CARBONTECH

Proactive and Reactive Approaches:

Effectiveness of Composite Reinforcement with Leak Sealing Clamps

Who are we?

PROACTIVE & REACTIVE APPROACHES

- **PROACTIVE**: We are a producer of reliable and high-quality Revowrap Composite Repair and Leak Seal systems.

- We provide full pipe repair and engineering support in accordance with ISO-24817.

- Manufacturing facility in Sharjah, UAE & South Africa with
- R&D and testing facilities in South Africa.

- Carbontech Regional Offices in USA, Australia, Singapore, Holland and Poland.

- **REACTIVE**: Sister Company: Beruseal Leak Sealing providing engineered and custom-made leak sealing clamp enclosures.

BERUSEAL
INNOVATIVE & INVOLVED

REVOWRAP

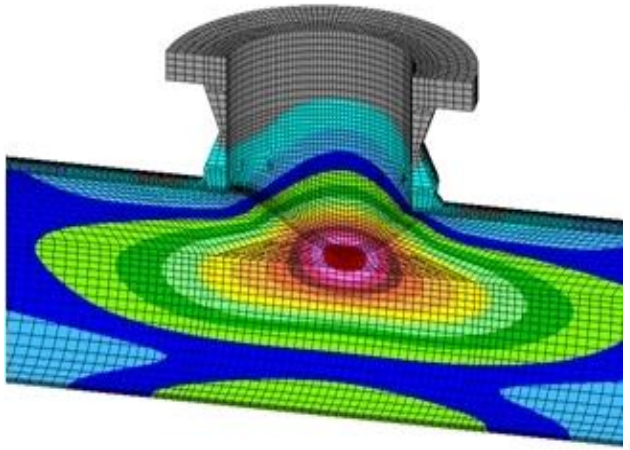
The Reactive Approach

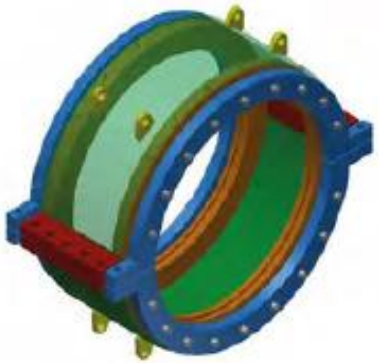
Established in 2005

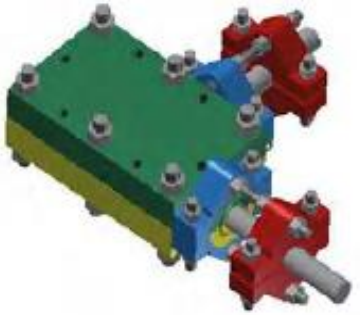
- ISO 9001 / 14001 certified
- OHSAS 18001 certified
- ISO3834 certified ISO 3434
- ISO 45000

- In-house Engineering department
- Fabrication and Machining
- Engineering clamps for standard geometries (elastomer based)
- Engineered clamps for custom configurations (elastomer based)
- On site improvised clamps

- Leaks up to 250 BAR & 650°C
- Leaking & Passing Pipes, valves, flanges - any configuration
- Designs done in house according to Various Standards
- Off the shelve Quickseal stock for 1’’-12’’ standard configurations







SASOL TOTAL

ExxonMobil Chevron

YARA

BERUSEAL
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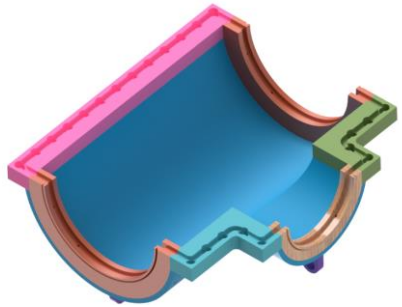
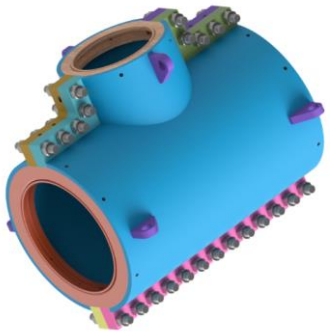
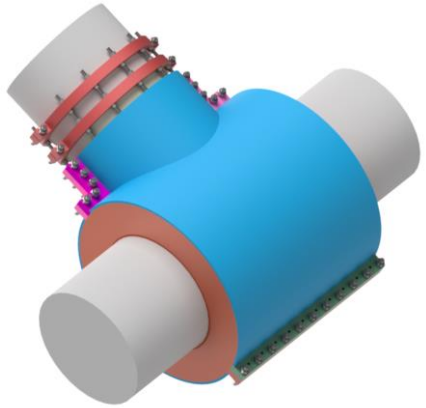
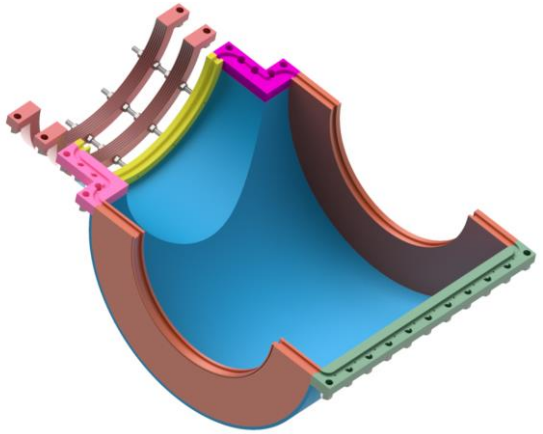
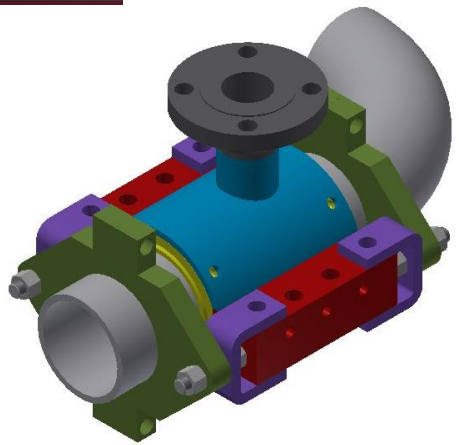
REVOWRAP





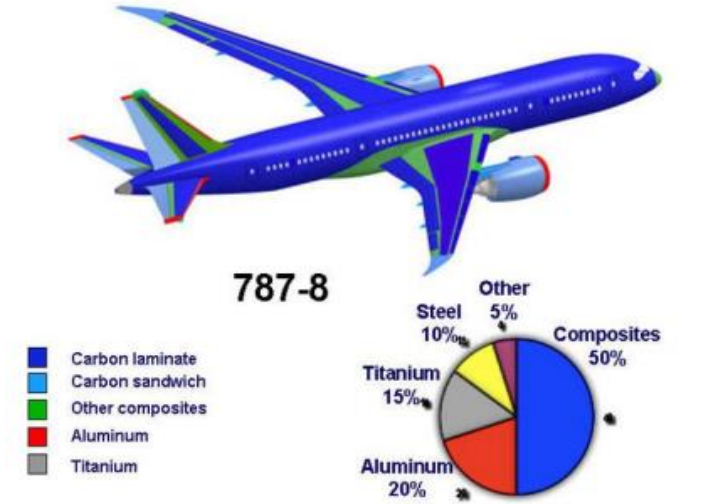






What are Composite Materials?

- Two or more distinct constituent materials combined to form a new material, such as (Concrete, Fiber reinforced plastics, etc.) to produce material properties that are different to the properties of those elements on their own.



What is a Composite Repair ?

- A composite system that is designed to reinforce and restore piping integrity back to the original design specification of the pipe using a fiber impregnated with a resin system.

- Preformed plates, sleeves or coils manufactured off site and then bonded onto the component on site.

- Hand applied, wet lay-up system; the resin is worked into the fibre reinforcement on site then directly applied (commonly used for pipework applications)

- **Reinforcement fabric**: Glass fibre, Kevlar or Carbon Fibre with various woven fabric architectures.

- **Resin system** (matrix): Epoxy (with various hardeners) Polyurethane and Esters (both Poly and Vinyl Ester)

- **Primer**: Epoxy adhesion promoting layer.

Preformed

Wet Layup

Advantages of a Composite Repair

- Can be applied live, No Shutdown and Maintain Production.
- Extend Asset Lifetime.
- Requires No Hot Work Permit.
- Corrosion Resistant.
- No shielding of Cathodic Protection.
- Can be used on all soil types.
- Fast Application Requiring Minimal on-site facilities.
- Can be applied to any pipe geometry and in confined spaces.
- Lightweight and easy transportation.
- ISO/ASME Standards for Engineered Repairs and can be Designed and Guaranteed for up to 20-years.

Where can Composite Repairs be utilised?

Components that can be repaired using composite repairs include:

- Piping Systems (all components, e.g., bends, tees)
- Pipelines
- Vessels & Storage Tanks (e.g., shells, supports, nozzle attachments)
- Risers & Caissons.
- Structural Repairs (roofs, beams, piles, struts, concrete, etc.)

Generic defect types that can be repaired include:

- Internal Defects, e.g., corrosion pits
- External Defects, e.g., dents
- Through-Wall Defects & Leaks
- Cracks (under certain conditions may be repaired depending on crack orientation & loads)

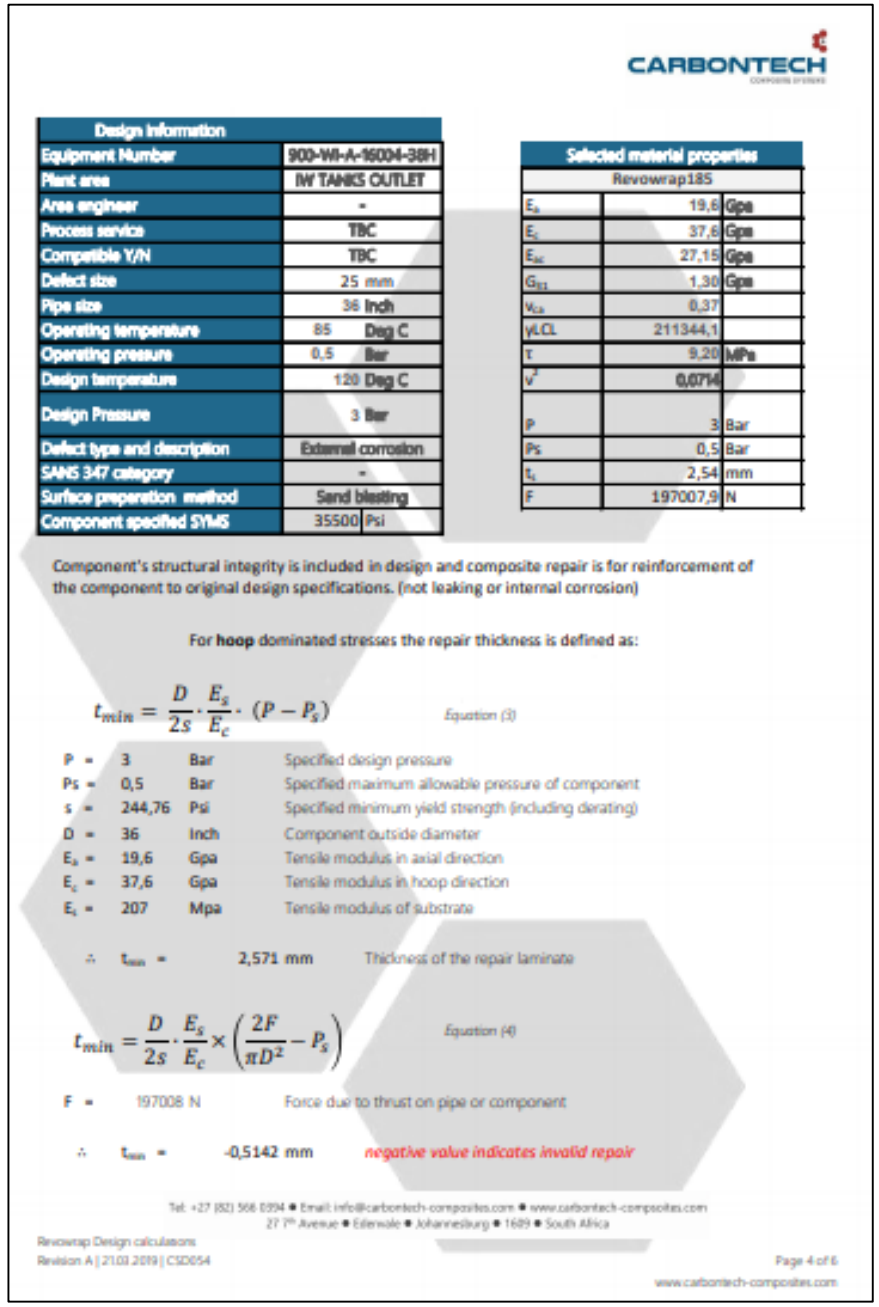
Design Scenarios:

- For **external defects**, the application of a composite repair will prevent further corrosion

- For **internal defects and through wall defects**, the application of a composite repair will not stop internal corrosion. Therefore, need to assume that internal defect will grow through wall during design life

- **Short lifetime** (less than 2 years) is intended where the repair is required to survive until the next shutdown – less conservative allowable strain and adhesion strength values used .

- **Long lifetime** (up to 20 years) is intended to denote those situations where the repair is required to reinstate the pipe to its original design lifetime – more conservative allowable strain and adhesion strength values used



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Design Information	
Equipment Number	900-WI-A-1600M-38H
Plant area	IW TANKS OUTLET
Area engineer	-
Process service	TBC
Compatible Y/N	TBC
Defect size	25 mm
Pipe size	36 Inch
Operating temperature	85 Deg C
Operating pressure	0,5 Bar
Design temperature	120 Deg C
Design Pressure	3 Bar
Defect type and description	External corrosion
SANS 347 category	-
Surface preperation method	Sand blasting
Component specified SYMS	35500 Psi

Selected material properties	Revowrap185	
E_a	19,6	Gpa
E_c	37,6	Gpa
E_{ac}	27,15	Gpa
G_{12}	1,30	Gpa
v_{ca}	0,37	
γLCL	211344,1	
T	9,20	MPa
v^2	0,0714	
P	3	Bar
Ps	0,5	Bar
t_s	2,54	mm
F	197007,9	N

Component's structural integrity is included in design and composite repair is for reinforcement of the component to original design specifications. (not leaking or internal corrosion)

For **hoop** dominated stresses the repair thickness is defined as:

$$t_{min} = \frac{D}{2s} \cdot \frac{E_s}{E_c} \cdot (P - P_s)$$ Equation (3)

P =	3	Bar	Specified design pressure
Ps =	0,5	Bar	Specified maximum allowable pressure of component
s =	244,76	Psi	Specified minimum yield strength (including derating)
D =	36	Inch	Component outside diameter
E_a =	19,6	Gpa	Tensile modulus in axial direction
E_c =	37,6	Gpa	Tensile modulus in hoop direction
E_s =	207	Mpa	Tensile modulus of substrate

∴ t_{min} = 2,571 mm Thickness of the repair laminate

$$t_{min} = \frac{D}{2s} \cdot \frac{E_s}{E_c} \times \left(\frac{2F}{\pi D^2} - P_s\right)$$ Equation (4)

F = 197008 N Force due to thrust on pipe or component

∴ t_{min} = -0,5142 mm *negative value indicates invalid repair*

Tel: +27 (82) 568 0394 ● Email: info@carbontech-composites.com ● www.carbontech-composites.com
27 7th Avenue ● Edenvale ● Johannesburg ● 1609 ● South Africa

What are the Applicable Standards?

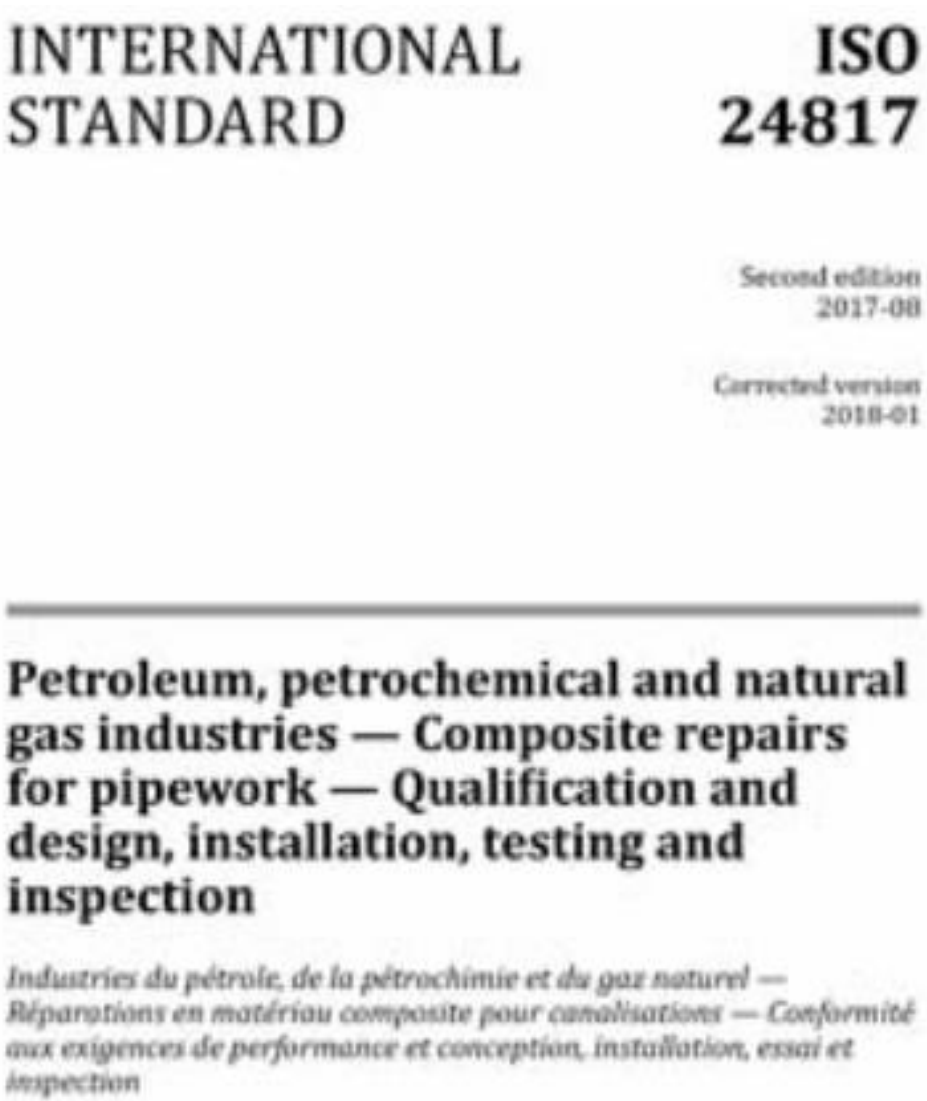
- **ISO/TS 24817** (August 2017) is the International Standard:

"Petroleum, petrochemical and natural gas industries: Composite repairs for pipework - Qualification and Design, Installation, Testing and Inspection."

- **ASME standard – PCC-2**
  - Article 4.1 and 4.2 for low and high-risk applications.

- Beams – Ciria RP 645 – Repair of beams using externally bonded fibre reinforced polymers

- Tanks, vessels, circular struts – ISO/TS 24817, BS 5500


INTERNATIONAL STANDARD

ISO 24817

Second edition
2017-08

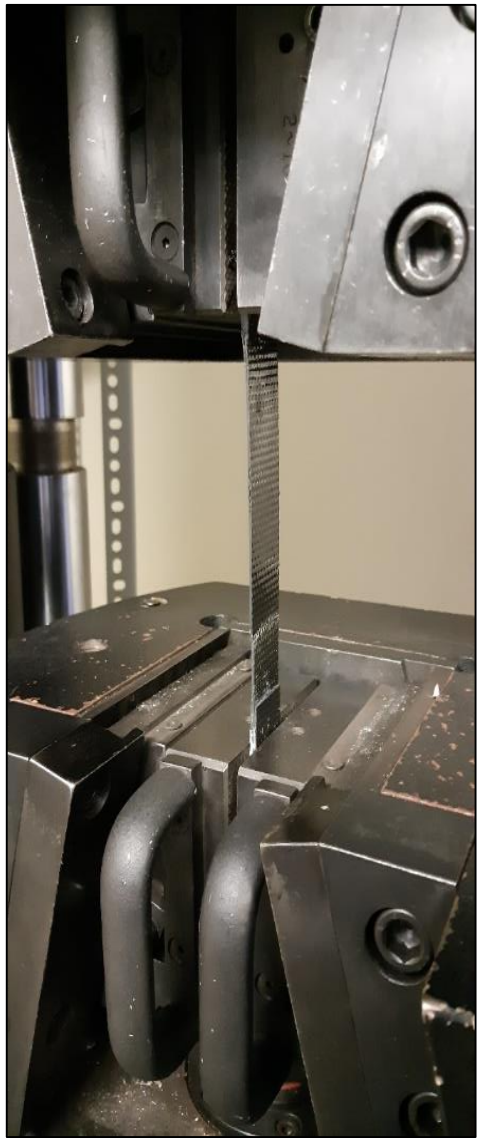
Corrected version
2018-01

Petroleum, petrochemical and natural gas industries — Composite repairs for pipework — Qualification and design, installation, testing and inspection

Industries du pétrole, de la pétrochimie et du gaz naturel — Réparations en matériau composite pour canalisations — Conformité aux exigences de performance et conception, installation, essai et inspection

ISO TS 24817 & ASME PCC-2 Revowrap Input & Product Qualification

Property	Revowrap 110	Revowrap 185	Revowrap 225
Ply thickness	0.4mm	0.52mm	0.52mm
Hoop Tensile Modulus	48.8Gpa	37.6GPa	30,7GPa
Hoop Tensile Strength	568Mpa	453.1MPa	454.1MPa
Hoop Tensile Strain to failure	1.1%	1.3%	1.1%
Poisson's ratio	0.33	0.37	0.38
Axial Tensile Modulus	41GPa	19.6GPa	20.5GPa
Axial Tensile Strength	229MPa	182.7MPa	183.1MPa
Axial Tensile Strain to failure	1.1%	1.3%	1.1%
Shear Modulus	1.6Gpa	1.3Gpa	1.7Gpa
Shear strength	73.6Mpa	82.1MPa	106.8MPa
Heat distortion temperature (HDT)	124.08°C	226.8°C	247.07°C
Short term Lap shear strength - Sa2.5	14.1MPa	9.2MPa	9.58MPa
Short term Lap shear strength - ST3	7.71Mpa	4.8MPa	5.45MPa
Short term Lap shear strength - ST2	5.86Mpa	4.7MPa	4.2MPa
Energy Release Rate	194.7 J/m2	89.48 J/m2	69.28 J/m2
CTE Hoop Direction (mm/mm/°C)	1.45E-06	1.88E-06	1.86E-06
CTE axial Direction (mm/mm/°C)	1.45E-06	1.88E-06	1.86E-06
Compressive Modulus of Filler	2.55GPa	1.19GPa	2.33GPa



Product Range

- Carbontech works with various independent Laboratories and verification bodies during the development of the products, more than 200 various tests have been conducted on our products:

Qualified in Accordance with ISO24817	Revowrap110	Revowrap185	Revowrap225
Maximum service temperature limits for non leaking defects	109°C	211.8°C	233°C
Minimum application temperature	16°C	18°C	23°C
Cure time @ 29°C	8 hours	14 hours	16 hours
Shelf Life	2 Years	1 year	1 year
Maximum allowable working pressure	No Limits	No Limits	No Limits
Maximum application size	No Limits	No Limits	No Limits

CERTIFICATE

Conformity based on EN ISO 24817:2017 "Petroleum, petrochemical and natural gas industries - Composite repairs for pipework - Qualification and design, installation, testing and inspection"

Certificate-No.: NS005/20/24817/001

Name and address of manufacturer: CARBONTECH COMPOSITE SYSTEM (PTY) LIMITED
Unit A5 – Growthpoint Industrial Estate, Meadowdale, Germiston 1609, Repubic of South Africa

This is to certify that the manufacturer has demonstrated composite repairs for pipework - qualification and design, installation, testing and inspection according to standard EN ISO 24817:2017.

Technical rule / regulation:
- EN ISO 24817:2017
- TR Latvia documents

Report Nr.: NS005/24817/001

Product's name, type, model, identification: Revowrap carbon fiber engineered composite repair system, Revowrap 110, Revowrap 185, Revowrap 225

Scope: Petroleum, petrochemical, natural gas, power generation and mining industry / pipelines

Riga, 01.09.2020.

M.Lupane
Certification Center of TUV Rheinland Group-LRTDEA Ltd.

TUV Rheinland Group – LRTDEA Ltd
VAT no. 40003221612
Katlakalna street 9A, Riga, LV-1073
E-mail: tuv@tuv.lv
WEB: http://www.tuv.lv

TÜVRheinland®
LRTDEA

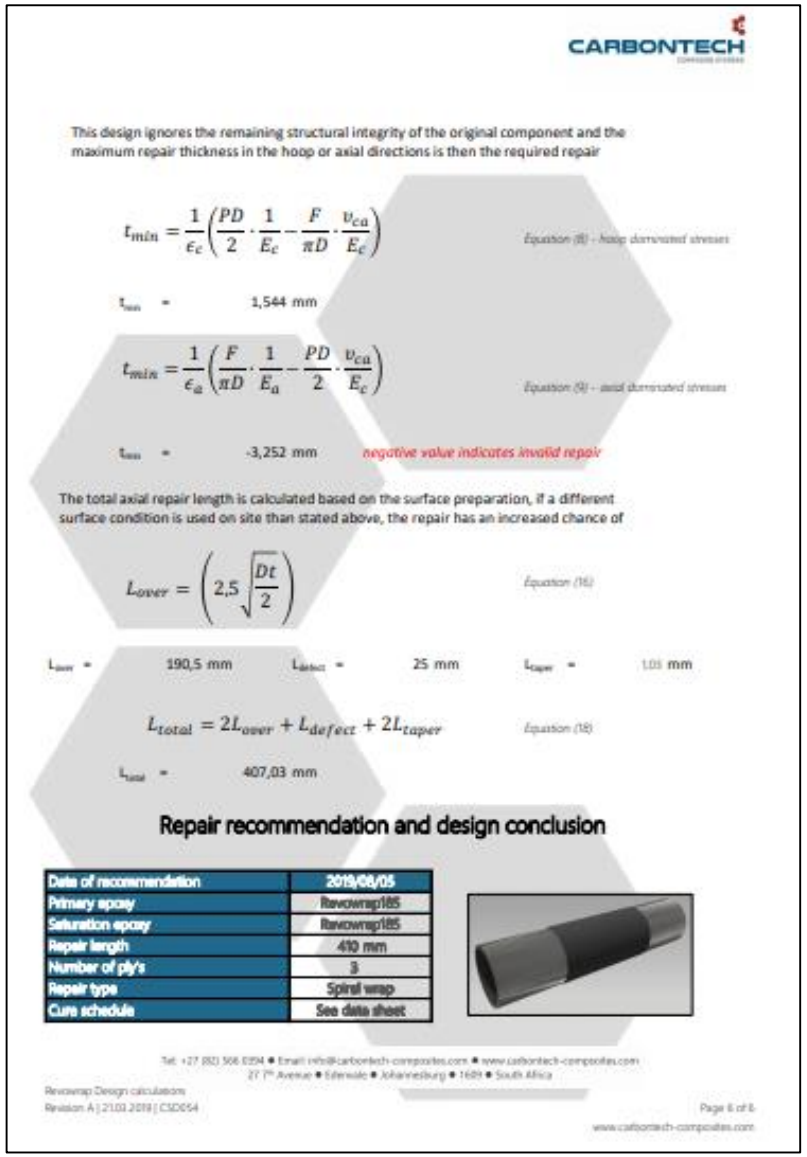
How to Qualify and Design Repairs According to ISO/TS 24817

Design of a composite repair answers the following questions:

- Is the repair strong enough in all loading directions? (strength calculation)
- Does the repair take all the load or does the substrate and repair share the load? This requires an accurate estimate of the remaining wall thickness.
- Will the repair remain bonded to the surface? (Energy release rate and adhesive bond calculations)
- Is the axial extent of repair sufficient to ensure load transfer between repair and substrate?

Design Outputs:

- Thickness of the repair laminate (the number of layers)
- Total axial repair length.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This design ignores the remaining structural integrity of the original component and the maximum repair thickness in the hoop or axial directions is then the required repair

$$t_{min} = \frac{1}{\epsilon_c}\left(\frac{PD}{2}\cdot\frac{1}{E_c} - \frac{F}{\pi D}\cdot\frac{v_{ca}}{E_c}\right)$$

Equation (8) - hoop dominated stresses

t_{min} = 1,544 mm

$$t_{min} = \frac{1}{\epsilon_a}\left(\frac{F}{\pi D}\cdot\frac{1}{E_a} - \frac{PD}{2}\cdot\frac{v_{ca}}{E_c}\right)$$

Equation (9) - axial dominated stresses

t_{min} = -3,252 mm negative value indicates invalid repair

The total axial repair length is calculated based on the surface preparation, if a different surface condition is used on site than stated above, the repair has an increased chance of

$$L_{over} = \left(2{,}5\sqrt{\frac{Dt}{2}}\right)$$

Equation (16)

L_{over} = 190,5 mm L_{defect} = 25 mm L_{taper} = 101 mm

$$L_{total} = 2L_{over} + L_{defect} + 2L_{taper}$$

Equation (18)

L_{total} = 407,03 mm

Repair recommendation and design conclusion

Date of recommendation	2019/08/05
Primary epoxy	Revowrap185
Saturation epoxy	Revowrap185
Repair length	410 mm
Number of ply's	3
Repair type	Spiral wrap
Cure schedule	See data sheet

Tel: +27 (82) 506 0354 ● Email: info@carbontech-composites.com ● www.carbontech-composites.com
27 7th Avenue ● Edenvale ● Johannesburg ● 1609 ● South Africa

Revowrap Design calculations
Revision A | 21.03.2019 | CSD054

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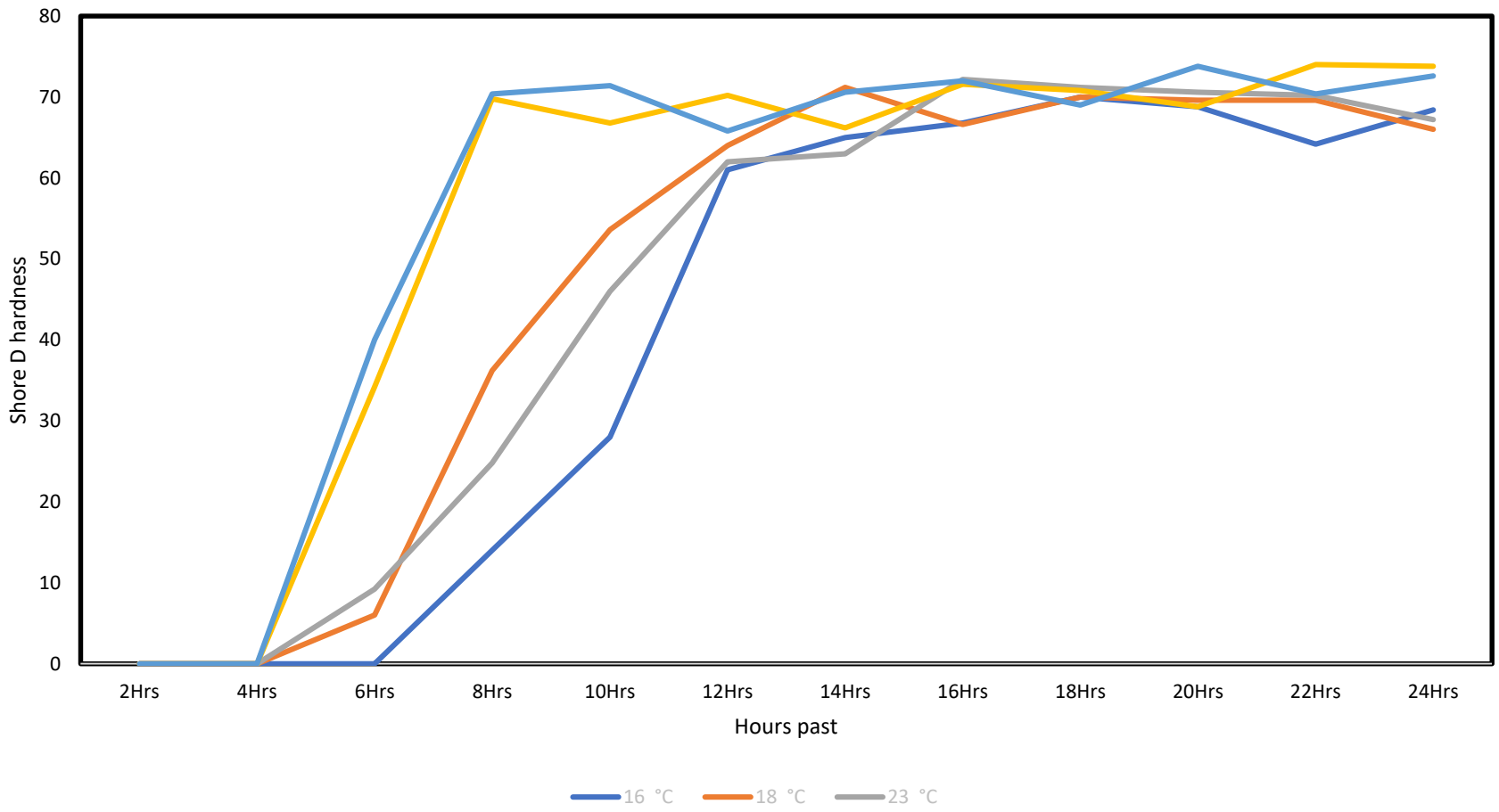
REVOWRAP 110 CURE RATES



Approach to applying composite repair technology

DETERMINE THE SCOPE OF WORK

Client Consultation, Site Surveys

NDT/Inspection reports and photos

Complete Repair Data Sheet

ENGINEERED DESIGN CALCULATION

Determine repair lifetime, materials & requirements

Adhering to relevant standards & guidelines ISO-24817 ASME-PCC2

Commercial & Technical Proposal

METHOD STATEMENT, HSE & INSTALLATION

Delivery of materials

Mobilisation of trained and approved applicators

Application of repairs to relevant standards, safety & QA/QC controls

REPAIR MANAGEMENT

Submission of Closeout Report and Guarantee Certificate

Informing client of impending end of repair life

How to Install Composite Repairs?

- The repair, the surface preparation and substrate is an indivisible unit, change any one of these three variables and the repair system must be re-qualified.

- Carbontech repairs are always applied by trained, competent applicators.

- Get the surface preparation and other installation issues correct, if not, no matter how well designed the repair it will leak or fail. Check surface preparation (Testex tape - Measurement of surface roughness)

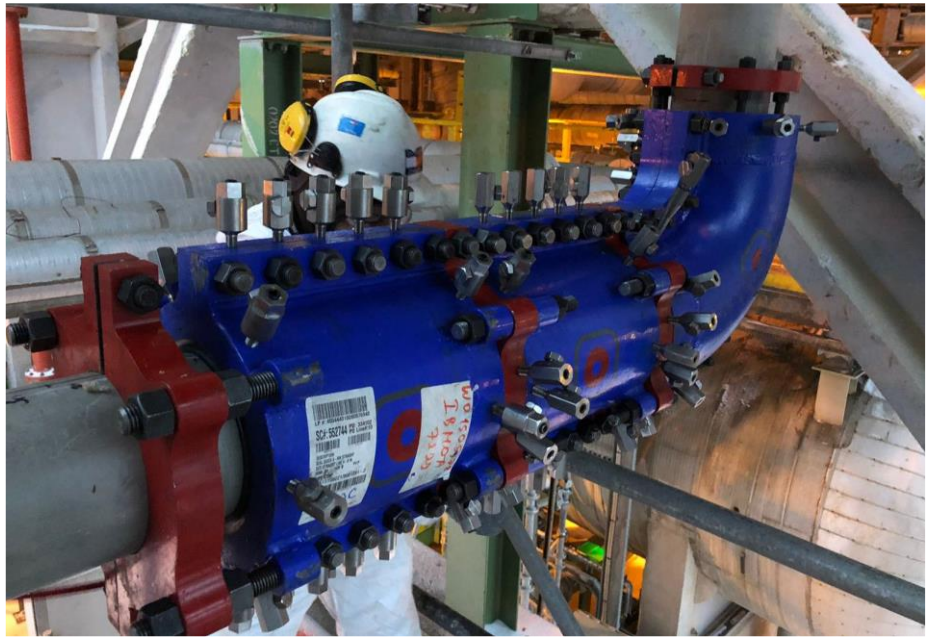
➢ Carbontech Repairs are qualified to surface preparation procedures, SA2½, ST2 and ST3 – note, pressure containment capacity reduced with ST3 and significantly with ST2

- The cure of a repair laminate is strongly influenced by temperature and the correct mixing of resin constituents prior to application. It is important that the prevailing temperature conditions are considered in estimating the time for cure.
- Measurement of Shore D hardness
- Installation details and QA checks are contained in close-out report.

REACTIVE: On-site Improvised / Engineered Clamps

Are often only effective after a leak is detected and take up space and add significant weight

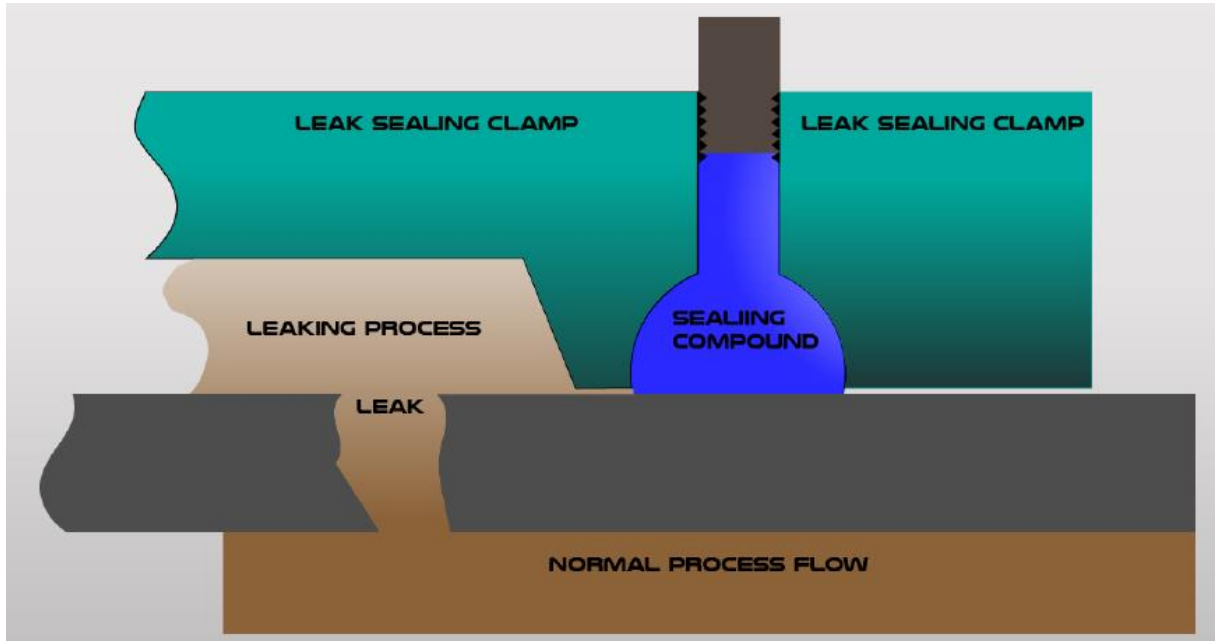
- Installed in emergencies
- Intended to be temporary
- Limits permanent options for repair

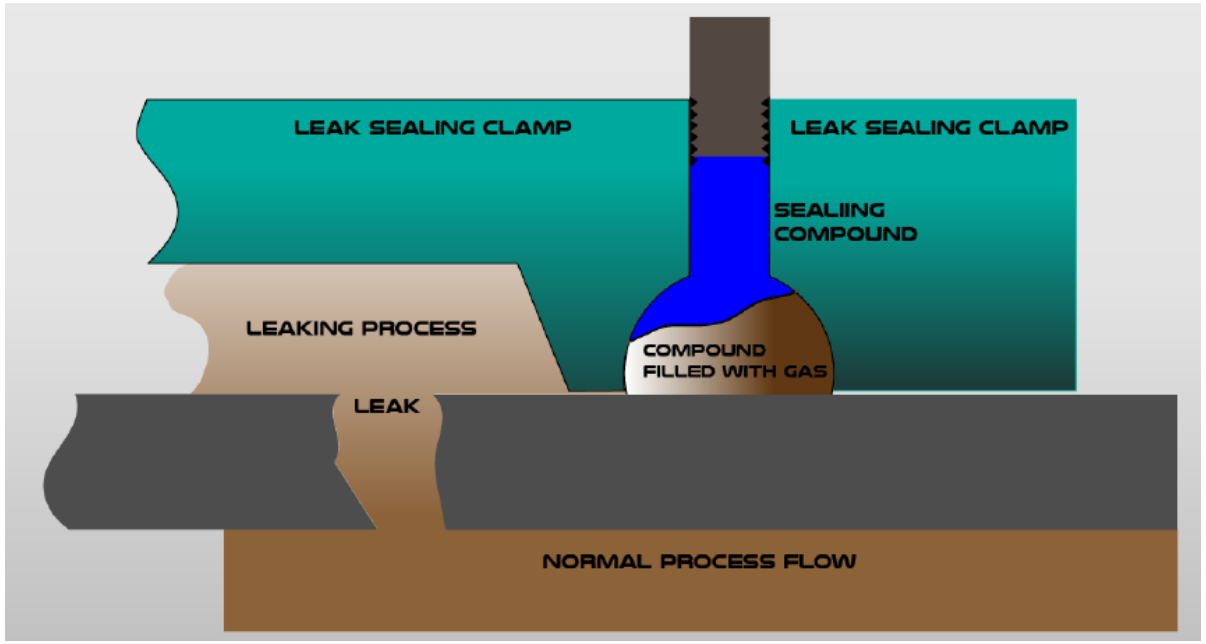


- Designed rapidly for a short term
- Installed using a pumped elastomer
- Susceptible to leaking under varying operating conditions

Why do leak sealing clamps fail?

- Leak sealing depends on compressible media (elastomers)
- Rapid gas decompression is a phenomenon affecting most elastomers
- Gas present in fluids condenses in elastomers
- Structural failure occurs when pressure moves from high to low
- RGD is why clamps need reinjection





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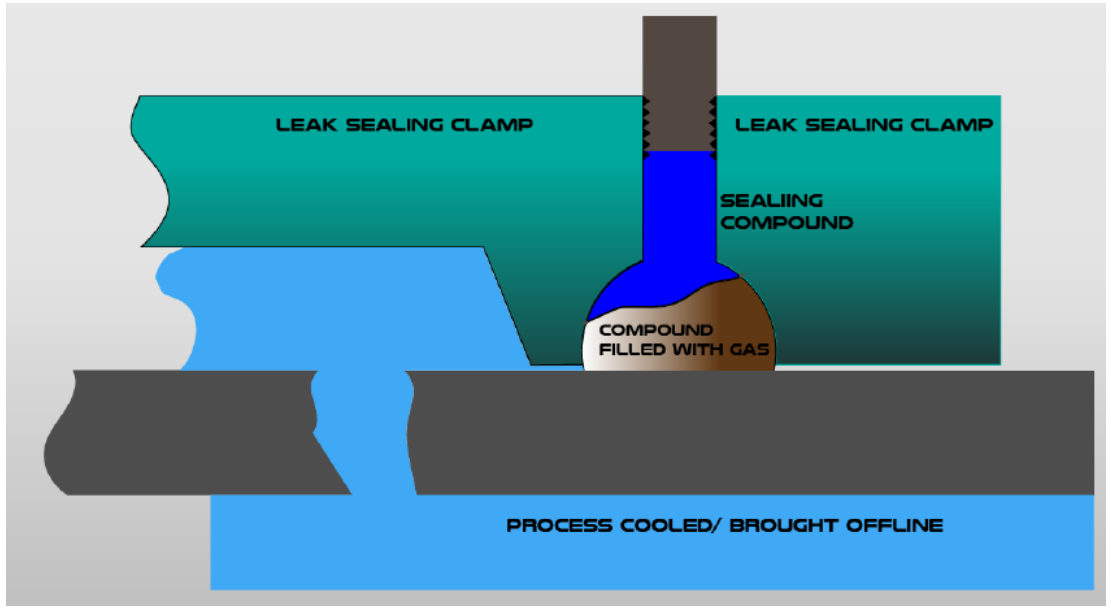
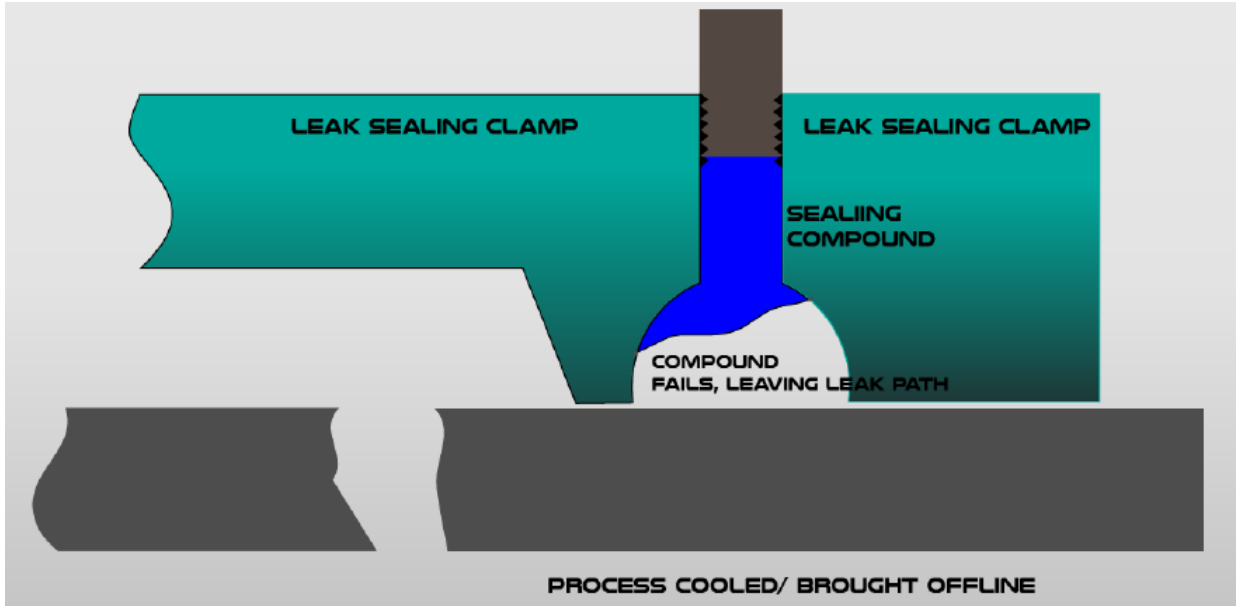
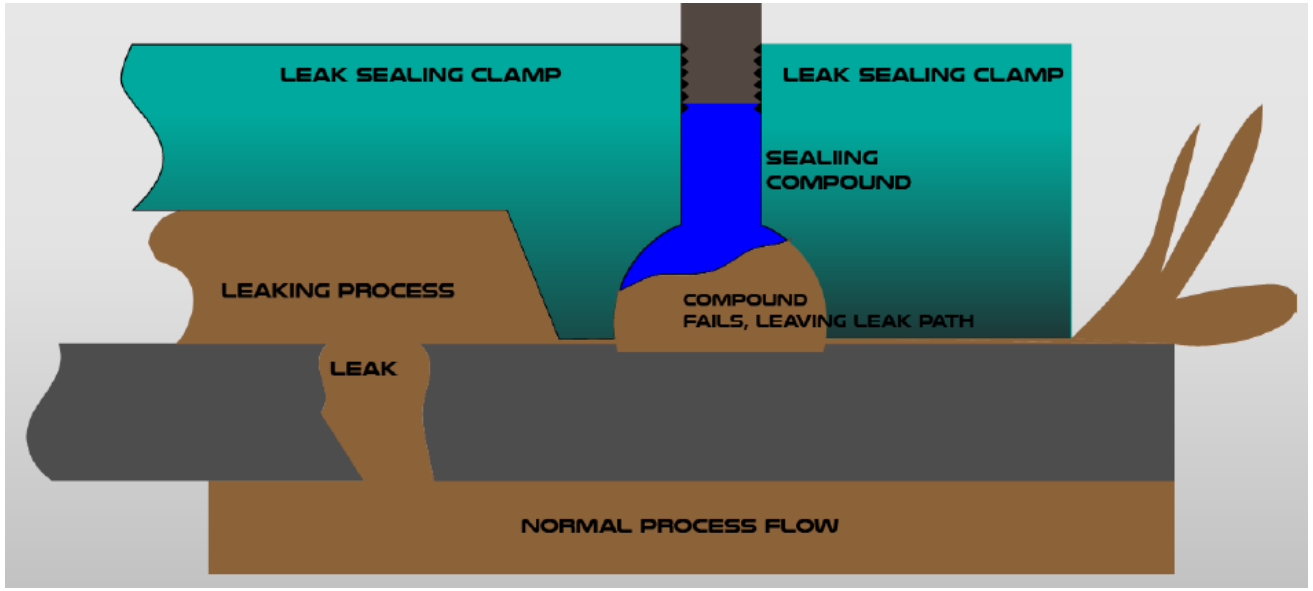
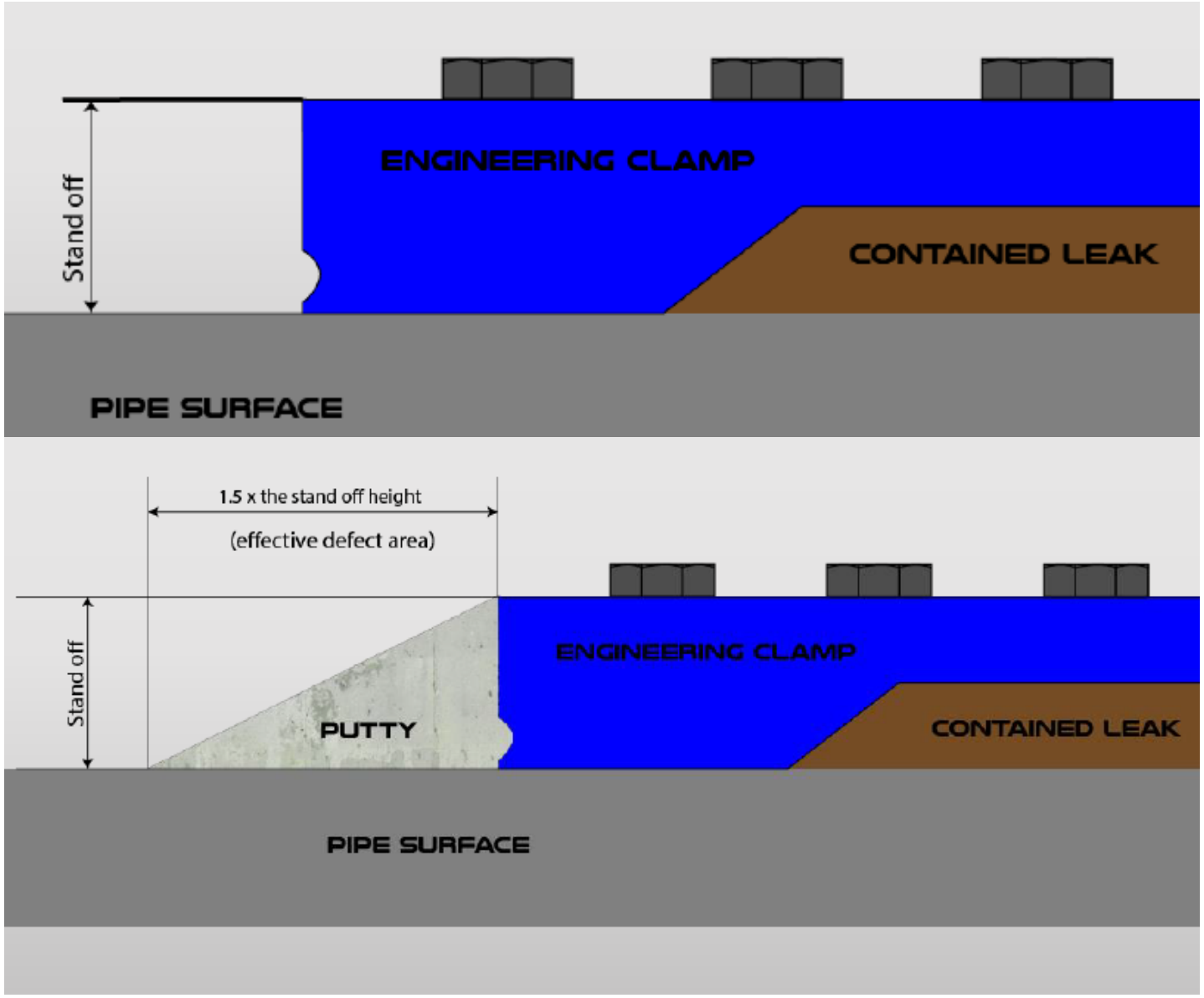






What happens when we need both Clamp & Composite?



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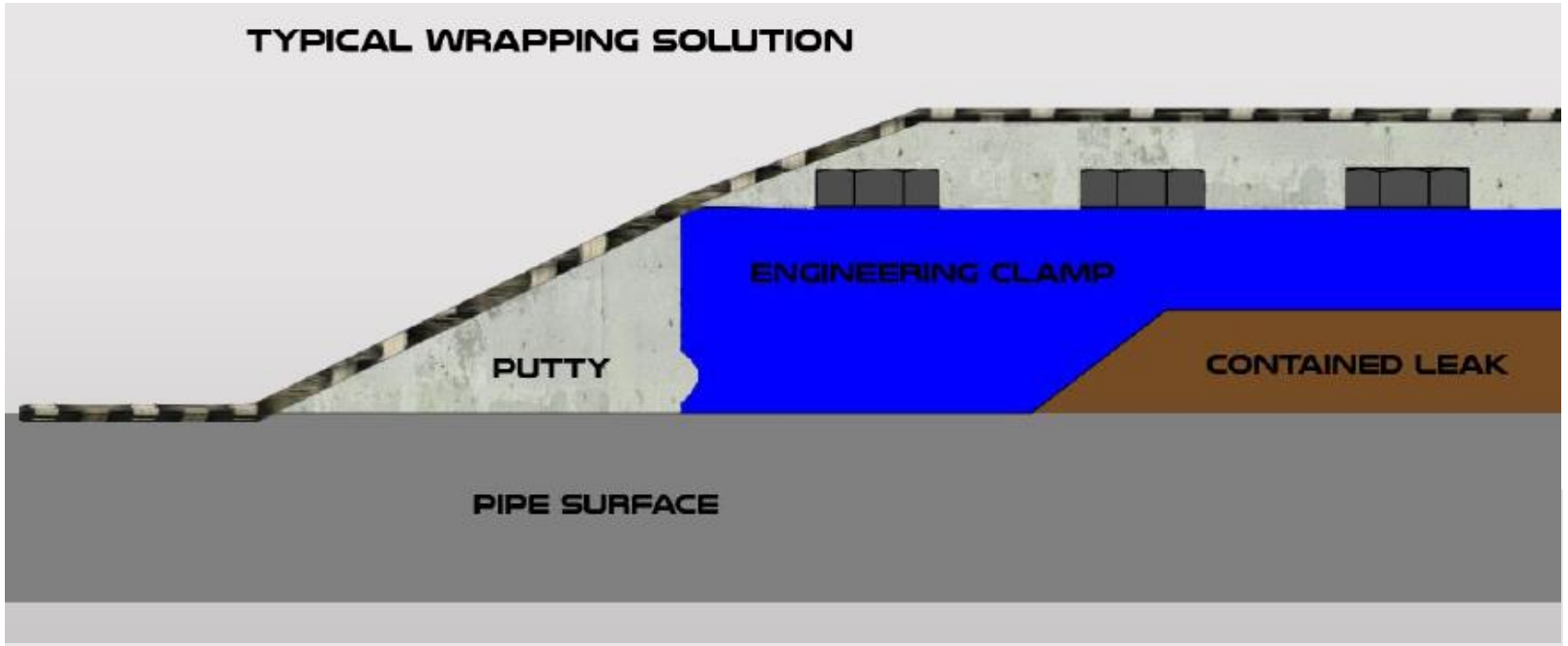
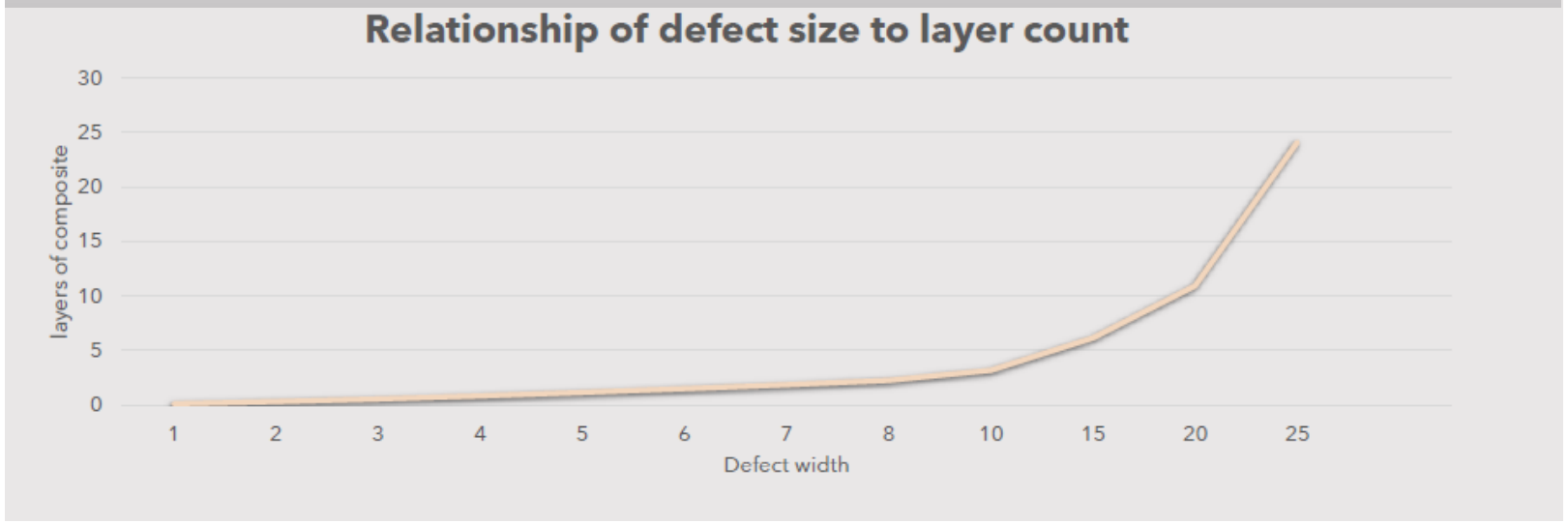




Possible Improvements

- Improve designed geometry
- Reducing standoff height
- Reducing area of elastomer to seal

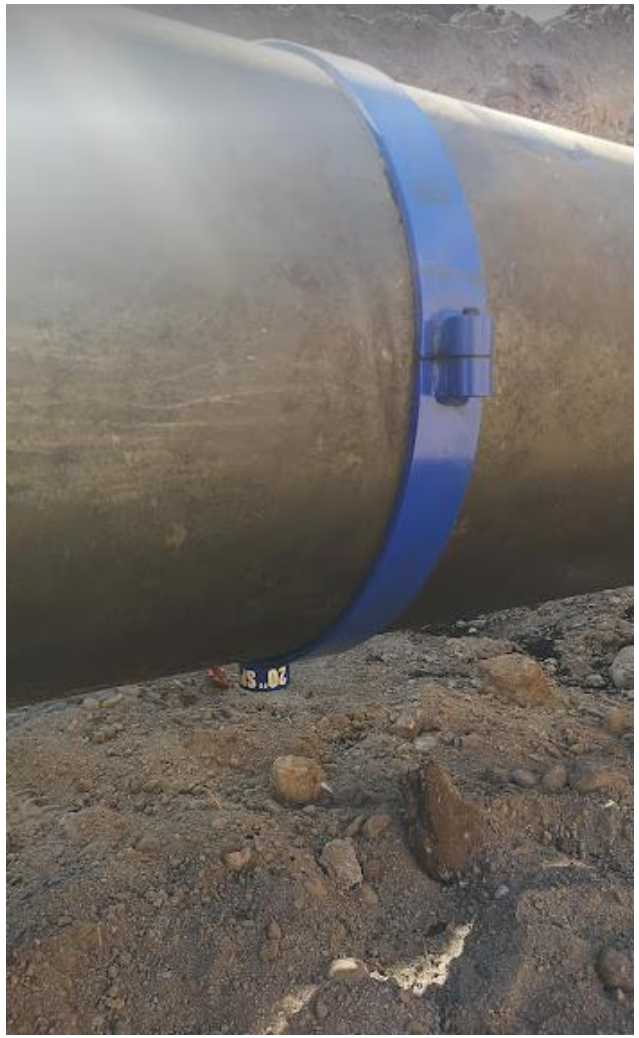
Spitze Clamp

- Made for the reactive market
- Meant to become proactive
- Low profile, limited elastomer

Max. Design Pressure	200bar
Max Design Temperature	380degC
Max Defect Size Up To	25mm
Application Time	10 Mins
Diameters	1" to 56”
Shelf Life	Unlimited

Spitze Clamp

Spitze Clamp



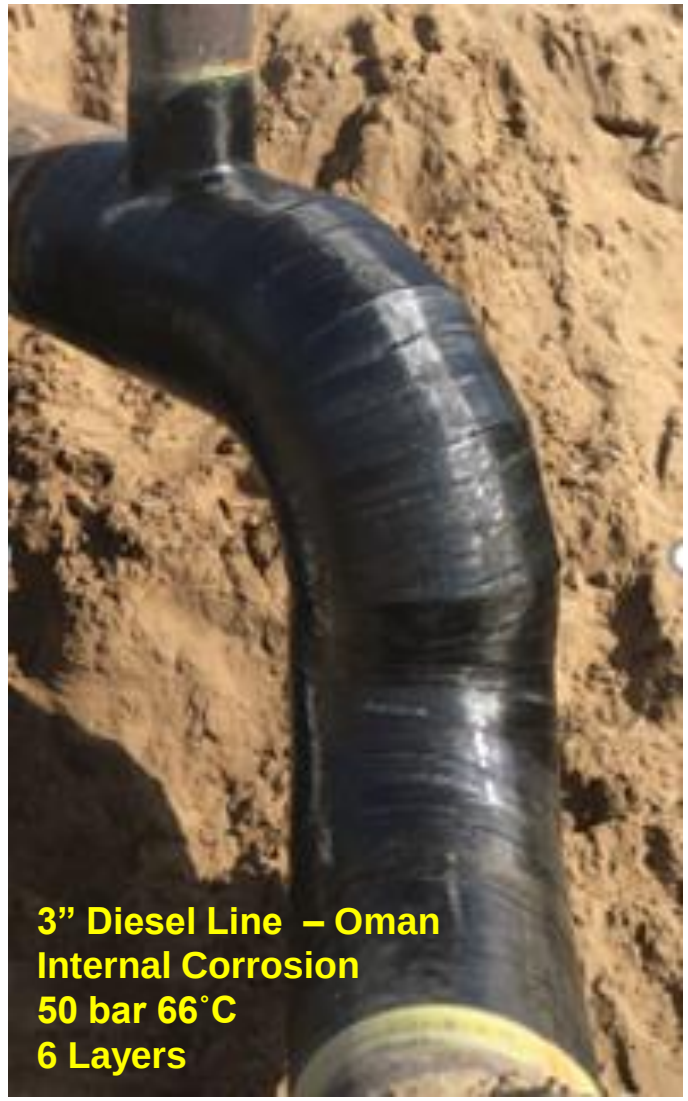
Spitze Clamp

VS

Conventional Clamp

Revowrap Installations

Revowrap Installations



Revowrap Installations

- Reference : Crude Oil Lines – Iraq
- Multiple weld failures
- Design Condition : 60 bar & 80˚C
- 8-Layers 20 Year Repair Life terms

REVOSHIELD

MATERIAL PROPERTIES:

Fabric Type / Weave Pattern (ARO)	Quad axial E glass
Availability of Fabric Widths	50mm - 330mm
Ply Thickness	0.62mm
Fabric Type / Weave Pattern (Pipe Support)	Plain weave E glass
Availability of Fabric Widths	50mm - 330mm
Ply Thickness	0.25mm
Tensile Modulus-Hoop : ASTM D3039 (3)	7.028 Gpa
Tensile Modulus-Axial : ASTM D3039 (3)	5.688 GPa
Tensile Strength-Hoop: ASTM D3039 (3)	215.47 MPa
Tensile Strength-Axial: ASTM D3039 (3)	41.47 MPa
Pull-Off Adhesion Strength ASTM4541	6.86 Mpa
In Plane Shear Stress: ASTM D5379 (5)	30.32 Mpa
In Plane Shear Modulus: ASTM D5379 (5)	2.674 GPa
Lap Shear Strength - SP3: ASTM D3165 (9)	12.4 MPa
Resin	2-Part Epoxy
Heat Distortion Temperature	99.5°C
Minimum Application Temperature	9°C
Working Time @ 23°C	1 Hour
Shelf Life	2-Years
Shore D Hardness - ISO 868 : 2003	85

REVOSHIELD s a field applied abrasion and chemically resistant coating designed to protect pipes against long-term external corrosion and abrasion stresses sustained during Pipe Support, Thrust Boring, Micro Tunneling, HDD directional drilling and Road Crossing applications. Revoshield can be used in aggressive soil types and creates a highly abrasion resistant outer layer to protect pipe support locations, field joints, heat shrink, painted and FBE coatings.

Service

- Revowrap repairs are designed on a fit-for-purpose basis and applied by Revowrap certified installers supported by a technically competent and experienced team.
- Carbontech has regional offices and partners located in all Oil and Gas producing regions that understand local conditions.
- Emergency Service: Immediate Provision of Design Calculations, Materials & Project Supervision.


CARBONTECH
Thank You
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