tester :
 Notes :
 Machine data :

Pre-load : 0.5 MPa
 Test speed : 0.01 1/min

Test results:

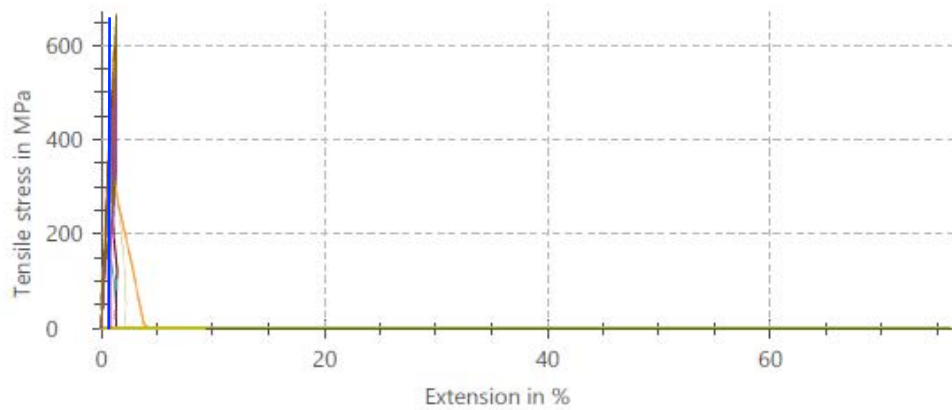
Legend	No.	E MPa	P N	S MPa	ε at failure %	h mm	b mm	A mm ²
	1	58900	11600	590	-	0.82	23.96	19.65
	2	48000	10500	520	-	0.83	24.24	20.12
	3	51600	9690	505	-	0.79	24.3	19.20
	4	43000	13100	596	-	0.91	24.23	22.05
	5	42100	10700	532	-	0.83	24.29	20.16
	6	49300	13500	666	-	0.83	24.32	20.19

ASTM D 3930_Carbon tech_26-11-2019.zs2

Page 1/2



Series graph:



Statistics:

Series	E	P	S	ε at failure	h	b	A
n = 6	MPa	N	MPa	%	mm	mm	mm ²
x	48800	11500	568	-	0.835	24.22	20.23
s	6150	1510	60.9	-	0.03987	0.1337	0.97
v [%]	12.59	13.13	10.71	-	4.78	0.55	4.81

Axial direction

Zwick / Roell

05.06.20

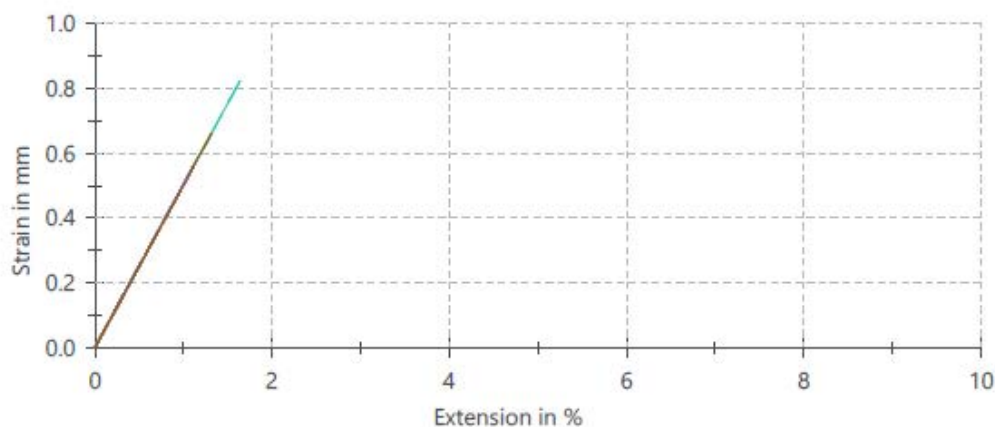
Test report

Customer : CARBON TECH COMPOSITE SYSTEM
Job no. : ATS-LAB-052
Test standard : ASTM D 3039
Type and designation : N/A
Material : Revo 110 Axial modulus
Test climate :
Tester : Gertrude Makgatho
Notes :
Machine data :
Pre-load : 0.5 MPa
Test speed : 0.01 1/min

Test results:

Legend	No.	E MPa	P N	S MPa	ε at failure %	h mm	b mm	A mm ²
	1	36700	2600	120	1.0	0.87	24.9	21.66
	2	41700	6500	300	-	0.87	24.87	21.64
	3	40400	4210	199	-	0.85	24.93	21.19
	4	44700	7020	326	-	0.87	24.79	21.57
	5	42900	4270	207	-	0.84	24.59	20.66
	6	39800	4770	224	-	0.86	24.79	21.32

Series graph:



ASTM D 3930_Carbon tech_Revo 110 Axial modulus 05_06_2020.zs2

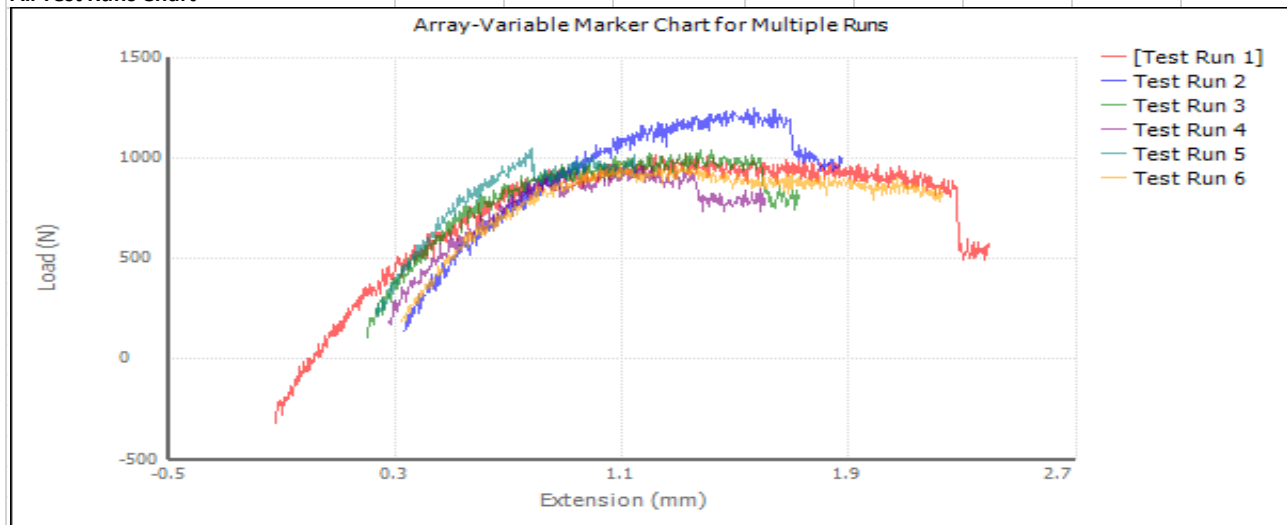
Page 1/2

Statistics:

Series	E	P	S	ε at failure	h	b	A
n = 6	MPa	N	MPa	%	mm	mm	mm ²
$\bar{x}$	41000	4900	229	1.0	0.86	24.81	21.34
s	2760	1630	74.5	-	0.01265	0.1227	0.38
v [%]	6.74	33.21	32.47	-	1.47	0.49	1.80

APPENDIX 4 – In Plane Shear Modulus Test Data:

User Name			Marcelle					
Test Name			BE06-07 (Shear)					
All Test Runs Chart								



Name	Test Run End Reason	Length of Parallel Section (mm)	Initial Marked Gage Length (mm)	Humidity (%)	Test Rate (mm/min)	Temperature (°C)	Maximum Force (N)	Maximum Stress (MPa)	Upper Yield Strength (MPa)
Test Run 1	Test Stopped	60	50	50	2	23	1017,271	109,676	37,282
Test Run 2	Test Stopped	60	50	50	2	23	1244,875	105,384	21,288
Test Run 3	Test Stopped	60	50	50	2	23	1036,25	109,691	21,884
Test Run 4	Test Stopped	60	50	50	2	23	959,514	99,944	30,499
Test Run 5	Test Stopped	60	50	50	2	23	1044,616	106,272	25,036

1. **SCOPE**

Aerosud was contracted by Carbontech Composite Systems (PTY) LTD to perform compressive testing of Revowrap 110 composite samples. The samples were tested for compressive modulus and compressive strength. This testing was conducted in accordance with ASTM D695.

2. **REFERENCE DOCUMENTS**

2.1 **International**

ASTM D695 Standard Test Method for Compressive Properties of Rigid Plastics

3. **DESCRIPTION OF TEST SPECIMEN**

The specimen provided were rectangular block with a total length average of 50.9 mm, average width of 12.67 mm and average thickness of 12.58 mm were tested as per as per ASTM D695 specification. The specimens were subjected to a compression test speed of 1.3mm/min.

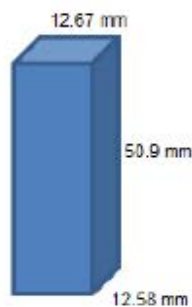


Figure 1: Compression test specimen for R110

4. **DESCRIPTION OF TEST EQUIPMENT**

The tensile testing was performed using the 100 kN Zwick tensile tester, serial number AS3305.



Figure 2: Figure 1: 100 kN Zwick Tensile tester

5. TEST METHOD USED

The specimen was tested in tensile mode as per ASTM D3039 at room temperature with the following test parameter used:

- Test Speed: 1.3 mm/min
- Preload: 50 N
- Actual Test Temperature: 22.8 °C
- Actual Humidity: 50.1%

6. TEST RESULTS

The figures and tables below provide the results of the tensile testing conducted.

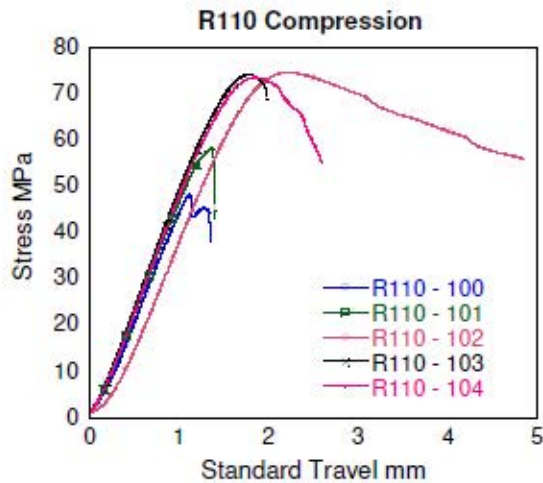


Figure 3: Plot of the R110 compression test specimen

Samples	Compression Modulus mpsi	Compressive Strength kpsi	% Strain	b mm	h mm	l mm	A ₀ mm ²
R110-100	0.360	7.02	2.6	12.65	12.5	50.88	161
R110-101	0.373	8.49	2.7	12.65	12.66	50.89	161
R110-102	0.348	10.8	9.5	12.65	12.64	50.88	161
R110-103	0.388	10.8	3.9	12.67	12.49	50.89	161
R110-104	0.382	10.7	5.1	12.71	12.63	50.96	161
Average	0.370	9.57	4.8	12.666	12.58	50.9	161
Standard Deviation	0.0162	1.73	2.8	0.02608	0.08204	0.03391	0.00

Table 1: Compression test of the R110 Specimen



TEST REPORT

DOC NO: Q020-4

MECHANICAL TESTING
COMPRESSION TESTING OF REVOWRAP 110 AS PER
ASTM D695

ISSUE: 01

7. **CONCLUSION**

The information and test results contained in this report are accurate and reflects the testing that was conducted by Aerosud personnel.

01 July 2020

Page 5 of 8
MQ001-997 ISSUE A

 AEROSUD Aviation	TEST REPORT MECHANICAL TESTING COMPRESSION TESTING OF REVOWRAP 110 AS PER ASTM D695	DOC NO: Q020-4 ISSUE: 01
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8. APPENDICES

8.1 Tensile Tester AS3305 Compressive Force Calibration Certificate

	Force Calibration Certificate Version 01 - 2019-01-01	
Form No. CAL004		
Calibration date: 31/12/2019 Date of issue: 20/12/2019 Performed by: Leandria G. M. Silva Start Temperature: 22.6 End Temperature: 22.6 Calibration Facilities: <i>[Signature]</i>		
Technical Signature: <i>[Signature]</i> Sheldon Kroll		
Force Calibration Certificate Customer Name: Aerosud Aviation (Pty) Ltd Address: Cnr Van Rynswald Ave & Van Der Stuyk Str City: Centurion Physical Calibration Location: On-site Composite Laboratory Make, Model / Serial No: ZW300 2100 220004 Frame Capacity (kN): 55000 Load cell Range (kN): 10000 Serial number: 772325 Calibrated range: 10000 Selected units: (N x 1000) Standard used: 1 Serial Number: 34413000 Traceable to: PCOLC 3570 Capacity (kN): 100 (1) Resolution (kN): 0.001 Poll mode: 100.00 Units: kN Specification: 0.05/10 Procedure Used: P 01 Constant force (indicated / true): CT Machine output calibrated: PC Machine adjusted: Machine adjusted 1 (kN) Change overpoint 1 (kN): no Change overpoint 2 (kN): -30		

Calibration performed in Compression

Set Range kN	Standard Serial	Method Used	Furnace Resolution	Proced File	Run in kN				Average kN	Error kN	Error %	Net Dev kN	Range kN	Repeatability %	Uncertainty kN
					Run 1	Run 2	Run 3	Run 4							
0		GP	0.0001												
-1	04011022	GP	0.0001	-1.0211	-1.0206	-1.0201	-1.0199		-1.0204	0.0008	-0.01%	0.0007	0.0005	0.48	0.0048
-2	04011024	GP	0.0001	-2.0210	-2.0209	-2.0204	-2.0201		-2.0204	0.0005	-0.01%	0.0001	0.0005	0.48	0.0005
-5	04011026	GP	0.0001	-5.0202	-5.0205	-5.0201	-5.0201		-5.0202	0.0007	-0.01%	0.0003	0.0005	0.48	0.0003
-10	04011028	GP	0.0001	-10.0208	-10.0203	-10.0201	-10.0204		-10.0204	0.0002	-0.01%	0.0001	0.0005	0.48	0.0001
-20	04011030	GP	0.0001	-20.0202	-20.0198	-20.0191	-20.0194		-20.0194	0.0001	-0.01%	0.0001	0.0005	0.48	0.0001
-30	34403200	GP	0.0001	-30.0444	-30.0444	-30.0444	-30.0444		-30.0444	0.0001	-0.01%	0.0001	0.0005	0.48	0.0001
-40	34403200	GP	0.0001	-40.0408	-40.0408	-40.0408	-40.0408		-40.0408	0.0001	-0.01%	0.0001	0.0005	0.48	0.0001
-50	34403200	GP	0.0001	-50.0410	-50.0410	-50.0410	-50.0410		-50.0410	0.0001	-0.01%	0.0001	0.0005	0.48	0.0001
-60	34403200	GP	0.0001	-60.0410	-60.0410	-60.0410	-60.0410		-60.0410	0.0001	-0.01%	0.0001	0.0005	0.48	0.0001
-70	34403200	GP	0.0001	-70.0410	-70.0410	-70.0410	-70.0410		-70.0410	0.0001	-0.01%	0.0001	0.0005	0.48	0.0001
-80	34403200	GP	0.0001	-80.0410	-80.0410	-80.0410	-80.0410		-80.0410	0.0001	-0.01%	0.0001	0.0005	0.48	0.0001
-90	34403200	GP	0.0001	-90.0410	-90.0410	-90.0410	-90.0410		-90.0410	0.0001	-0.01%	0.0001	0.0005	0.48	0.0001
-100	34403200	GP	0.0001	-100.0410	-100.0410	-100.0410	-100.0410		-100.0410	0.0001	-0.01%	0.0001	0.0005	0.48	0.0001

- Notes:**
- The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95%. The uncertainty of measurement has been evaluated in accordance with the principles defined in the GUM, Guide to Uncertainty of Measurement, ISO, Geneva, 1995.
 - On this certificate the actual target load for each calibration step is listed in the first column. Deviation to the target load is indicated in the second column. The target load is the load that is used for the calibration. The target load is the load that is used for the calibration. The target load is the load that is used for the calibration.
 - This certificate is issued in accordance with the conditions of the approval granted by the South African Bureau of Standards. It is a record of the measurement made. The certificate is the property of the client. It is not to be used for any other purpose. The certificate is the property of the client. It is not to be used for any other purpose.
 - This certificate is valid at the time of issue of the certificate. The continued validity of the certificate will depend on the use to which the instrument is put and the results achieved.
 - This calibration has been performed with an ISO 9001:2015 certified laboratory. The results are the results of the calibration. The results are the results of the calibration.
 - Standards used in the calibration of this certificate have been certified by NBS/NIST accredited laboratories and therefore provide an excellent chain of traceability to national standards maintained by NBS/NIST.
 - This certificate meets the requirements for ISO 17025 clause 7.6.

Reviewed i.a.w. AQI 01.018.06

Pass ☒ Fail ☐

Stamp  Date: **2019/08/26**

End of Certificate

Sanas (Pty) Ltd P.O. Box 1111, 1622 Page 1 of 1	A. B. (Pty) Ltd, the Advanced Laboratory Solutions P.O. Box 1111, 1622 1614, South Africa Tel: +27 (0)10 446 6866 Email: info@revowrap.com	Sanas (Pty) Ltd, the Advanced Laboratory Solutions P.O. Box 1111, 1622 1614, South Africa Tel: +27 (0)10 446 6866 Email: info@revowrap.com
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01 July 2020

Page 6 of 8
MQ001-997 ISSUE A



TEST REPORT
MECHANICAL TESTING
COMPRESSION TESTING OF REVOWRAP 110 AS PER
ASTM D695

DOC NO: Q020-4
ISSUE: 01

8.2 Tensile Tester AS3305 Speed and Displacement Calibration Certificate

	Displacement and Speed Certificate Version 3	
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Certificate Number	313028
Customer Name	Aerosud Aviation Pty Ltd
Address	C/o Van Wykswayd & Van der Spuy Str (Pretoria Airport) Germiston
Make, Model / Serial No	IMAC 2100 75001
Machine Travel	500
Max calibrated speed (mm/min)	500
Calibrated displacement (mm)	500
Standard used	Displacement
Standard	ISO 4170
Traceable serial No	04004-1956
Travel limit	2000
Resolution	0.01
Resolution	0.01
Resolution	0.01
Machine output calibrated	PC

Form No. CAL305
Date of Issue 2019/07/26

Date of Calibration	2019/07/26
Calibration performed by	Advanced Laboratory Solutions
Start Temperature	22.5 °C
End Temperature	22.5 °C
Calibration Technician	
Liaison Officer	
Technical Signature	
Shed No	

Displacement verification check

Cal Group	Standard Used	Output Resolution	Pre cal	Run 1 to 5 for crosscheck / displacement					Average disp mm	Error mm	Error %	Std Dev %	Range %	Uncertainty ±
				Run 1	Run 2	Run 3	Run 4	Run 5						
100	024410	0.010	100.00	100.03	100.00	100.00			100.00	0.00	0.00%	0.00%	0.00%	0.00%
200	024410	0.010	200.00	200.03	200.00	200.00			200.00	0.00	0.00%	0.00%	0.00%	0.00%
300	024410	0.010	300.00	300.03	300.00	300.00			300.00	0.00	0.00%	0.00%	0.00%	0.00%
400	024410	0.010	400.00	400.03	400.00	400.00			400.00	0.00	0.00%	0.00%	0.00%	0.00%
500	024410	0.010	500.00	500.03	500.00	500.00			500.00	0.00	0.00%	0.00%	0.00%	0.00%

Speed verification check

Cal Group	Standard Used	Output Resolution	Pre cal	Run 1 to 5 for crosscheck / speed					Average mm/min	Error mm/min	Error %	Std Dev %	Range %	Uncertainty ±
				Run 1	Run 2	Run 3	Run 4	Run 5						
100	024410	0.010	100.00	100.03	100.00	100.00			100.00	0.00	0.00%	0.00%	0.00%	0.00%
200	024410	0.010	200.00	200.03	200.00	200.00			200.00	0.00	0.00%	0.00%	0.00%	0.00%
300	024410	0.010	300.00	300.03	300.00	300.00			300.00	0.00	0.00%	0.00%	0.00%	0.00%
400	024410	0.010	400.00	400.03	400.00	400.00			400.00	0.00	0.00%	0.00%	0.00%	0.00%
500	024410	0.010	500.00	500.03	500.00	500.00			500.00	0.00	0.00%	0.00%	0.00%	0.00%

- Notes**
- The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor $k=2$ providing a level of confidence of approximately 95%. The uncertainty of measurement has been estimated in accordance with the principles declared in the ISO Guide to Uncertainty of Measurement, 1995, Edition 2.
 - This calibration is valid at the time of issue of the certificate. The continued retention of accuracy will depend on the care with which the equipment is handled and used.
 - Standards used in the execution of this calibration have been certified by SANAS accredited laboratories and through the above provide an unbroken chain of traceability to national standards by NIST/UK National Metrology Institute of South Africa.

End of Certificate

Reviewed i.a.w. AQI 01.018.06	
Pass ☒	Fail ☐
Stamp	Date: 2019/07/26

Sanas No: 000 000 000 Sanas No: 000 000 000	A D Scientific (Pty) Ltd, an Advanced Laboratory Solutions P.O. Box 71104, Germiston, 1609 275 Regus Crescent, Northmead, 1614, South Africa (Registration & Accreditation: 01/01/2017)	E-mail: info@revowrap.com Web: www.revowrap.com
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	TEST REPORT MECHANICAL TESTING COMPRESSION TESTING OF REVOWRAP 110 AS PER ASTM D695	DOC NO: Q020-4 ISSUE: 01
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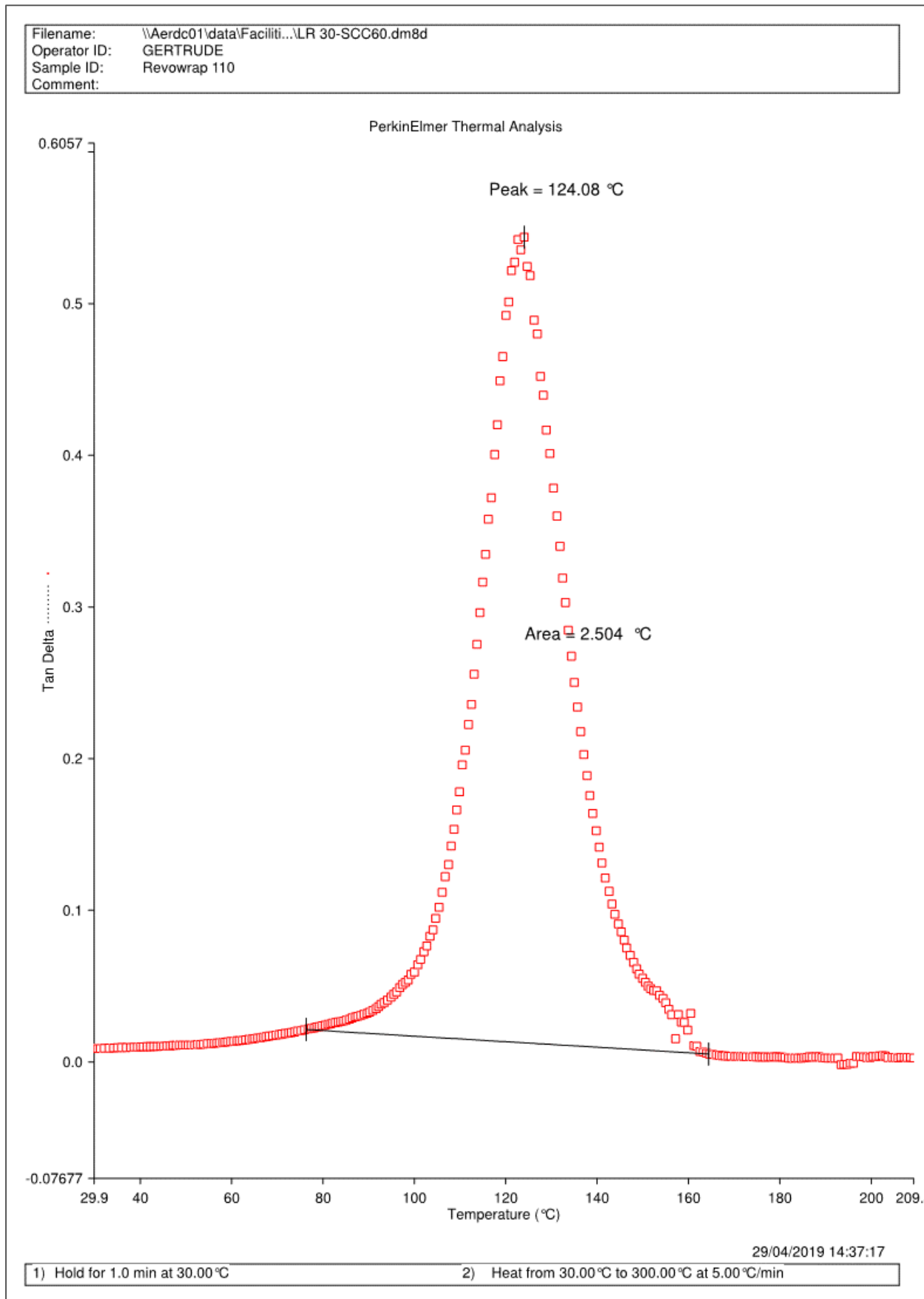
9. AMENDMENT RECORD

ISSUE	DATE	DESCRIPTION OF CHANGE	ORIGINATOR
01	2020-07-01	Creation of document	G Makgatho

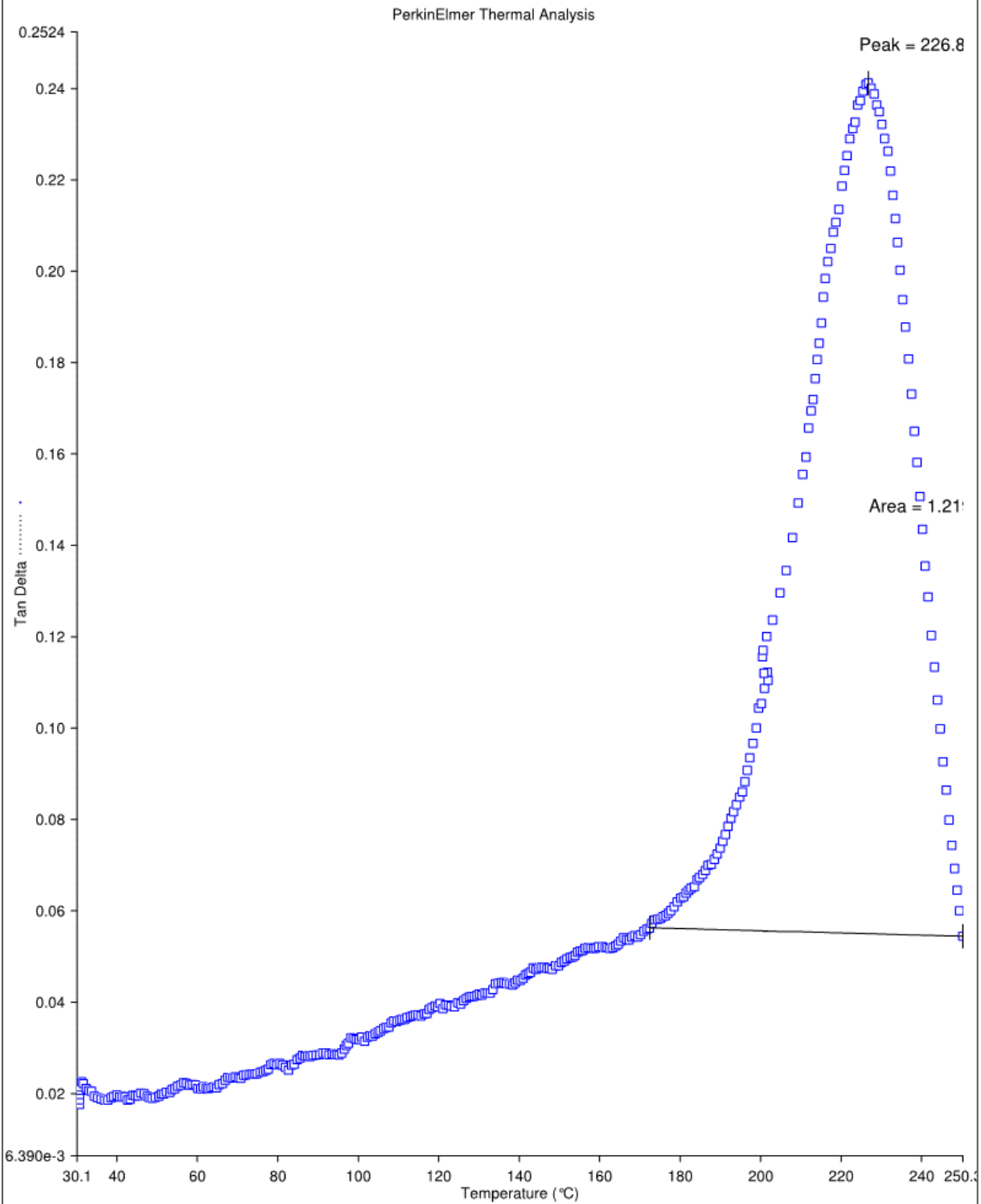
01 July 2020	Page 8 of 8 MQ001-997 ISSUE A
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APPENDIX 6 – HDT Test Data:



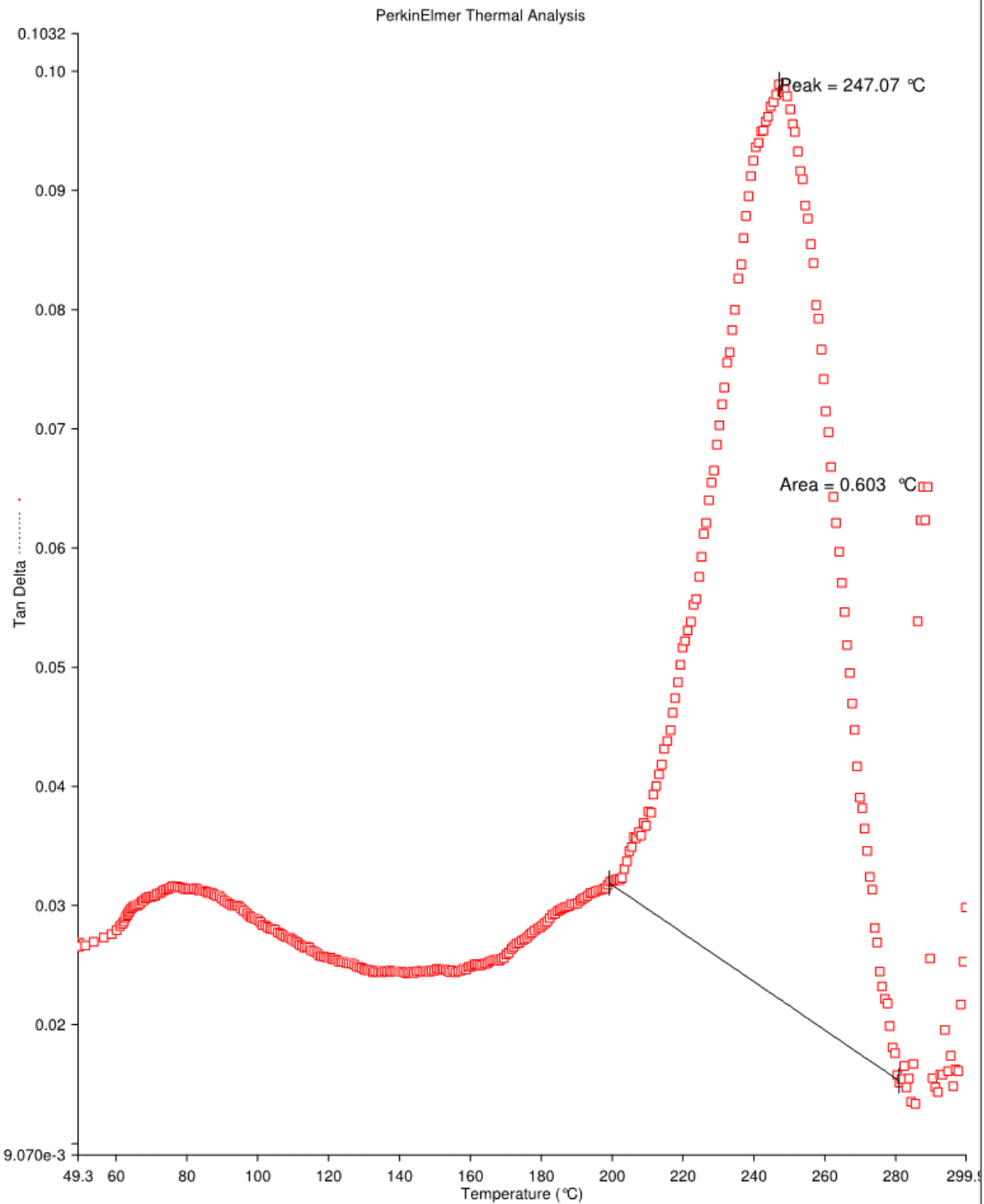
Filename: \\aerdc01\data\facilities...\2020-2025.dm8d
Operator ID: GERTRUDE
Sample ID: Revowrap 185
Comment:



29/04/2019 14:27:14

1) Hold for 1.0 min at 30.00 °C 2) Heat from 30.00 °C to 300.00 °C at 5.00 °C/min

Filename: \\Aerdc01\data\Facilities\...2029 + H.dm8d
Operator ID: GERTRUDE
Sample ID: Revowrap 225
Comment:



29/04/2019 14:35:50

1) Hold for 1.0 min at 30.00 °C

2) Heat from 30.00 °C to 300.00 °C at 5.00 °C/min

1. **SCOPE**

Aerosud was contracted BY Carbontech Composite Technologies to perform qualification lap shear testing on the resin used in their REVOWRAP 110 product.

The lap shear testing was conducted as per ASTM D3165.

2. **REFERENCE DOCUMENTS**

2.1 **Aerosud**

2.2 **International**

ASTM D3165 Standard Test Method for Strength Properties of Adhesives in Shear by Tension Loading of Single-Lap-Joint Laminated Assemblies

3. **DESCRIPTION OF TEST SPECIMEN**

Carbontech provided pre-manufactured Single Lap Joint laminated specimen of bristle blasted and sand blasted steel specimen. The specimen geometry is as follows:

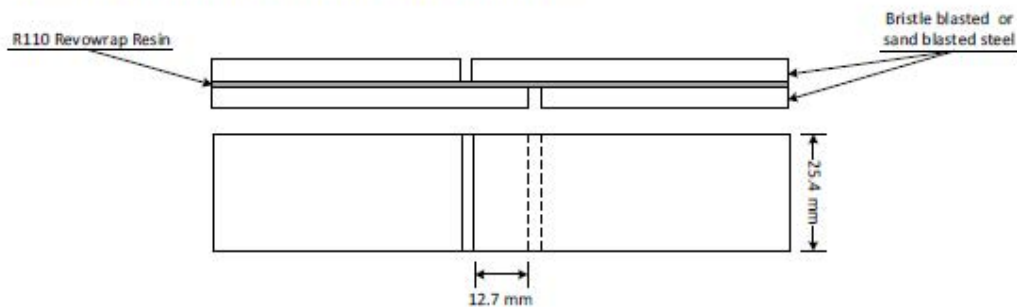


Figure 1: Single Lap Joint Laminated Specimen

Some sample preparation was required to remove excess resin from test and grip areas. This was achieved using a belt sander.

4. DESCRIPTION OF TEST EQUIPMENT

The lap shear testing was performed using the 100 kN Zwick tensile tester, serial number AS3305.

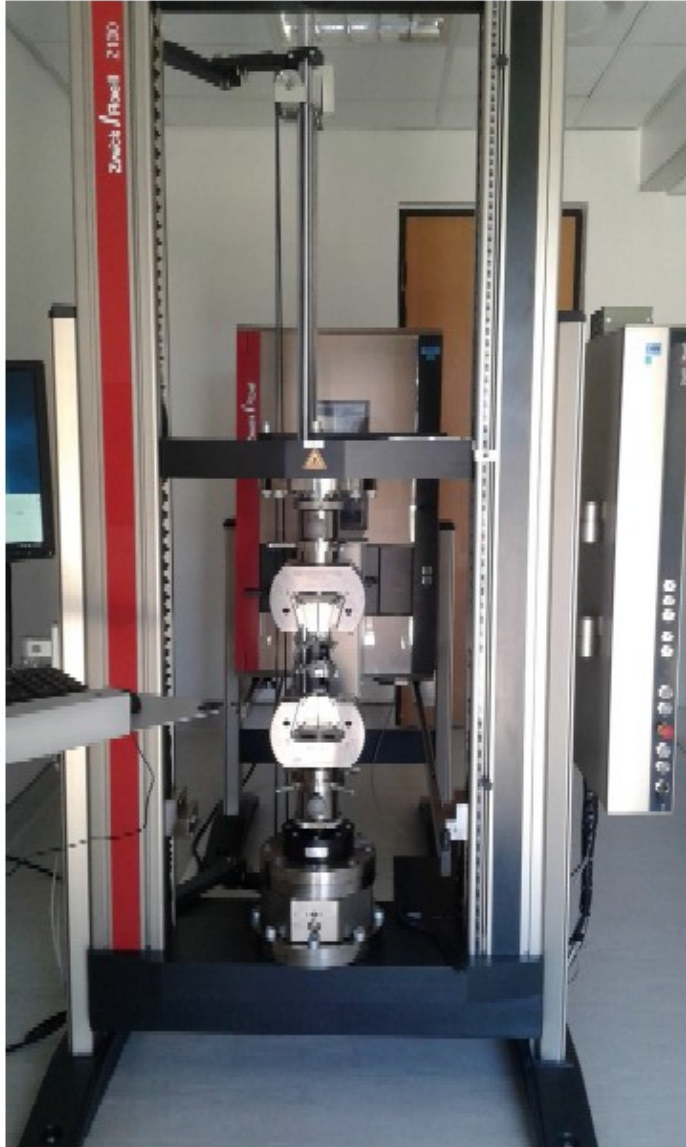


Figure 2: 100 kN Zwick Tensile tester

Refer to section 8 for calibration certificates.

The specimen test set-up was as follows:

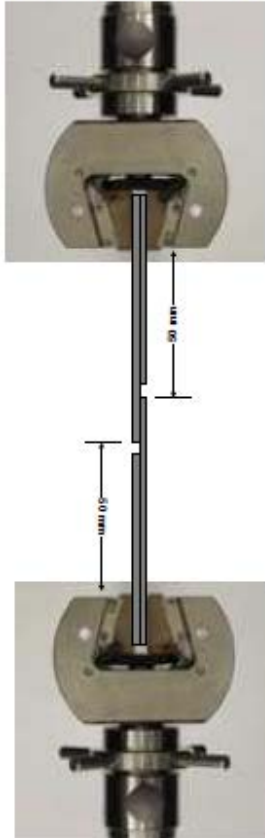


Figure 3: Test Set-up Illustration

5. **TEST METHOD USED**

The specimen was tested in tensile mode as per ASTM D3165 at room temperature with the following test parameter used:

- Test Speed: 1200 psi/min
- Actual Test Temperature: 21.2 °C
- Actual Humidity: 50.8%

6. TEST RESULTS

Generally, the samples showed good bonding characteristics. This was also evident in the high shear strength and maximum force values. The mode of failure was adhesion and acceptable mixture of adhesion and cohesion.

The figures and tables below provide the results of the lap shear testing conducted.

6.1 Bristle Blasted Specimen Results

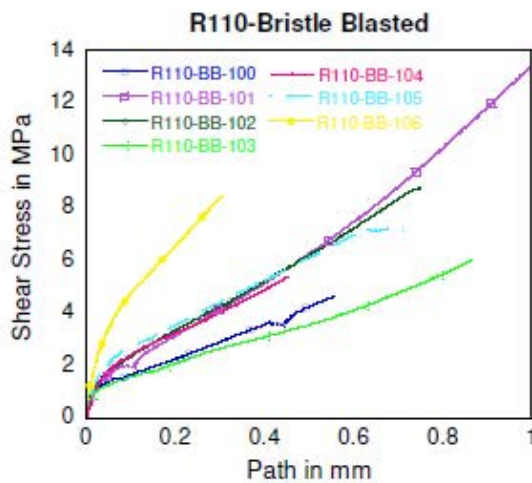


Figure 4: Plot of the R110 Bristle blasted samples

Samples	Shear stress MPa	Maximum Force N	Force at Break N	L mm	W mm	A mm ²	Thickness A
R110-BB-101	4.63	1400	1390	11.91	25.31	301	3.81
R110-BB-102	13.30	3890	3820	11.55	25.32	292	3.66
R110-BB-103	8.76	2560	2540	11.51	25.42	293	3.52
R110-BB-104	6.00	1790	1790	11.73	25.44	298	3.79
R110-BB-105	5.40	1610	1610	11.71	25.42	298	3.63
R110-BB-106	7.42	2190	2100	11.57	25.45	294	3.72
R110-BB-107	8.44	2480	2470	11.58	25.37	294	3.58
Average	7.71	2270	2250	11.65	25.39	296	3.67
Standard Deviation	2.91	837	814	0.1405	0.0572	3.41	0.1082

Table 1: Results of the R110 Sandblasted Specimen

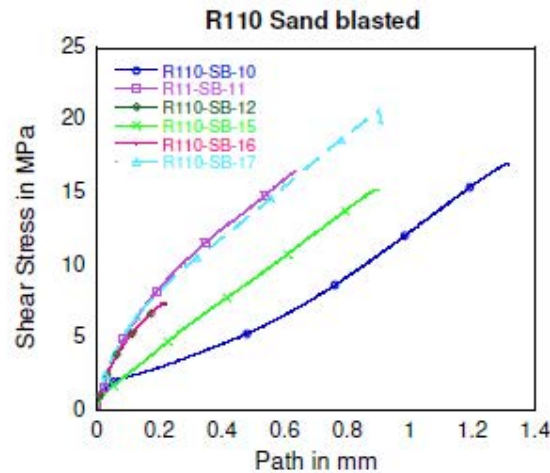


Figure 5: Plot of the R110 Sand blasted samples

Samples	Shear Stress MPa	Maximum force N	Force at break N	L mm	W mm	A mm ²	Thickness A
R110-SB-10	17.0	5050	5000	11.60	25.54	296	3.70
R110-SB-11	16.50	4600	4600	10.98	25.44	279	3.80
R110-SB-12	7.42	2090	2080	11.08	25.48	282	3.79
R110-SB-15	15.30	4960	4950	12.75	25.49	325	3.81
R110-SB-16	7.46	2410	2400	12.50	25.85	323	3.79
R110-SB-17	20.80	6810	6300	12.89	25.42	328	3.79
Average	14.1	4320	4220	11.97	25.54	306	3.78
Standard Deviation	5.46	1780	1640	0.8538	0.1591	22.3	0.04156

Table 2: Results of the R110 Sand blasted samples

7. CONCLUSION

The information and test results contained in this report are accurate and reflects the testing that was conducted by Aerosud personnel.

	TEST REPORT MECHANICAL TESTING LAP SHEAR TESTING OF REVOWRAP 110 AS PER ASTM D3165	DOC NO: Q020-2 ISSUE: 01
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8. APPENDIX – AS3305 CALIBRATION CERTIFICATES

8.1 Force Calibration in Tension

	Force Calibration Certificate Version 2.0 February 2018																																																																																																																																																																		
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td colspan="2">Certificate Number</td> <td colspan="2">3178</td> </tr> <tr> <td colspan="2">Customer Name</td> <td colspan="2">Aerosud Aviation (Pty) Ltd</td> </tr> <tr> <td colspan="2">Address</td> <td colspan="2">One Van Ryneveld Ave & Van Der Spuy Str Pretoria 0001 Gauteng</td> </tr> <tr> <td colspan="2">Physical Calibration location</td> <td colspan="2">Pretoria</td> </tr> <tr> <td colspan="2">Calibration Laboratory</td> <td colspan="2">Advanced Laboratory Solutions</td> </tr> <tr> <td colspan="2">Make, Model / Serial No</td> <td colspan="2">2MACH 2100 72001</td> </tr> <tr> <td colspan="2">Force Capacity (kN)</td> <td colspan="2">1000N</td> </tr> <tr> <td colspan="2">Load cell Range (kN)</td> <td colspan="2">1000N</td> </tr> <tr> <td colspan="2">Serial number</td> <td colspan="2">770033</td> </tr> <tr> <td colspan="2">Calibrated range</td> <td colspan="2">1000N</td> </tr> <tr> <td colspan="2">Selected units</td> <td colspan="2">(N or kN)</td> </tr> <tr> <td colspan="2">Standard used</td> <td colspan="2">F 1</td> </tr> <tr> <td colspan="2">Serial Number</td> <td colspan="2">34683050</td> </tr> <tr> <td colspan="2">Traceable cert No</td> <td colspan="2">POLC 3572</td> </tr> <tr> <td colspan="2">Capacity (kg)</td> <td colspan="2">100 (kg)</td> </tr> <tr> <td colspan="2">Readout used</td> <td colspan="2">0.0001</td> </tr> <tr> <td colspan="2">Full scale</td> <td colspan="2">100.00</td> </tr> <tr> <td colspan="2">Unit</td> <td colspan="2">kN</td> </tr> <tr> <td colspan="2">Resolution</td> <td colspan="2">0.0001</td> </tr> <tr> <td colspan="2">Procedure Used</td> <td colspan="2">P 01</td> </tr> <tr> <td colspan="2">Constant force (Indicated / true)</td> <td colspan="2">C/F</td> </tr> <tr> <td colspan="2">Machine output calibrated</td> <td colspan="2">Machine adjusted 1</td> </tr> <tr> <td colspan="2"></td> <td colspan="2">Change over point 1 (kN)</td> </tr> <tr> <td colspan="2"></td> <td colspan="2">20</td> </tr> <tr> <td colspan="2"></td> <td colspan="2">Change over point 2 (kN)</td> </tr> <tr> <td colspan="2"></td> <td colspan="2"></td> </tr> </table>			Certificate Number		3178		Customer Name		Aerosud Aviation (Pty) Ltd		Address		One Van Ryneveld Ave & Van Der Spuy Str Pretoria 0001 Gauteng		Physical Calibration location		Pretoria		Calibration Laboratory		Advanced Laboratory Solutions		Make, Model / Serial No		2MACH 2100 72001		Force Capacity (kN)		1000N		Load cell Range (kN)		1000N		Serial number		770033		Calibrated range		1000N		Selected units		(N or kN)		Standard used		F 1		Serial Number		34683050		Traceable cert No		POLC 3572		Capacity (kg)		100 (kg)		Readout used		0.0001		Full scale		100.00		Unit		kN		Resolution		0.0001		Procedure Used		P 01		Constant force (Indicated / true)		C/F		Machine output calibrated		Machine adjusted 1				Change over point 1 (kN)				20				Change over point 2 (kN)																																																														
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100	848/1385	CF	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001																																																																																																																																																										
110	848/1385	CF	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001																																																																																																																																																										
Notes: - The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor K = 2 providing a level of confidence of approximately 95%. The uncertainty of measurement has been evaluated in accordance with the principles defined in the GUM, Guide to the Expression of Uncertainty in Measurement, JCGM, Geneva, 1995. - On this certificate the actual target load for each calibration step is listed in the first column. Load weight calibrations are performed with constant force. Force using test cell force standards are usually performed using constant force standards from the machine under test. The method for each calibration point is given in column 3. Load (constant force) or CF (constant indicated force). Error calculation is an adjusted accuracy. - This certificate is issued in accordance with the conditions of the contract signed by the client and Advanced Laboratory Solutions. It is a permanent record of the measurements made. Copyright of this certificate is jointly owned by SANAS and Advanced Laboratory Solutions. This certificate may not be reproduced either in full or in part, except with the prior written approval of SANAS and of Advanced Laboratory Solutions. - This calibration is valid for the first 12 months of the certificate. The subsequent extension of accuracy will depend on the care with which the instrument is handled and used. - This calibration has been performed with SANAS 1000 and 10000 A. The instrument has been verified by SANAS and Advanced Laboratory Solutions. The instrument has been verified by SANAS and Advanced Laboratory Solutions. The instrument has been verified by SANAS and Advanced Laboratory Solutions. - Standard used in the creation of this calibration has been verified by SANAS accredited laboratories and therefore provides an accurate chain of traceability to national standards maintained by NBSA. Advanced Laboratory Solutions of South Africa and in Pretoria. - This machine meets the requirements for ISO 9001 class 0.8.																																																																																																																																																																			
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SANAS 1000 0000 ALB SANAS 1000 1111 ALB Page 1 of 1	A.S. Laboratory (Pty) Ltd. An Advanced Laboratory Solutions P.O. Box 11100, Pretoria, 0001 273 Argus Crescent, Northmead Business Park (between Main, Butha Buthe, Cnr. Gert van Rensburg Registration Number: 2005/0000000/07	E-mail: support@carbon-tech.co.za Web: www.carbon-tech.co.za																																																																																																																																																																	

22 June 2020

Page 7 of 9
MQ001-997 ISSUE A

8.2 Speed and Displacement

sanas		Displacement and Speed Certificate		advanced laboratory SOLUTIONS	
Certificate Number: 017006		Form No. CAL008		Date of Issue: 28/03/19	
Customer Name: Aerosud Aviation (Pty) Ltd		✓ AS3305			
Address: Cnr Van Rensselaer Ave & Van Der Spuy Str Pretoria					
Make, Model / Serial No: 77001 77002 77003					
Machine model: 500		Date of Calibration: 08/2019		Calibration performed by: (Signature)	
Max calibrated speed (mm/min): 500		Start Temperature: 22.6 °C		End Temperature: 22.9 °C	
Calibrated displacement (mm): 500		Calibration Technician: (Signature)		Laboratory Manager: (Signature)	
Standard used: Displacement		Speed		Machine Rest: (Signature)	
Encoder: 024410		024410			
Transducer cat No: 2000M-400		2000M-400			
Travel (mm): 2000		2000			
Resolution (mm): 0.01		0.01			
Resolution: 0.01		0.01			
Procedure used: P010		P010			
Machine output calibrated: PC					

Cal Stage (mm)	Standard Used	Output Resolution	Pre cal Run	Run 1	Run 2	Run 3	Run 4	Run 5	Average (mm/min)	Error (mm)	Error (%)	Std Dev (%)	Range (%)	Uncertainty (%)
100	024410	0.010	100.00	100.50	100.50	100.50			100.50	0.50	0.05%	0.05%	0.05%	0.05%
200	024410	0.010	200.00	200.30	200.30	200.30			200.30	0.30	0.01%	0.01%	0.01%	0.01%
300	024410	0.010	300.00	300.30	300.30	300.30			300.30	0.30	0.01%	0.01%	0.01%	0.01%
400	024410	0.010	400.00	400.30	400.30	400.30			400.30	0.30	0.01%	0.01%	0.01%	0.01%
500	024410	0.010	500.00	500.30	500.30	500.30			500.30	0.30	0.01%	0.01%	0.01%	0.01%

Cal Stage (mm)	Standard Used	Output Resolution	Pre cal Run	Run 1	Run 2	Run 3	Run 4	Run 5	Average (mm/min)	Error (mm/min)	Error (%)	Std Dev (%)	Range (%)	Uncertainty (%)
100	024410		100.00	100.30	100.30	100.30			100.30	0.30	0.03%	0.01%	0.01%	3.10%
200	024410		200.00	200.30	200.30	200.30			200.30	0.30	0.03%	0.01%	0.01%	2.10%
300	024410		300.00	300.30	300.30	300.30			300.30	0.30	0.03%	0.01%	0.01%	2.10%
400	024410		400.00	400.30	400.30	400.30			400.30	0.30	0.03%	0.01%	0.01%	2.10%
500	024410		500.00	500.30	500.30	500.30			500.30	0.30	0.03%	0.01%	0.01%	2.10%

Notes

- The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k = 2 providing a level of confidence of approximately 95%. The uncertainty of measurement has been estimated in accordance with the principles defined in the GUM, Guide to Uncertainty of Measurement, ISO, Geneva, 1995.
- This calibration is valid at the time of issue of the certificate. The continued retention of accuracy will depend on the care with which the instrument is handled and used.
- Standards used in the retention of this calibration have been certified by SANAS accredited laboratories and through the above provide an unbroken chain of traceability to national standards by NMISA National Metrology Institute of South Africa.

End of Certificate

Issued On: 28/03/19 ALB Issued By: 000 0000 ALB Page 1 of 1	80 Elandsburg (Pty) Ltd, 80 Elandsburg Laboratory Solutions P.O. Box 11000, Bryanston, 2021 370 Hugo Street, Northwilde Business Park Northwilde Road, Northwilde, 2160, South Africa Registered Provider: 000 000000	Email: support@carbontech.co.za Web: www.carbontech.co.za
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Reviewed i.a.w. AQI 01.018.05 Pass ☒ Fail ☐ Stamp: ASQ NSP Date: 2019/05/26

	TEST REPORT MECHANICAL TESTING LAP SHEAR TESTING OF REVOWRAP 110 AS PER ASTM D3165	DOC NO: Q020-2 ISSUE: 01
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9. AMENDMENT RECORD

ISSUE	DATE	DESCRIPTION OF CHANGE	ORIGINATOR
01	2020-06-22	Creation of document	G Makgatho

22 June 2020

Page 9 of 9
MQ001-997 ISSUE A



APPENDIX 8 – Short Term Survival Test Details and Test Data

The standards have identical parameters as well as calculations for the repair parameters.

The calculation for the test parameters is as follows: $P_f = \frac{2ts_a}{D}$

Where: P_f = test pressure

t = Original wall thickness of component

s_a = measured yield strength of component – based on pipe spool MTC

D = Outer diameter of component

$$P_f = \frac{2ts_a}{D}$$

$$P_f = \frac{2(7.1)(241)}{168.3}$$

$$P_f = 20.33\text{MPa or } 203.3\text{Bar}$$

Then the repair thickness is to be applied is defined as follows:

$$t_{\text{repair}} = \frac{1}{0.008s_c} \left(\frac{P_f D}{2} - s_a t_s \right)$$

Where: t_{repair} = Original wall thickness of component

s_c = Tensile modulus of composite in the hoop direction

t_s = Remaining wall thickness of the component

$$t_{\text{repair}} = \frac{1}{0.008(48800)} \left(\frac{20.33(168.3)}{2} - 241(1) \right) = 3.76$$

$$t_{\text{repair}} = 3.76\text{mm}$$

Where: t_{ply} = per ply thickness determined from the tensile samples

$$t_{\text{ply}} = 0.4\text{mm}$$

$$\therefore \text{number of plies} = \frac{t_{\text{repair}}}{t_{\text{ply}}} = \frac{3.76}{0.4} = 9.4 \approx 10 \text{ plies}$$

The pipe spool was repaired with Revowrap 110 using 5 wraps with a 50% overlap to produce the 10 layers required.



Pipe spool MTC for short term survival test

2012

Steelma g Facility
ArcelorMittal South Africa Ltd
 Iscor Road
 Newcastle 2940
 PO Box, Newcastle 2940
 South Africa

MAT CIAL TEST CERTIFICATE

EN10204: 2004 Type 3.1
 Licensed under
 AP 51.31. 0318
 0000012015 - 14986604MMS
 PR02014/000/01/01/00 26/01/02

Contract No/Customer Order: 58104
Material No: 1000040397
Cast/Heat No: 1807512

Page 1 of 1

6" STD PIPE

Product: FULLY KILLED HOT FINISHED CARBON STEEL SEAMLESS TUBE
ASTM A53B:12/A530:12/A106B:18 ASME SA53B:17/SA106B:17 NDE
ARCELORMITTAL SA ASTM A53B/A106B ASME SA53B/SA106B (1500ch040) 168.300 OD X 7.110 WT X 6.000 L CAST NO: 1807512 PROD/
Q NO: T0913029904 NDE

General Information:

Quantity	Mass	Dimensions		Total Length
		Tube OD	Thickness	Length
123(ea)	20,857,110(kg)	168.300(mm)	7.110(mm)	6,000(m)

Chemical Composition:

Element(%)	R05-(Cr+Ni+Mo+Cu+V)					R22-(V+Nb+Ti)					R24-(Nb+V)												
	C	Si	Mn	S	P	Cr	Ni	Mo	Cu	V	Al	Ti	Sn	Ca	N	B	Nb	CE	PCM	R05	R22	R24	
Minimum	0.300	-	1.20	0.045	0.050	0.40	0.40	0.150	0.400	0.080	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat	0.180	0.25	0.91	0.004	0.014	0.13	0.01	0.007	0.007	0.003	0.030	0.002	0.002	0.0012	0.0014	0.0002	-	0.36	0.24	-	-	-	-
Product	0.180	0.25	0.91	0.004	0.014	0.13	0.01	0.007	0.007	0.003	0.030	0.002	0.002	0.0012	0.0014	0.0002	-	0.36	0.24	0.16	-	-	0.003
Product (ADD)	0.180	0.25	0.91	0.004	0.014	0.13	0.01	0.007	0.007	0.003	0.030	0.002	0.002	0.0012	0.0014	0.0002	-	0.36	0.24	0.16	-	-	0.003

Mechanical Properties:

Specification Limits	UTS (Rm) MPa	Yield (0.2%) MPa	%EL 50mm	Orientation and type of tensile test:	
				Longitudinal, Strip, 25.4mm	Orientation of Impact test piece:
Minimum	415	240	30.0	Category	OTHER TESTS Results
Maximum	-	-	-	Flattening	PASSED
(1) Actual	473	303	34.0	Hydrostatic	Hydrostatic test not required
(2) Actual	477	307	38.0	Category	OTHER TESTS Results
				NDI: EMI	PASS - ASTM E570 - 12 5% NOTCH
				NDI: UT	UT not required
				HV 10 Kg	146 149 150

Remarks:

Material in accordance with NACE MR0175/ISO15156-2:15, MR0103:15, Dimensions to ASME B36.10:15, End finish to ASME B16.25:17, Material conforms to the hot yield strength requirements as per ASME Sect II, Pt D, Table Y-1, 2017.
 Material conforms to the visual and dimensional requirements and is made to a suitable fine grain practice.

Quality Assurance Engineer, Certification: M Makgoba

I hereby certify that the material was manufactured, tested and inspected to and fully comply with the requirements of referenced specifications. No changes, amendments or additions may be made to this document. Any changes which are effected shall invalidate this certificate.

Certified by: 

Date of Release: 2018.11.05

APPENDIX 9 – Toughness Parameter Testing Report

TEST REPORT	
	AEROSUD SUPERVISION OF CARBONTECH ENERGY RELEASE RATE LOWER CONFIDENCE LIMIT (GAMMA) TESTING AS OUTLINED IN THE ISO 24817 AND ASME PCC-2 STANDARDS
DOC NO: Q020-1	ISSUE : 02

TEST REPORT	
AEROSUD SUPERVISION OF CARBONTECH ENERGY RELEASE RATE LOWER CONFIDENCE LIMIT (GAMMA) TESTING AS OUTLINED IN THE ISO 24817 AND ASME PCC-2 STANDARDS	
Compiled By:	 Darnelle Hood
Approved By:	 Gertrude Makgatho

24 June 2020	Page 1 of 13 MQ001-997 ISSUE A
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TEST REPORT



AEROSUD SUPERVISION OF CARBONTECH ENERGY
RELEASE RATE LOWER CONFIDENCE LIMIT (GAMMA)
TESTING AS OUTLINED IN THE ISO 24817 AND ASME
PCC-2 STANDARDS

DOC NO: Q020-1

ISSUE : 02

1. **SCOPE**

Aerosud was contracted to supervise Energy Release Rate Lower Confidence Limit (Gamma) Testing at CARBONTECH of the Revowrap 110 repair product. The testing was performed on the 27th May 2020.

The Aerosud personnel that supervised the testing was Gertrude Makgatho and Darnelle Hood.

All test specimen was produced and tested by CARBONTECH using CARBONTECH test equipment. Refer to section 0 for definition of test equipment used. The manufacturing of the test specimen was not supervised by Aerosud.

This test report describes the results of the testing that was supervised by Aerosud and does not provide any outcome on the suitability of the Revowrap 110 material.

2. **REFERENCE DOCUMENTS**

ASME PCC-2: Repair of Pressure Equipment and Piping

ISO 25817: Petroleum, Petrochemical and Natural Gas Industries – Composite Repairs for Pipework – Qualification and Design, Installation, Testing and Inspection

3. **DESCRIPTION OF TEST SPECIMEN**

The test specimen used comprises of a steel pipe with pre-drilled holes to simulate defects in pipes. The pre-drilled holes were wrapped with Revowrap 110. See below for additional information on the pipe and wrap material.

1) Pipe with end cap welded on as follows

- Material ASTM 106 Grade B carbon steel
- 555mm X 114.3mm X 6.02mm
- The following holes were drilled into pipes – 10, 15, 20 and 25mm.



2) Revowrap 110 consisting of 3K – 3K carbon fibre tape and epoxy resin.

24 June 2020

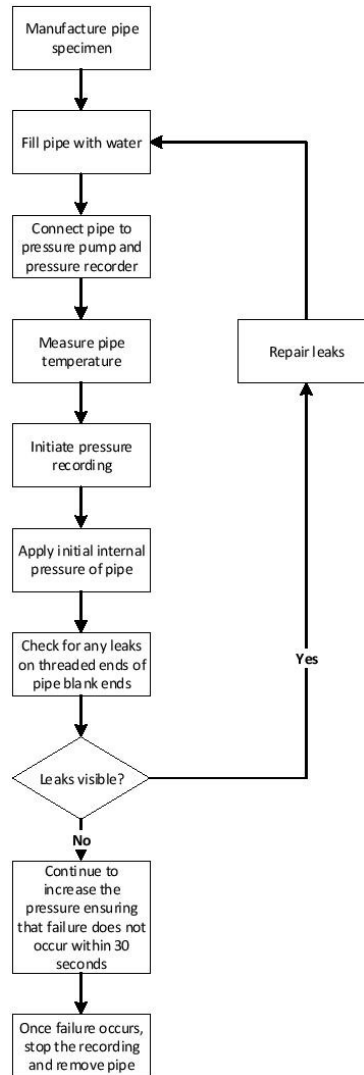
Page 2 of 13

MQ001-997 ISSUE A

	TEST REPORT AEROSUD SUPERVISION OF CARBONTECH ENERGY RELEASE RATE LOWER CONFIDENCE LIMIT (GAMMA) TESTING AS OUTLINED IN THE ISO 24817 AND ASME PCC-2 STANDARDS	DOC NO: Q020-1 ISSUE : 02
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4. TEST METHOD USED

The pressure testing was conducted as follows:



24 June 2020

Page 3 of 13
MQ001-997 ISSUE A

TEST REPORT



AEROSUD SUPERVISION OF CARBONTECH ENERGY
RELEASE RATE LOWER CONFIDENCE LIMIT (GAMMA)
TESTING AS OUTLINED IN THE ISO 24817 AND ASME
PCC-2 STANDARDS

DOC NO: Q020-1

ISSUE : 02

5. DESCRIPTION OF TEST EQUIPMENT

The test equipment used comprised of a pressure pump, pressure transducer and data logger. The figure below provides an overview of the test set-up.



5.1 High Pressure Line

A MAXIMATOR pressure pump equipped with two calibrated pressure gauges as follows:



Refer to section 8.1 and 8.2 for calibration certificates.

24 June 2020

Page 4 of 13
MQ001-997 ISSUE A

TEST REPORT



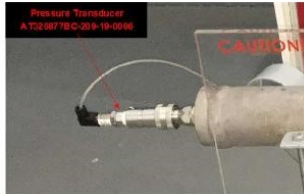
AEROSUD SUPERVISION OF CARBONTECH ENERGY
RELEASE RATE LOWER CONFIDENCE LIMIT (GAMMA)
TESTING AS OUTLINED IN THE ISO 24817 AND ASME
PCC-2 STANDARDS

DOC NO: Q020-1

ISSUE : 02

5.2 Pressure transducer

A calibrated pressure transducer was used to measure the pressure inside the pipe.

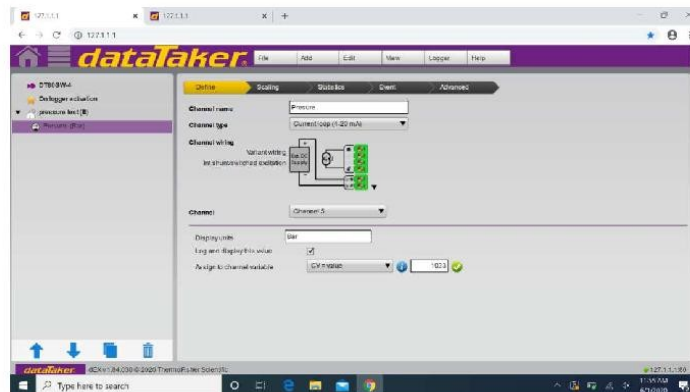


Refer to section 8.3 for calibration certificate.

5.3 dataTaker DT80GW



The wiring and setting used for logging the pressure readings are as follows:



24 June 2020

Page 5 of 13
MQ001-997 ISSUE A

	TEST REPORT AEROSUD SUPERVISION OF CARBONTECH ENERGY RELEASE RATE LOWER CONFIDENCE LIMIT (GAMMA) TESTING AS OUTLINED IN THE ISO 24817 AND ASME PCC-2 STANDARDS	DOC NO: Q020-1 ISSUE : 02
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6. TEST RESULTS

The results of the pressure tests that was supervised is as follows:

Pipe Serial #	Hole Size (mm)	Test Temperature (°C)	Failure Pressure (Bar)	Failure Mechanism
R110-10TW-101	10	16.6	93.13557	De-lamination
R110-15TW-105	15	16.8	89.19135	De-lamination
R110-15TW-106	15	15.8	110.6425	De-lamination
R110-15TW-107	15	15.8	89.50675	De-lamination
R110-20TW-108	20	14.0	29.5598	De-lamination
R110-20TW-109	20	14.1	55.83048	De-lamination
R110-20TW-110	20	14.3	50.05015	De-lamination
R110-25TW-100	25	16.3	43.61477	De-lamination
R110-25TW-102	25	13.9	47.07852	De-lamination
R110-25TW-104	25	13.0	42.19894	De-lamination

7. CONCLUSION

The information and test results contained in this report are accurate and reflects the observations made by Aerosud personnel that observed the testing conducted by CARBONTECH on the 27th May 2020.

24 June 2020	Page 6 of 13 MQ001-997 ISSUE A
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	TEST REPORT AEROSUD SUPERVISION OF CARBONTECH ENERGY RELEASE RATE LOWER CONFIDENCE LIMIT (GAMMA) TESTING AS OUTLINED IN THE ISO 24817 AND ASME PCC-2 STANDARDS	DOC NO: Q020-1 ISSUE : 02
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8. APPENDICES

8.1 Pressure Gauge J1202917-1



**CERTIFICATE
OF
CALIBRATION**

Certificate No P1031571



"The South African National Accreditation System (SANAS) is a member of the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement (MRA). This arrangement allows for the mutual recognition of technical test and calibration data by member accreditation bodies worldwide. For more information on the arrangement please consult www.ilac.org"

Calibration of a	:	Pressure Gauge
Manufacturer	:	SA Gauge
Description	:	3 Y 100 G 12B 0-250 bar/psi
Model No	:	N/A
Serial No	:	J1202917-1
Calibrated for	:	Carbontech Composite Systems
Address	:	Growthpoint Industrial Estate Unit A5, Bell Street, Germiston
Job Card No	:	J1243485
Temperature	:	22 ± 2 °C
Calibration Date	:	20-05-2020
Issue Date	:	20-05-2020
Re-calibration Date	:	20-05-2021
Calibrated by	:	Dinesh Betchan 
Checked by	:	Riaan Reinach 

This certificate is issued without alteration and in accordance with the conditions of accreditation granted by SANAS. The results reflected in the certificate is a correct record of the measurements made at the time of calibration. Subsequently the accuracy will depend on factors such as care exercised in handling the instrument and the frequency of use. Recalibration should be performed after a period so chosen to ensure that, under normal circumstances, the instrument accuracy remains within the desired limits. The uncertainty of all measurements were traceable to the national measurement standards of South Africa, unless otherwise noted. Copyright of this certificate is owned jointly by SA Gauge and SANAS may not be reproduced other than in full, except with prior written approval of SA Gauge and SANAS. The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k = 2 providing a level of confidence of approximately 95%. The uncertainty of measurement has been estimated in accordance with the principles defined in the GUM, Guide to Uncertainty of Measurement, ISO, Geneva, 1993.

SANAS Authorized Technical Signatory
Dinesh Betchan

SA Gauge (Pty) Ltd
P.O. Box 22069
Glenamathu
4023
RSA
Tel: +27 (0)11 5792014/798
Fax: +27 (0)11 5792001

8 Woodfield Close
Springfield Park
Durban
Email: sanasp@sa-gauge.com
Website: www.sa-gauge.com
(Pty) Ltd 2003/01 704003

Page 1 of 2

24 June 2020	Page 7 of 13 MQ001-997 ISSUE A
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	TEST REPORT AEROSUD SUPERVISION OF CARBONTECH ENERGY RELEASE RATE LOWER CONFIDENCE LIMIT (GAMMA) TESTING AS OUTLINED IN THE ISO 24817 AND ASME PCC-2 STANDARDS	DOC NO: Q020-1 ISSUE : 02
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Certificate No P1031571

1. LABORATORY STANDARDS AND EQUIPMENT USED:

Asset No	Standards or Equipment	Serial Number	Certificate Number	Expiry Date
2-23	TEMPERATURE RECORDER	11062	114569	31-07-2020
2-12	BETA 321	9036015	S20200106-3	31-01-2021

2. PROCEDURE

2.1 The UUT was calibrated in accordance with procedure CM-P-2-01 and the manufacturers recommendation if available.

2.2 The UUT was set to zero prior to calibration.

2.3 UUT resolution: 5 bar

3. RESULTS

3.1 PRESSURE

UUT Display (bar)	Applied Pressure (As Found) (bar)		Applied Pressure (As Left) (bar)	
	Upward	Downward	Upward	Downward
0	0	0	0	0
50	50.12	49.90	50.12	49.90
100	100.27	100.06	100.27	100.06
150	150.40	150.21	150.40	150.21
200	200.36	200.15	200.36	200.15
250	250.54	N/a	250.54	N/a

3.2 REPEATABILITY

UUT Display (bar)	Applied Pressure (bar)	
	Upward	Downward
150	150.40	150.21
150	150.43	150.24
150	150.38	150.19

Uncertainty of measurement: ± 2 bar

4. NOTES

4.1 N/A

End of certificate


 SANJAS Authorized Technical Signatory

Page 2 of 2

24 June 2020	Page 8 of 13 MQ001-997 ISSUE A
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	TEST REPORT AEROSUD SUPERVISION OF CARBONTECH ENERGY RELEASE RATE LOWER CONFIDENCE LIMIT (GAMMA) TESTING AS OUTLINED IN THE ISO 24817 AND ASME PCC-2 STANDARDS	DOC NO: Q020-1 ISSUE : 02
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8.2

Pressure Gauge 1243485-1

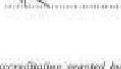


**CERTIFICATE
OF
CALIBRATION**

Certificate No P1031572



"The South African National Accreditation System (SANAS) is a member of the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement (MRA). This arrangement allows for the mutual recognition of technical test and calibration data by member accreditation bodies worldwide. For more information on the arrangement please consult www.ilac.org"

Calibration of a	: Pressure Gauge
Manufacturer	: SA Gauge
Description	: 3 B 63 G 14B 0-16 bar/psi
Model No	: N/A
Serial No	: J1243485-1
Calibrated for Address	: Carbonteck Composite Systems Growthpoint Industrial Estate Unit A5, Bell Street, Germiston
Job Card No	: J1243485
Temperature	: 22 ± 2 °C
Calibration Date	: 20-05-2020
Issue Date	: 20-05-2020
Re-calibration Date	: 20-05-2021
Calibrated by	: Dinesh Betchan 
Checked by	: Riaan Reinach 

This certificate is issued without alteration and in accordance with the conditions of accreditation granted by SANAS. The results reflected in the certificate is a correct report of the measurements made at the time of calibration. Subsequently the accuracy will depend on factors such as care exercised in handling the instrument and the frequency of use. Recalibration should be performed after a period is chosen to ensure that, under normal circumstances, the instrument accuracy remains within the desired limits. The accuracies of all measurements were traceable to the national measurement standards of South Africa, unless otherwise noted. Copyright of this certificate is owned jointly by SA Gauge and SANAS. The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k = 2 providing a level of confidence of approximately 95%, the uncertainty of measurement has been estimated in accordance with the principles defined in the GUM, Guide to the Expression of Uncertainty in Measurement, ISO, Geneva, 1995.

SANAS Authorized Technical Signatory
Dinesh Betchan

SA Gauge (Pty) Ltd
P.O. Box 72589
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Page 1 of 2

24 June 2020	Page 9 of 13 MQ001-997 ISSUE A
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TEST REPORT



AEROSUD SUPERVISION OF CARBONTECH ENERGY
RELEASE RATE LOWER CONFIDENCE LIMIT (GAMMA)
TESTING AS OUTLINED IN THE ISO 24817 AND ASME
PCC-2 STANDARDS

DOC NO: Q020-1

ISSUE : 02

Certificate No P1031572

1. LABORATORY STANDARDS AND EQUIPMENT USED:

Asset No	Standards or Equipment	Serial Number	Certificate Number	Expiry Date
2-23	TEMPERATURE RECORDER	T1002	114569	31-07-2020
2-03	PRESSURE MODULE	P903670	S20200106-8	31-01-2021
2-07	MC 1200	9074064	74025-1	30-11-2021

2. PROCEDURE

- 2.1 The UUT was calibrated in accordance with procedure CM-P-2-01 and the manufacturers recommendation if available.
2.2 The UUT was set to zero prior to calibration.
2.3 UUT resolution: 0.2 bar.

3. RESULTS

3.1 PRESSURE

UUT Display (bar)	Applied Pressure (As Found) (bar)		Applied Pressure (As Left) (bar)	
	Upward	Downward	Upward	Downward
0	0	0	0	0
4	4.053	4.042	4.053	4.042
8	8.072	8.065	8.072	8.065
12	12.094	12.073	12.094	12.073
16	16.048	N/A	16.048	N/A

3.2 REPEATABILITY

UUT Display (bar)	Applied Pressure (bar)	
	Upward	Downward
8	8.072	8.065
8	8.064	8.053
8	8.085	8.070

Uncertainty of measurement: ± 0.12 bar

4. NOTES

4.1 N/A

End of certificate


SANAS Authorized Technical Signatory

Page 2 of 2

24 June 2020

Page 10 of 13
MQ001-997 ISSUE A

	TEST REPORT AEROSUD SUPERVISION OF CARBONTECH ENERGY RELEASE RATE LOWER CONFIDENCE LIMIT (GAMMA) TESTING AS OUTLINED IN THE ISO 24817 AND ASME PCC-2 STANDARDS	DOC NO: Q020-1 ISSUE : 02
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8.3 Pressure Transmitter AT326877BC-209-19-0006



**CERTIFICATE
OF
CALIBRATION**

 Certificate No P1031573



"The South African National Accreditation System (SANAS) is a member of the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement (MRA). This arrangement allows for the mutual recognition of technical test and calibration data by member accreditation bodies worldwide. For more information on the arrangement please consult www.ilac.org"

Calibration of a	: Pressure Transmitter
Manufacturer	: Goms
Description	: Pressure Transmitter 0-250 bar (4-20 mA)
Model No	: 3100B0250S01B000
Serial No	: AT326877BC-209-19-0006
Calibrated for Address	: Carbontech Composite Systems Growthpoint Industrial Estate Unit A5, Bell Street, Germiston
Job Card No	: J1243485
Temperature	: 22 ± 2 °C
Calibration Date	: 20-05-2020
Issue Date	: 20-05-2020
Re-calibration Date	: 20-05-2021
Calibrated by	: Dinesh Betchan 
Checked by	: Rinnu Reinach 

This certificate is issued without alteration and is in accordance with the conditions of accreditation granted by SANAS. The results reflected in the certificate is a correct report of the measurements made at the time of calibration. Subsequently the accuracy will depend on factors such as care exercised in handling the instrument and the frequency of use. Recalibration should be performed after a period so chosen to ensure that, under normal circumstances, the instrument accuracy remains within the desired limits. The accuracy of all measurements were traceable to the national measurement standards of South Africa, unless otherwise noted. Copyright of this certificate is owned jointly by SA Gauge and SANAS and may not be reproduced other than in full, except with prior written approval of SA Gauge and SANAS. The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k = 2 providing a level of confidence of approximately 95%, the uncertainty of measurement has been estimated in accordance with the principles defined in the GUM, Guide to Uncertainty of Measurement, ISO, Geneva, 1995.

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Dinesh Betchan

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Page 1 of 2

24 June 2020	Page 11 of 13 MQ001-997 ISSUE A
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TEST REPORT



AEROSUD SUPERVISION OF CARBONTECH ENERGY
RELEASE RATE LOWER CONFIDENCE LIMIT (GAMMA)
TESTING AS OUTLINED IN THE ISO 24817 AND ASME
PCC-2 STANDARDS

DOC NO: Q020-1

ISSUE : 02

Certificate No P1031573

1. LABORATORY STANDARDS AND EQUIPMENT USED:

Asset No	Standards or Equipment	Serial Number	Certificate Number	Expiry Date
2-23	TEMPERATURE RECORDER	TL002	114569	31-07-2020
2-12	BETA 321	9036015	S20200106-3	31-01-2021

2. PROCEDURE

- 2.1 The UUT was calibrated in accordance with procedure CM-P-2-04 and the manufacturers recommendation if available.
- 2.2 The UUT was set to zero prior to calibration.
- 2.3 UUT resolution: N/A

3. RESULTS

3.1 PRESSURE

Applied Pressure (bar)	UUT Display (As Found) (mA)		UUT Display (As Left) (mA)	
	Upward	Downward	Upward	Downward
0	4.125	4.125	4.125	4.125
50	7.356	7.356	7.356	7.356
100	10.562	10.562	10.562	10.562
150	13.770	13.770	13.770	13.770
200	16.953	16.953	16.953	16.953
250	20.132	N/a	20.132	N/a

3.2 REPEATABILITY

Applied Pressure (bar)	UUT Display (mA)	
	Upward	Downward
150	13.770	13.770
150	13.770	13.770
150	13.770	13.770

Uncertainty of measurement: ± 0.4 (0.02 mA)

4. NOTES

4.1 N/A

End of certificate


SANAS Authorized Technical Signatory

Page 2 of 2

24 June 2020

Page 12 of 13
MQ001-997 ISSUE A

	TEST REPORT AEROSUD SUPERVISION OF CARBONTECH ENERGY RELEASE RATE LOWER CONFIDENCE LIMIT (GAMMA) TESTING AS OUTLINED IN THE ISO 24817 AND ASME PCC-2 STANDARDS	DOC NO: Q020-1 ISSUE : 02
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9. AMENDMENT RECORD

ISSUE	DATE	DESCRIPTION OF CHANGE	ORIGINATOR
01	2020-06-18	Creation of document	Darnelle Hood
02	2020-06-24	Corrected date in document footer	Darnelle Hood

24 June 2020

Page 13 of 13
MQ001-997 ISSUE A



Appendix 10

Carbontech Composite Systems – Revowrap 110 Cathodic disbondment test

INTRODUCTION:

The purpose of this document is to report the methodology used and results of Cathodic disbondment testing done on the Revowrap110 composite repair system. The testing was done according to the ASTM G8 at a temperature of 21-25 degrees Celsius. The results presented are for 30 continuous days of exposure.

SAMPLE PREPARATION

In accordance with ASTM G8 method A 1" Sch 40 carbon steel pipes were grit blasted and four layers of Revowrap110 composite material was applied to the prepared area. The composite material is applied by hand lamination as would be done on site so best to simulate the conditions faced. The estimated film thickness of the composite is estimated at 100 -110mils [2.54mm- 2.79mm] and in preparation of the test, had an intentional holiday drilled through the composite to the substrate. There is also an additional hole drilled outside of the test area for the positive pole of the circuit.

An electrolyte solution of 1% each NaCl, Na₂SO₄, and Na₂CO₃ is used in the testing and a constant voltage of 1.5Vdc is passed through the system, this is monitored by means of a reference electrode.

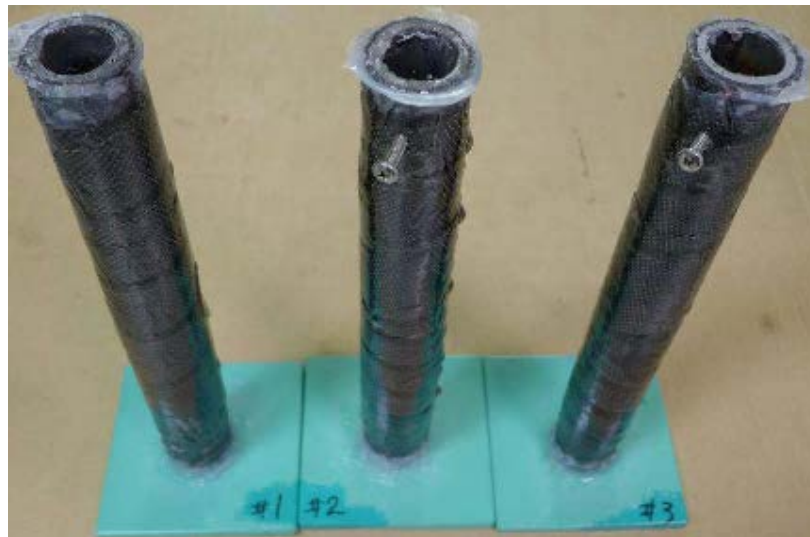


Figure 1 Showing samples with positive pole

EQUIPMENT

The equipment used in the testing is listed as:

- CUCUSO₄ reference electrode
- Magnesium anode
- ELECTROLYTE USED – 1% each NaCl, Na₂SO₄, and Na₂CO₃.
- Hand tools required for inspecting the delamination from the substrate.

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RESULTS

Final results as stipulated:

Recorded Information	Findings from inspection
Manufacturer	Carbontech Americas
Product Description	Revowrap110™
Color	Gray
Number of Specimens	3
Surface	Smooth
Material Description	By Manufacturer and VTEC
Date of Selection	January 2023
Purpose of test	Cathodic Disbonding of Coatings
Method of sample mounting	Method A
Immersion Depth	6 inches
Resistance Measurement	-1.5 V
Pipe Size	1", sch 40
Holiday Amount	1 per specimen
Size of Initial Holiday	0.25"
Immersed Area (nominal)	27.5 in ²
Duration	30 days
Source, production date and production run number	Carbontech Americas, Jan 3rd 2023 Batch codes: Primary: Part A T110521 Part B 070620B0 Saturation: Part A TO40521 Part B 070620B0
Visual Results	The carbon laminate was removed and the primer was intact without disbondment.

Sample measurements:

Sample	DFT, mm	Max DFT, mm	Min DFT, mm	Disbondment, mm
1	3.73	4.6	3.24	0
2	4.48	4.74	4.20	0
3	3.24	3.48	2.94	0

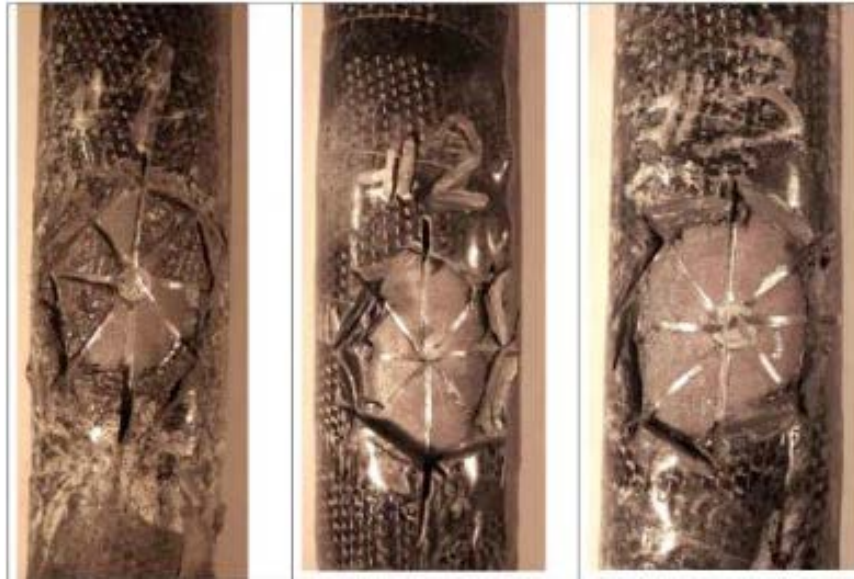


Figure 2 showing Post Test, the sample is within the allowable delamination.

CONCLUSION

As per ASTM G8, the samples are allowed no more than 10mm of delamination present at the end of the testing period to be deemed suitable for use on Cathodically protected pipelines. As such, these results show that the Revowrap110™ system is suitable for repair applications on catholically protected pipelines.



SUMMARY OF REVOWRAP 110 QUALIFICATION TEST RESULTS:

ISO TS24817 and ASME PCC2 REPAIR SYSTEM QUALIFICATION DATA			
	Revowrap 110		
Property	SI	Imperial	Test Method
Ply Thickness (mm, inches)	0.4	0.01575	ASTM D3039
Tensile Modulus – Hoop (GPa, ksi)	48.8	7078	ASTM D3039
Tensile Modulus – Axial (GPa, ksi)	41.0	5947	ASTM D3039
Tensile Strength – Hoop (MPa, ksi)	568	82.4	ASTM D3039
Tensile Strength – Axial (MPa, ksi)	229	33.2	ASTM D3039
Tensile Strain to Failure	1.1%		ASTM D3039
In Plane Shear Modulus (GPa, ksi)	1.6	232	ASTM D5379
Compressive Modulus – Filler Putty (GPa, ksi)	2.55	369.8	ASTM D695
Poisson's Ratio	0.33		ASTM D3039
CTE (mm/mm/°C, in/in/°F)	1.45x10 ⁻⁶	8.06x10 ⁻⁷	ASTM E831
Heat Distortion Temperature (°C, °F)	124	255	ASTM D648-07
Shore D Hardness	92		ASTM D2583
Lap Shear Strength - SA2.5 (MPa, ksi)	14.1	2.05	ASTM D3165
Lap Shear Strength - Bristle Blaster® (MPa, ksi)	7.71	1.12	ASTM D3165
Lap Shear Strength - Hand Sanded (MPa, ksi)	5.86	0.85	ASTM D3165
Short Term Survival Test	Pass – pressure tested to 21MPa		ASME PCC2 – III, ISO 24817 Annex C
Toughness Parameter (J/m ² , in-lb/in ²)	194.7	1.11	ASME PCC2 – IV, ISO 24817 Annex D
Impact Performance Test	Pass		ASME PCC2 – VI, ISO 24817 Annex F