Engineered Composite Systems for Pressure Equipment Alterations

AB-539

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FOREWORD

As provided for under Section 40 of the Pressure Equipment Safety Regulation, the Administrator in the pressure equipment discipline has established that ABSA document AB-539 “Engineered Composite Systems for Pressure Equipment Alterations” provides guidelines and specifies requirements that must be met for registration of alteration designs and procedures that include engineered composite systems.

The next reaffirmation of AB-539 is scheduled for 2029.

1.0 INTRODUCTION

This document was developed to establish the requirements for the use of engineered composite systems in the post-construction alteration activities of pressure equipment. Use of an engineered composite system may be considered, if there is a valid technical and safety justification, to provide for the safe and continued operation of pressure equipment that is not compliant with the original registered design until the equipment can be repaired, altered, or replaced. The pressure equipment owner-user is responsible for determining if the use of an engineered composite system is appropriate and if the installation and use can be safely performed.

This document assumes that an integrity and defect assessment has already been performed and a decision has been made to consider use of an engineered composite system. This document does not establish guidelines or requirements for pressure equipment integrity assessments, or defect assessments.

This document does not provide all the necessary information required to perform a pressure equipment alteration using an engineered composite system. It is the responsibility of the owner-user, in conjunction with any other organization responsible for the design, manufacturing, or installation of engineered composite systems, to ensure that all of the necessary engineering, installation, and safety requirements are addressed for any given installation.

ASME PCC-2 Part 4 Article 401, and ISO 24817 are standards defining the requirements for the external application of engineered composite systems to damaged pressure equipment. Information from these publications, and other relevant good engineering practices, has therefore been referenced in the applicable sections of this document to provide guidance on the qualification, design, installation, testing, inspection, and removal of engineered composite systems.

This requirements document was developed through consultation with the public, plant owner-users, engineered composite system suppliers, installer organizations, the Technical Safety Authority of Saskatchewan, and other stakeholders; their input has been invaluable in compiling this document. The scope, recommended use and limitations established by this document reflect common and practical use of ECS for alteration of pressure equipment. With intent of further consultations, available relevant information, acquired knowledge and experience, the scope, recommended use and limitations may be modified in future editions of this document.

This requirements document will be reviewed periodically to ensure that it is aligned with current industry practices. We would welcome any suggestions you have to improve this document. Please provide your comments to:

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2.0 DEFINITIONS

For the purpose of this document, the following definitions apply:

Certified testing organization – a testing organization that is certified or accredited to ISO/IEC 17025 or other nationally or internationally recognized accreditation that is acceptable to ABSA and the owner-user

Note: Examples of some acceptable accreditation bodies that provide accreditation for testing programs includes but is not limited to: The Standards Council of Canada (SCC), American Society for Testing and Materials, the U.S. Department of Defense, American Association for Laboratory Accreditation, National Aerospace and Defense Contractors Accreditation Program (NADCAP)

Composite – a thermoset polymer resin that is reinforced by fibers

Composite system – a system comprised of multiple elements such as the substrate material, substrate surface preparation methods, composite materials (laminate, fibers, and resin), filler material, adhesive, composition methods, sealing, coating, etc.

Cure (curing) – the setting of a thermosetting resin by an irreversible chemical reaction

Cure schedule – a time-temperature profile qualified to generate a specified glass transition temperature or heat distortion temperature of the resin

Design lifetime – the maximum application lifetime of the laminate

Engineered composite systems (ECS) – a composite system which has been designed and applied under a specified, controlled process so that under the design conditions, there is a high degree of confidence that the repair will maintain its integrity over the design lifetime

Engineered composite system designer – a company or a person that designs and certifies the design of the engineered composite system

Engineered composite system installer organization – a company or an owner-user that installs the engineered composite system

Engineered composite system procedure qualification record (ECSPQR) - a record of variables recorded during the qualification of the ECS using test specimens

Engineered composite system procedure specification (ECSPS) – a written document providing direction to the person applying the ECS

Engineered composite system supplier – a company that supplies the engineered composite system materials and installation instructions

Filler material – material used to repair external surface imperfections prior to the application of the composite / laminate

Glass transition temperature – the temperature at which a resin undergoes a marked change in physical properties

Heat distortion temperature – the temperature at which a standard bar of the resin polymer deflects by a specified amount under a given load

Installation Instructions – instructions provided by the ECS supplier in the method statement for each ECS application. Installation instructions include details such as: acceptable environmental conditions during ECS application, material storage, surface preparation, resin system mixing, laminate lay-up for the component geometry, laminate consolidation procedure (fiber wetting), cure schedule, key hold points, and batch testing reports of the qualified ECS materials.

Note: Installation instructions are used as input for the ECS procedure specification.

Installer– a person who is qualified to apply an engineered composite system

Integrity assessment – an examination of an item of pressure equipment, related processes and documentation to determine its conformity to the requirements established by ABSA

Laminate – the part of the ECS that is the composite.

Note: Composites are composed of discrete lamina or layers which are wrapped or stacked, one on top of the other. This stacked construction is the laminate. Common alternate terms used in industry include: repair laminate, and composite material.

Method statement – describes the main procedures carried out prior to and during ECS applications that are generic in nature for a particular ECS and include the following information: Health and safety, quality assurance, installation procedure and environmental information

Owner – a lessee, a person in charge, a person who has care and control and a person who holds out that the person has the powers and authority of ownership or who for the time being exercises the powers and authority of ownership

Owner-user – an owner that has implemented a quality management system, recognized by ABSA, to manage the integrity of pressure equipment

Ply – a single wrap or layer (lamina) of a laminate

Post cure – additional elevated temperature applied after resin has hardened to ensure the required glass transition temperature is achieved

Pressure equipment – a boiler, a fired-heater pressure coil, a thermal liquid heating system and other equipment designed to contain expansible fluid under pressure, including, but not limited to, pressure vessels, pressure piping systems, and fittings, as defined in the regulations

Resin – all of the components that make up the matrix portion of a composite

Risk assessment – a comprehensive and systematic process of evaluating the potential risks to people, environment, and property that may be a result of operating pressure equipment

Note: In the context of this document, the wording in the above definition" result of operating pressure equipment "includes risks related to performing activities for the use of an ECS, while the pressure equipment is in operation.

Substrate – the surface on which the ECS installation is carried out.

Type A Defect – a defect within the substrate, not through-wall and not expected to become through-wall within the design lifetime of the ECS

Type B Defect – a through-wall defect or a defect within the substrate where at the end of service life the remaining wall thickness is less than 1 mm

User Design Specification (UDS) – a document created by the owner-user containing sufficient detail to provide a complete basis for the design and installation of an ECS for pressure equipment alterations.

Work Pack – describes the job specific procedures related directly to the procedures carried out prior to and during ECS application and include the following information: Scope of work, health and safety, risk assessment, ECS details, Installer qualification level and specific installation instructions

3.0 REFERENCE PUBLICATIONS

The following publications have been referenced in this document in a way that some or all of their content is used as a requirement of this document. Only the referenced editions listed apply.

The organizations that are involved in the use of ECS shall have access to these referenced standards, in order to use this AB-539 document.

ISO 24817:2017(E) – Petroleum, petrochemical and natural gas industries – Composite repairs for pipework – Qualification and design, installation, testing, and inspection

ASME PCC-2-2018 – *Repair of pressure equipment and piping – Part 4: Nonmetallic and bonded repairs – Article 401 – Nonmetallic composite repair systems: High-risk applications*

ISO 8501 – 1:2007 *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

SSPC-SP 10/NACE No. 2, Near-White Blast Cleaning -*The Society for Protective Coatings (SSPC); National Association of Corrosion Engineers (NACE); The Association for Materials Protection and Performance (AMPP)*

SSPC-SP2, Hand Tool Cleaning-*The Society for Protective Coatings (SSPC); The Association for Materials Protection and Performance (AMPP)*

SSPC-SP 3, Power Tool Cleaning-*The Society for Protective Coatings (SSPC); The Association for Materials Protection and Performance (AMPP)*

SP 11, Bare Metal Power Tool Cleaning-*The Society for Protective Coatings (SSPC); The Association for Materials Protection and Performance (AMPP)*

SSPC-SP 15, Commercial Grade Power Tool Cleaning-*The Society for Protective Coatings (SSPC); The Association for Materials Protection and Performance (AMPP)*

4.0 SCOPE AND REQUIREMENTS FOR ECSs

The scope of this document is to provide a systematic approach outlining the requirements and recommendations for the procedure qualification, design, installation, testing, inspection, and registration of engineered composite systems (ECSs) for pressure equipment alterations.

The requirements of this document shall be satisfied by anyone planning to design, register, and install an ECS on pressure equipment. ECSs are applied to restore the structural integrity of a pressure component that has been degraded or damaged by service-induced deterioration mechanisms or external mechanical damage.

The use of ECSs on pressure equipment may introduce new risks which may further damage pressure equipment and cause the pressure equipment to fail. Some examples of the new risks include, but are not limited to, new damage mechanisms initiated under the composite material, and development of operating and residual stresses due to constrained differential expansion. It is the owner-user's responsibility to assess and address all applicable risks and the impact of damage mechanisms, failure modes, and the addition of operating and residual stresses when an ECS is used.

4.1 Responsibilities

4.1.1 Owner-user

Owner-users shall develop, implement, and maintain all documents, processes, and procedures used to perform or contract the design, manufacturing, installation, and use of an ECS within the scope of their quality management system (AQP-8000 series PEIMS / IMS).

4.1.2 Engineered Composite System Supplier

ECS suppliers shall develop, implement, and maintain all documents, processes, and procedures used for the manufacturing and specification of ECS materials within the scope of their quality management system.

4.1.3 Engineered Composite System Designer

ECS designers shall ensure that the design of the ECS conforms with all owner-user design specifications, shall have adequate training and shall be deemed competent by the pressure equipment owner-user, in the design, application, inspection, and re-evaluation of ECSs.

4.1.4 Engineered Composite System Installer Organization

ECS installer organizations shall ensure that the ECS is installed to the satisfaction and acceptance of the owner-user, and conforms to the registered alteration procedure. The ECS installer organization shall have

personnel that are qualified in the application, installation, examination, testing, and repair of ECSs.

4.1.5 ABSA

ABSA shall review ECS designs and procedures for pressure equipment alterations. This is intended to ensure, within reasonable bounds, that the relevant technical requirements are documented and addressed by the owner-user and its representatives, and that all administrative requirements are met for the purpose of ECSPS and alteration procedure registration, installation and maintenance.

4.2 Applicability

ECSs may be used as a temporary means of restoring the structural integrity of pressure equipment identified in Table 4.1. The application of an ECS is limited to installation on pressure equipment designed for the below listed conditions:

- Design Pressure (Note 1) ≤ 3500 kPag (500 psig)
- Design Temperature ≤ 250°C (482°F)
- Minimum Design Temperature ≥ -50°C (-58°F)

Refer to Annex A for complete applicability details for each general pressure equipment category.

Notes:
1) Design pressure refers to the pressure equipment maximum allowable working pressure (MAWP) registered with ABSA in accordance with PESR Section 19(1)(-v).

Table 4.1 – Applicability of General Pressure Equipment Categories

Material of Construction (Substrate)	Pressure Equipment Category(1)		
	Pressure Piping Systems	Pressure Vessels	Boilers and BEP
Metallic	**Y**	N	N
Non-metallic	N	N	N

Y – Permitted as defined in Annex A
N – Not Permitted

Notes:
1) Refer to Annex A for complete applicability details
2) This table does not apply to ECS maintenance activities. Refer to Section 6.1.3 of this document for maintenance and monitoring requirements. It is intended that the maintenance and monitoring procedures will include the post-installation examination and testing recommendation provided in Table 8.3 of this document.

4.3 Limitations

ECSs shall only be considered for installation on pressure equipment managed by owner-users who hold a Certificate of Authorization Permit, that includes performing or contracting the design, manufacturing, and installation of ECSs within the scope of their quality management system (AQP-8000 series PEIMS / IMS).

ECSs shall not be considered for use in the following applications:

a) Pressure equipment in public occupancy service
b) Pressure relief devices, or flanged joints connecting a pressure relief device
c) Complex fittings, such as valves, filters, miniature pressure vessels, or other appurtenances installed in a piping system
d) New construction of pressure equipment
e) For the purpose of re-rating (i.e. up-rating of in-service pressure equipment)
f) Pressure equipment operating under a fitness-for-service assessment
g) Areas of pressure equipment that may interact with engineered pressure enclosures (EPEs)
h) Areas of pressure equipment that may interact with hot taps

4.4 Exclusions

The following types of composite systems do not meet the requirements of this document:

a) Any pre-fabricated / pre-cured components or laminates made using composite materials, such as composite sleeves, split composite sleeve systems, etc.
b) Generic type composite wraps that are not engineered for a specific installation

4.5 Registration Requirements

A person that is planning to install an ECS on pressure equipment shall ensure the following is registered with ABSA prior to commencement of the alteration:

a) ECS procedure specification (ECSPS); and
b) Application-specific alteration procedure

Refer to Annex B for detailed requirements for ECSPS and alteration procedure registration.

4.6 Alteration Reporting Requirements

After the ECS installation is complete, the alteration of the affected pressure equipment shall be inspected, verified and certified on an alteration data report acceptable to ABSA.

Refer to Annex B for detailed alteration report requirements.

5.0 ENGINEERED COMPOSITE SYSTEM

5.1 Engineered Composite System

The ECS is a combination of the following elements and procedures:

- Substrate (base metal surface)
- Method of surface preparation
- Load transfer material (filler material)
- Primer layer adhesive (an adhesive used in some systems to bond the composite laminate to the substrate)
- Composite material (laminate, fibers, and resin)
- Application method (sealing, coating, and other elements as needed)
- Curing protocol

Limitations on the elements allowed for the ECSs are specified in this section.

5.1.1 Substrate

The substrates shall be:

a) Metallic substrate materials covered in the applicable codes of construction listed in Annex A of this document. Metallic substrate materials include, for example, carbon steel, stainless steels, duplex and super duplex stainless steels, aluminum, and titanium.

Qualification testing completed on one representative alloy for each substrate group shall be considered as applicable to all alloys within that group. For example, testing on 316L stainless steel will be applicable to all other austenitic grades of stainless steel, but not to duplex or super duplex alloys.

5.1.2 Surface Preparation

One of the following surface preparation methods shall be used:

a) Abrasive blast cleaning to SA 2½ (SSPC-SP10, NACE No. 2) with non-metallic grit only, such as olivine sand, garnet, iron furnace slag, copper refinery slag, nickel refinery slag,

aluminum silicate slags, and fused aluminum oxide. The abrasive media used in qualification testing shall be defined in the test reports. Blasting media that leaves a residue on the surface after blasting, such as walnut blasting, shall not be used unless the qualification testing was completed with such media.

b) Power tool cleaning to ST-3 (SSPC SP3, SP11 and SP15). The tools and method used in qualification testing shall be defined in the test reports.

c) This document is only applicable to preparation of surfaces using hand tools (ST-2 or SSPC-SP2) if the qualification testing is completed on samples representative of impaired pipe that has been in service (i.e. not if tested on as-new pipe). The condition of the pipe at time of preparation, tools and method used in qualification testing shall be defined in the test reports.

It is intended that the methods used for ECSPS qualification testing be replicated for preparation on site and that no other methods shall be used as alternatives to those qualification tested.

Note: The above-referenced cleaning specifications are as provided by the following surface preparation standards: Preparation of steel substrates before application of paints and related products (ISO 8501), and those published by The Society for Protective Coatings (SSPC), National Association of Corrosion Engineers (NACE) and Association for Materials Protection and Performance (AMPP).

5.1.3 Reinforcing Fibers

The reinforcing fibers shall be the following continuous fibers in woven or stitched fabric form:

a) Glass fiber (E-glass, S-glass or ECR-glass fiber, or equivalent)
b) Aramid fiber
c) Carbon fibers

An ECS that uses carbon fiber (or other electrically conductive components) shall include a method to provide electrical isolation of the fiber from the host substrate in order to prevent bimetallic (galvanic) corrosion. The isolation layer must be considered as part of the ECS and included during the qualification testing.

5.1.4 Polymer Matrix

The polymer matrix shall be one of the following thermoset polymers:

a) Polyester resins
b) Vinyl ester resins

c) Epoxy resins (Bisphenol A, F or novolac systems)
d) Water-cured polyurethane resins

Thermoplastic resins (polymers) shall not be used in the polymer matrix of the ECS.

5.1.5 Quality Assurance

a) The manufacturers producing the ECS materials shall have an ISO 9001 quality management system, or equivalent, in place that provides controls for consistent and repeatable production quality.
b) ECS materials supplied shall be issued with relevant batch numbers and expiration dates.
c) The quality program shall include batch testing of the qualified ECS materials and include as a minimum:

    - Tensile properties of the reinforcing fibers
    - Physical properties of the fabrics, i.e. fabric mass per unit area
    - Glass transition temperature of the polymer matrix
    - Cure characteristics of the polymer matrix (such as gel time)
    - Compression strength of the filler material

d) Test results shall be retained or be retrievable by the ECS supplier and be traceable by batch number.

    - Test results shall be traceable to both the fiber testing and fiber production.

e) The frequency of sampling and ECS material testing shall be specified in the ECS supplier's QMS.

5.2 Engineered Composite System Material Qualification by Supplier

Qualification of the ECS shall be completed in accordance with Table 5.2.2.1 through Table 5.2.3.1 of this document.

- All ECS components listed in Section 5.1 of this document shall be tested to determine the mechanical properties and thermal performance.
- Materials performance and test data shall be measured by a certified testing organization.
- ECS qualification data shall be measured for a representative member of each family of substrate materials (e.g., carbon steel, low- and

high-alloy steel, stainless steel, aluminum, etc.) for which use of the ECS is desired.
- The same cure schedule shall be used for all test samples and specified in the qualification record/report.

Note:
a) ECS supplier qualifies the ECS.
b) ECS supplier develops installation instructions for the use of the ECS.
c) ECS installer develops engineered composite system procedure specification (ECSPS) based on those instructions.
d) ECS installer qualifies the ECSPS.

5.2.1 Substrate and Surface Preparation

a) The specific method of surface preparation of a specific substrate group, as described in section 5.1 of this document, shall be an integral part of the ECS and its qualification.
b) Qualification data are not transferable between different substrate groups or different methods of surface preparation.
c) Any change in the surface preparation method or substrate group requires requalification of the ECS (see section 5.2.3 of this document).
d) The surface roughness achieved on the samples used to measure the lap shear strength, τ, and the energy release rate, γ, shall be recorded and quoted in the qualification report.

5.2.2 Qualification Testing Requirements for ECSs Used on Type A Defects

Table 5.2.2.1 Qualification Requirements for the Laminate

Property	Symbol	Test Method	Notes
Tensile strength in the axial direction	s_a	ISO 527 or ASTM D3039	Report cure schedule and test temperature
Tensile strength in the circumferential direction	s_c	ISO 527 or ASTM D3039	Report cure schedule and test temperature
Tensile strain to failure in the axial direction	ε_{fa}	ISO 527 or ASTM D3039	Report cure schedule and test temperature Minimum value must be >1%
Tensile strain to failure in the circumferential direction	ε_{fc}	ISO 527 or ASTM D3039	Report cure schedule and test temperature Minimum value must be >1%
Tensile modulus in the axial direction	E_a	ISO 527 or ASTM D3039	Report cure schedule and test temperature
Tensile modulus in the circumferential direction	E_c	ISO 527 or ASTM D3039	Report cure schedule and test temperature
Layer (ply) thickness	t_{layer}	-	Derive from tensile test samples
Poisson's ratio	ν_{ca}	ISO 527 or ASTM D3039	Load in the circumferential direction, reaction in the axial direction

Shear modulus	G	V-notched beam shear test (ASTM D5379) or V-notched rail shear test (ASTM D7078)	Report cure schedule and test temperature
Barcol or Shore D Hardness		EN 59, ISO 868, ASTM D2583, or ASTM D2240	Report cure schedule and test temperature
Thermal expansion coefficient in axial direction	α_a	ISO 11359-2, ASTM E831, or ASTM D696	
Thermal expansion coefficient in circumferential direction	α_c	ISO 11359-2, ASTM E831, or ASTM D696	
Glass transition temperature	T_g	ISO 11357-2, ASTM E1640, or ASTMD6604	Report cure schedule associated with measured value and the pre-measurement heating cycle used for the test Measure for all relevant components (including primers, resins, fillers, and coatings)

Table 5.2.2.2 Qualification Requirements for the Interface Adhesion Strength

Property	Symbol	Test Method	Notes
Lap shear strength	τ	EN 1465 or ASTM D3165	Follow general guidance of standards; metal adherents may be used provided sample of composite included between the plates Minimum value of 5,000 kPa (725 psi) Report surface preparation procedure, roughness achieved, and substrate used Report cure schedule and test temperature
Lap shear strength after immersion in water at a minimum temperature of 40°C for 1,000 hours	τ_{LT}	EN 1465 or ASTM D3165	Must be ≥ 0.3τ. Report surface preparation procedure and substrate used Report cure schedule and test temperature Report roughness achieved
Lap shear strength after conditioning at the elevated design temperature for 1,000 hours	τ_{HT}	EN 1465 or ASTM D3165	Must be ≥ 0.3τ Report surface preparation procedure and substrate used Report conditioning temperature Report roughness achieved
Where a primer is used, glass transition temperature	T_g	ISO 11357-2, ASTM E1640, or ASTM D6604	Report cure schedule associated with measured value, and the pre-measurement heating cycle used for the test

Table 5.2.2.3 Qualification Requirements for Fillers

Property	Symbol	Test Method	Notes
Compressive modulus of filler material	–	ASTM D695 or ISO 604	
Compression strength of filler material	–	ASTM D695 or ISO 604	
Glass transition temperature of filler	–	ISO 11357-2, ASTM E1640, or ASTM D6604	Report cure schedule associated with measured value, and the pre-measurement heating cycle used for the test

Table 5.2.2.4 Qualification Requirements for ECSs Used on Type A Defects

Property	Symbol	Test Method	Notes
Short-term pipe spool survival test	–	See section 5.4	Laminate must not fail

5.2.3 Qualification Requirements for ECSs Used on Type B Defects

Table 5.2.3.1 Qualification Requirements for ECSs Used on Type B Defects

Property	Symbol	Test Method	Notes
Energy release rate, circular defects	$\mathcal{J}_{LCL}$	ISO 24817, Annex D	Report surface preparation procedure, roughness achieved and substrate used Report cure schedule and test temperature
Energy release rate, slot defects Test results will be provided for consideration and review	$\mathcal{J}_{w}$	See Annex E of this document	Report surface preparation procedure, roughness achieved and substrate used Report cure schedule and test temperature
Impact survival test	–	ISO 24817, Annex F: “Measurement of Impact Performance”	Report surface preparation procedure and substrate used
Qualification requirements for additional substrate groups or additional methods of surface preparation	–	Section 5.5	Report surface preparation procedure, roughness achieved, and substrate used Report cure schedule and test temperature

5.3 Engineered Composite System Qualification Report

The data recorded in accordance with the requirements in Section 5.2 of this document shall be presented using a format equivalent to that shown in this section.

5.3.1 Qualification Report– ECS Elements

ECS Supplier Name:	*[Add ECS supplier company name]*
ECS Name:	*[Add ECS product name]*
Polymer system:	*[Add trade name for polymer system]*
Fabric details:	*[Specify fiber type, fiber orientation, fiber count in each orientation, mass per unit area of fabric, weave type, and trade name]*
Filler reference:	*[Add trade name for polymer system]*
Other (e.g. primer):	*[Add trade names]*
Surface preparation methods and substrates qualified (state combinations tested):	*[Confirm surface preparation procedure used for preparation of samples for lap shear tests]*
Cure schedule:	*[Specify cure schedule used for test samples]*
Maximum service temperature for Type A defects and cure requirement:	*[Maximum service temperatures (taken from standard T_g-offset)]*
Maximum service temperature for Type B defects and cure requirement:	*[Maximum service temperatures (taken from standard T_g-offset)]*
Component test completed (See section 5.6 of this document)	*[Yes / No]*

5.3.2 Qualification Report – Laminate (for ECSs used on Type A Defects)

Property	Detail	Symbol	Test Report Reference	Value	Units
Test temperature		T_{test}			°C / °F
Tensile strength	Circumferential	s_c			MPa / ksi
Tensile strain to failure	Circumferential	ε_{fc}			%
Tensile modulus	Circumferential	E_c			GPa / ksi
Tensile strength	Axial	s_a			MPa / ksi
Tensile strain to failure	Axial	ε_{fa}			%
Tensile modulus	Axial	E_a			GPa / ksi
Ply thickness		t_{layer}			mm / in
Poisson's ratio	Circumferential	v_{ca}			–
In-plane shear modulus	Circumferential	G			GPa / ksi
Coefficient of thermal expansion	Circumferential	α_c			µin / in / °F or mm / mm /°C

Coefficient of thermal expansion	Axial	α_a			µin / in / F or mm / mm / °C
Shore D hardness					–
Barcol hardness					–

5.3.3 Cure Data – Laminate

Property	Symbol	Cure Temperature (°C)	Cure Time (hours)	Value	Units
Glass transition temperature	T_g				°C / °F

5.3.4 Qualification Report – Filler

Property	Detail	Symbol	Test Report Reference	Value	Units
Compressive modulus	Filler				GPa / ksi
Compression strength	Filler				GPa / ksi
Glass transition temperature	Filler		Detail cure schedule		°C / °F

5.3.5 Qualification Report – Primer *(if relevant)*

Property	Detail	Symbol	Test Report Reference	Value	Units
Glass transition temperature	Primer		Detail cure schedule		°C / °F

5.3.6 Qualification Report – Adhesion

Surface preparation and substrate details (list substrate, preparation method, roughness values measured and cure temperature and time before testing					
Property	**Detail**	**Symbol**		**Value**	**Units**
Lap shear (ambient)		τ			
Conditioning temperature / environment	Water at a minimum of 40°C / (104°F)				°C / °F
Conditioning temperature / environment	Air at elevated design temperature of ___°C / (___°F)				°C / °F

5.3.7 Qualification Report – Short Term Pipe Spool Survival Test

Detail	Test Report Reference	Value	Units
Percent wall loss qualified (%):			%
Cure temperature and time before testing			°C / °F
Test temperature			°C / °F
Test pressure			kPag / psig

5.3.8 Qualification Report – Energy Release Rates (For ECSs Used on Type B Defects)

Substrate tested				
Surface preparation method tested				
Surface roughness measured				
Number of layers used to measure γ_{LCL}				
Cure time and temperature before testing				
Test temperature				°C / °F
Property	**Symbol**	**Test Report Reference**	**Value**	**Units**
Energy release rate	γ_{LCL}			J/m^2

List additional substrate/surface preparation combinations tested in separate tables.

Impact Test			
Substrate tested			
Surface preparation method tested			
Surface roughness measured			
Number of layers used to measure γ_{LCL}			
Number of layers used for impact test			
Property	**Test Report Reference**	**Value**	**Units**
Cure time and temperature before testing	Hours		°C/°F
Test temperature			°C/°F
Energy Release rate calculated			γ_{LCL}
Confirm energy release rate is ≥ γ_{LCL}			

5.4 Short Term Pipe Spool Survival Test

This section establishes and describes the test method to be used for demonstration that an ECS is suitable for application on a type A defect. The purpose of this test is to confirm the ECS has acceptable inter-laminar shear and bond strength. It demonstrates the structural integrity of an ECS up to the yield level of the original pipe.

5.4.1 Method

a) The following qualification test shall be completed using a steel pipe of at least 100 mm (4 in.) outside diameter, and minimum length of 6 times the outside diameter in addition to the length of the installed laminate.

b) The steel pipe shall have a minimum specified yield strength of 235 MPa (35,000 psi), e.g., ASTM A106 Grade B or international equivalent.
c) The ECS supplier may select the depth of the defect to be tested, i.e., percentage of wall loss.
d) The ECS shall be qualified only for defect depths up to this chosen depth [see (c)].
e) A defect shall be machined in the pipe to a depth equivalent to the wall loss for which the ECS is being qualified.
   - The defect shall have a length, l, of a minimum of one-half of the outside pipe diameter along the axial direction of the pipe spool, and a width, *w*, of one-fourth of the outside pipe diameter around the hoop direction of the pipe spool.
   - A radius, or a taper may be machined outside the edge of the defect, the radius, or the taper needs to be sized to provide sufficient transition from the defect to the pipe surface, but the dimensions of machined (transition) area shall not exceed 2*l* nor 2*w*, as shown in Figure 5.4.1.1 of this document.
   - To avoid stress concentrations, the interior and exterior corners should be machined with a radius.
   - The edge of the laminate shall be at least 3 times the pipe diameter away from the ends of the pipe spool.
f) The test pressure of the spool, P_f, shall be determined by calculation using:

$$P_f = \frac{2ts_{sa}}{D}$$

Where:
D – is the outside diameter of pipe
t – is the wall thickness of undamaged spool
s_{sa} – is the yield strength obtained by a tensile test or from a mill certificate of spool pipe

g) A laminate shall be applied over the defect in the test spool and shall survive a test to the pressure P_f.
h) The thickness of the laminate expressed in terms of number of layers shall be calculated using the equation below, where t_s is the remaining wall thickness of the pipe spool at the defect and s_c is the characteristic tensile strength of the ECS in the hoop direction and t_{layer} is a layer (ply) thickness.

$$n_{layers} = \left\lceil \frac{1}{t_{layer} s_{ch}} \left(\frac{P_f D}{2} - s_{sa} t_s \right) \right\rceil$$

i) s_{ch} is defined as the mean strength in the hoop direction and is the characteristic tensile strength, s_c, minus two standard deviations.

j) The altered spool shall be pressurized to P_f, and the minimum time to reach P_f shall be 30 s.
k) Qualification requires the altered pipe to survive loading to P_f and show no visual signs of degradation when inspected in accordance with ISO 24817:2017 Table 16.

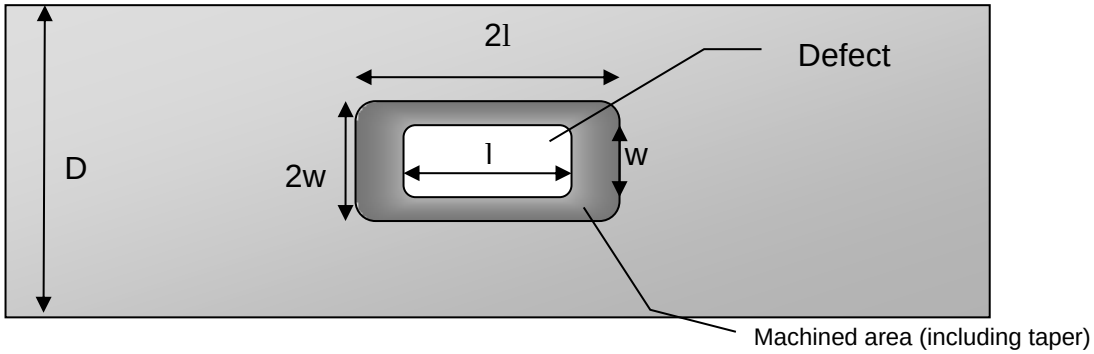


Figure 5.4.1.1 – Schematic of defect to be used for short-term burst test, where l > D/2 and w > D/4

5.4.2 Test Report

A report shall be prepared giving the test conditions, depth of wall loss for which the ECS has been qualified, details of the ECS, the pressure test result and the maximum wall thickness that can be altered using an ECS.

5.5 Qualification for Use of ECSs on Type B Defects on Other Substrates or Using Other Methods of Surface Preparation

Where an ECS has been fully qualified for one substrate and method of surface preparation, this simplified qualification procedure may be used for other combinations.

Only three tests are required to be completed. The three tests should be identical to three of the nine tests in terms of laminate thickness and defect size used in the full qualification test program. $\gamma_{mean,substrate2}$ shall be the mean value of the three tests completed.

The value of γ for this combination of substrate and surface preparation, $\gamma_{LCL,substrate2}$, is given by:

$$\gamma_{LCL,substrate2} = \gamma_{LCL,substrate1} \frac{\gamma_{mean,substrate2}}{\gamma_{mean,substrate1}}$$

5.5.1 Test Report

A report shall be prepared giving the test conditions (including test temperature) and details of the ECS including the materials of construction, surface preparation technique, substrate, surface roughness measured, cure schedule, the individual data points, and the calculation of the value of $\gamma_{LCL,substrate2}$.

5.6 Qualification Requirements for Other Components

Additional testing is required to confirm the ECS procedure specification is applicable to components with more complicated geometry. The qualification test shall therefore be repeated for each unique fabric style provided by an ECS supplier. Fabric style shall be defined in terms of:

- Fiber orientations
- Fiber content in each orientation
- Total fabric mass per unit area

One test shall be considered applicable to all ECS polymers that use the same application method. For example, it only needs to be completed using a low temperature ECS variant where both low and high temperature systems are offered, provided both systems have been fully qualified separately otherwise, and both systems have the same form (e.g. both are liquid epoxies). The tests must be repeated where the ECSs utilize different polymers, for example:

- Repeat for both epoxy and polyurethane systems even if they use the same reinforcement fabric styles
- Repeat where the form of the polymer changes between ECSs (e.g. for liquid epoxy systems and pre-impregnated epoxy systems even if they use the same reinforcement fabric styles)

A single pressure test shall be completed on an equal tee of either 4 NPS or 6 NPS diameter. A through-wall defect shall be created as shown in Figure 5.6.2. The defect shall be either 20 mm (0.8”) or 25 mm (1”) in size. The defect may be simulated by placing a circular polymeric release film of the appropriate diameter over a smaller diameter hole prior to application of the laminate. The holes shall not be filled or sealed by any means (mechanical or chemical) prior to application of the laminate.

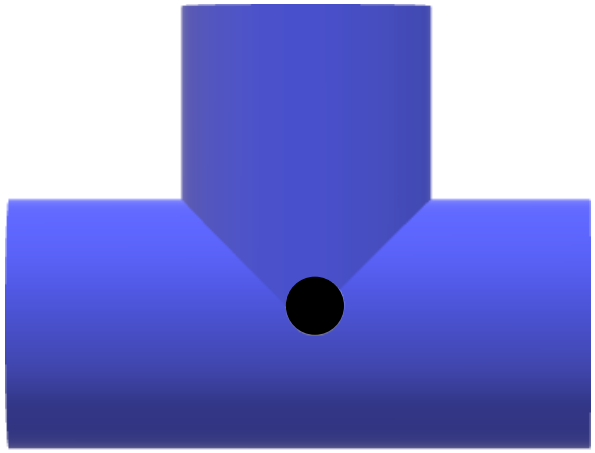


Figure 5.6.2 – Schematic of Component Test Pipe

A laminate of twice the thickness used in the qualification tests in section 5.2.3 of this document shall be applied to the tee with overlaps satisfying requirements of ISO 24817:2017, equation (18). The cure time and temperature shall be equivalent to that used for the tests in section 5.2.3 of this document.

Internal pressure shall be applied and the value at which the laminate begins to leak shall be recorded. The test will only be considered valid if the failure takes the form of delamination of the laminate from the substrate, followed by leaking for the edge of the laminate. Results shall be discarded if failure results through weeping through the laminate or yielding of the substrate. In this event, a new test shall be completed using a larger hole size.

The pressure at which the leak is recorded shall be equal to or greater than the pressure predicted for the thickness of laminate used in the qualification tests in section 5.5 of this document using ISO 24817:2017 equation (12), with factors f_{T2} and f_{leak} set to 1 and the value of γ_{LCL} derived in section 5.2.3 of this document.

5.7 Requalification

If a change or modification to the laminate materials is made, then the testing specified in 5.7.1 and 5.7.2 of this document shall be completed.

If the modified ECS is found to be of lower performance than the original system, then it shall be treated as a new system and validated according to section 5.2 of this document.

If the modified ECS is found to be of higher performance than the original system, then it may be treated as a new system and validated according to section 5.2, or the qualification data from the original ECS may be used.

5.7.1 Requalification Tests for Type A Defects

Requalification tests shall include the testing specified in Table 5.2.2.1 and Table 5.2.2.2 of this document.

5.7.2 Requalification Tests for Type B Defects

Requalification tests shall include the testing specified in Table 5.2.2.1, Table 5.2.2.2 and Table 5.2.3.1 of this document. Only three pressure tests are required and results shall be compared with γ_{LCL} of the original ECS as set out in section 5.5 of this document.

5.8 Installation of Engineered Composite Systems

5.8.1 General Requirements

a) The installation of an ECS shall meet the requirements of ISO 24817:2017 Section 8 and Annex J, and any additional requirements or limitations defined within this document.
b) ECS installer organizations shall have a documented installation procedure that ensures the successful and repeatable alteration of pressure equipment utilizing the ECS.
c) The ECS supplier shall provide full installation instructions.
d) Personnel involved in the installation of an ECS shall be trained and qualified according to Section 7 of this document.

5.8.2 Responsibilities

Responsibilities shall be defined and assigned within the work pack and accepted by all parties involved. In addition to the responsibilities defined in the work pack:

a) The owner-user is responsible for acceptance of the following prior to using the ECS:

    i. ECS installation procedures
    ii. Method statement and work pack
    iii. Inspection and test plan (ITP)
    iv. Acceptance and sign-off of ECS alteration report

b) The inspector is responsible for all verifications as defined within the inspection and test plan (ITP) and Section 8 of this document.

5.8.3 Installation Instructions

The installation instructions shall meet the requirements referenced under section 5.8.1(a) of this document. The installation instructions shall be the same as those used in the ECS qualification. The installation instructions shall be incorporated into the installation procedures.

5.8.4 Additional Requirements

In addition to the requirements referenced under the section 5.8.1(a) of this document, any additional requirements specified herein, or project specific requirements specified by the owner-user or parties involved in the installation process shall be defined within the ECS installer organization's work pack. The additional requirements shall not affect, or overrule, the requirements of the installation instructions used in the ECS qualification. In the event of conflict, the ECS supplier shall be consulted.

As a minimum the additional requirements shall include the following:

a) Requirement for the ECS installer organization to hold a quality management system certificate of authorization permit covering the applicable scope of work
b) Addition of a section to the ECS installer organization's QMS to cover the scope of work related to engineered composite systems
c) Ensuring competencies of personnel for installation are in accordance with Section 7 of this document
d) Development of the alteration ITP
e) Responsibility for providing risk assessment information including hazards for the alteration location and environmental conditions
f) Responsibility for providing heating and hoarding to facilitate the installation of laminate
g) Ensuring the completion of the alteration to the requirements of the registered alteration procedure
h) Providing product specific instructions for use and application; instructions shall match those used in the ECSPS and may include unique or one-off application guidelines
i) Specify the time between the surface preparation and first coating application based on site conditions; the time shall be as short as possible and shall not exceed the lesser of the maximum time specified within the installation procedure (if specified) or the maximum time specified per ISO 24817:2017 Annex J

6.0 DESIGN METHODOLOGY

ECS design requirements shall be determined by applying the methods given in ISO 24817:2017 Section 7.5, implemented as described here. All requirements of ISO 24817 Section 7.5 not specifically mentioned here shall be applied as written in the standard.

6.1 Owner-User Requirements

The owner-user has the ultimate responsibility for all pressure equipment within their care and control. The owner-user is required to determine that the ECS is suitable for intended application and service conditions, and that the ECS provides for an equivalent standard of safety to the altered pressure equipment. In addition, the owner-user shall ensure that the use of ECS and the subject equipment is managed safely and meets or exceeds all technical, safety, and regulatory requirements. The owner-user shall have implemented an effective quality management system (AQP-8000 series PEIMS / IMS) that meets and conforms to the requirements defined in Section 9 of this document.

6.1.1 Integrity Assessment

The owner-user shall perform an integrity assessment of the damaged equipment and perform a preliminary root cause analysis and document the results per the owner-user's quality management system (AQP-8000 series PEIMS / IMS) and management of change procedure.

6.1.2 Risk Assessment

The owner-user shall perform a risk assessment, and accept the risks related to installation and maintenance of an ECS. The owner-user may seek input from the ECS supplier (where required) as per ISO 24817:2017 Section 7.1.

6.1.3 Maintenance and Monitoring

The ECS and the subject pressure equipment shall be maintained and monitored to ensure the continued safe operation until a permanent repair, alteration, or replacement can be made and the ECS safely removed. A description of the methods of maintenance and monitoring that will be used while the ECS is installed shall also be established. The frequency of maintenance and monitoring shall consider the type of ECS, accessibility, process fluid, service conditions, and the risk assessment results. ECS suppliers shall provide recommendations to the owner-user for maintenance and monitoring of the ECS that shall be considered by the owner-user and implemented into the owner-user's maintenance and monitoring plan.

6.1.4 Removal of Engineered Composite Systems

The owner-user shall specify a date when the ECS will be removed and the pressure equipment permanently repaired, altered, or replaced (i.e. shall specify the design lifetime of the ECS).

At the end of the design lifetime, the owner-user shall:

a) Remove the ECS and permanently repair, alter, or replace the pressure equipment; or
b) Re-evaluate the ECS design to determine if the design lifetime can be extended. If the ECS design lifetime can be extended, the owner-user shall:
    i. Compile all supporting records and assessments used to revalidate the ECS design lifetime,
    ii. Define and document inspection and monitoring requirements to support the extended design lifetime, and
    iii. Complete and file a new AB-323, *Alteration Report for Installation of ECSs* as per the owner-user quality management system (AQP-8000 series PEIMS / IMS).

6.1.5 Record Keeping Requirements for ECS

The owner-user shall keep all pertinent information regarding each ECS until the ECS is removed and the pressure equipment is repaired, altered, or replaced. The records of each ECS shall be available for ABSA audits. In addition, each record shall include:

a) Risk assessment
b) Technical justification
c) Detailed design records
d) Root cause analysis
e) Installation procedure (including QA records)
f) Maintenance and monitoring records
g) Re-evaluation records
h) Removal confirmation date by the owner-user
i) Certificate of alteration
j) Any other pertinent information as may be needed to establish evidence of safe installation and operation of the ECS and associated equipment

6.1.6 User Design Specification (UDS)

The owner-user shall supply to the ECS designer UDS stamped by a Professional Engineer. The UDS shall include data required by ISO 24817-2017 Section 7.4, ISO 24817-2017 Annex A, details of the service environment where the ECS is to be applied, and any other details that must be considered in the ECS design.

6.2 Design Conditions

The pressure equipment design conditions, as registered with ABSA, shall be used for design of the ECS. In addition, the ECS shall be designed to sustain conditions at the minimum test pressure registered with ABSA plus adequate margin, regardless of any pressure test exemption provided for in Table 8.3 of this document. The maximum permitted test pressure (i.e. minimum required test pressure plus allowable margin) considered shall be clearly documented to ensure the pressure is not exceeded during testing.

6.3 Environmental Compatibility

This section is intended to supplement ISO 24817:2017 *Section 7.5.2.*

Where the environment is strongly acidic (pH < 3.5), strongly alkaline (pH > 11), highly saline, or is a strong solvent, e.g. methanol, glycol, benzene and toluene in concentration greater than 25%; and the repair will be exposed to the line contents (type B defects only), the ECS supplier shall provide written evidence to demonstrate the basis on which they have determined the compatibility with the ECS. This may include:

a) Testing (in which case the test details including test method, environment, temperature, exposure times, and properties followed must be specified)
b) Experience (in which case successful experience must be documented including environment, temperature, and time in service)
c) Expert opinion (in which case the basis for the decision should be documented)

6.4 Design Temperature Effects

This section is intended to supplement ISO 24817:2017 *Section 7.5.3.*

The requirements of ISO 24817:2017 shall be complied with as follows:

a) T_g shall be taken as the value quoted in qualification testing
b) f_{T2} in Table 8 shall be calculated as follows:

$$f_{T2} = 0.0000625[T_m - T_d + (T_{test} - T_{amb})]^2 + 0.00125[T_m - T_d + (T_{test} - T_{amb})] + 0.7$$

6.5 Cure Requirements

The post-cure heating requirements for the ECS shall be specified in the output of the ECS design assessment and be part of the ECSPS. Post-cure heating requirements are defined below:

6.5.1 Designs for Type A Defects

The minimum cure used in ISO 24817:2017 Annex C qualification testing shall be applied to all ECSs unless the ECS supplier specifies a higher temperature post-cure is required.

6.5.2 Designs for Type B Defects

The laminate shall be heated in line with a post-cure cycle verified during qualification testing to achieve a glass transition temperature of at least 20°C above the operating temperature if:

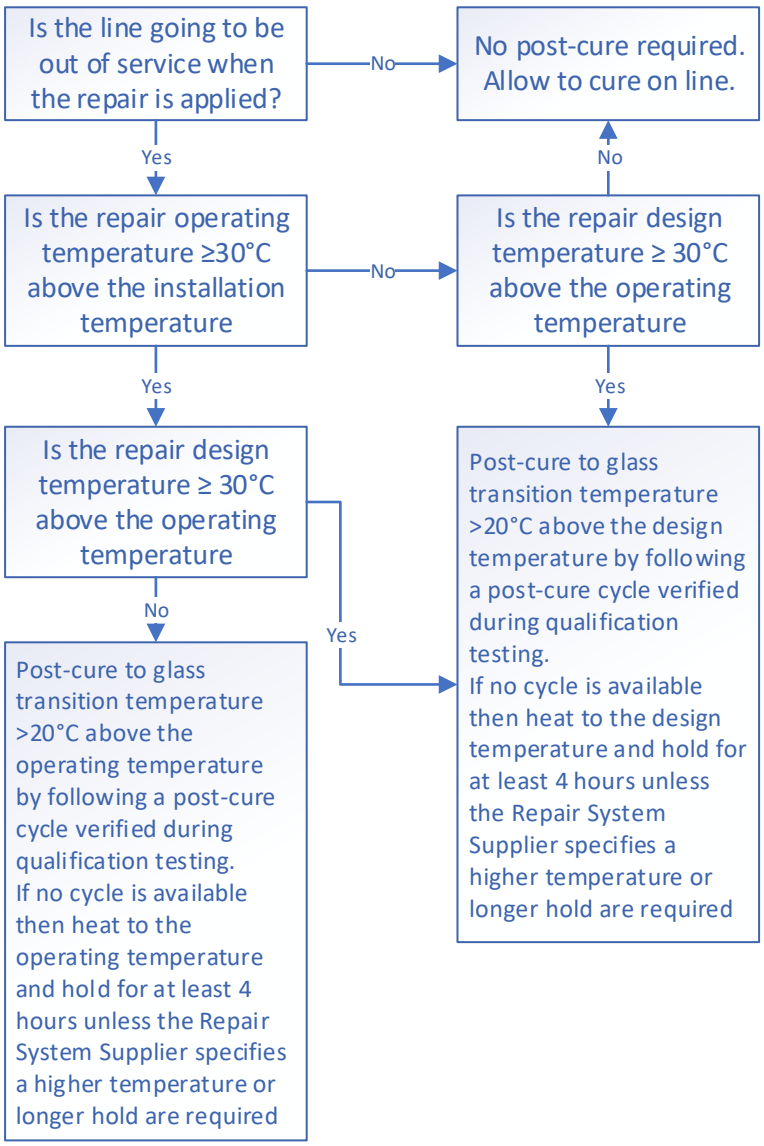
a) the line is out of service when the ECS is applied, and
b) the pressure equipment operating temperature is ≥ 30°C above the installation temperature.

Where no verified heating cycle is available then the laminate shall be heated to at least the operating temperature of the pressure equipment and held there for at least four hours unless the ECS supplier specifies a higher temperature or longer hold are required.

If the ECS design temperature is ≥ 30°C above the operating temperature then the laminate shall be cured in line with a post-cure cycle verified during qualification testing to achieve a glass transition temperature of at least 20°C above the design temperature.

Where no verified cycle is available then the laminate shall be heated to at least the design temperature of the line and held there for at least four hours unless the ECS supplier specifies a higher temperature or longer hold is required.

Post-cure heating shall not be attempted on pressure equipment that is in service.



6.6 Design Based on Substrate Load Sharing

This section is intended to supplement ISO 24817:2017 *Section 7.5.4.*

ISO 24817:2017 Equations 1, 2, 5, and 6 shall not be used.

6.7 Design Based on Laminate Allowable Strains (Defect Type A)

This section is intended to supplement ISO 24817:2017 *Section 7.5.5.*

All ECSs must be supported by calculations using ISO 24817:2017 equations 3, 4, 8, and 9.

Calculated laminate thicknesses shall be < D/12 for pipes of 6” outside diameter or greater.

Calculated laminate thicknesses shall be < D/6 for pipes below 6” outside diameter.

The value of ΔT in equation 10 shall be calculated as the difference between the temperature at which the laminate first hardens and the design temperature. If the laminate is applied at ambient temperatures and hardens before being post-cured, then the ambient temperature shall be used as the lower value.

6.8 Design Based on Allowable Stresses Determined by Performance Testing (Defect Type A)

ISO 24817:2017 *Section 7.5.6 shall not be used.*

6.9 Design of ECSs for Through-Wall Defects (Defect Type B)

This section is intended to supplement ISO 24817:2017 *Section 7.5.7.*

Refer to Annex E of this document for guidance on the design for type B through-wall defects.

6.10 Axial Extent of Repair

This section is intended to supplement ISO 24817:2017 *Section 7.5.8.*

The laminate shall extend beyond the defect by at least the maximum of 50 mm and the amount determined using ISO 24817:2017, equation 18.

The overlap shall also comply with the considerations in equation 19 when ECSs have been designed using ISO 24817:2017, equation 12.

7.0 COMPETENCIES OF INSTALLERS AND INSPECTORS

This section provides guidance on the training, qualification, and competency certification of installers and inspectors of ECSs. This section is intended to supplement ISO 24814 Annex I.

Owner-user and installer organizations shall establish and document the competency requirements for all personnel involved with the installation and inspection of ECSs. The competency requirements shall consider elements such as qualifications, experience, and skill in assessing and certifying the competency of those who install and inspect ECSs.

7.1 Requirements and Responsibilities of Installer Organizations

Installer organizations shall have verifiable processes and procedures for training, qualification, and certification of all personnel involved in the installation of ECSs. Competency process and procedures, as a minimum, shall address the following elements:

7.1.1 Training

a) The installer organization is responsible for the training of all personnel involved in the application of ECSs as per the manufacturer's instruction.
b) Qualified trainers shall be used to train installers and other supervisors.
c) Competency shall be established, and the minimum training requirements of ISO 24814 Annex I shall apply.

7.1.2 Qualification

a) The installer organization shall have a qualification procedure / process for each specific installation technique and ECS.
b) This qualification process shall be documented and available to the owner-user for review.

7.1.3 Training Records

a) The installer organization shall keep a verifiable training record for all personnel that perform ECS installations.
b) The training records shall be kept in accordance with the installer organization's QMS.

7.1.4 Documented Evidence and Maintenance of Competency

a) The ECS installer organization shall have a complete record of competency for all personnel that perform ECS installations.
b) Each record, at a minimum, should include certifications, training, and a record of completed installations.
c) The record shall be reviewed in accordance with the timeline specified in the installer organization's quality management system.
d) The record shall be available to the owner-user for review and acceptance.
e) The ECS installer organization shall revalidate the competency of the installation personnel that have not been actively involved in ECS applications for 12 months or longer.

7.2 Requirements and Responsibilities of Owner-Users

Owner-user organizations shall have verifiable processes and procedures for training, qualification, and certification of all employed personnel involved in the installation of ECSs. Owner-user organizations shall also have processes and procedures to verify the training and competency of all personnel contracted to perform ECS installations and inspections. Competency process and procedures, as a minimum, should address the following elements:

7.2.1 Training

a) The owner-user is responsible for the training of inspectors in the application and inspection of ECSs.
b) The inspector at a minimum shall have training and certification for in-service pressure equipment inspection.
c) The inspector shall complete basic training in the application of engineered composite systems.

7.2.2 Training Records

a) Training records shall be kept in accordance with the owner-user's quality management system (AQP-8000 series PEIMS / IMS).

8.0 EXAMINATION AND TESTING

This section provides guidance on the pre-installation, in-process, and post-installation examination and testing requirements for ECSs. This section is intended to supplement ISO-24817-2017 Section 9.

The owner-user is responsible for assuring that the overall quality control, detailed examinations, tests, and retention of records associated with alterations using ECSs are performed. All records shall be retained for the duration of the installed life of the ECS. The owner-user may designate specific examination and testing activities to responsible parties. The responsible parties for each criterion identified below shall be identified on an inspection and test plan acceptable to both the owner-user and installer organization prior to commencing the alteration.

8.1 Pre-Installation

Table 8.1 of this document provides recommendations on the minimum pre-installation activities that should be performed on the substrate and laminate prior to installation.

Table 8.1 – Pre-Installation Examination and Testing Recommendations

Section	Criteria	Allowable Limits	Method
Substrate (Prior to ECS Application)	Baseline Inspection	A baseline inspection shall be conducted as per the owner-user documentation requirements	As per owner-user requirements
	Design Conditions[1]	In accordance with the ECS design and registered ECSPS	Visual
	Wall Thickness	In accordance with the ECS design and registered ECSPS	UT, RT
	Surface Temperature	In accordance with the ECS design and registered ECSPS	Calibrated instrument
	Surface cleanliness	In accordance with the ECS design and registered ECSPS	Visual comparison with ISO 8501-1 or equivalent SSPC or NACE standards
	Surface preparation and anchor profile	In accordance with the ECS design and registered ECSPS	Visual, replica tape with micrometer, digital surface micrometer
	Defect	Defect nature and dimensions are within the limits of the ECS design, registered ECSPS, and installer competency	Visual, UT, RT
	Geometry	Free of protruding sharp edges and in accordance with the ECS design and registered ECSPS	Visual
	Leaking defect	Confirm that any leak sealing device used has stopped the leak;confirm size of leak sealing device is within defect size considered in design of ECS	Visual
ECS Materials	Packaging / Containers	Sealed, clear labels with batch number and expiry (within date)	Visual
	Fabric	No fabric defects[2]	Visual
	Epoxies	No crystallization	Visual

Notes:

1. Design conditions include material, design pressure, design temperature, MDMT.
2. Fabric defects include creases, stretched fibers, tearing, discoloration, changes in pattern, changes in color, changes in weave across the material area, and other visible manufacturing defects or physical damage.

8.2 In-Process

Table 8.2 of this document provides recommendations on the minimum activities that should be performed on the substrate and laminate during installation. In-process activities include curing time.

Table 8.2 – In-Process Examination and Testing Recommendations

Section	Criteria	Allowable Limits	Method
Environmental Conditions	Ambient Temperature & Humidity	Ensure above the greater of the minimum allowable temperature for mixing epoxies as specified by the Manufacturer and the atmospheric dew point temperature.	Calibrated instrument
	Weather Conditions	Area is shielded from adverse weather conditions, including moisture for the duration of the installation.	Visual
Substrate	Surface Temperature	In accordance with the ECS design, the registered ECSPS, and at least 3°C above the dew point.	Calibrated instrument
	Geometry	Free of protruding sharp edges and in accordance with the ECS design, registered ECSPS, and installer competency.	Visual
	Leaking Defect	Zero leakage during application of ECRS	Visual
Laminate	Application of ECS[1]	In accordance with the ECS design.	Visual
Resin-Rich Surface Layer	Surface & Ambient Temperature	In accordance with ECS design, curing schedule, and registered ECSPS	Calibrated instrument

Notes:

1. Application of ECSs includes installation technique, mixing ratio, laminate length, layer count, fabric orientation, pits, wrinkles, dry spots, foreign matter, and polymer color.

8.3 Post-Installation

Table 8.3 of this document provides recommendations on the minimum post-installation activities that should be performed on the surface of the installed ECS and the interface or bond between the substrate and the installed ECS.

Table 8.3 – Post-Installation Examination and Testing Recommendations

Section	Criteria	Allowable Limits	Method
Substrate (Under ECS)	Internal Corrosion	In accordance with the ECS design	RT
	Baseline Inspection	A baseline inspection shall be conducted as per the owner-user documentation requirements	Per owner-user requirements
	Defect growth	No leakage and/or growth exceeding the design defect size	RT, PA, PAC
Bond Between Substrate and ECS	Delamination / Edge Lifting	None allowed	Visual, Tap Test, RT, PA, PAC
	External Corrosion	None allowed	Visual
Laminate	Geometry	Verify axial extent, taper length, and laminate thickness are as per the ECS design	Visual
	Pressure Test[2]	In accordance with code of construction and the ECS design	Per code of construction
	Corrosion protection	Verify that adequate corrosion protection is reinstated as per the ECS design	Visual
	Damage Protection	Verify that adequate protection is present to prevent damage of the installed ECS	Visual
	Identification of alteration location	Verify that adequate markings are present to identify the alteration area	Visual
Resin Rich Surface Layer (Cured)	Surface Defects[1]	Reference Table 16 of ISO 24817-2017	Visual
	Fabric Orientation	In accordance with the ECS design and registered ECSPS	IR device
	Surface Hardness	In accordance with material specifications, ECS design, and registered ECSPS	Shore D Hardness Testing

Notes:

1. Surface defects include pits, wrinkles, dry spots, foreign matter, polymer color, impact damage, etc.
2. Pressure testing is required except as exempted below.

   The owner-user may waive the pressure test when the ECS is installed on live pressure equipment. In order to waive the pressure test, the owner-user shall ensure that the following additional requirements are met:

   a. The owner-user shall perform a risk assessment to assess and accept the risks related to waiving of the pressure test.
   b. A service test shall be performed after installation of the ECS utilizing process fluid in accordance with owner-user specification for not less than 10 minutes.
   c. Additional daily monitoring shall be performed during the first two weeks of service.

9.0 QUALITY MANAGEMENT SYSTEM REQUIREMENTS

Organizations involved with the design, manufacturing, installation, and use of an engineered composite system shall maintain a quality management system that will establish that all of the requirements of the applicable regulations, codes, and standards will be met.

9.1 ECS Suppliers

The owner-user and the ECS installer organization shall be satisfied that the ECS Supplier has implemented an effective quality management system (ISO 9001 or equivalent).

The ECS supplier’s quality management system shall include appropriate controls of the composite system manufacturing process to ensure quality. The quality management system shall address the manner in which the organization controls the entire composite system manufacturing process, including but not limited to, the control of design (i.e. development of material specifications), material selection, procurement, manufacturing, inspection, final product testing, traceability, certification, and marking with the batch/lot number and production date. The ECS supplier’s QMS shall also include processes and procedures to address the requirements of Section 5.1.5 of this document.

9.2 ECS Installer Organization

ECS installer organizations shall hold an Alberta quality management system certificate of authorization permit, the scope of which includes the work to be carried out.

The quality management system shall include appropriate controls of the composite system installation process to ensure quality. The quality management system shall address the manner in which the organization controls the entire composite system installation process, including but not limited to the control of design, material selection, procurement, composite system procedure qualification, installation, inspection, testing, marking, certification, and qualification of all personnel involved in the installation of composite systems as per the requirements of Section 7.1 of this document.

9.3 Owner-Users

Owner-users who perform or contract the design, manufacturing, and installation of composite systems shall hold an Alberta quality management system (AQP-8000 series PEIMS / IMS) certificate of authorization permit, including written processes and procedures for the control of design, material selection, procurement, installation, inspection, testing, marking, certification, post-installation integrity management, and removal of composite systems, and qualification of all personnel involved in the installation of composite systems as per the requirements of Section 7.2 of this document.

A.0 ANNEX A (NORMATIVE) – Applicability

This document is applicable to a variety of components and defects. The following sections summarize the types of defects that can be temporarily altered using ECSs for each pressure equipment category.

A.1 Pressure Piping Systems

A.1.1 ASME B31.1 – Power Piping

a) Boiler External Piping (BEP) designed and constructed for ASME B31.1 power piping shall not be altered using ECSs.

Note: Boiler External Piping (BEP) refers to the piping systems that are external to the boiler itself but are an integral part of the boiler steam or water heating process. See ASME Sec I and ASME B31.1 for references.

b) Other piping systems that are classified as Non-Boiler External Piping (NBEP) may be altered using ECSs, subject to acceptance by ABSA.

ECS alterations on NBEP are limited to addressing the following defects: general wall thinning, local wall thinning, pitting, blisters, laminations, and through-wall penetration.

Note: Some examples of Non-Boiler External Piping (NBEP) that may be designed and constructed per ASME B31.1 include steam distribution, feedwater, condensate, blowoff, auxiliary steam, drain systems, de-superheating, soot blower, turbine exhaust, instrument and control piping.

A.1.2 ASME B31.3 – Process Piping

Pressure piping systems designed and constructed for ASME B31.3 process piping applications may be altered using ECSs. The scope of ECS alterations are limited to the defects and fluid services permitted in the Table A.1.

Table A.1 – ASME B31.3 Defect Applicability for Metallic Substrates

Type of Defect (Note 1)	Fluid Service (Per ASME B31.3)						
	Category ‘ D’	Normal (P≤3500 kPag & T≤250°C)	Normal (P>3500 kPag & T>250°C)	High Pressure	Elevated Temperature	High Purity	Category ‘ M’
General wall thinning	**Y**	**Y**	N	N	N	N	N
Local wall thinning	**Y**	**Y**	N	N	N	N	N
Pitting	**Y**	**Y**	N	N	N	N	N
Gouges / dents	N	N	N	N	N	N	N
Blisters	**Y**	**Y**	N	N	N	N	N
Laminations	**Y**	**Y**	N	N	N	N	N
Circumferential cracks	N	N	N	N	N	N	N
Longitudinal cracks	N	N	N	N	N	N	N
Through-wall penetration (Note 2)	**Y**	**Y**	N	N	N	N	N

Y - Permitted / N - Non-permitted

Notes:
1) The defect size permitted for temporary alteration using an ECS shall be established during design of the ECS.
2) Leaks resulting from through-wall penetrations shall be stopped before application of the ECS.

A.1.3 ASME B31.5 – Refrigeration Piping

Pressure piping systems designed and constructed per ASME B31.5 for refrigeration applications may be altered using ECSs, provided the owner has an AQP-8000 series PEIM System.

ECS alterations on refrigeration piping systems are limited to addressing the following defects: general wall thinning, local wall thinning, pitting, blisters, and laminations.

ECS alterations on refrigeration piping systems may be permissible on through-wall penetration where where P<3500 kPag and T<250C and MDMT > -45C (-50F).

Note: ECS are typically used on piping systems at temperatures as low as 45C (-50F), however this can vary depending on the specific material used and ECS qualification.

A.1.4 ASME B31.9 – Building Services Piping

Pressure piping systems designed and constructed per ASME B31.9 for building services may be altered using ECSs, provided the owner has an AQP-8000 series PEIM system.

ECS alterations on ASME B31.9 piping systems are limited to addressing the following defects: general wall thinning, local wall thinning, pitting, blisters, and laminations.

ECS alterations on ASME B31.9 piping systems may be permissible on through-wall penetration where where P<3500 kPag and T<250C and MDMT > -45C (-50F).

A.1.5 CSA Z662 – Steam Distribution Pipelines

Use of ECSs on piping systems designed and constructed for CSA Z662 steam distribution pipeline applications, as defined by AER Directive 077, is not within the scope of this document.

A.2 Boilers

Boilers and boiler external piping shall not be altered using ECSs.

A.3 Pressure Vessels, Thermal Liquid Heating Systems, and Fired-Heater Pressure Coils

Pressure Vessels, thermal liquid heating systems, and fired-heater pressure coils shall not be altered using ECSs.

B.0 ANNEX B (INFORMATIVE) – REGISTRATION REQUIREMENTS

Registration of an ECS is achieved through a two step process:

- ECS procedure specification (ECSPS) registration; and
- Registration of an application-specific alteration procedure (i.e. design and installation procedure)

Both registrations shall be obtained prior to starting any physical work. A submitter of an ECSPS is responsible to communicate to the owner-user any applicable conditions and/or limitations of the procedure registration.

For complex designs, an Alberta safety codes officer may require the involvement of a Professional Engineer in accordance with applicable provincial legislation.

Refer to Figure B.4 of this document for guidance on the typical ECS workflow process and responsibilities associated with ECS activities.

B.1 ECS Procedure Specification (ECSPS) Registration

ECSPSs shall be submitted to the ABSA for review and registration. The information to register this type of procedure includes the following:

a) **The engineered composite system procedure specification (ECSPS):**

The contents of the ECSPS shall meet the requirements of this document and describe all variables for each ECS. These variables shall align with the ECS qualification, design requirements in Sections 5.0 and 6.0 of this document. The information required to be in the ECSPS may be in any format, written or tabular, to fit the needs of each organization, as long as every variable is included or referenced.

b) **Supporting procedure qualification records (ECSPQRs) covering the full range of the ECSPS**:

The contents of the ECSPS shall meet the requirements of this document and document all variables for each test coupon. All variables, if recorded, shall be the actual variables (including ranges) as determined from the test coupons. If variables are not monitored during installation on the test coupon, they shall not be recorded. It is not intended that the full range of a given range of variables to be used in production be used during qualification, unless required due to a specific variable or based on direction from the ECS supplier. The information required to be in the ECSPQR may be in any format to fit the needs of each organization, as long as every variable is included. Also the type of tests, number of tests, and test results shall be listed in the ECSPQR.

c) **Installation instructions provided by the ECS supplier:**

The installation instructions shall include batch testing reports of the qualified ECS materials in accordance with Section 5.1.5 of this document.

d) **Any other information requested by ABSA to survey the ECSPS and determine whether it is suitable for registration.**

B.2 Alteration procedure registration

The purpose of the alteration procedure registration is to confirm that the owner-user has completed the necessary steps to install an ECS safely. The information to register an ECS alteration procedure includes the following:

a) Owner-user's name
b) Plant location and address
c) Code of construction, including the relevant edition which the pressure equipment is compliant with
d) ECS installation location
    - For piping, the line number and copies of the registered line list, P&ID, and isometric drawing showing the installation location
e) The design pressure and temperature
f) Details on the damage mechanism and size / type of defect
g) Details of the ECS design, dimensions, and installation requirements
h) Material specifications
i) ECS procedure specification number
j) Inspection and testing details
k) Design calculations, including the design life of the composite laminate
l) A report of physical tests conducted for the purpose of establishing the working pressure of the altered pressure equipment (if applicable)
m) Risk assessment summary, including the root cause
n) Maintenance and monitoring details, including for emergency mitigation
o) Timeline for the permanent repair, alteration, or replacement of the pressure equipment

Any other information that is necessary to determine if the ECS is suitable for registration.

B.3 ECS Alteration Report – Inspection and Certification

ABSA Form AB-323: *Alteration Report for Installation of Engineered Composite Systems,* shall be used to document and certify each alteration using an ECS in Alberta. A sample AB-323 can be found in Figure C.1, Annex C of this document. A fillable version of this form is available on ABSA's website at www.absa.ca.

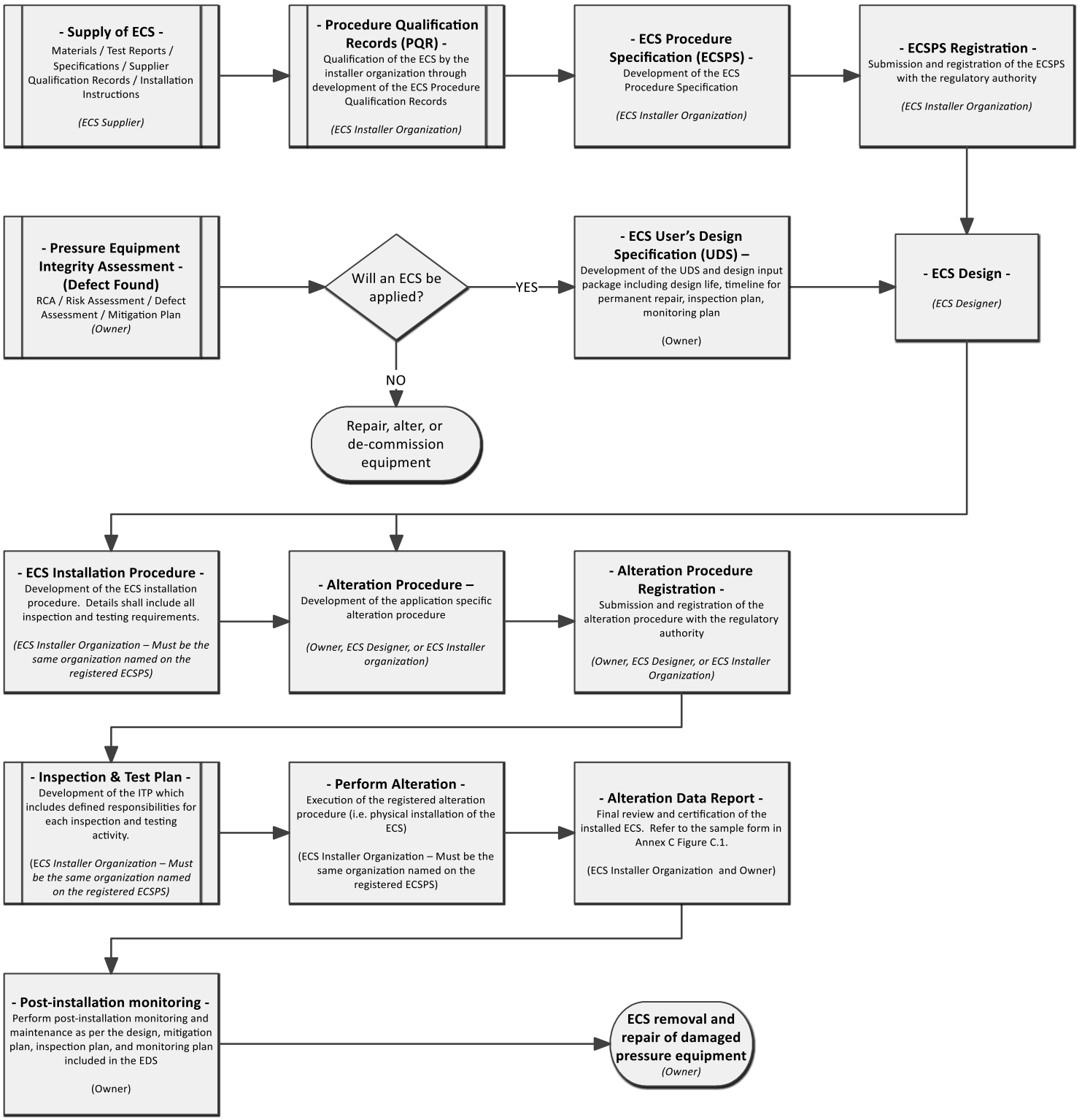
The installer organization is responsible for completing the ECS alteration report and ensuring that the report:

a) Is certified by the installer organization
b) Is certified by an in-service inspector that is certified by the ABSA
c) Contains an owner-user's statement, signed by an official, or designate, of the owner-user having responsibility over the integrity and regulatory compliance of the altered pressure equipment. The owner-user's signature provides for the:
    - Acceptance of the installed ECS and all risks associated with its use in the alteration to ensure safe operation of the subject pressure equipment
    - Certification that the ECS installation details have been reviewed and found to comply with the user's design specification and registered alteration procedure design

The owner organization must maintain the ECS alteration report (AB-323) within their PEIMS for as long as the ECS is installed, ensuring it is available for audits or upon request by ABSA's SCO.

B.4 Typical ECS Process Flow Diagram

Figure B.4 – Typical ECS Process Flow Diagram



C.0 ANNEX C (INFORMATIVE) – SAMPLE FORM

The following sample form is provided in this Annex:

Figure C.1 – Alteration Report for Installation of Engineered Composite Systems

ALTERATION REPORT
FOR INSTALLATION OF ENGINEERED COMPOSITE SYSTEMS

AB-323 2024-10

Alteration Organization	(Name and Address)					
	Alteration Org. Job No.:		Provincial Quality Prog. No.:		Expiry Date:	
Owner	(Name and Address)					
	Provincial Quality Prog. No.:				Expiry Date:	
Location of Installation	(Address)					

Pressure Piping

Provincial Piping Design Registration No.	Composite System Design Responsibility
	☐ Owner ☐ Alteration Organization

Engineered Composite System Procedure Specification

Contractor:	Provincial Registration No.	Engineered Composite System Procedure Specification No.(s) Used
Owner:	Provincial Registration No.	Engineered Composite System Procedure Specification No.(s) Used

Construction Code

Construction Code:

Lines

Drawing & Rev. No., and Line No.	Fluid (air / steam / etc.)	Des. Press. (kPa)	Min and Max Des. Temp. (°C)	Min and Max Oper. Temp. (°C)	Pipe Mat'l Spec & Grade	C.A (mm)	Original Pipe NPS & Schedule	Pipe Coating (existing)	NDE

Description of Defect Area

Type of Defect:
Nature of Defect:
Size of defect at time of installation (Area / Depth):
Max size of defect per registered alteration procedure (Area / Depth):
Cause of defect (Corrosion / Erosion):

Description of Work Performed

Document No. of the registered alteration procedure:	Registration Letter Date:
Surface Roughness / Anchor Profile Specification:	Time from completion of surface preparation to application of 1st layer:
Ply or Layer Thickness (mm):	Layer and reinforcement orientation:
Number of layers installed:	Installed laminate thickness (mm):
Installed laminate length (mm):	Installed taper length (mm):
Minimum Temperature During Curing (°C):	Maximum Temperature During Curing (°C):
Curing Time (hrs):	Post cure barcol or shore harness measurement:
Laminate design lifetime:	

Description of Environmental Conditions During Installation

Minimum Substrate Temperature (°C):	Maximum Substrate Temperature (°C):
Minimum Ambient Temperature (°C):	Maximum Ambient Temperature (°C):
Pipe pressure during installation (kPag):	Pipe contents during installation:
Humidity (%):	External Environment:

SAMPLE

ALTERATION REPORT

FOR INSTALLATION OF ENGINEERED COMPOSITE SYSTEMS AB-323 2024-10

Non-Destructive Examination (Specify type and extent)

Pressure Test

Test Pressure (kPag):	Test Type (i.e. Code, service leak, etc.):	Test Medium:

Remarks

SAMPLE

Certificate of Compliance

I certify that the statements made in this Report are correct and that all design, material, construction and workmanship on this alteration conform to the requirements of the Provincial Regulations.

Alteration Organization Name: _____ Quality Program Reg'n No.: _____ Program Expiry Date: _____

Authorized Representative:

Name _____ Signature _____ Date _____

Date work was completed _____

Certificate of Inspection

I have inspected the alterations described in this report. To the best of my knowledge, this work has been done in accordance with the Provincial Regulations.

Authorized Inspector or Certified In-Service Inspector:

Name* _____ Signature _____ Date _____

*Include inspector's National Board commission number and/or provincial certificate number.

Owner's Statement

As an official, or designate, of the Owner, having responsibility for the integrity and regulatory compliance of the pressure equipment, I accept use of the installed engineered composite system and all risks associated with its use in this alteration to ensure safe operation of the subject pressure equipment.

I also certify that I have reviewed the details of the ECS installation and confirm that it complies with the User's Design Specification and registered design specific to this alteration.

Official, or designate, of the Owner:

Name* _____ Function / Title _____ Signature _____ Date _____

The owner organization must maintain the ECS alteration report (AB-323) within their PEIMS for as long as the ECS is installed, ensuring it is available for audits or upon request by ABSA's SCO.

D.0 ANNEX D (INFORMATIVE) – ECSPS AND PQRs

This annex provides guidance on the minimum information to be documented in each engineered composite procedure specification.

D.1 ECS Procedure Specification

The ECS procedure specification (ECSPS) is a written document providing direction to the person applying the ECS.

The ECS procedure specification used by the organization having responsibility for operational control of the ECS process (i.e. ECS installer organization) shall have been qualified by that organization. ECS procedure specifications address the conditions (including ranges, if any) under which the application of the ECS must be performed.

The ECS procedure specification, at a minimum, shall demonstrate that the ECS meets the requirements of this document, and contains the following information:

a) Name of the organization responsible for the ECSPS
b) Name, signature, and date of the organization's employee approving the ECSPS
c) ECSPS name / number, revision, and date
d) The applicable construction code(s) where the ECSPS will be used
e) Substrate geometry (i.e. straight piping, tee, elbow, etc.)
f) Supporting procedure qualification record numbers
g) Design and environmental condition data:
    i. Maximum design pressure and temperature
    ii. Minimum design temperature
    iii. Minimum / maximum substrate temperature during installation
    iv. Minimum / maximum ambient temperature during installation
    v. Humidity range (percentage)
    vi. Other external environmental restrictions
h) Substrate data:
    i. P-no. and group no. or material specification (i.e. type, grade, UNS number)
    ii. Geometry limits (i.e. minimum and maximum diameter)
    iii. Defect types
i) Laminate data:
    i. Manufacturer's name and specification for each raw material (i.e. fiber, fabric, resin)
    ii. Ply or layer thickness
    iii. Layer and reinforcement orientation
    iv. Minimum / maximum number of layers
    v. Mechanical property ranges:

- Circumferential direction (tensile modulus, strain to failure, tensile strength, Poisson's ratio, thermal expansion coefficient)
- Longitudinal direction (tensile modulus, strain to failure, tensile strength, thermal expansion coefficient)
- Shear modulus
- Barcol or Shore hardness (of cured laminate)
- Glass transition temperature or heat distortion temperature for each cure temperature / time combination
- Peak exothermic temperature measured for the glass transition temperature sample
- Impact performance

j) Substrate surface preparation technique:
   i. Surface roughness / anchor profile specification
   ii. Surface preparation method and medium used
   iii. Time from completion of surface preparation to application of first layer
   iv. Short-term lap strength
   v. Long-term lap strength

k) Curing data:
   i. Minimum / maximum curing temperature
   ii. Minimum / maximum curing time

l) Any other information that is necessary to determine if the ECSPS is suitable for registration.

D.2 ECS Procedure Qualification Record (PQR)

The PQR is a record of variables recorded during the qualification of the ECS by the ECS installer organization, using test coupons. It also contains the test results of the tested specimens by the ECS supplier. Recorded variables for each PQR normally fall within a small range of the actual variables covered by the ECSPS.

The ECS PQR, at a minimum, shall demonstrate that the test coupon installation meets the requirements of this document as derived from the PQR test coupons, and contain the information required by Sections 5.2, 5.3, 5.4, 5.5, 5.6, and 5.7 of this document.

E.0 ANNEX E (INFORMATIVE) – DESIGN CONSIDERATIONS FOR PRESSURE CONTAINMENT

ISO 24817 and ASME PCC-2 include four calculation methods that can be used to reliably assess the leak-sealing pressure limits of a repair. This annex explains the assumptions and limitations of the models and gives guidance on how to select and apply them accordingly.

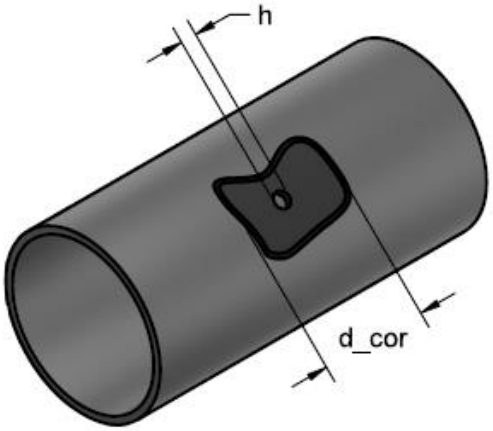
E.1 Recommendations for Model and Defect Size Selection

The objective of the following graphics is to give a guide on how to select the most appropriate model provided by the standards for common applications. Guidance is also given on selecting a relevant defect size to use in the calculations to ensure the predicted repair performance will match that achieved in practice. The following text refers to equation numbers in ISO 24817:2017 and uses SI units only for clarity.

It is recommended that the size of defect used in ISO 24817:2017 formulas (12) to (15) should be at least 15mm. Defect sizes below 15 mm may be considered if supported by engineering, and analyses acceptable to ABSA are provided. Defect sizes below 10 mm shall not be used.

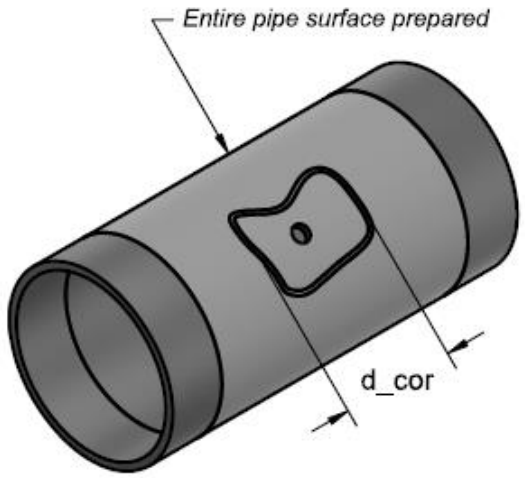
The energy release rate value used with ISO 24817:2017 equation 14 shall be the lower of the value derived in qualification testing and 200 J/m^2 unless supported by engineering, and analyses acceptable to ABSA are provided.

E.1.1 Scenario 1 – Leaks in Plain Pipe



Local area of corrosion size, d_{cor}, with a single perforation (hole), size *h.*

If the damage was caused by internal corrosion then the size of the perforation is clearly defined, although it will continue to grow over time. The predicted size of *h* at ‘end of repair life’ must be used for the calculations.

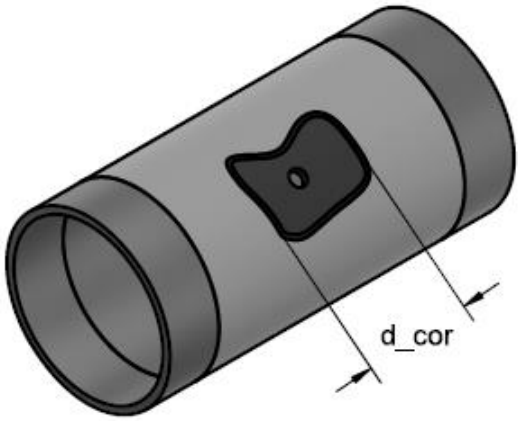


If the entire area around the pin hole can be fully prepared by the qualified method then the repair thickness can be calculated using equation 12 of ISO 24817:2017.

d should be considered in increments of 5 mm.

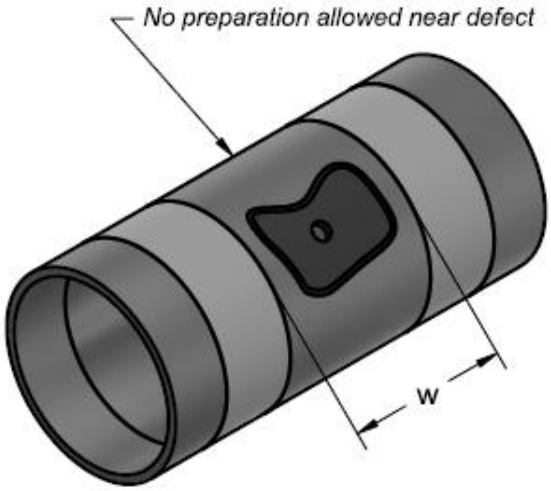
If the corroded area is filled with epoxy putty then the extent of putty must be taken as the defect size, $d = d_{cor}$.

If the hole is localised with good metal surrounding it then it is reasonable to assume *d = h.*



If the defect area cannot be prepared (perhaps due to the thin wall, for example) then the defect size should be set to the size of the area unprepared, $d = d_{cor}$.

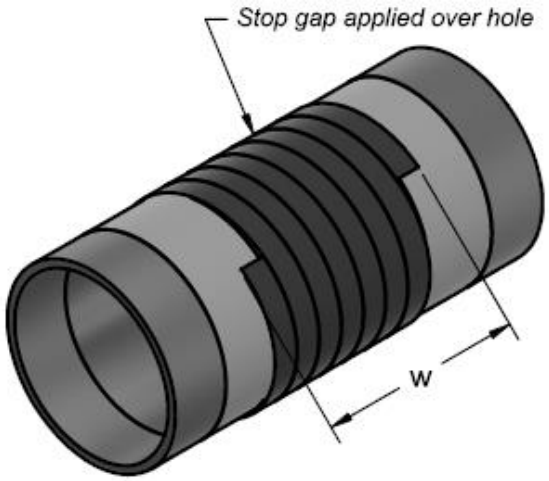
Equally, if the area of corrosion is deep and the perforation is in the center then the repair will only be bonded around the full extent of the defect and the size of defect modelled should be $d = d_{cor}$.



If the entire area around the defect cannot be prepared then this must be modelled using ISO 24817:2017 equations 13 and 14 (the lower thickness calculated can be used) of ISO 24817:2017, even though the perforation is very small. The repair is only bonding to well-prepared pipe in the areas shown, creating a slot defect with width *w*.

Model using equations 13 and 14 of ISO 24817:2017.

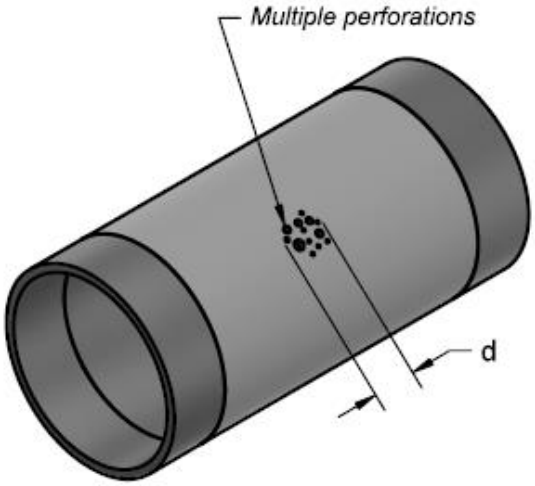
Set *w* as the width of pipe unprepared.



If a stop-gap is applied over a small perforation then the defect must be modelled using equations 13 and 14 (the lower thickness calculated can be used) of ISO 24817:2017, with the slot width, *w*, being taken as the size of the stop-gap, even though the perforation is very small.

Model using equations 13 and 14 of ISO 24817:2017.

Set *w* large enough to cover the stop gap and all fairing.



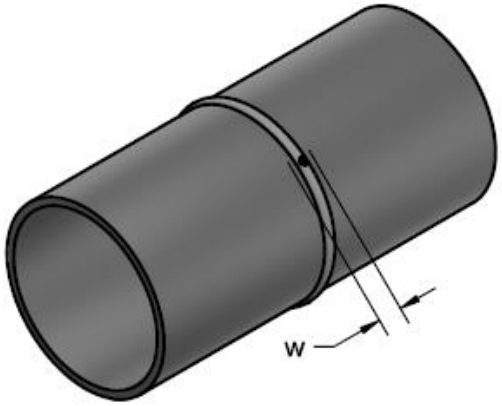
Where there are multiple perforations close to each other then the defect size should be selected to encompass all perforations and may be assessed using equation 12 of ISO 24817:2017.

Defects may be treated as individual defects provided they are surrounded by fully-prepared, sound metal and are spaced by more than *4d*.

Model using equation 12 of ISO 24817:2017.

Set *d* as the diameter of a sufficiently large circle to enclose all perforations (if interacting) – do not use the side of a square for this value.

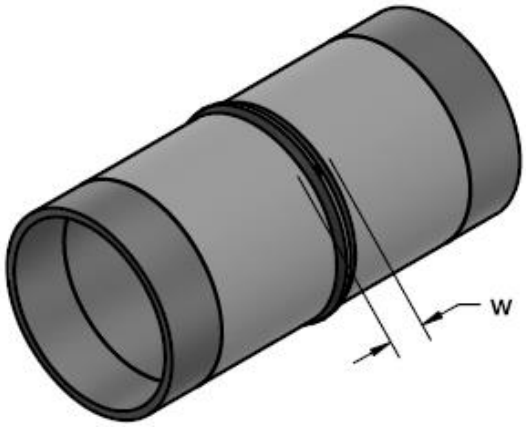
E.1.2 Scenario 2 – Leaks on Girth Welds



This scenario constitutes a pin hole on a girth weld.

DO NOT use equation 12 of ISO 24817:2017.

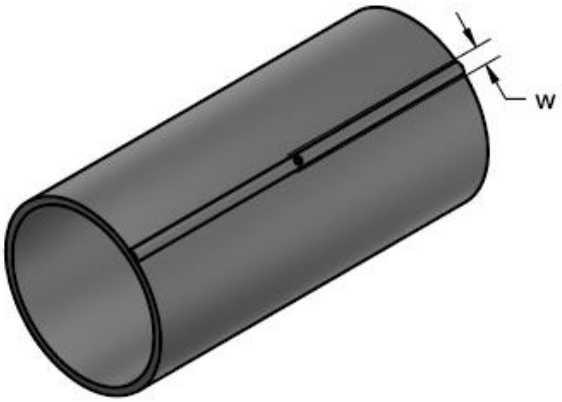
Use equations 13 and 14 of ISO 24817:2017, taking the smallest repair thickness.



Selection of the size *w* to use should include an allowance for fairing and stop gaps.

ISO 24817 mandates a minimum value of *w* of 15 mm but it is considered unlikely that this will be sufficient from a practical view point. It is recommended that 25 mm is also checked to gauge how close to the limits a repair might be. If the required thickness increases to an unacceptable level then a composite may not be a reliable solution.

E.1.3 Scenario 3 – Leak on Seam Weld

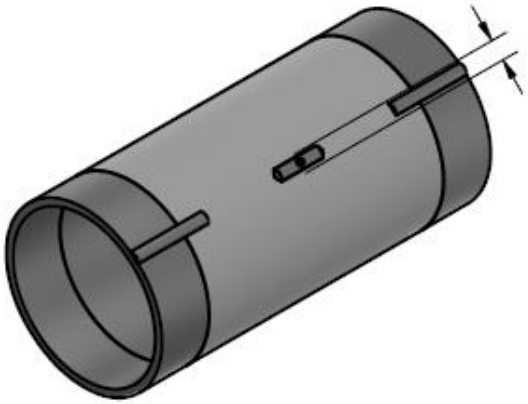


This scenario constitutes a pin hole on a longitudinal or helical seam weld.

DO NOT use equation 12 of ISO 24817:2017.

Use equation 15 of ISO 24817:2017.

Selection of the size *w* to use should include an allowance for fairing.

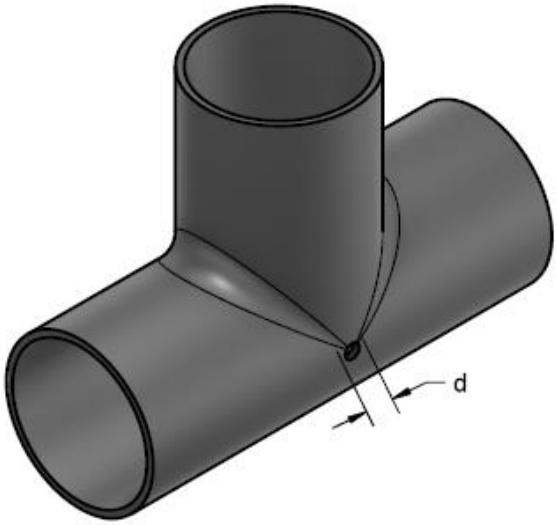


Full surface preparation around the defect is required.

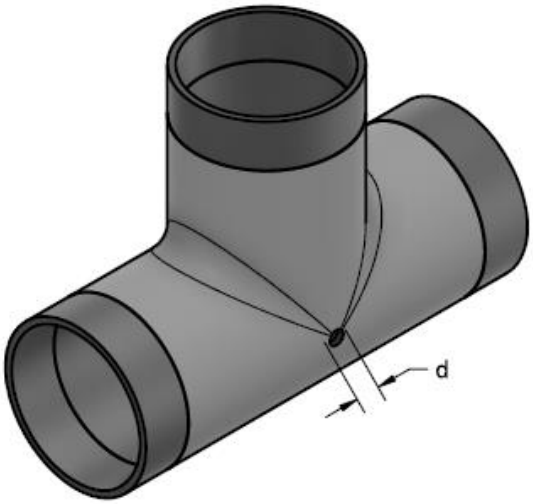
Ideally, the weld bead in the termination length should be ground flush to remove leak paths along which pressure can track and accumulate.

If a stop gap is applied that extends 360° around the pipe circumference, then equations 13 and 14 of ISO 24817:2017 should be considered instead.

E.1.4 Scenario 4 – Tees



This scenario constitutes a hole on a tee, and several methods should be considered depending on the location of the hole. For a hole on the flank of a tee, the appropriate defect selection will depend on the extent of surface preparation that can be completed.

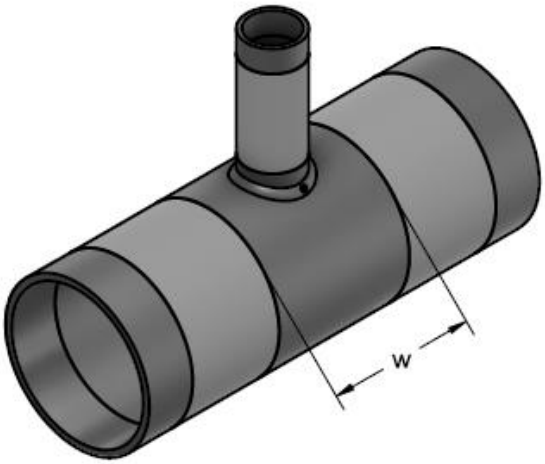


If full preparation is possible then:

1. If the hole is on plain metal then use equation 12 of ISO 24817:2017.
2. If the hole is on a weld then use equations 13 and 14 of ISO 24817:2017.

Base calculations on the diameter of the pipe on which the defect is located (header or branch as appropriate).

Include the geometrical stress concentration factor for the tee (2) in the final repair thicknesses proposed (both for Type A and Type B assessments) as mandated by ISO 24817, if the hole is within the overlap distance from the opening on the header.

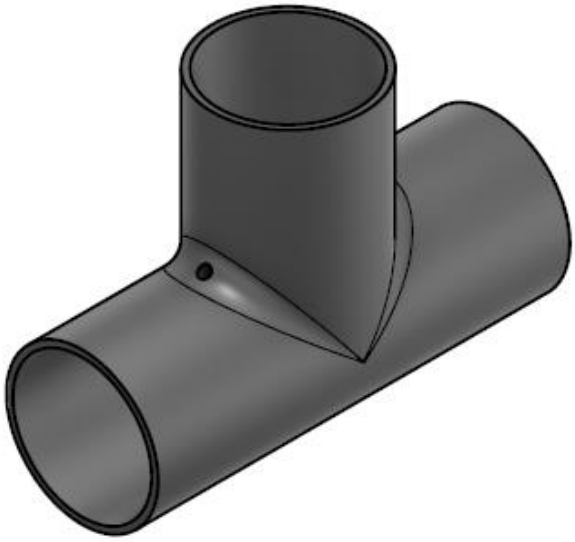


If full preparation is only possible away from the defects (due to thin wall) then design as a slot using equations 13 and 14 of ISO 24817:2017, taking the smallest repair thickness. Base calculations on the diameter of the header.

Selection of the size *w* to use should include an allowance for fairing, stop gaps, and the lengths where surface preparation is not completed.

The geometry of the tee will not affect the Type B assessment (because the tee geometry is remote from the crack growth) but should be included in the Type A assessment (because the repair will need to carry all loads around the tee).

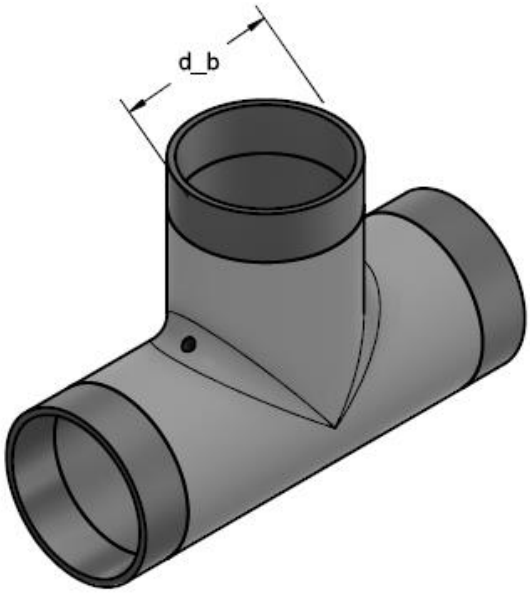
For a hole in the crotch of a tee, in weld metal, the appropriate defect selection will depend on the extent of surface preparation that can be completed.



If surface preparation cannot be completed at the defect, then consider using equations 13 and 14 of ISO 24817:2017, taking the smallest repair thickness. Base calculations on the diameter of the header.

Selection of the size *w* to use should include an allowance for fairing, stop gaps, and the lengths where surface preparation is not completed.

The geometry of the tee will not affect the Type B assessment (because the tee geometry is remote from the crack growth) but should be included in the Type A assessment (because the repair will need to carry all loads around the tee).



If extensive surface preparation is possible then it is not clear which model most closely reflects how the pressure will load the repair interface. The models are based on de-bonding on a flat plate or around the circumference of a pipe and so none of the methods closely reflect the scenario here. Assessment using equation 14 of ISO 24817:2017 based on the larger diameter of the header is the most conservative approach but will limit cases for which the repairs can be used.

Alternatively, a reliable prediction of performance for de-bonding on the header can be made using equation 12 of ISO 24817:2017, with $d = d_b$, the branch diameter. The thickness required using equations 13 and 14 of ISO 24817:2017 for the branch should be considered in addition, and the greatest thickness of all assessments selected.

Include the geometrical stress concentration factor for the tee (2) in the final repair thicknesses proposed (both for Type A and Type B assessments) as mandated by ISO 24817 if the hole is within the overlap distance from the intersection.

E.2 Final Comments

The approaches and concepts described above can be applied to other geometries where damage is commonly found. For example, defects at trunnions can be considered in the same manner as tees.

If there is any doubt about how the pressure will load the repair interface, then assessing performance using equation 14 of ISO 24817:2017 (with a relevant value of energy release rate) will generally give a lower bound to expected behavior.

10.0 REVISION LOG

Edition #	Revision #	Date	Description
1st Edition issued 2021-03-18			
1	1	2023-02-24	Minor Editorial Revision
2	0	2024-10-10	Reaffirmation with some revisions as follows: • Paragraphs A-1.1, A-1.3, A-1.4, Table A-1, B3 • Form AB-323 • Minor editorial revisions