Composite Solutions for Returning Strength to Damaged Assets

By Peter Johnson
Belzona Polymerics

World Leader in Composite Repair Solution

developed by working closely with major Oil and Gas companies since the 1970s.

Belzona Materials:

Resist aggressive chemicals and corrosion, slow down erosion

Provide complete protection in high temperature and high pressure environments

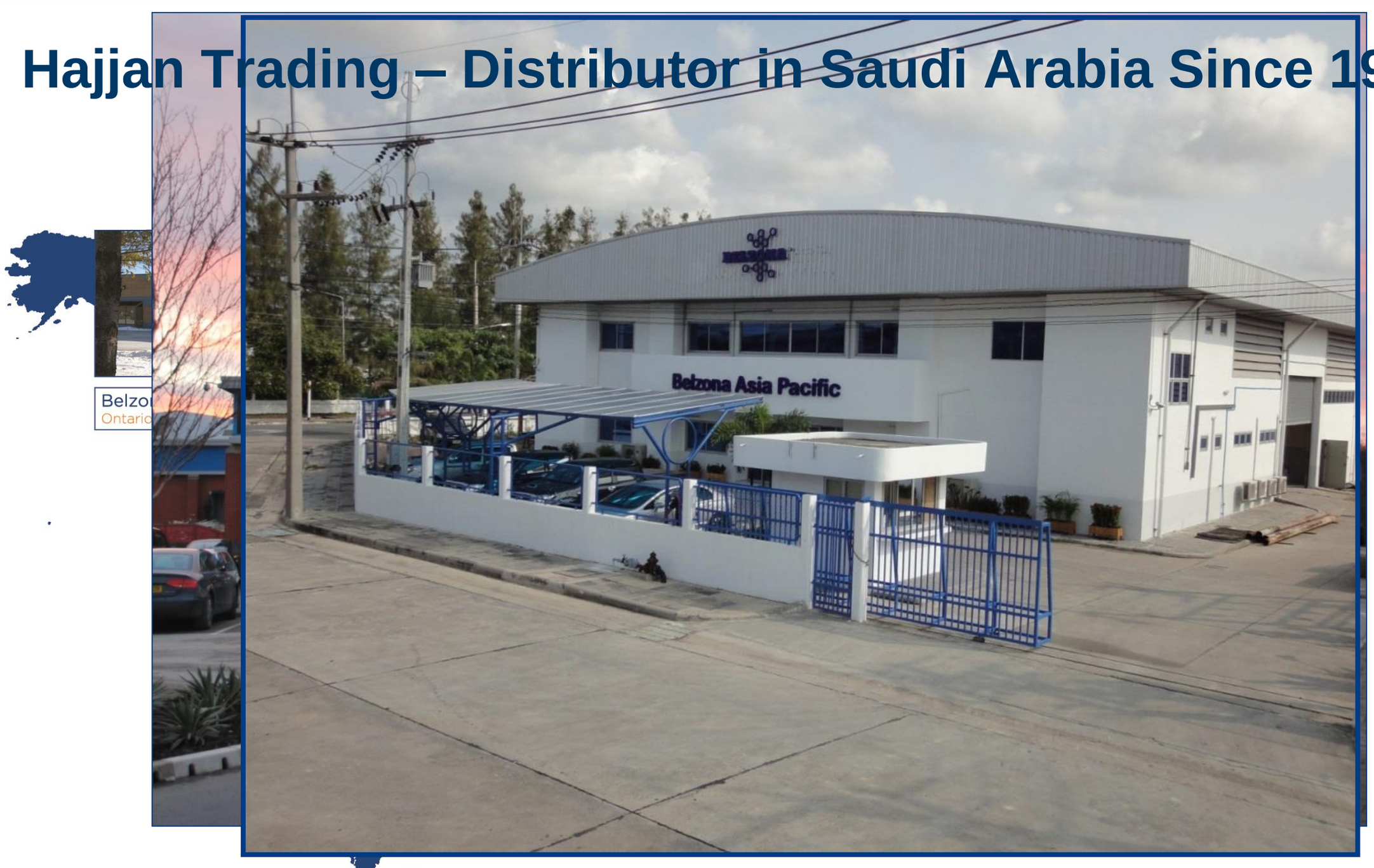
Success demonstrated by prequalification testing and case studies

BELZONA®
Repair • Protect • Improve

Global Presence - Local Service

More than 140 Distributors operating in over 120 countries

Hajjan Trading – Distributor in Saudi Arabia Since 1982



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Composite Solutions for Returning Strength to Damaged Assets

1. **Composite Cold Bonding**
2. **Composite Wrapping**

Used for;
Tanks, Vessels, Pipes…

Suffering from;
corrosion, wall thinning, leaking…

without Hot welding

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Composite Cold Bonding and Structural Repair

For Pipework, Vessels, Tanks, Decks, Towers, Supports, Internal parts, etc…

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Composite Cold Bonding - Advantages

- No Hot Welding
- Save Shutdown Cost/Time
- Simple / Quick Repair Time
- Strength can be calculated based on Test Data and Material properties
- No Corrosion After Repair
- No Heat Distortion to the base metal

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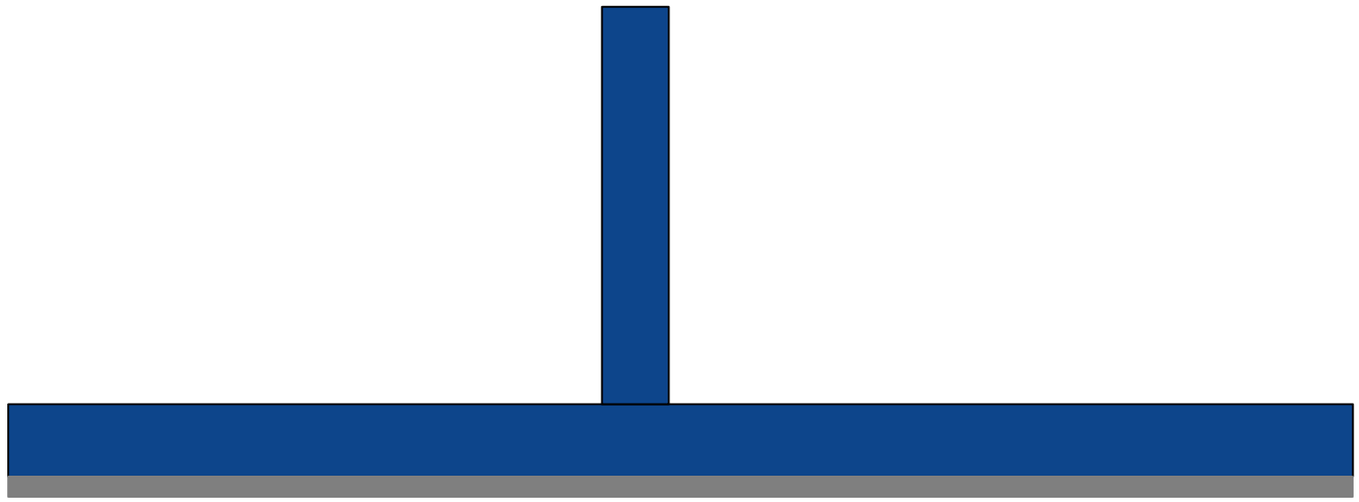
Cold Bonding

Paste Method

Think of it as a “Composite sandwich”



Example: bonding deck/ tank external fittings

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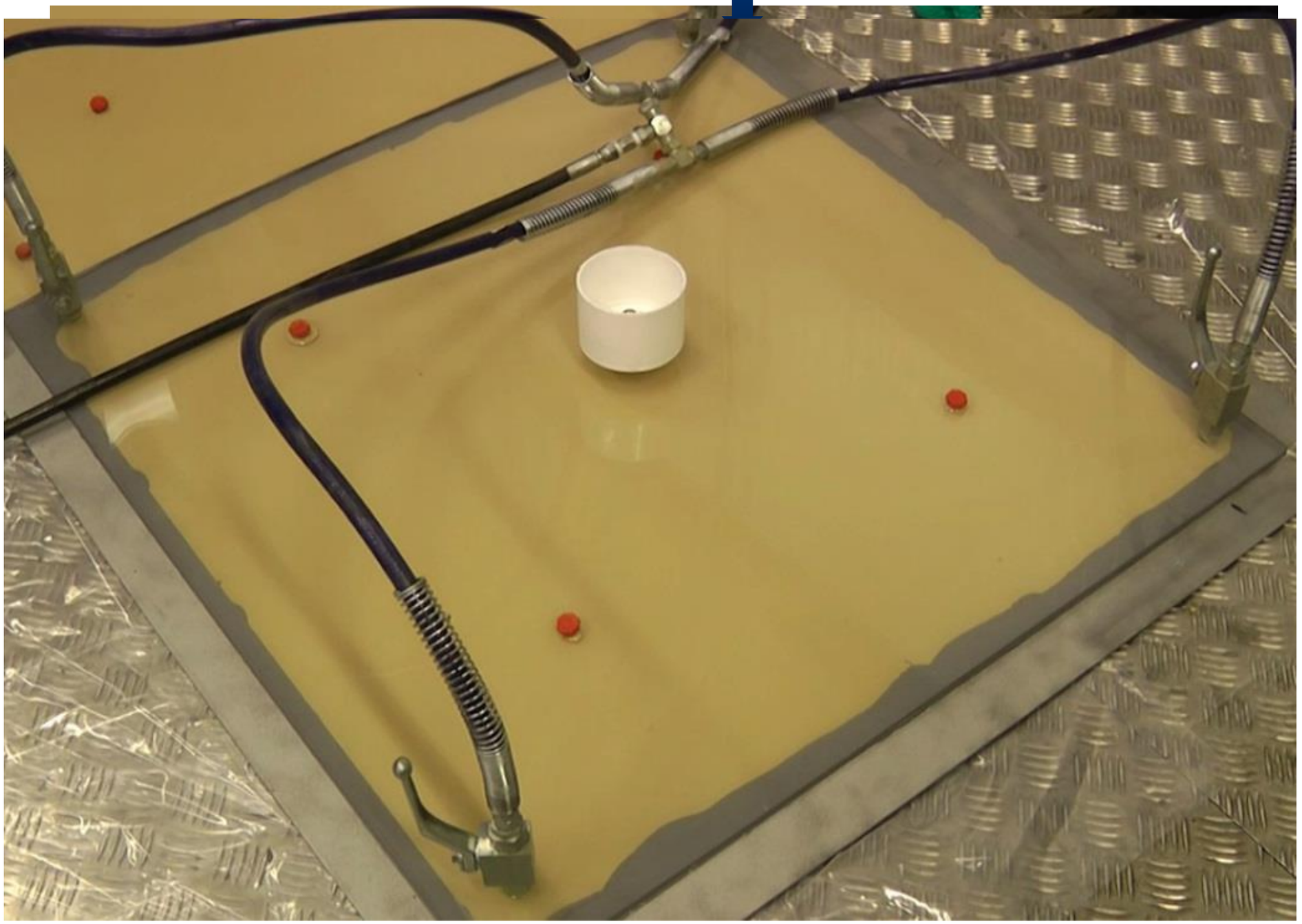
Cold Bonding

Injection method

Demonstration with Perspex to show material distribution



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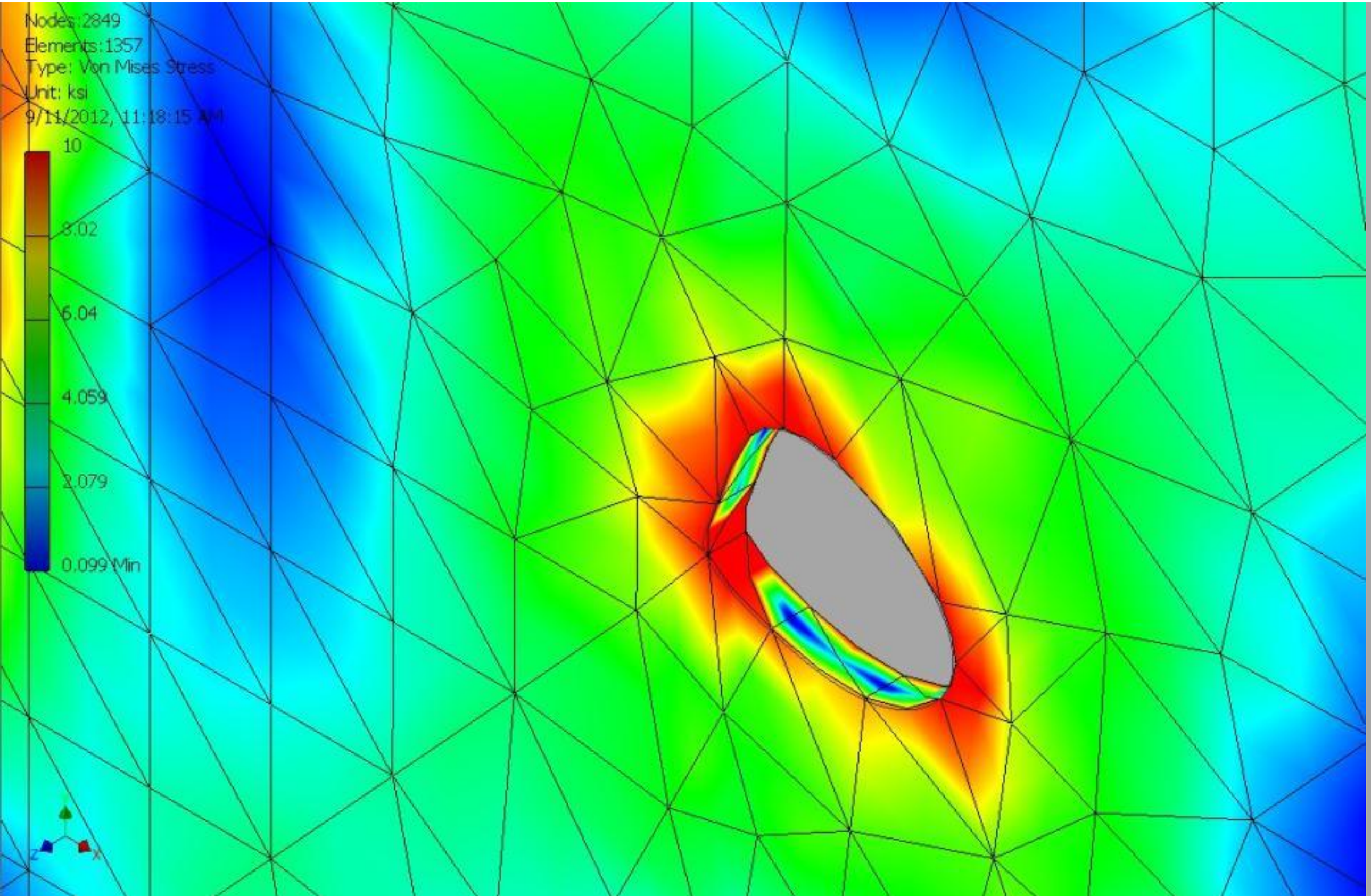
The Science & The Proof



The Science & The Proof

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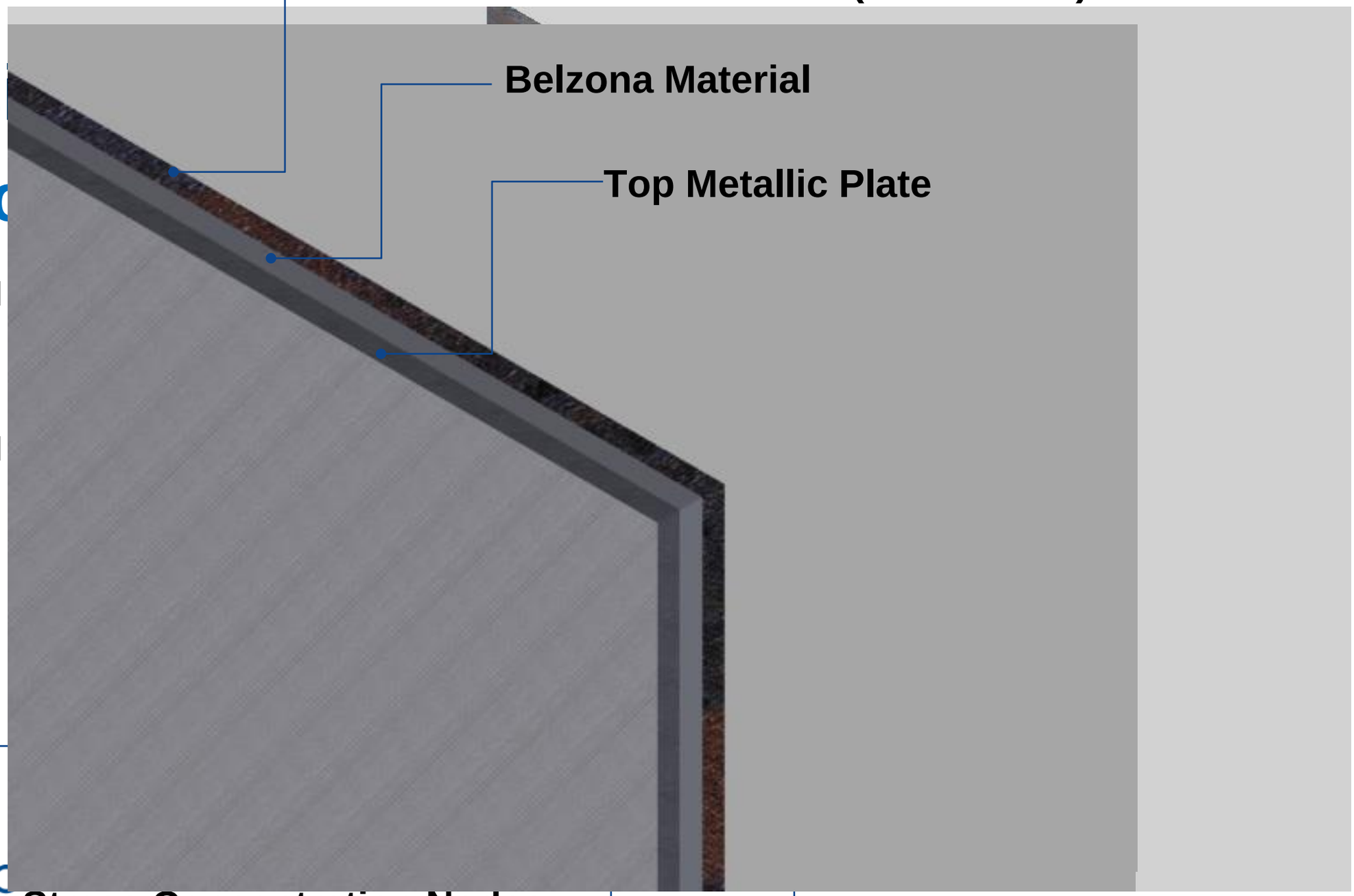

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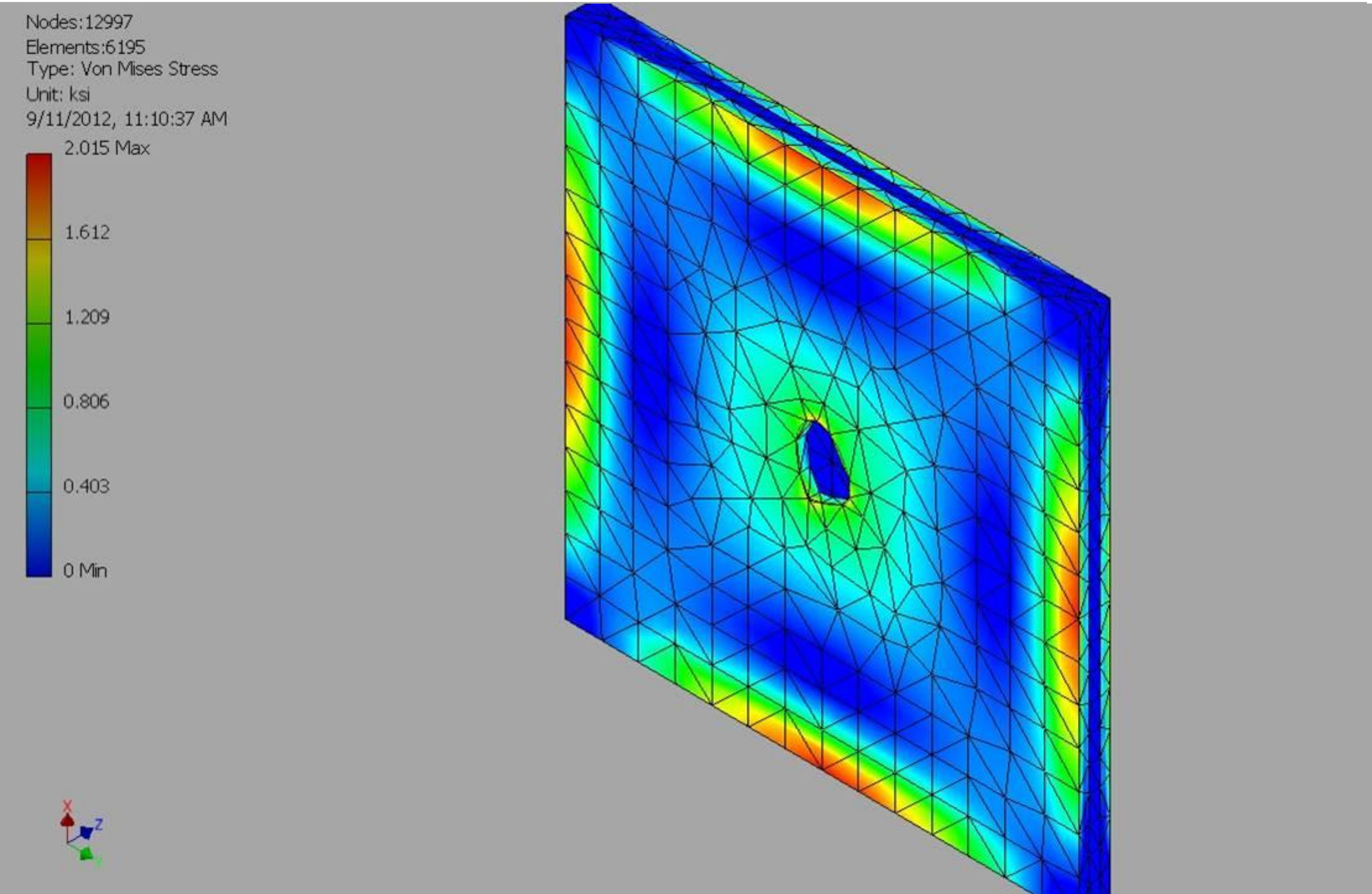
The Science & The Proof



Opus, Bonding Separator Internals

2003, Fittings bonded with no risk of metal distortion

Excellent adhesion

and compressive strength

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Opus, Bonding Separator Internals

2003, Fittings bonded with no risk of metal distortion

Inspection after 8 years in service, flawless

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Refinery Sprinkler System Bonding

Mobil, Altona Refinery, Australia

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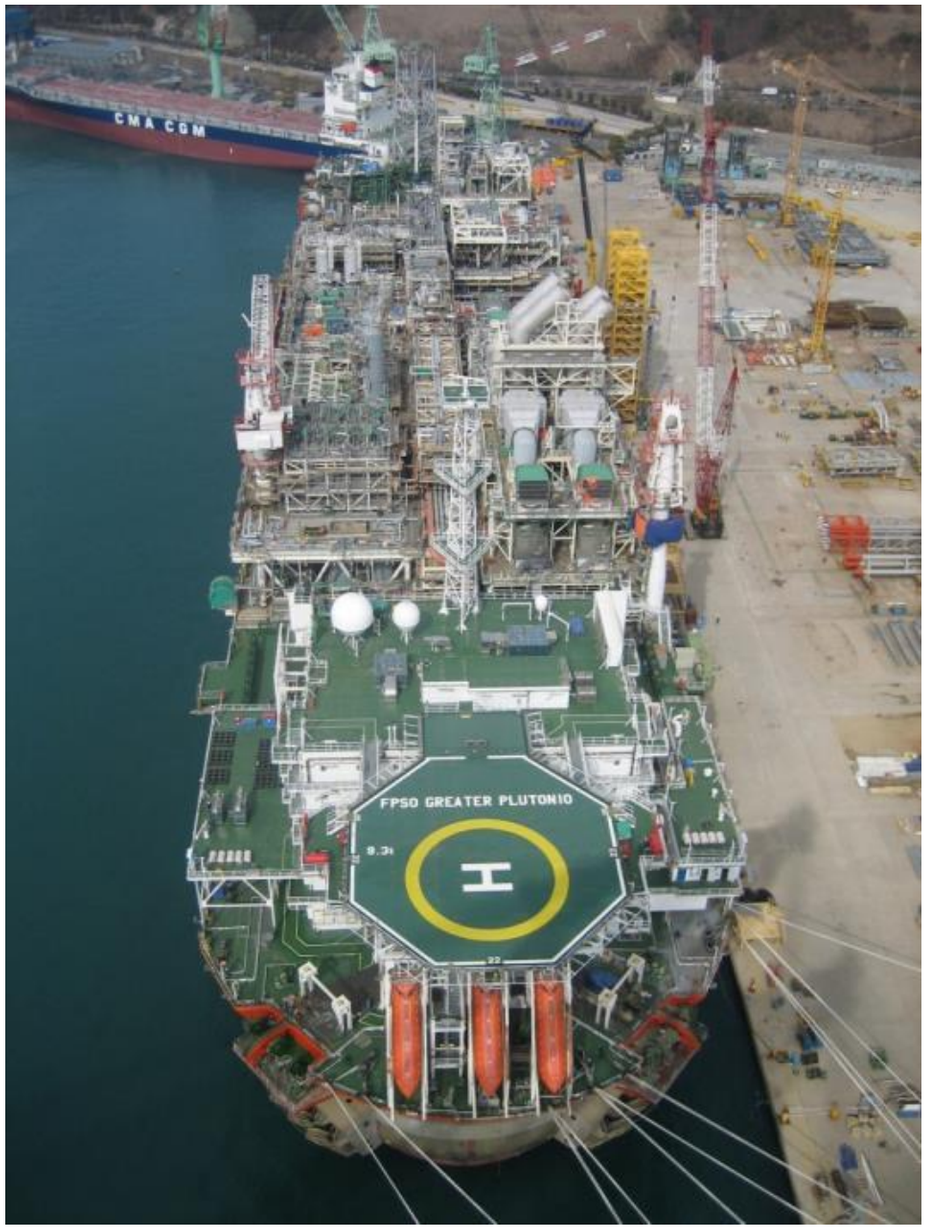
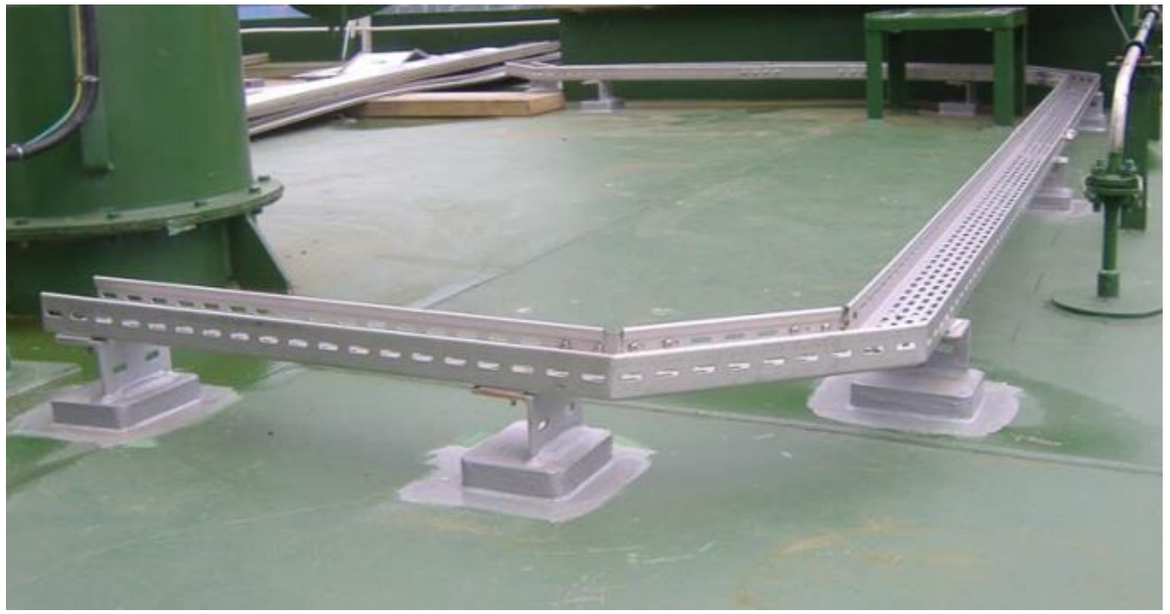
Deck Bonding

Cable tray supports bonding for BP Greater Plutonio





Belzona was chosen due superior characteristics and vendor support

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Pipe Support Bonding

Gas Separation Plant , Thailand - Jan 2013

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Pipe Support Bonding

Gas Separation Plant , Thailand - Jan 2013

Condition of Corrosion Under Support – After Wet Blasting
Severe metal loss revealed

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Pipe Support Bonding

Gas Separation Plant , Thailand - Jan 2013

Belzona 1111 Supermetal was used for bonding metal plates provided by customer
Plate size was 350 mm.x 250 mm. Bonding thickness was 2 mm.

Apply Belzona 1111 on the metal plate

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Pipe Support Bonding

Gas Separation Plant , Thailand - Jan 2013

Belzona 1111 Supermetal was used for bonding metal plates provided by Customer
Plate size was 350 mm.x 250 mm. Bonding thickness was 2 mm.
Pipe section was lifted up , bonded with metal plate securing with strap.

Bond metal plate with corroded pipe

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Pipe Support Bonding

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Bond metal plate with corroded pipe

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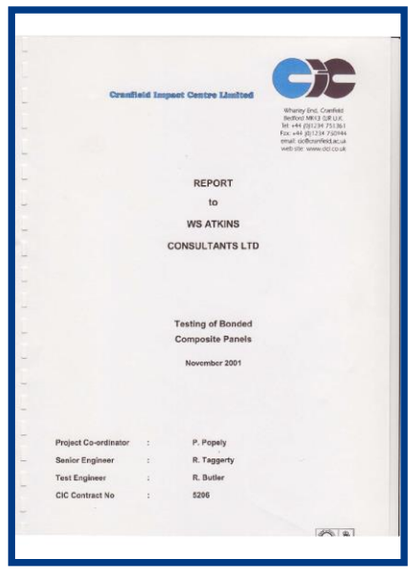
The Science & The Proof

- Independent Testing
  - **Cranfield Impact Centre Limited**
    - **Tested Several Properties**
      - **Bending Moment – 7418 Lb (3364 Kg) To Break**
      - **Impact Loading – 500 Joules Impact (No Damage)**
      - **Drag Loading – 1 Tonne Drag (No Damage)**
      - **Lap Shear – 4945 Lb (2243 Kg) To Break**
  - **Plate Bonding on Buchan Alpha**
    - **Based on excellent results Belzona was chosen as the solution and is on-going throughout North sea**


Cranfield Impact Centre Limited

REPORT
to
WS ATKINS
CONSULTANTS LTD

Testing of Bonded
Composite Panels

November 2001

Project Co-ordinator : P. Popely
Senior Engineer : R. Taggerty
Test Engineer : R. Butler
CIC Contract No : 5206

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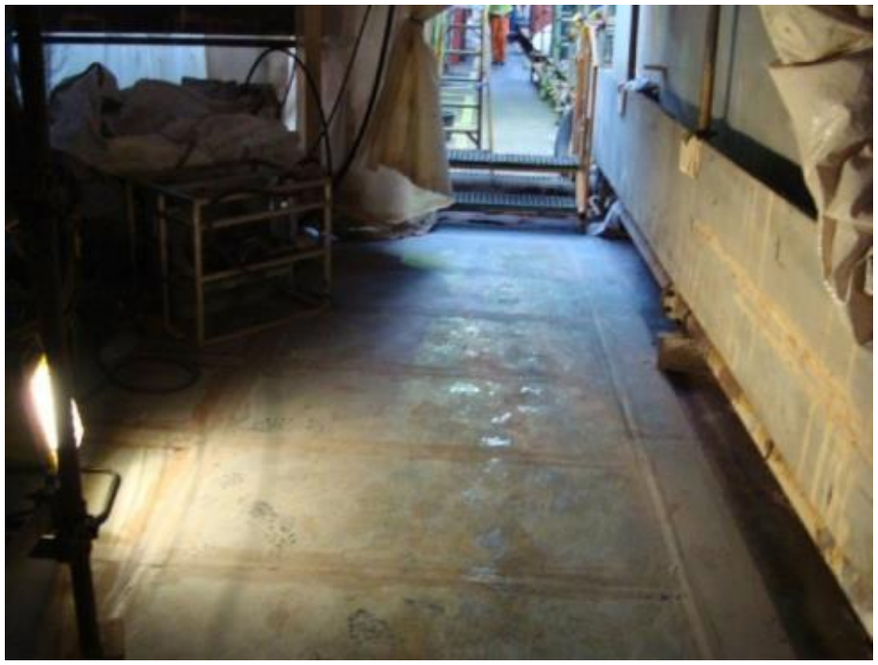
Deck Bonding

CNR, Ninian Central Platform at the North Sea

Application



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Deck Bonding

CNR, Ninian Central Platform at the North Sea

Inspection one year later

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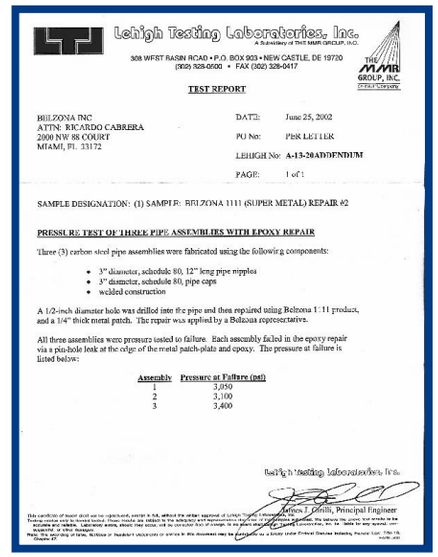
The Science & The Proof

- Independent Testing
  - **Lehigh Testing Laboratories, Inc.**
    - Three different pipes pressure tested
    - Pipe 1 – 3” DIA / SCH 80 / 12” Nipples
    - Pipe 2 – 3” DIA / SCH 80 / Pipe Caps
    - Pipe 3 – Welded construction pipe
    - All pipes have: ½” hole and repaired with ¼” plate
  - **Results**
    - Pipe 1 – 3050 psi (214 Kg/cm^2) to failure
    - Pipe 2 – 3100 psi (217 Kg/cm^2) to failure
    - Pipe 3 – 3400 psi (239 Kg/cm^2) to failure



Lehigh Testing Laboratories, Inc.
A Subsidiary of THE MMR GROUP, INC.
308 WEST RASIN ROAD • P.O. BOX 903 • NEW CASTLE, DE 19720
(302) 328-0500 • FAX (302) 328-0417

THE MMR GROUP, INC.

TEST REPORT

BELZONA INC
ATTN: RICARDO CABRERA
2000 NW 88 COURT
MIAMI, FL 33172

DATE: June 25, 2002
PO No: PER LETTER
LEHIGH No: **A-13-20ADDENDUM**
PAGE: 1 of 1

SAMPLE DESIGNATION: (1) SAMPLE: BELZONA 1111 (SUPER METAL) REPAIR #2

PRESSURE TEST OF THREE PIPE ASSEMBLIES WITH EPOXY REPAIR

Three (3) carbon steel pipe assemblies were fabricated using the following components:

- 3" diameter, schedule 80, 12" long pipe nipples
- 3" diameter, schedule 80, pipe caps
- welded construction

A 1/2-inch diameter hole was drilled into the pipe and then repaired using Belzona 1111 product, and a 1/4" thick metal patch. The repair was applied by a Belzona representative.

All three assemblies were pressure tested to failure. Each assembly failed in the epoxy repair via a pin-hole leak at the edge of the metal patch-plate and epoxy. The pressure at failure is listed below:

Assembly	Pressure at Failure (psi)
1	3,050
2	3,100
3	3,400

Lehigh Testing Laboratories, Inc.

James J. Smith, Principal Engineer

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Pipe Leak Bonding Repair

Offshore Oil&Gas Operator, Thailand - 2005

- Prepare another **2 x pipe spools**, specification as follows:
- **4-inch pipe, API 5L Gr. B, Sch. XS (8.56 mm)**
- Pressure-Temp Rating = **1,350 psig** at -20 to 100 F.
- Drill small hole (approx. **10 mm Dia**.) and grinding of metal wall to imitate the leak and corrosion.

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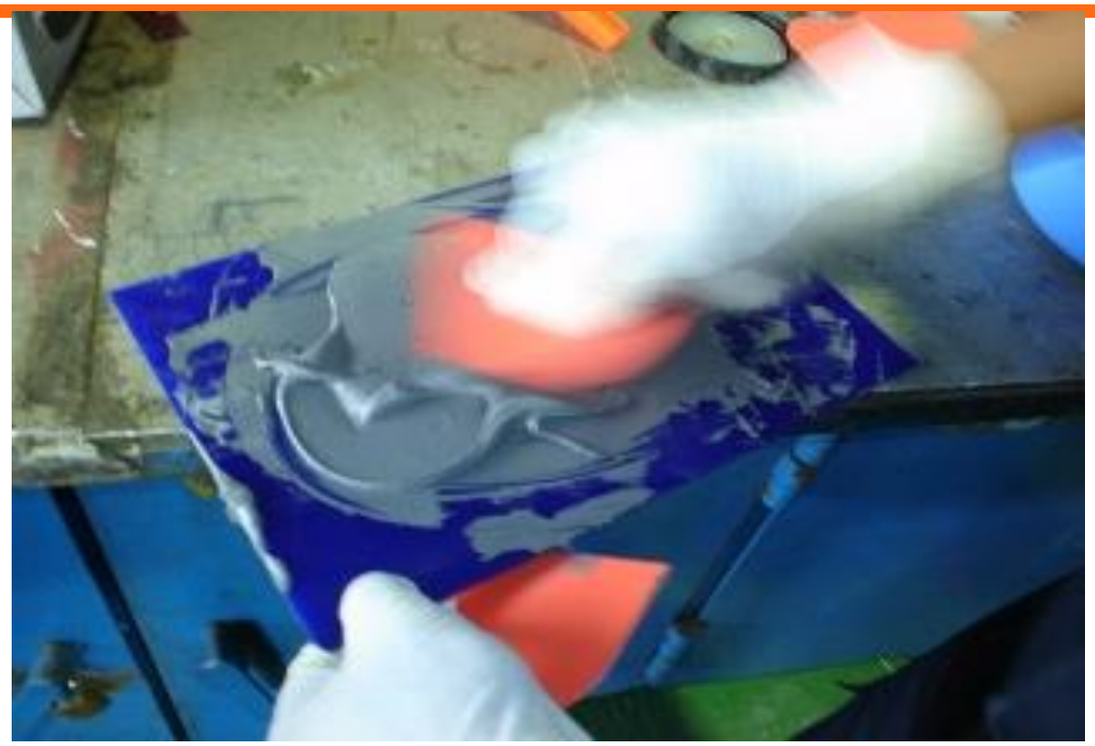
Pipe Leak Bonding Repair

Offshore Oil&Gas Operator, Thailand - 2005

- Follow the same procedures for **Abrasive Blasting** and Cleaning Surface with **Belzona 9111** (N.F. Cleaner/ Degreaser).
- Followed by application of **Belzona 1111**.

Pipe Leak Bonding Repair

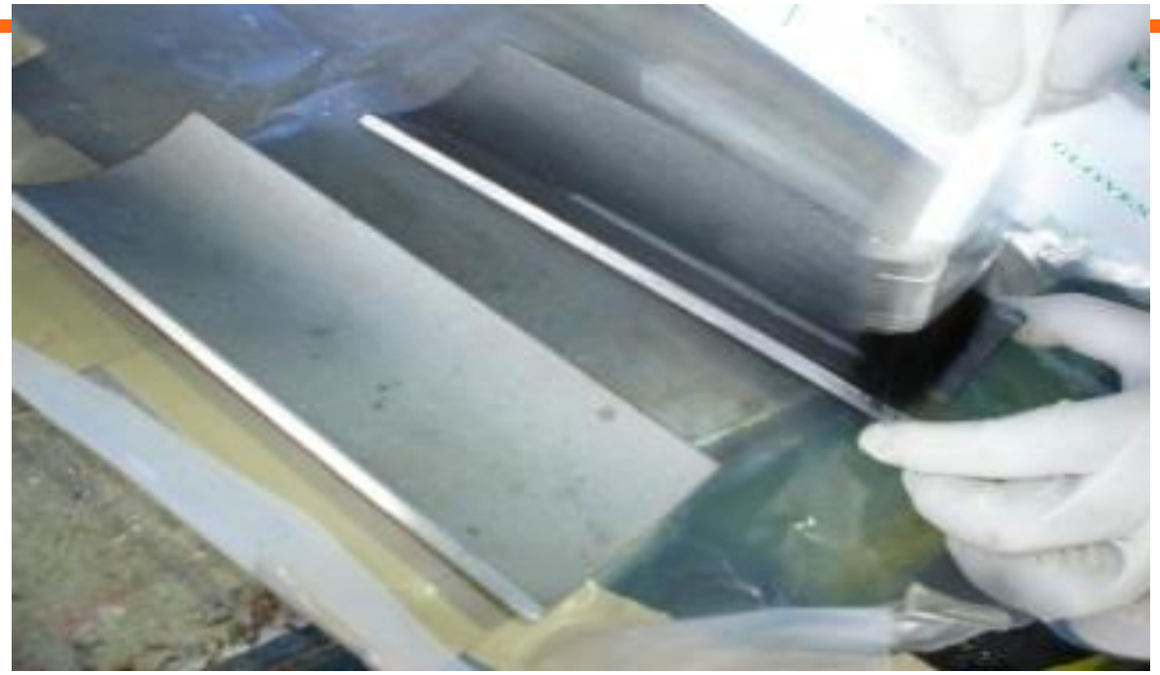
Offshore Oil&Gas Operator, Thailand - 2005



- Belzona 1111 was mixed and applied to the defect area

Pipe Leak Bonding Repair

Offshore Oil&Gas Operator, Thailand - 2005



- **Plate bonding spool:**
- 6-inch pipe sleeve, same wall thickness at 1/4 of circumferential was blasted and cleaned prior to Belzona 1111 application.

- Belzona 1111 was then spread over pipe surface and internal area of plate sleeve.

Pipe Leak Bonding Repair

Offshore Oil&Gas Operator, Thailand - 2005

- **Plate bonding spool:**
- Edges chamfered to ensure Belzona 1111 spread with 45 degree at base of pipe.

Pipe Leak Bonding Repair

Offshore Oil&Gas Operator, Thailand - 2005

- **Hydrostatic Test**
- **Adhesive failure between plate and product**
- **Pressure retention 200 bar**

Composite Wrapping

Belzona SuperWrap

ISO24817 / ASME PCC2
Compliant Repair
For Pipeworks , Vessels

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Composite Wrapping - Advantages

Belzona SuperWrap

- No Hot Welding
- Save Shutdown Cost/Time
- Simple / Quick Repair Time
- Reinstate the Pipe Strength compliant with ISO/ASME Standard
- No Corrosion After Repair
- No Heat Distortion to the base metal

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Composite Materials & Standardisation

Belzona SuperWrap

- Composite material repairs return strength to a weakened substrate by providing adhesion and hoop strength.
  - Adhesion is affected by surface profile and area.
  - Adhesion can be increased by
    - Selecting materials with high mechanical adhesion
    - Increasing surface area contact
  - Hoop strength is affected by the composite cohesive strength
  - How can hoop strength be increased?
    - No voids or creases
    - Proper wetting/consolidation
    - Stronger fiber

Composite Materials & Standardisation

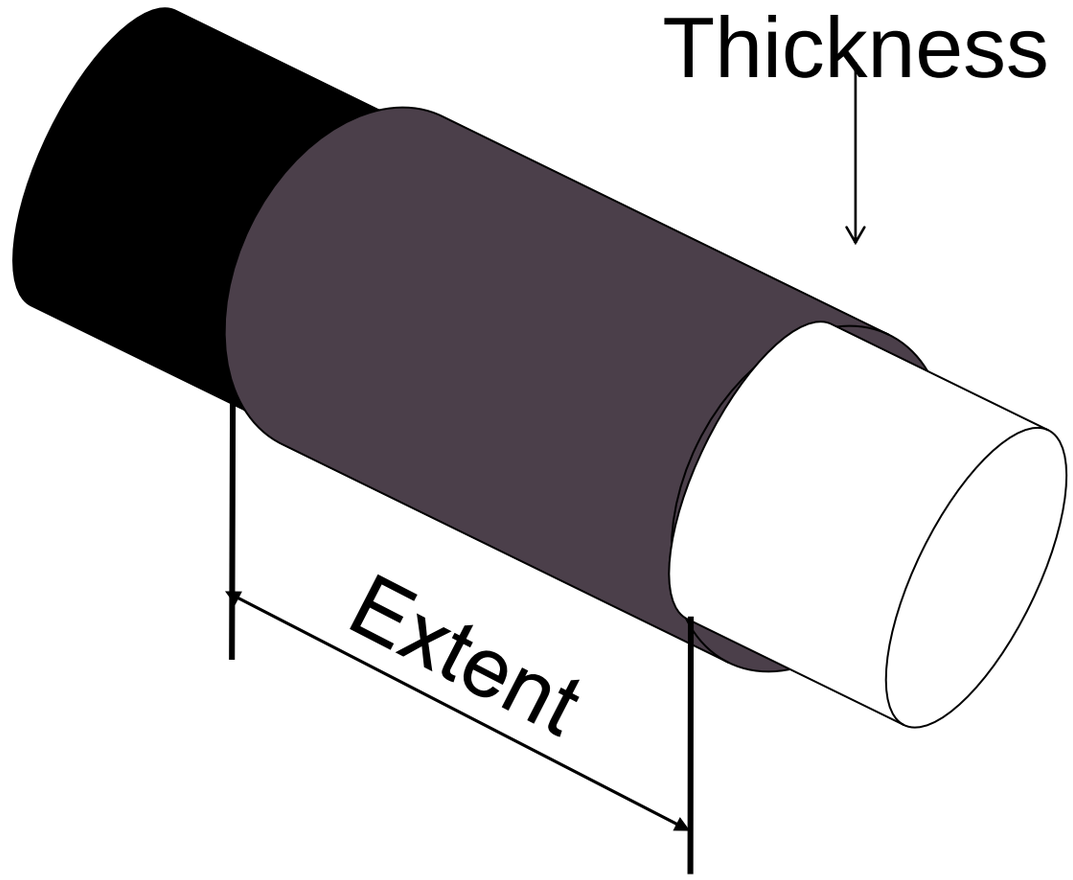
Belzona SuperWrap

Compliant Solution

- Composite repair is pre-qualified against industry recognized standards
- Solution is mathematically engineered and applied by factory-trained personnel

Two critical variables to design for a composite repair are:

- Thickness
- Axial Extent



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Composite Materials & Standardisation

Belzona SuperWrap

Governing documentation for nonmetallic composite solutions covering

- Required performance properties for the composite materials to be qualified
- Requirements for the design of the composite repair
- Training requirements for application, supervision, and designing of the composite repair system
- Requirements for successful execution including ASR, method statements, QA/QC documentation

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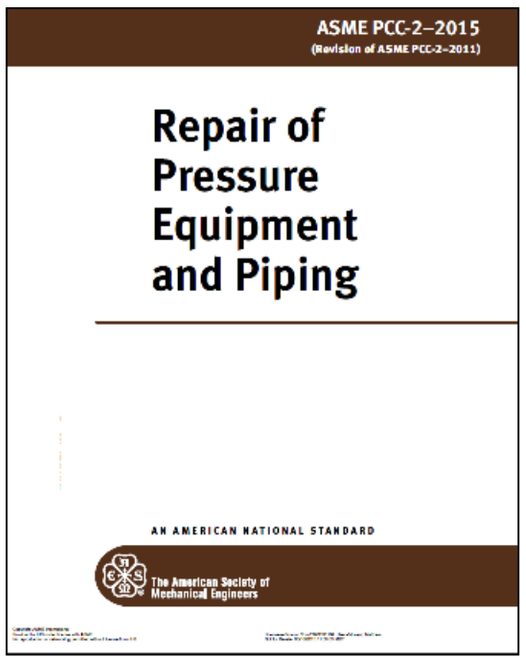
Composite Materials & Standardisation

Belzona SuperWrap

ASME PCC 2



"Repair of Pressure Equipment and Piping: Nonmetallic Composite Repair Systems for Piping and Pipework"

ISO 24817

"Requirements and recommendations for the qualification and design, installation, testing and inspection of composite pipe repairs"

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What is Compliance?

- Compliance is achieved when a standard is met
  - ISO/24817(2015),
  - ASME PCC-2 Section 4.1
    - Belzona's compliant piping repair system is SuperWrap
- There are many non compliant repair systems that can also be used for pipe repair

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How Does a Wrap Comply?

- Prequalification testing carried out in accordance with ISO/24817 and ASME PCC-2
- Correct failure mode
- Validated training to ensure application standards
- Designs carried out in accordance with standards

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Introducing a Compliant Solution

Surface Preparation

1. Surface preparation prior to installation of the repair must be the same as that used for pre-qualifying the repair system.
2. Belzona SW II has been pre-qualified onto carbon and stainless steel substrates.

SSPC-SP 10 – ISO 8501-1 Sa 2 ½ - NACE No. 2

NEAR WHITE METAL

Minimum average substrate profile of 75 micron (3 mil)

SSPC-SP 11

POWER TOOL CLEANING TO BARE METAL

Minimum average substrate profile of 25 micron (1 mil)

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Introducing a Compliant Solution

Belzona SuperWrap Resin

Resin Selection - 100% solids epoxy based

- Outstanding mechanical adhesion
- Low tendency to creep
- No shrinkage when curing
- High HDT values
- High heat resistance
- Extremely durable

Resin Type	Application Temperature Level (ºC)	Maximum Service Temperature (ºC)
Cool Climates	*Above 5*	*80*
Tropical Climates	*Above 20*	*85*
High Operating Temps	*5 - 40*	*150*

SuperWrap II Resins

SuperWrap II Resin Options

Belzona 1981

- Fast curing resin designed for application in cold environments
- Application temperature 5 – 20 °C

Belzona 1982

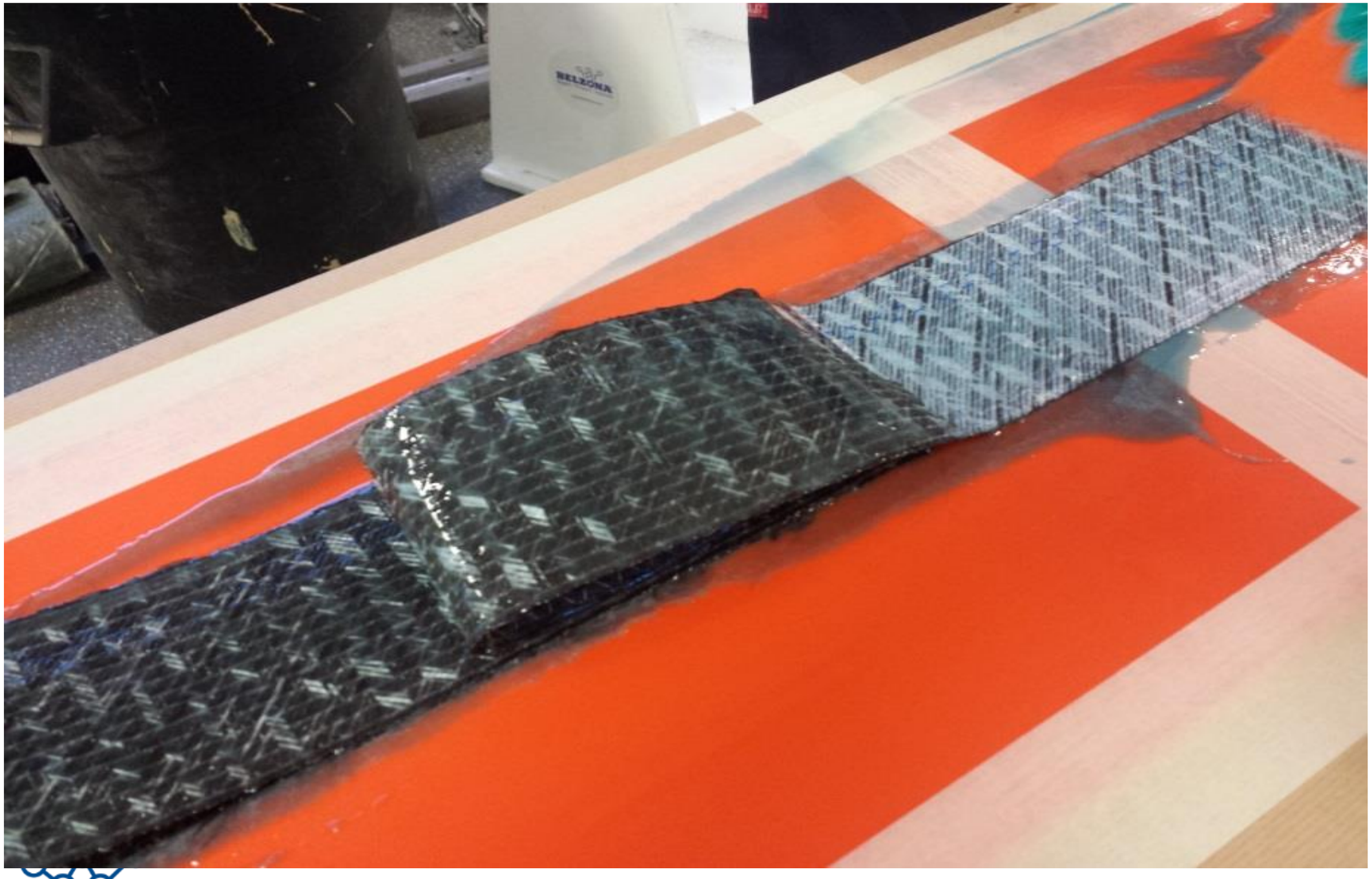
- Long working life resin designed for application in warmer environments
- Application temperature 20 – 40 °C

Belzona 1983

- Resin designed for application at service temperature levels up to 150°C (302°F)
- Application temperature 5 – 40 °C

Introducing a Compliant Solution

Belzona SuperWrap Reinforcement Sheet



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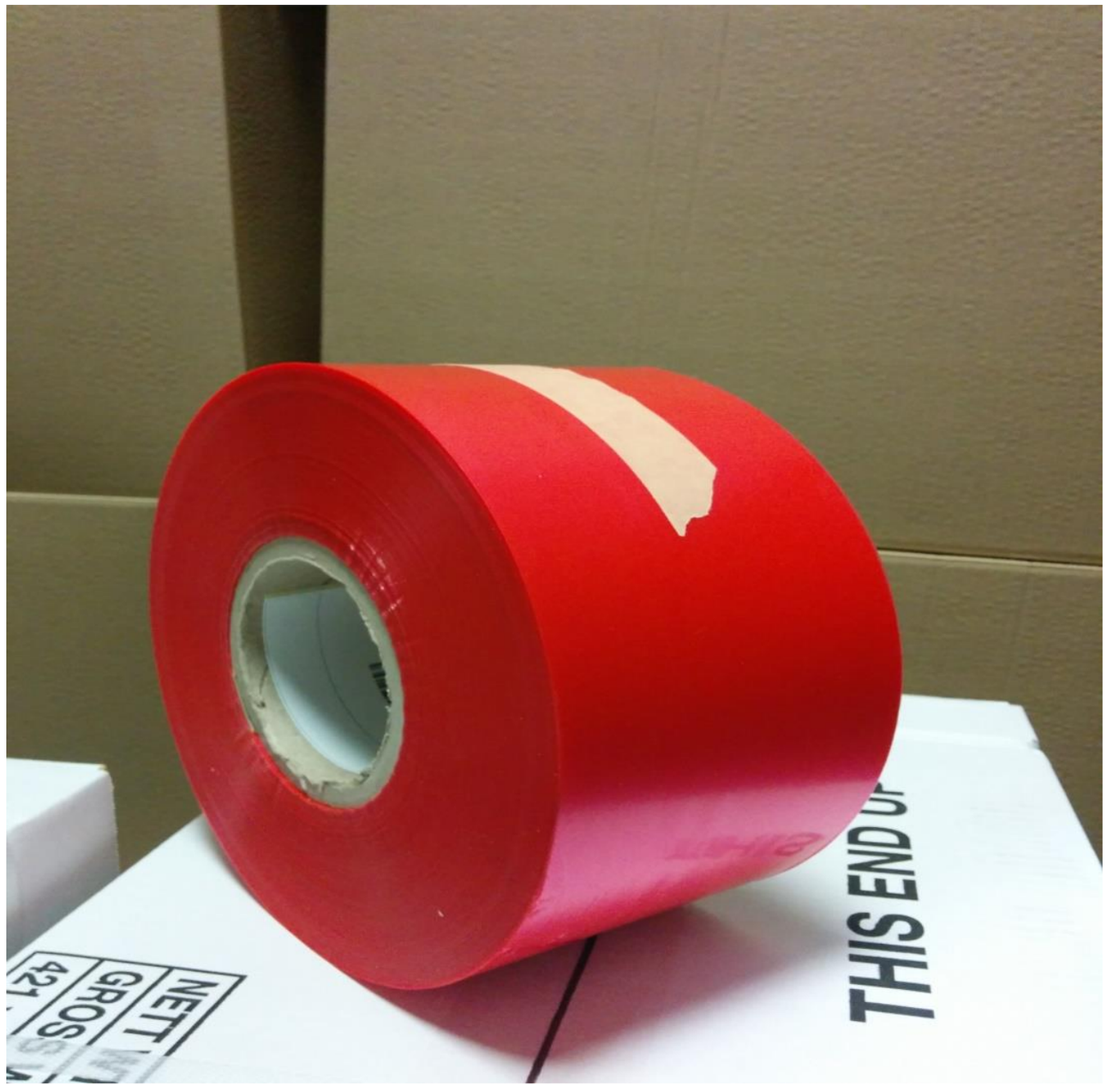
Introducing a Complaint Solution

Belzona SuperWrap Release Film



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Application Procedure for Superwrap II

Belzona SuperWrap Application

- Treat the defect Area
  - Plate Bond
  - Live Leak
- Prepared beyond repair area
  - Sa 2.5 or SP11
  - 75 microns or 25 microns
- Degrease

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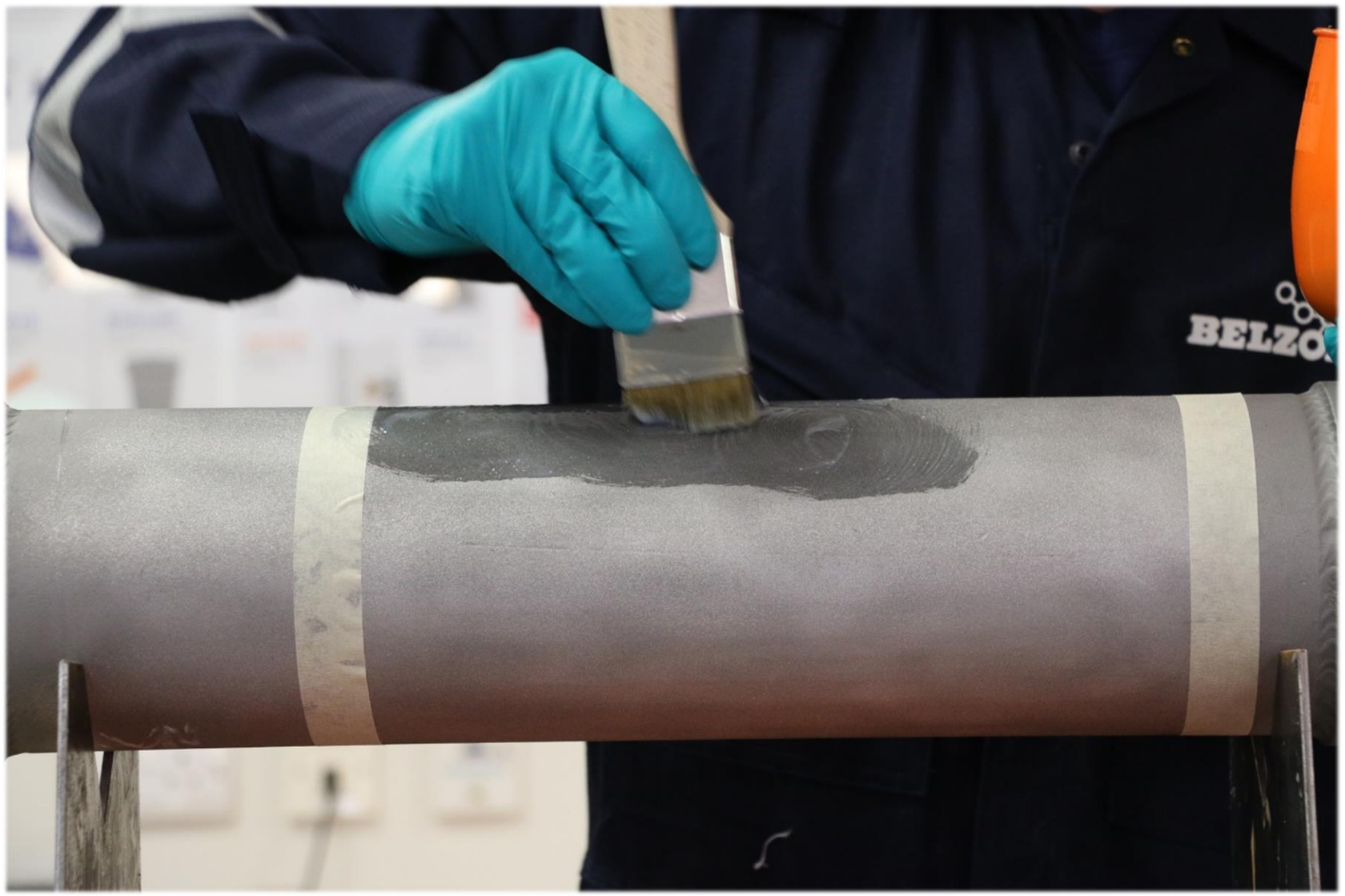
Application Procedure for Superwrap II

Belzona SuperWrap Application

Mix and apply resin to wet out the surface profile



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Application Procedure for Superwrap II

Belzona SuperWrap Application

Wet out Belzona 9381 Reinforcement sheet with same resin

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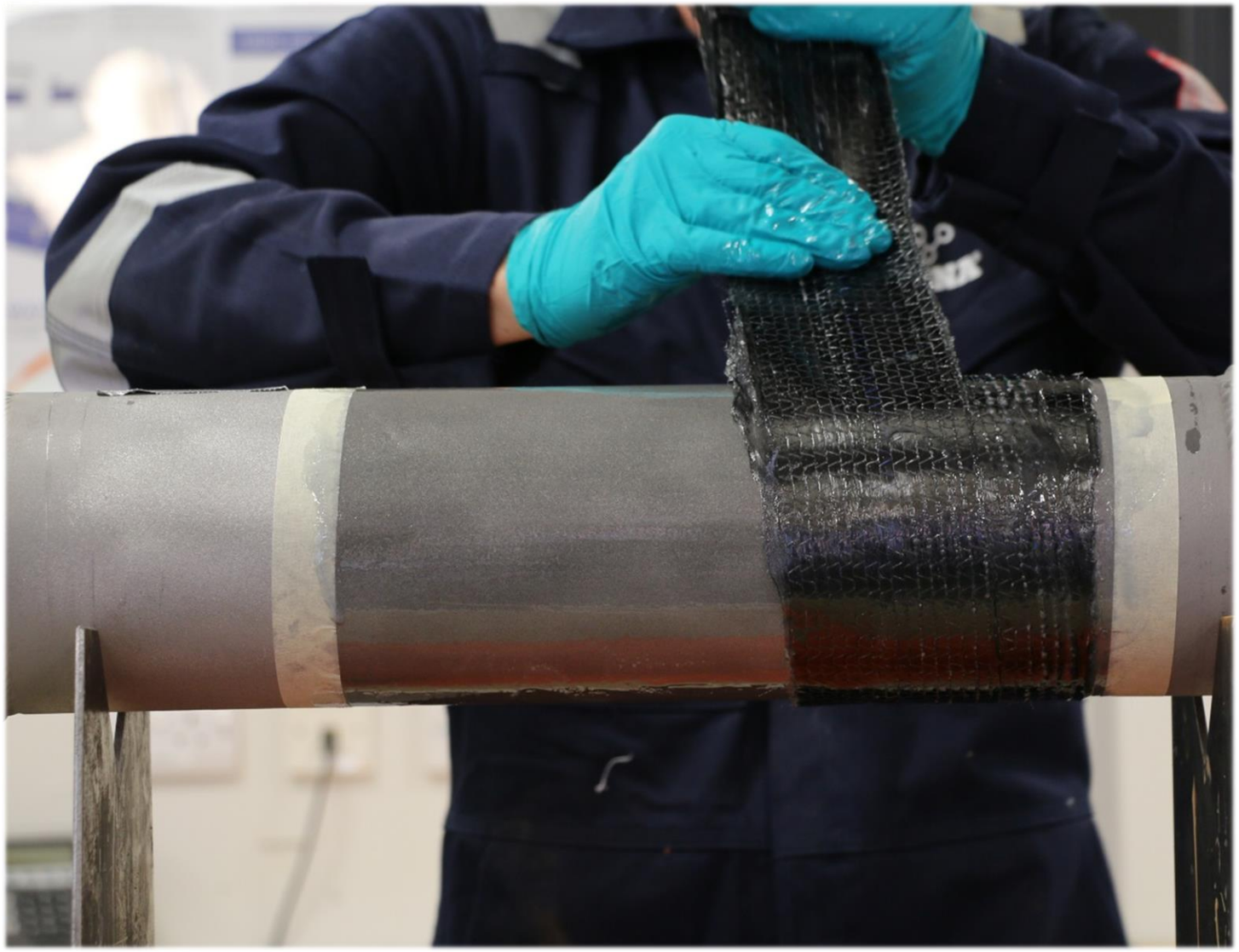
Application Procedure for Superwrap II

Belzona SuperWrap Application

Wrap wetted out reinforcement sheet around pipe



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Application Procedure for Superwrap II

Belzona SuperWrap Application

Repeat this Process to build up the required number of wraps / layers

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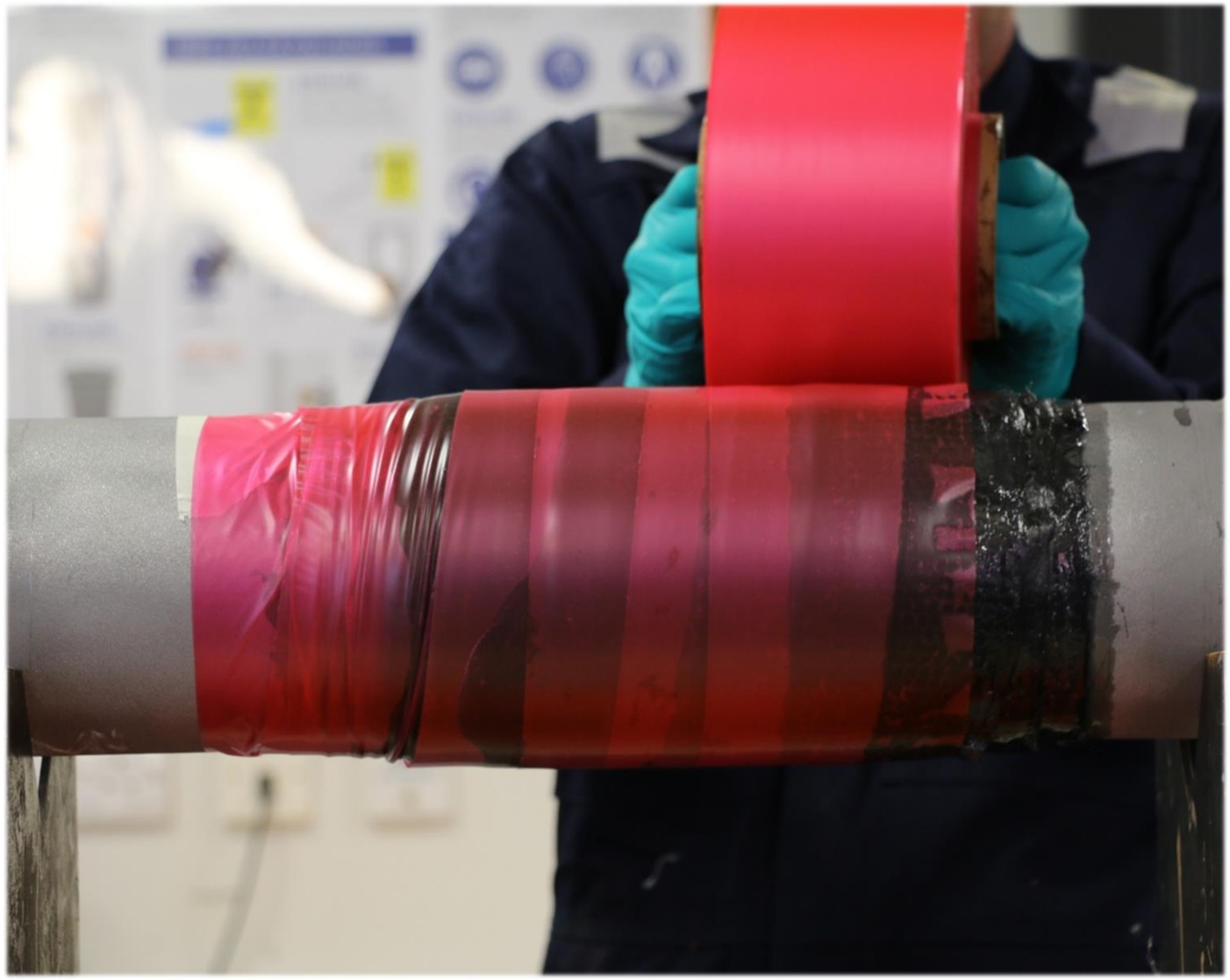
Application Procedure for Superwrap II

Belzona SuperWrap Application

Tightly wrap
Belzona 9382
around the repair



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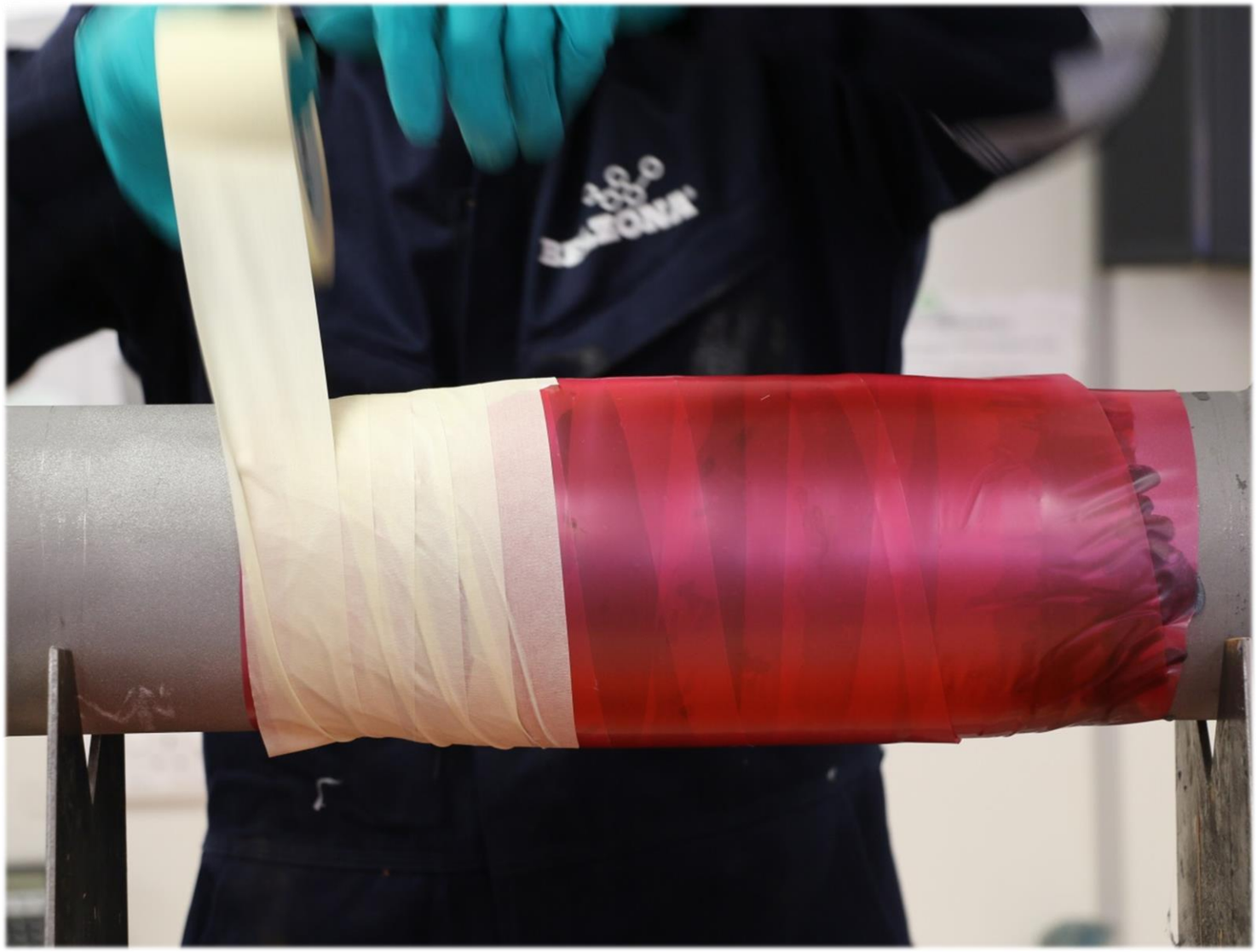
Application Procedure for Superwrap II

Belzona SuperWrap Application

Secure ends in place with masking tape



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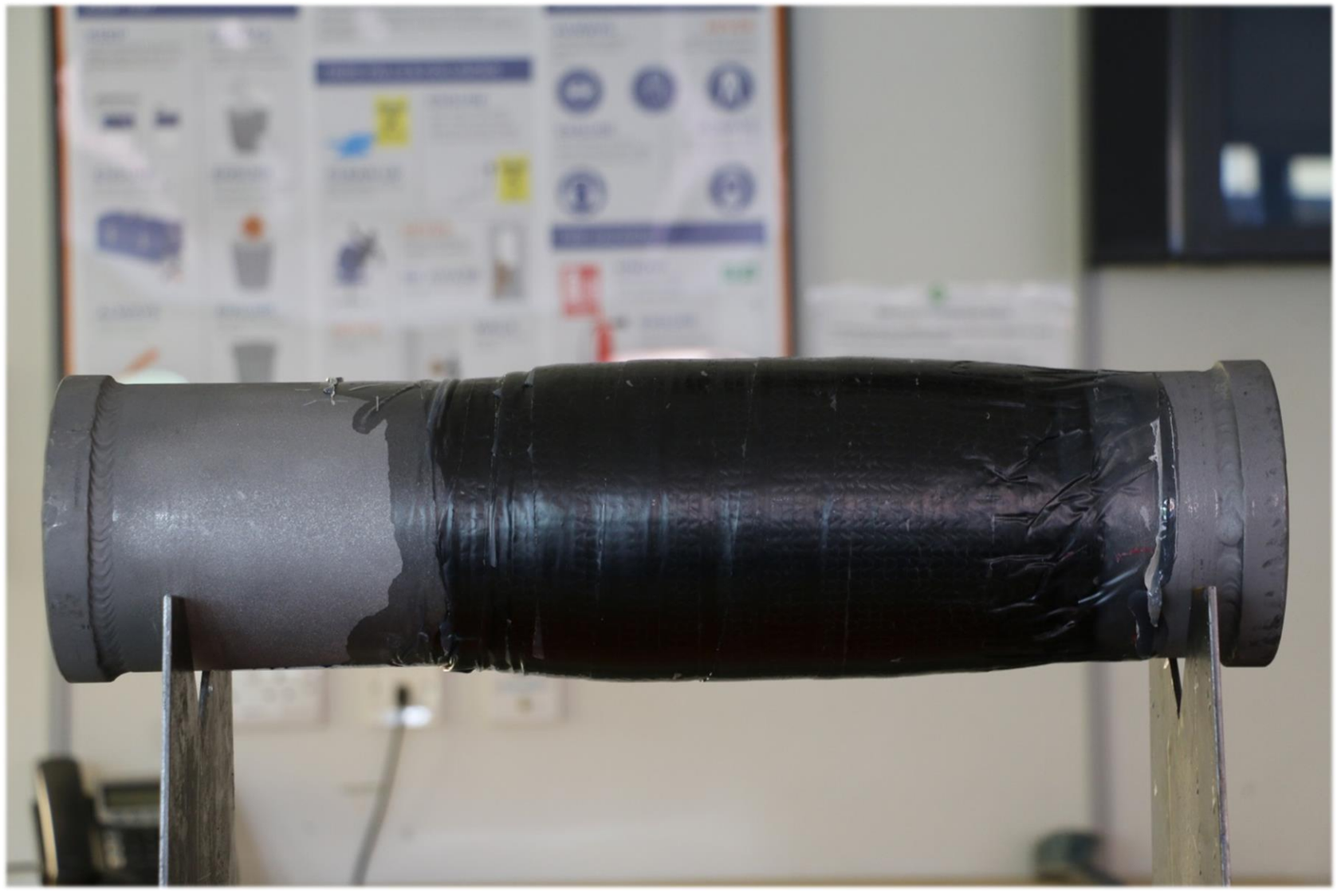
Application Procedure for Superwrap II

Belzona SuperWrap Application

Once cured, remove 9382 and masking tape



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Composite Materials & Standardisation

Belzona SuperWrap Properties

Property	Details	Test Methods
Tensile Properties	Tensile Strength, Tensile Modulus, Poisson's Ratio, Strain to Failure	ASTM D3039 – Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials
Thermal Expansion	Coefficient of Thermal Expansion	ISO 11359 – Plastics – Thermomechanical Analysis
Material Glass Transition	Glass Transition Temperature	ISO 11357-2 – Plastics – Differential scanning calorimetry– Determination of-glass transition temperature and glass transition step height
Lap Shear Adhesion Strength	Shear strength of composite bonded to substrate	EN 1465 – Lap Shear Strength, Adhesives, Rigid to Rigid Bonded Assemblies
Structural Integrity	Wrapped pipe with defect to survive short-term pressure test	ISO 24817 – Annex C Short-term Pipe Spool Survival Test

Composite Materials & Standardisation

Belzona SuperWrap Properties

Property	Details	Test Methods
Impact Performance	Low velocity 5 J impact performance	ISO 24817 – Annex F – Measurement of impact performance
In-Plane Shear Modulus	Shear Modulus by V-Notched Beam Method	ASTM D 5379 Standard Test Method for Shear Properties of Composite Materials by the V-Notched Beam Method
Energy Release Rate	Toughness parameter for the repair/substrate interface	ISO 24817 – Annex D -Measurement of γ_{LCL} for through-wall defect calculation
Long-Term Strength	Long-term (creep rupture) strength of the composite repair	ISO 14692 – Annex E – Measurement of performance test data
Long-Term Lap Shear Performance	Measurement of lap shear adhesion strength after 1000 hours of heat exposure (at 40ºC)	EN 1465 – Lap Shear Strength, Adhesives, Rigid to Rigid Bonded Assemblies

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Composite Materials & Standardisation

Belzona SuperWrap Properties

Properties	Reinforced Belzona 1981	Reinforced Belzona 1982	Carbon Steel (For comparison reasons)
Tensile Strength	(H) 524 MPa	(H) 505 MPa	400-550 MPa*
	(A) 126 MPa	(A) 121 MPa	
Young's Modulus	(H) 38,800 MPa	(H) 38,600 MPa	200 GPa*
	(A) 18,300 MPa	(A) 15,475 MPa	
Poisson's ratio	(H) 0.26	(H) 0.26	0.27 – 0.3*
	(A) 0.27	(A) 0.13	
Thermal Exp. (mm/mm°C)	(H) 9.44 E-06	(H) 11 E-06	8-12 E -06*
	(A) 13 E-06	(A) 21 E-06	

Composite Materials & Standardisation

Belzona SuperWrap Properties

Performance Testing	Reinforced Belzona 1981	Reinforced Belzona 1982
Tensile Shear Adhesion	15.5 MPa	12.3 MPa
	15.5 MPa *(Imm)	18.95 MPa
Energy Release Rate	68.57 J/m^2	76.53 J/m^2
Short-Term Survival Test Annex C	Passed when tested up calculated testing pressure level of 39.2 MPa	
Long-Term Survival Test	60 MPa sustained for 1,000 h	60 MPa sustained for 1,000 h

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Approvals and Specs

Belzona SuperWrap Testing

- **ABS**
  Approved
- **KOC**
  Specified
- **EMEPI**
  Specified
- **OHE**
  Tested

Ovalway Hydraulic Engineering Ltd
Unit 11
Cannon Park Way
Middlesbrough
TS1 5JU

Telephone: (01642) 247106 / 247498
Fax No: (01642) 241874
Email: ohe@ovalway.co.uk

Ovalway Hydraulic Engineering

DETAILED REPORT

Ref.	20912 Rev 0
Customer	Belzona
Location.	Ovalway Workshop
Engineer.	S.Chambers
Att. dates.	20/07/16

TO:

FROM:

ELEVATED TEMPERATURE TEST.

High pressure system set up using 47,500 psi capable oil Hydratron air driven pump. On the delivery side of the pump 30000 bar transducer connected to a 50/60 Data logger. Fittings were filled with hydraulic oil, purged of all air and placed within the test enclosure below before proof testing.

SUBJE

OUR RI

Dear Si

We are
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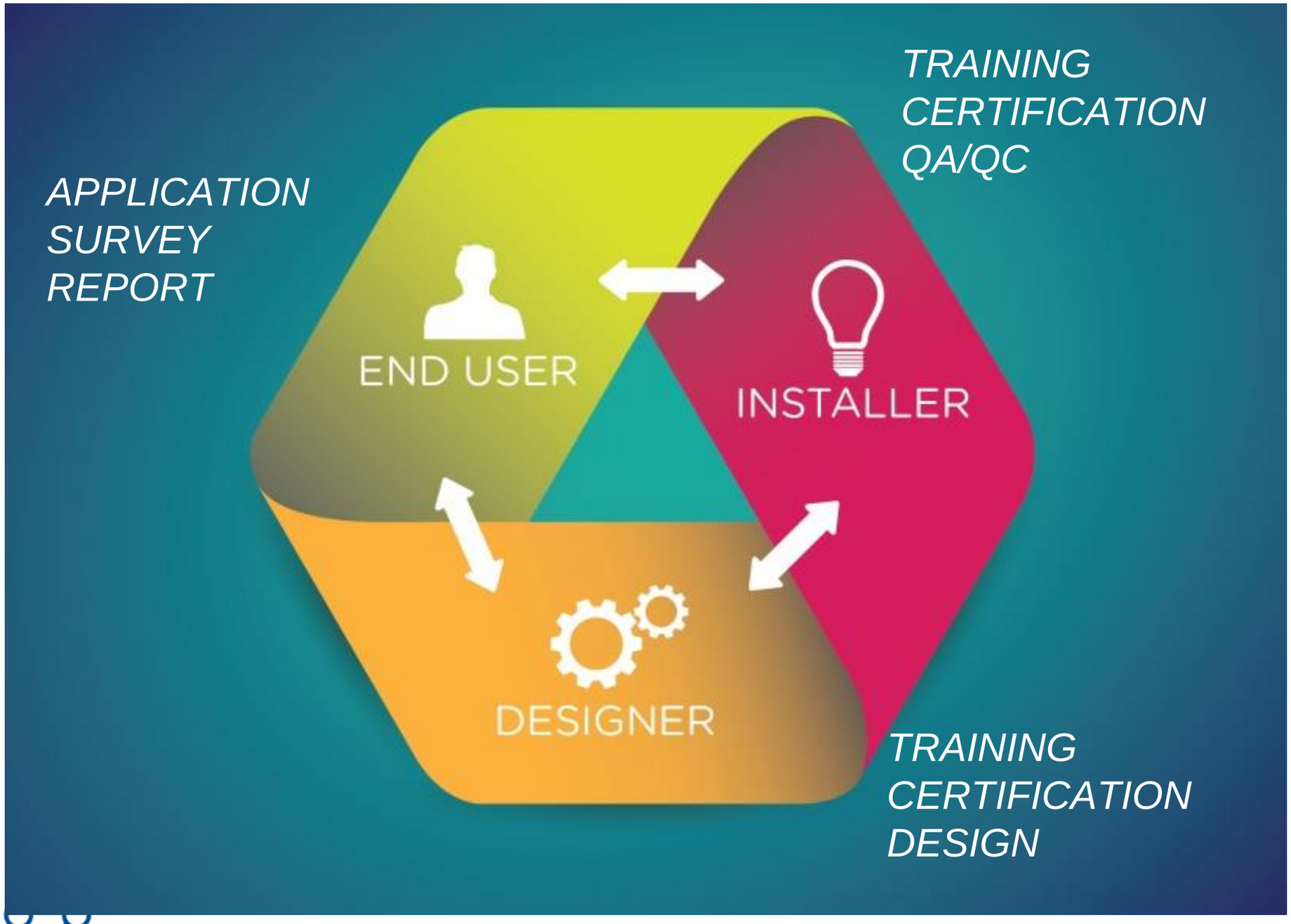
here be

PRODUCT CATEGORY : **NON-METALLIC COMPOSITE MATERIALS** for THE REPAIR OF PIPING & PIPELINES. (**SUPERWRAP II** Only).

BELZONA®
Repair • Protect • Improve

Delivering success

Belzona SuperWrap Process



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Composite Wrap Overview

Belzona SuperWrap Compliance

- Hybrid reinforcement sheet infused with resin and compressed with release film
- Tested in accordance with ISO 24817 and ASME PCC-2
- Designed in accordance with equations from standards
- Installers/Supervisors trained in accordance with standards
- Engineered Design Life

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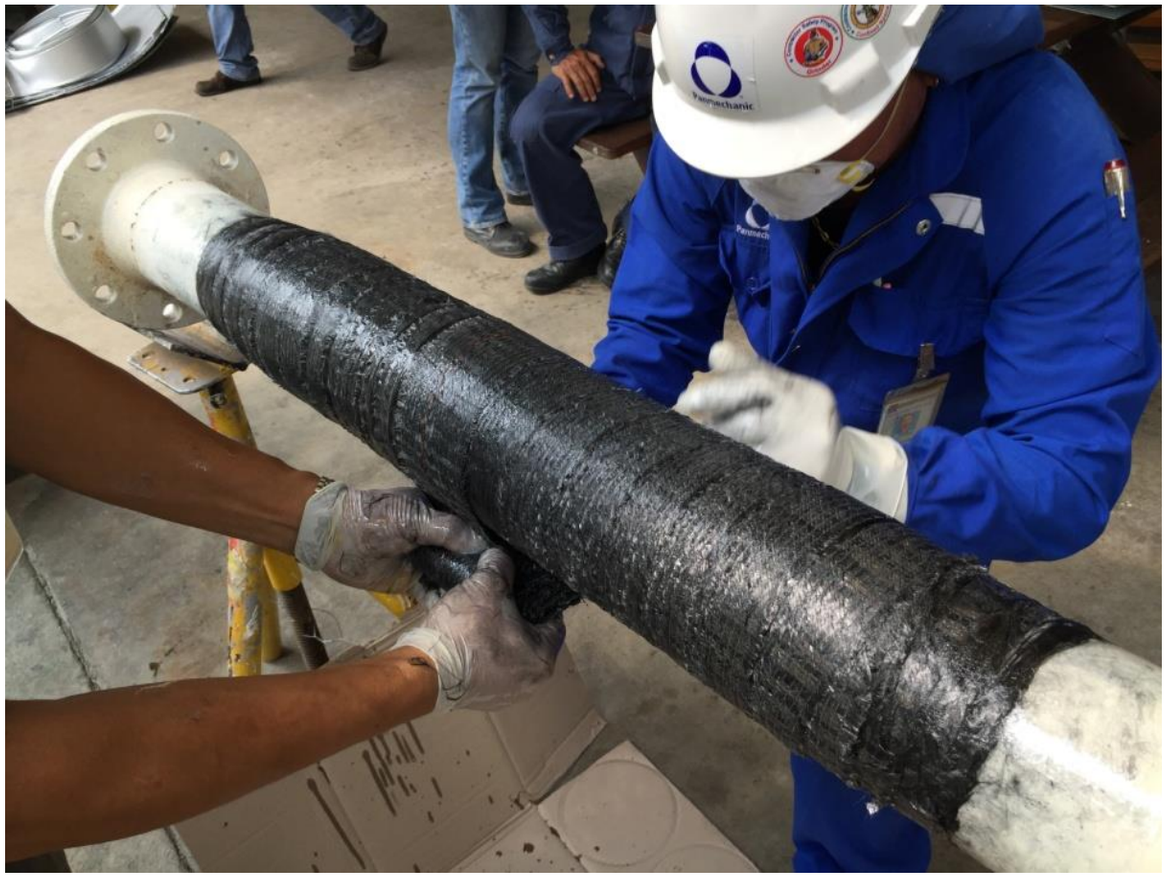
Composite Wrapping

Belzona SuperWrap



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Composite Wrapping

Belzona SuperWrap

Riser Pipe , Gulf of Thailand

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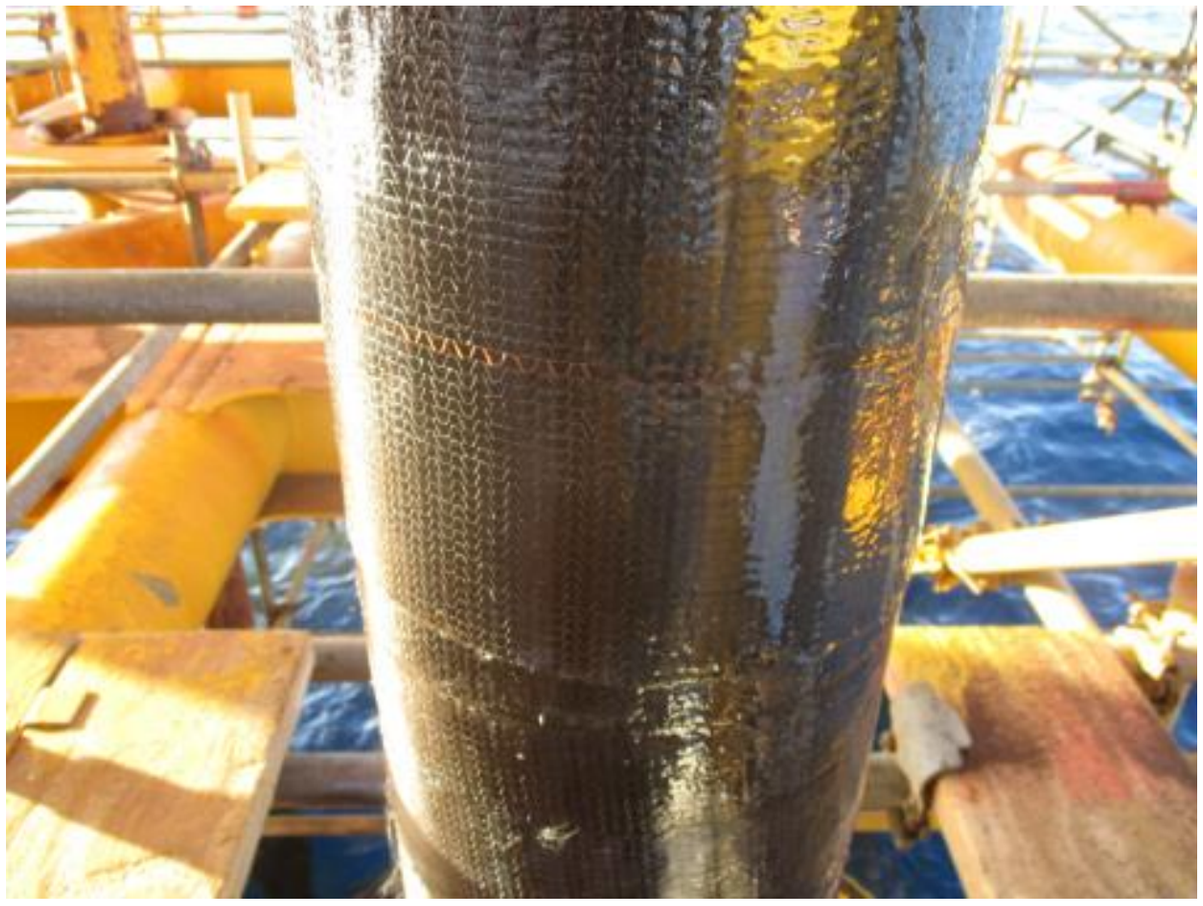
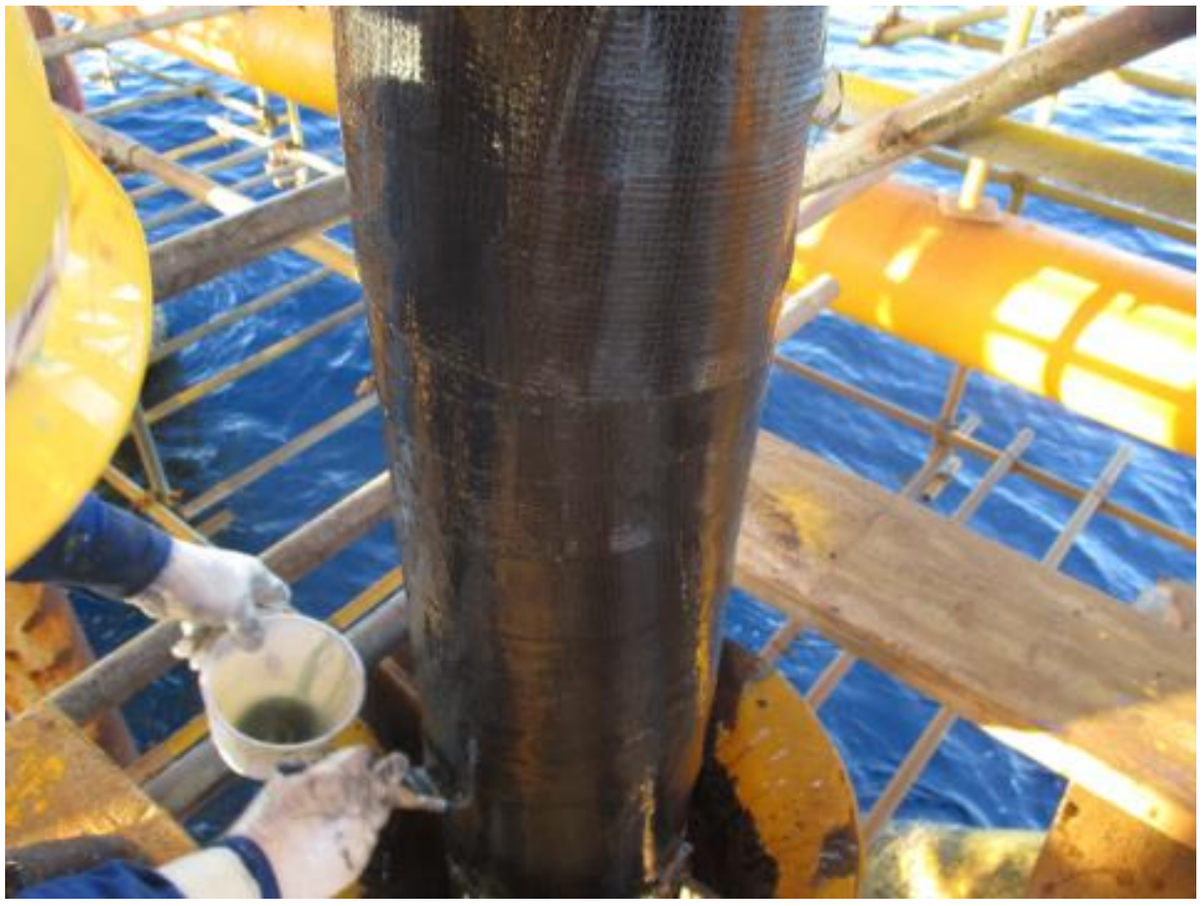
Composite Wrapping

Belzona SuperWrap





Riser Pipe , Gulf of Thailand

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Composite Wrapping

Belzona SuperWrap Bend and Tee

Gas Flowline , Gulf of Thailand

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Different Geometry

Belzona SuperWrap on different Shapes

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Composite Solutions for Returning Strength to Damaged Assets

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Thank you for your time

Any questions?

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