



شرکت ملی گاز ایران

مدیریت پژوهش و فناوری

امور استاندارد

معرفی و خلاصه مراحل تصویب مقررات فنی در کمیته تخصصی و شورای استاندارد

دستورالعمل

تعمیر کامپوزیتی خطوط لوله گاز طبیعی

**Composite Repair for Natural Gas
Pipelines**

IGS-C-PL-003(0)

مهرماه ۱۴۰۴

تاریخ جلسه: ۱۴۰۴/۰۷/۱۴	بسمه تعالی	
شماره جلسه: ۶۶۵	صور تجلسه	شرکت ملی گاز ایران

شورای استاندارد شرکت ملی گاز ایران			عنوان جلسه
مکان جلسه	مجازی	شماره جلسه در سال جاری	شرکت کنندگان در جلسه
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اعضاء حاضر: آقایان محسن مظلوم فارسی‌باف، وحید خوش خواهش، آقایان غلامعلی میرزایی، مهران ابدالی، حسین محمد صالح، مهرداد مطلبی			
اعضاء غایب: راحله اصغری (با اطلاع قبلی)، ارژنگ حمداله‌زاده، مقدم بیگلریان، رضا مسگریان، علیرضا شکوهیان			
حاضرین غیر عضو: آقایان مصطفی جوانمردی صاحب و رضا خدایی			

خلاصه موارد مطرح شده در جلسه:

- ۱- ارائه پیش‌نویس استاندارد "تعمیر کامپوزیتی خطوط لوله گاز طبیعی" IGS-C-PL-003(0)
- ۲- ارائه نتیجه بررسی و مقایسه پیش‌نویس دستورالعمل "بهینه‌سازی برنامه‌های نگهداشت تجهیزات (PMO)" تهیه شده در مدیریت دارایی‌های فیزیکی با دستورالعمل "بهینه سازی برنامه‌های نگهداشت تجهیزات (PMO)" در شرکت‌های گاز استانی "مطرح شده در شورای استاندارد شماره ۶۶۲ مورخ ۱۴۰۴/۴/۲۳

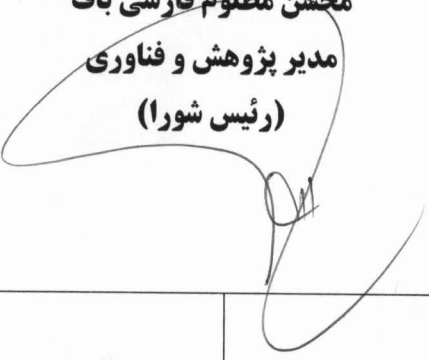
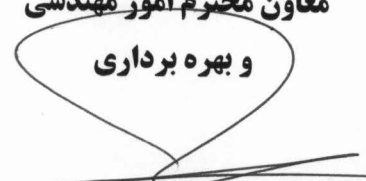
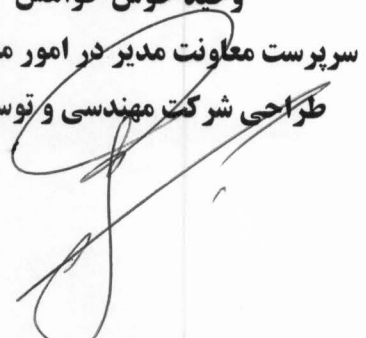
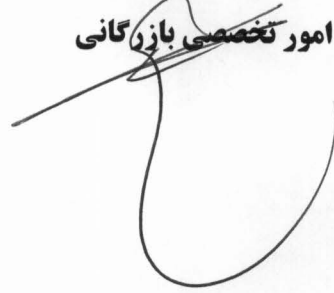
۱- ارائه پیش‌نویس استاندارد "تعمیر کامپوزیتی خطوط لوله گاز طبیعی" IGS-C-PL-003(0)

در ابتدا آقای خدایی، دبیر محترم کمیته کامپوزیت بیان نمودند که پیش‌نویس استاندارد مذکور بنا به مکاتبات و درخواستهای شرکت انتقال گاز به شماره نامه‌های گ/۱۱۰/۰۰۰/۱۶۵۶۴ مورخ ۱۳۹۸/۰۴/۲۰ و گ/۱۱۰/۰۰۰/۴۶۳۰۸ مورخ ۱۴۰۰/۱۱/۲۰ و برخی شرکتهای گاز استانی از جمله نامه شرکت گاز استان تهران به شماره گ/۳۶/۰۰۰/۲۱۸۶۶۸ مورخ ۱۴۰۰/۱۱/۲۷ در کمیته کامپوزیت بر اساس استانداردها و دستورالعمل‌های بین‌المللی و با بهره‌گیری از توان فنی متخصصان درون سازمانی و برون سازمانی از جمله استفاده از دانش اعضای هیئت علمی دانشگاه‌ها به خصوص پژوهشگاه پلیمر و پتروشیمی تدوین گردید. در ادامه ایشان به صورت مختصر روند تدوین استاندارد شامل برگزاری جلسه و اخذ نظرات ذی‌نفعان درون و برون سازمانی، مطالعه استانداردهای مرتبط، تدوین بر اساس روش پذیرش تغییر یافته و سپس اخذ مجدد نظرات ذی‌نفعان از جمله کمیته ایمنی را توضیح دادند. همچنین ایشان بخش‌های مختلف پیش‌نویس شامل هدف و دامنه کاربرد، ارزیابی اولیه عیوب، کاربردها، الزامات مواد مصرفی، طراحی و صلاحیت سنجی، اجرا، آزمون و بازرسی، نشانه گذاری، حمل و جابجایی و دیگر بخش‌های مهم را به صورت مختصر تشریح نمودند و در پایان پس از بحث و تبادل نظر پیش‌نویس استاندارد مورد تأیید اعضای محترم شورای استاندارد قرار گرفت.

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۲- ارائه نتیجه بررسی و مقایسه پیش نویس دستورالعمل "بهینه سازی برنامه های نگهداشت تجهیزات (PMO)" تهیه شده در مدیریت دارایی های فیزیکی با دستورالعمل "بهینه سازی برنامه های نگهداشت تجهیزات (PMO)" در شرکت های گاز استانی" مطرح شده در شورای استاندارد شماره ۶۶۲ مورخ ۱۴۰۴/۴/۲۳ آقای جوانمردی دبیر محترم کمیته دارایی های فیزیکی توضیح دادند که با توجه به تکلیف مشخص شده در شورای استاندارد، هر دو پیش نویس مقایسه شد و کمیته مذکور مقرر نمودند که دستورالعمل تهیه شده توسط مدیریت گازرسانی به عنوان مبنا قرار گیرد و از سایر مدارک و مستندات و همچنین پیش نویس ارائه شده توسط مدیریت دارایی های فیزیکی نیز استفاده گردد نهایتاً اعضای محترم شورای استاندارد نیز تصمیم کمیته تخصصی ذیربط را تایید نمودند.

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محسن مظلوم فارسی باف مدیر پژوهش و فناوری (رئیس شورا) 	
مهران ابدالی رئیس امور بازرسی فنی شرکت انتقال گاز 	حسین محمد صالح معاون محترم امور مهندسی و بهره برداری 
وحید خوش خواهش سرپرست معاونت مدیر در امور مهندسی و طراحی شرکت مهندسی و توسعه گاز 	غلامعلی میرزایی رئیس امور تخصصی بازرگانی 
	مهرداد مطلبی چالستری رئیس امور استاندارد (دبیر و عضو شورا) 

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عنوان استاندارد: تعمیر کامپوزیتی خطوط لوله گاز طبیعی	کد استاندارد: IGS-C-PL-003(0)
استاندارد جدید	بازنگری استاندارد: ☐
واحد متقاضی: شرکت انتقال گاز کمیته تخصصی: کمیته تخصصی کامپوزیت تدوین کننده استاندارد: کمیته تخصصی کامپوزیت دبیر کمیته: رضا خدایی	

الف) سابقه استاندارد:

معرفی استاندارد این استاندارد دستورالعمل تعمیر خطوط لوله انتقال، تغذیه و توزیع گاز طبیعی با استفاده از فناوری کامپوزیت می باشد که در آن طراحی، انتخاب مواد، اجرا، تست و بازرسی سیستمهای تعمیر کامپوزیت خطوط لوله مبتنی بر اعمال خارجی سیستم مذکور آورده شده است.	
ضرورت تدوین/بازنگری تعمیر خطوط لوله گاز طبیعی در حال سرویس به منظور حفظ پایداری گازرسانی همیشه از دغدغه های بهره برداران این خطوط بوده و هست. در روشهای رایج معمولاً تعمیرات با انجام عملیات کار گرم و جوش کاری انجام می شود که علاوه بر زمانبر بودن، دارای مخاطرات ایمنی بالایی نیز هست. سیستمهای تعمیرات کامپوزیت از بیش از یک دهه پیش تا کنون به مدد بهره برداران خطوط لوله در سطح جهان در صنایع مختلف از جمله نفت و گاز آمده است و وجود روشی ایمن، سریع و کارا در سطح شرکت ملی گاز ایران، در کنار دیگر روشهای تعمیراتی می تواند در مقاطع حساس پایداری گازرسانی را تأمین نموده و در ضمن به عنوان یک سیستم تعمیراتی با قابلیت اطمینان بلند مدت (۲۰ ساله) نیز می تواند مورد استفاده بهره برداران قرار گیرد.	
مراجع و استانداردهای پایه استفاده شده ۴۶ مرجع داخلی و بین المللی به شرح زیر: ASME B31G , Manual for determining the remaining strength of corroded pipelines ASME B31.8 , Gas transmission and distribution systems ASME PCC-2 , Repair of pressure equipment and piping ASTM D543 , Standard practices for evaluating the resistance of plastics to chemical reagents ASTM D696 , Standard test method for coefficient of linear thermal expansion of plastics between -30°C and 30°C with a vitreous silica dilatometer ASTM D1598 , Standard test method for time-to-failure of plastic pipe under constant internal pressure ASTM D1599 , Standard test method for resistance to short-time hydraulic pressure of plastic pipe, tubing, and fittings	

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ASTM D2583, Standard test method for indentation hardness of rigid plastics by means of a Barcol impressor

ASTM D2992, Standard practice for obtaining hydrostatic or pressure design basis for fiberglass (glass-fiber-reinforced thermosetting-resin) pipe and fittings

ASTM D3039, Standard test method for tensile properties of polymer matrix composite materials

ASTM D3165, Standard test method for strength properties of adhesives in shear by tension loading of single-lap-joint laminated assemblies

ASTM D3681, Standard test method for chemical resistance of fiberglass (glass-fiber-reinforced thermosetting resin) pipe in a deflected condition

ASTM D5379, Standard test method for shear properties of composite materials by the v-notched beam method

ASTM D6604, Standard practice for glass transition temperatures of hydrocarbon resins by differential scanning calorimetry

ASTM E84, Standard test method for surface burning characteristics of building materials

ASTM E831, Standard test method for linear thermal expansion of solid materials by thermomechanical analysis

ASTM E1356, Standard test method for assignment of the glass transition temperatures by differential scanning calorimetry or differential thermal analysis

ASTM E1640, Standard test method for assignment of the glass transition temperature by dynamic mechanical analysis

ASTM E2092, Standard test method for distortion temperature in three-point bending by thermomechanical analysis

ASTM G8, Standard test methods for cathodic disbonding of pipeline coatings

BS 7910, Guide to methods for assessing the acceptability of flaws in metallic structures

EN 59, Glass reinforced plastics – Determination of indentation hardness by means of a Barcol hardness tester

EN 1465, Adhesives - Determination of tensile lap shear strength of rigid-to-rigid bonded assemblies

IGS-C-TP-010, 3-Layer Polyethylene coating system

IGS-C-TP-014-1, Fiber reinforced epoxy & vinyl ester coating system for external corrosion protection of field joints of steel pipe lines

IGS-O-CH-042, Painting Procedure for gas industry installations

INSO 23200-1, High pressure water jet machines- safety requirements

INSO 23273, Petroleum industry -Installation life cycle risk management

IPS-G-SF-130, General standard for disposal of solid waste

IPS-G-SF-870, General standard for soil pollution control

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ISO 75-3, Plastics - Determination of temperature of deflection under load - Part 3: High-strength thermosetting laminates and long-fiber-reinforced plastics

ISO 8501, Preparation of steel substrates before application of paints and related products - Visual assessment of surface cleanliness

ISO 8502, Preparation of steel substrates before application of paints and related products - Tests for the assessment of surface cleanliness

ISO 8503, Preparation of steel substrates before application of paints and related products - Surface roughness characteristics of blast-cleaned steel substrates

ISO 8504, Preparation of steel substrates before application of paints and related products - Surface preparation methods

ISO 4624, Paints and varnishes - Pull-off test for adhesion

ISO 527-1, Plastics - Determination of tensile properties - Part 1: General principles

ISO 527-4, Plastics - Determination of tensile properties - Part 4: Test conditions for isotropic and orthotropic fiber-reinforced plastic composites

ISO 868, Plastics and ebonite - Determination of indentation hardness by means of a durometer (Shore hardness)

ISO 10952, Plastics piping systems - Glass-reinforced thermosetting plastics (GRP) pipes and fittings - Determination of the resistance to chemical attack for the inside of a section in a deflected condition

ISO 11357-2, Plastics - Differential scanning calorimetry (DSC) - Part 2: Determination of glass transition temperature and glass transition step height

ISO 11359-2, Plastics - Thermomechanical analysis (TMA) - Part 2: Determination of coefficient of linear thermal expansion and glass transition temperature

ISO 14692, Petroleum and natural gas industries - Glass-reinforced plastics (GRP) piping

ISO 21809-1, Petroleum and natural gas industries - External coatings for buried or submerged pipelines used in pipeline transportation systems - Part 1: Polyolefin coatings (3-layer PE and 3-layer PP)

ISO 24817, Petroleum, petrochemical and natural gas industries - Composite repairs for pipework - Qualification and design, installation, testing and inspection

NIGC-PAM-PR-02, Fitness for service assessment procedure (FFS)

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ب) مراحل بررسی در کمیته تخصصی

ردیف	عنوان	اقدامات
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۲	تاریخ خاتمه بررسی در کمیته	۱۴۰۴/۰۵/۲۹
۳	تعداد جلسات کمیته استاندارد	۴۰ جلسه
۴	مراحل بررسی در کمیته استاندارد (نحوه تهیه پیش نویس، اهم نکات مورد بررسی و ...)	- بررسی نیازهای ذی نفعان استاندارد از طریق مکاتبات دریافتی از شرکت انتقال گاز - ارائه موضوع و بیان مزایای تعمیر کامپوزیتی لوله ها در شورای استاندارد و اخذ مجوز تدوین استاندارد از شورای مذکور - بررسی جلسات با مجریان ذی صلاح و صاحب نظران در قالب جلسات با اعضای مرتبط انجمن کامپوزیت ایران و ترسیم نقشه راه تدوین استاندارد و نیازسنجی مجریان - برگزاری جلسات مشترک با خبرگان و استاتید دانشگاهی صاحب نظر در زمینه تعمیرات کامپوزیت - مکاتبه و برقراری ارتباط با پژوهشگاه پلیمر و پتروشیمی و جذب یکی از اعضای هیئت علمی آن پژوهشگاه جهت حضور ثابت در روند تدوین استاندارد - مطالعه استانداردهای بین المللی و اسپکهای شرکتهای بهره بردار و مجری - انجام مقایسه میان استانداردهای مرتبط و گزینش جامعترین استاندارد به عنوان ساختار اصلی استاندارد - تدوین بخشهای مختلف استاندارد از طریق اضافه نمودن و اصلاح مطالب مدنظر اعضای کمیته با استفاده از منابع معتبر و تجربیات اعضا - ارجاع متن نهایی به کمیته ایمنی استانداردها و حضور در جلسات بررسی بخشهای ایمنی با حضور نمایندگان ایمنی شرکتهای تابعه و اعمال نظرات ایشان در بخشهای مرتبط - برگزاری جلسات جمع بندی پیش نویس به منظور اعمال نظرات اصلاحی اعضا و مجریان
۵	استعلام از سازندگان و مشاوران	- برگزاری جلسات با مجریان در خلال تدوین متن پیش نویس
۶	مهمترین موارد تغییر یافته نسبت به ویرایش قبلی	- ویرایش صفر استاندارد می باشد.

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پ) اعضاء کمیته تخصصی :

نام و نام خانوادگی	واحد سازمانی
مرتضی محمد علی پور کناری	شرکت انتقال گاز
مهدی رضایی	
حسن ساعی	
روح اله عسگرپور کبیر	
افشین امامی خواه	شرکت مهندسی و توسعه گاز
علی رضا حدادیان	مدیریت دارایی فیزیکی
بهروز چراغعلی	شرکت گاز استان تهران
سعید احمدی زاده (مدعو)	شرکت گاز استان گیلان
رضا خدایی	امور استandarدها
سید علی رضا ثابت	پژوهشگاه پلیمر و پتروشیمی

ت) نظر شورای استاندارد

در جلسه شماره ۶۶۵ مورخ ۱۴۰۴/۰۷/۱۴ شورای استاندارد مطرح و مورد تأیید قرار گرفت.

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APPROVED	مصوب



شرکت ملی گاز ایران
مدیریت پژوهش و فناوری
امور استانداردها

IGS

دستورالعمل

تعمیر کامپوزیتی خطوط لوله گاز طبیعی

Composite Repair for Natural Gas Pipelines

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Foreword

This standard specification is intended to be mainly used by N.I.G.C. and contractors, and has been prepared base on interpretation of recognized standards and technical documents, as well as knowledge, backgrounds and experiences in gas industries at national and international levels.

Iranian Gas Specification (IGS) are prepared, reviewed and amended by technical standard committees within NIGC standardization division of research and technology management and submitted to "the standards council of NIGC" for approval.

IGSs are subjected to revision, amendment or withdrawal, if required, and thus the latest edition of IGS shall be checked / inquired by NIGC'S users.

This standard must not be modified or altered by NIGC employees or its contractors. Any deviation or conflicts between this specification and other applicable standards, codes, procedure or well-known manufacturer's specifications must be resolved in writing by the user or its representative through Manager, Engineering Department or standardization division of NIGC.

The technical standard committee welcomes comments and feedbacks from concerned or interested corporate and individuals about this standard, and may revise this document accordingly based on the received feedbacks.

General Definitions

Throughout this standard the following definitions, where applicable, should be followed:

- 1- "STANDARDIZATION DIV." is organized to deal with all aspects of industry standards in NIGC. Therefore, all enquiries for clarification or amendments are requested to be directed to mentioned division.
- 2- "COMPANY": refers to National Iranian Gas Company (NIGC).
- 3- "SUPPLIER": refers to a firm who will supply the service, equipment or material to IGS specification whether as the prime producer or manufacturer or a trading firm.
- 4- "SHALL ": is used where a provision is mandatory.
- 5- "SHOULD": is used where a provision is advised only.
- 6- "MAY": is used where a provision is completely discretionary.

Website: <http://igs.nigc.ir>

1 Scope

This general specification is applicable to the design, material selection, qualification and installation for the external application of composite repair systems to be used for repair of carbon steel transmission and distribution natural gas pipelines during operation.

2 References

The reference documents listed below form an integral part of this general specification. The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ASME B31G, Manual for determining the remaining strength of corroded pipelines

ASME B31.8, Gas transmission and distribution systems

ASME PCC-2, Repair of pressure equipment and piping

ASTM D543, Standard practices for evaluating the resistance of plastics to chemical reagents

ASTM D696, Standard test method for coefficient of linear thermal expansion of plastics between -30°C and 30°C with a vitreous silica dilatometer

ASTM D1598, Standard test method for time-to-failure of plastic pipe under constant internal pressure

ASTM D1599, Standard test method for resistance to short-time hydraulic pressure of plastic pipe, tubing, and fittings

ASTM D2583, Standard test method for indentation hardness of rigid plastics by means of a Barcol impressor

ASTM D2992, Standard practice for obtaining hydrostatic or pressure design basis for fiberglass (glass-fiber-reinforced thermosetting-resin) pipe and fittings

ASTM D3039, Standard test method for tensile properties of polymer matrix composite materials

ASTM D3165, Standard test method for strength properties of adhesives in shear by tension loading of single-lap-joint laminated assemblies

ASTM D3681, Standard test method for chemical resistance of fiberglass (glass-fiber-reinforced thermosetting resin) pipe in a deflected condition

ASTM D5379, Standard test method for shear properties of composite materials by the v-notched beam method

ASTM D6604, Standard practice for glass transition temperatures of hydrocarbon resins by differential scanning calorimetry

ASTM E84, Standard test method for surface burning characteristics of building materials

ASTM E831, Standard test method for linear thermal expansion of solid materials by thermomechanical analysis

ASTM E1356, Standard test method for assignment of the glass transition temperatures by differential scanning calorimetry or differential thermal analysis

ASTM E1640, Standard test method for assignment of the glass transition temperature by dynamic mechanical analysis

ASTM E2092, Standard test method for distortion temperature in three-point bending by thermomechanical analysis

ASTM G8, Standard test methods for cathodic disbonding of pipeline coatings

BS 7910, Guide to methods for assessing the acceptability of flaws in metallic structures

EN 59, Glass reinforced plastics – Determination of indentation hardness by means of a Barcol hardness tester

EN 1465, Adhesives - Determination of tensile lap shear strength of rigid-to-rigid bonded assemblies

IGS-C-TP-010, 3-Layer Polyethylene coating system

IGS-C-TP-014-1, Fiber reinforced epoxy & vinyl ester coating system for external corrosion protection of field joints of steel pipe lines

IGS-O-CH-042, Painting Procedure for gas industry installations

INSO 23200-1, High pressure water jet machines- safety requirements

INSO 23273, Petroleum industry -Installation life cycle risk management

IPS-G-SF-130, General standard for disposal of solid waste

IPS-G-SF-870, General standard for soil pollution control

ISO 75-3, Plastics - Determination of temperature of deflection under load - Part 3: High-strength thermosetting laminates and long-fiber-reinforced plastics

ISO 8501, Preparation of steel substrates before application of paints and related products - Visual assessment of surface cleanliness

ISO 8502, Preparation of steel substrates before application of paints and related products - Tests for the assessment of surface cleanliness

ISO 8503, Preparation of steel substrates before application of paints and related products - Surface roughness characteristics of blast-cleaned steel substrates

ISO 8504, Preparation of steel substrates before application of paints and related products - Surface preparation methods

ISO 4624, Paints and varnishes - Pull-off test for adhesion

ISO 527-1, Plastics - Determination of tensile properties - Part 1: General principles

ISO 527-4, Plastics - Determination of tensile properties - Part 4: Test conditions for isotropic and orthotropic fiber-reinforced plastic composites

ISO 868, Plastics and ebonite - Determination of indentation hardness by means of a durometer (Shore hardness)

ISO 10952, Plastics piping systems - Glass-reinforced thermosetting plastics (GRP) pipes and fittings - Determination of the resistance to chemical attack for the inside of a section in a deflected condition

ISO 11357-2, Plastics - Differential scanning calorimetry (DSC) - Part 2: Determination of glass transition temperature and glass transition step height

ISO 11359-2, Plastics - Thermomechanical analysis (TMA) - Part 2: Determination of coefficient of linear thermal expansion and glass transition temperature

ISO 14692, Petroleum and natural gas industries - Glass-reinforced plastics (GRP) piping

ISO 21809-1, Petroleum and natural gas industries - External coatings for buried or submerged pipelines used in pipeline transportation systems - Part 1: Polyolefin coatings (3-layer PE and 3-layer PP)

ISO 24817, Petroleum, petrochemical and natural gas industries - Composite repairs for pipework - Qualification and design, installation, testing and inspection

NIGC-PAM-PR-02, Fitness for service assessment procedure (FFS)

3 Terms and Definitions

3.1 Barcol hardness

measure of surface hardness using a surface impresser

3.2 Blister

air void between layers within the laminate visible on the surface as a raised area

3.3 Composite

thermoset resin system that is reinforced by fibers

3.4 Crack

split in the laminate extending through the wall (perpendicular to the surface) such that there is actual separation with opposite surfaces visible

3.5 Curing

setting of a thermosetting resin system, such as polyester or epoxy, by an irreversible chemical reaction

3.6 Cure Schedule

time-temperature profile qualified to generate a specified T_g or HDT

3.7 Defect Type A

defect within the substrate, not through-wall and not expected to become through-wall within the repair design lifetime of the repair system

3.8 Defect Type B

through-wall defect or a defect within the substrate where the remaining wall thickness is less than 20 percent of original wall thickness of substrate, when the defect is discovered.

3.9 Defined Lifetime

actual application or service lifetime of the repair

3.10 Delamination

area between the repair laminate and the substrate which should be bonded together but where no bond exists, or an area of separation between layers in the repair laminate

3.11 Design Lifetime

maximum application lifetime of the repair

3.12 Differential Scanning Calorimetry (DSC)

method of determining the glass transition temperature of a thermosetting resin

3.13 Dry Spot or Un-impregnated/Dry Fiber

area of fiber not impregnated with resin, with bare, exposed fiber visible

3.14 Engineered Repair

repair 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

3.15 Exposed Fiber

area of fiber not impregnated with resin that projects from the body of the repair

3.16 Foreign Matter

any substance other than the reinforcing fiber or other materials that form part of the repair system

3.17 Finishing Materials

final layer of material to help compact the repair laminate, typically a polymeric film or a fabric

Note: They should be fully removed after the repair has hardened and before the repair is inspected or painted.

3.18 Fitness-for-Service (FFS) Evaluation

A methodology whereby flaws contained within a structure are assessed in order to determine the adequacy of the structure for continued service without failure

3.18 Glass Transition Temperature (T_g)

temperature at which a resin undergoes a marked change in physical properties

3.19 Hardener

component added to a thermosetting resin to effect cure

3.20 Heat Distortion Temperature (HDT)

temperature at which a standard test bar deflects by a specified amount under a given load

3.21 Installer

person who is qualified by the owner or delegated third party to apply a composite repair system

3.22 Filler Material

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

3.23 Layer

individual layer or wrap within the composite laminate

3.24 Leak

condition of a substrate wall that can allow the contents to contact and act directly upon the (composite) repair laminate

3.25 Occasional Load

load that occurs rarely and during a short time. These loads typically occur less than 10 times in the life of the component and each load duration is less than 30 min.

3.26 Owner

refers to one of the related and/or affiliated companies of the National Iranian gas company (NIGC) that holds legal ownership of the gas transmission or distribution pipelines to be repaired.

3.27 Pin Hole

pin-prick hole in the resin rich surface, not extending into the laminate

3.28 Pipeline

all parts of physical facilities through which gas moves in transportation, including pipe, valves, fittings, flanges (including bolting and gaskets), regulators, pressure vessels, pulsation dampeners, relief valves, appurtenances attached to pipe, compressor units, metering facilities, pressure-regulating stations, pressure-limiting stations, pressure relief stations, and fabricated assemblies.

3.29 Pit

depression in the surface of the laminate

3.30 Ply

single wrap or layer (lamina) of a repair laminate

3.31 Post Cure

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

3.32 Qualification Application Procedure

application procedure used to apply the repair system for the qualification tests

3.33 Qualification Test Temperature

test temperature at which qualification testing of the repair system is performed

3.34 Reinforcement

fiber embedded in the resin system to improve load bearing

Note: Possible fiber materials include aramid, carbon, glass, polyester or similar materials.

Reinforcement results in mechanical properties superior to those of the base resin.

3.35 Repair Laminate

The composite part(layer) of a repair system

Most composites considered in this standard is composed of discrete layers which are wrapped or stacked, one on top of the other. This stacked construction is the laminate.

3.36 Repair System

System comprised of the substrate, composite material (repair laminate), filler material, adhesive and including surface preparation and installation methods, used for repair of pipework.

The basic structure of a repair system in this context is considered in figure 1.

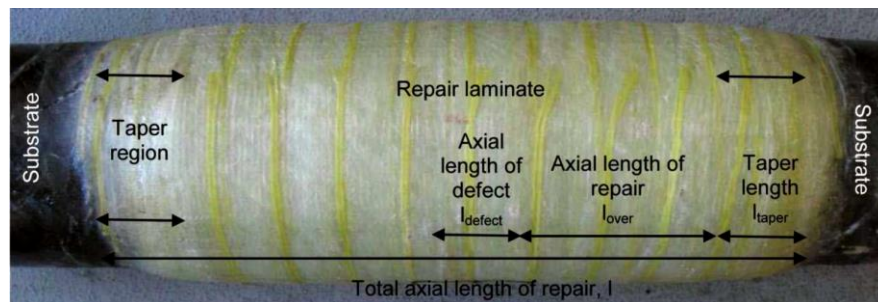


Figure 1 Schematic of a repair system (not to scale) and location of defects

3.37 Repair System Installer

company that installs the repair system

3.38 Repair System Supplier

company that designs and supplies the repair system

3.39 Resin System

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

Note: Often this includes a resin, filler(s), pigment, mechanical property modifiers and catalyst or hardener.

3.40 Substrate

surface on which a repair is carried out

Note: The surface may belong to pipeline and pipeline components.

3.41 Supervisor

experienced installer who is qualified by success fully completing the supervisor training course

3.42 Shore Hardness

measure of surface hardness using a surface impresser or durometer

3.43 Thermoset Resin System

resin system that cannot be melted or remolded following polymerization

3.44 Wrinkle

wavy surface or distinct ridge in the laminate where the reinforcing fabric has creased during application

4 Preliminary Defect Assessment

Defect assessment in the pipeline and related components can be performed with the prevailing fitness-for-service standard, e.g., ASME B31G, API 579-1/ASME FFS-1 as well as NIGC-PAM-PR-02.

The starting point for this standard is that a decision has been taken to repair a given defect with a composite repair system by the owner and the output from the defect assessment, such as minimum remaining wall thickness(t_a) and maximum allowable operating pressure(p_s) are used as input for the repair design. This standard is concerned with the subsequent activities of repair qualification, design, installation and inspection. Therefore, before implementing any composite repair, it is necessary to perform a defect assessment to determine the maximum allowable operating pressure of the pipe in the damaged conditions.

Some key issues in relation to defect assessment are as follows:

- inspecting the region to be repaired to ensure that no cracks are present in the substrate. If necessary, an appropriate nondestructive examination (NDE) technique, such as magnetic particle method can be used for confirmation;
- confirming the level of corrosion in terms of depth and length. It is assumed that prior to making the decision to make a repair that previous measurements have been made;
- providing measurement results of the anomaly to the repair provider to determine the appropriate composite repair design.

5 Applications

The qualification, design, installation, testing and inspection procedures for composite repair systems in this standard cover issues involving the repair of defects encountered in distribution and transmission natural gas pipelines and related components.

Procedures in this standard cover the repair of carbon steel pipelines originally designed in accordance with ASME B31.8.

This standard is not a defect assessment standard in which, no statements are made regarding whether a specific defect is acceptable or unacceptable for repair (clause 4). Repair systems are applied to restore structural integrity. The following repair situations are addressed:

- **external corrosion:**

where the defect is or is not through-wall. In this case, the application of a repair system will usually arrest further deterioration;

- **external damage:**

such as dents and gouges;

- **internal corrosion / erosion:**

where the defect is or is not through-wall. In this case, corrosion and/or erosion can continue after application of a repair system, and therefore the design of the repair system shall take this into account, i.e. the size of the defect at the end of the required design life of the repair should be taken as the size of the defect when is discovered and in designing stage of the repair system;

- **crack like defects:**

where the defect is or is not through wall. It is a requirement that the length of the crack is known and will not increase during the lifetime of the repair. For any case, the crack should be modelled as a Type A defect.

- **strengthening and/or stiffening in local areas.**

It is recommended merely for local defects.

As a general guide, table 1 summarizes the types of defect that can be repaired using repair systems.

Table 1 Types of Defect That Can be Repaired Using Repair Systems

Type of defect	Applicability of repair system
General wall thinning	Y for external N for internal unless reasons are identified and mitigations are in place
Local wall thinning	Y for external N for internal unless reasons are identified and mitigations are in place
Pitting	Y for external N for internal unless reasons are identified and mitigations are in place
Gouges/Dents	Y (provided it does not prevent from in- line inspection)
Blisters	Y
Laminations	Y
Circumferential cracks	R and in any case limited to temporary repairs (short term design)
Longitudinal cracks	N
Through wall penetration	N
Y implies generally appropriate. N implies not accepted. R implies can be used, but requires extra-consideration. For the case of cracks, it will be required to assess whether application of the repair will stop future crack growth or whether a conservative assumption about the ultimate length of the crack is required. If either assessment is negative, then application of a composite repair is not appropriate.	

The upper temperature limit is defined in 8.5.3.

The lower temperature limit is dependent on the type of repair laminate being used.

This limit is determined by the design requirements presented in 8.5.3.

The upper pressure limit is a function of defect type (internal, external, or through-wall), defect dimensions (depth and extent), pipe diameter, design temperature and repair design lifetime.

The lower pressure limit is determined by the design requirements presented in 7.5.9.7 of latest edition of ISO 24817.

6 Repair System Material

The composite materials constituting the repair laminate considered within this document are typically those with aramid, glass or similar material fiber reinforcement in a vinyl ester, epoxy or similar polymer matrix. Other fiber and matrix types are also permissible once qualified.

7 Summary of Key Issues

7.1 General

The key issues to be considered by the owner to ensure that a repair system complies with the requirements of this instruction are specified in the relevant clauses of this standard.

The repair system is defined as the combination of the following elements and procedures:

- a) substrate, (pipeline and fittings outer surface);
- b) surface preparation;
- c) application of filler material;
- d) application of primer layer;
- e) application of repair laminate;
- f) curing procedure.

This standard does not provide guidance on when to use a repair system. It starts from the point that a decision to use a repair system has already been taken and only gives guidance on how to use composite repair system effectively covering testing, design, installer training, installation and through to maintenance of a repair in service.

7.2 Repair Process

There are six key areas of the repair process that shall be considered.

7.2.1 Repair System Qualification

The owner shall confirm that the repair system proposed has been tested in accordance with the requirements of this standard (see clause 8). This would typically require the supplier to submit test reports or to provide delegated third-party verification that testing has been completed.

Qualification testing is specific to a particular pipe material and method of surface preparation for that material. The owner shall confirm that testing has been completed for the pipe material of interest and the method of surface preparation being considered.

7.2.2 Enquiry Stage

All relevant data, e.g. design conditions, corrosion mechanisms, inspection data and surface preparation limitations, shall be passed from the owner to the repair system supplier (see 8.4). Full details of design temperatures and pressures shall be provided. Any limitations on working conditions shall be identified and supplied to the repair system installer/supplier through completion of the design data sheet form (see Annex A). Risk assessment and an overview of site conditions should be supplied by the owner.

The status of the pipeline during repair application, e.g. live, no pressure but full and empty, shall be defined and passed on from the owner to the repair system supplier. Details of the expected surface temperature and local humidity shall also be provided.

A photographic record of the defect prior to repair design/application should be kept by the owner.

7.2.3 Design of Repair

The correct design procedure shall be followed as the flowchart which defined in Figure 1 of ISO 24817.

Repairs to lines suffering internal corrosion or erosion should consider the defect size expected at the end of the repair service life. The repairs would generally be less resistant to erosion than a metal pipe and repair life would normally be restricted to the point that the defect goes through-wall.

The repair system supplier shall demonstrate how the repair system will satisfy the design requirements of this standard regarding temperature where the pipe has an elevated design temperature but generally operates at ambient or has an elevated design temperature but the repair is installed at ambient (see 7.5.3).

Note: The equation 1 provided in clause 8.5.4 shall be considered.

7.2.4 Installer Training

Correct installation will ultimately determine successful performance of a repair as defined in Table 7. Repair installers shall have been trained in the application of the specific repair system in use.

The owner shall confirm that repair installers have been trained in compliance with the requirements of this standard. The repair system supplier shall demonstrate competence of the installers via evidence of training and experience (see Annex I of ISO 24817).

7.2.5 Installation of Repair

In terms of the performance of the repair system, the adhesion of the repair to the substrate is the key technical issue. The surface preparation procedure should be the same as that qualified by testing and assumed in the design. The pipe surface shall be dry and at a temperature above the dew point or otherwise in compliance with the conditions validated by repair qualification testing.

The actual defect size should be confirmed as being within the limits assumed in the design (e.g. physical dimension, unprepared surface area or surface area of filler).

Quality assurance (QA) measurements shall be recorded (as per the repair system supplier's method statement), as the repair is being applied (see Table 7). The repair shall be fully cured before the pressure is brought back to normal operating conditions. The repair system supplier shall provide details on how to assess the cure status of the repair laminate (see Table 7)

Note: Before applying repair system, the documents for all hold points shall be checked and signed by repair system supplier and installer and then approved by owner.

A photographic record of the repair application should be kept by the repair system supplier.

The completed QA measurements and photographs (if available) shall be submitted to and retained by the owner and the repair system supplier shortly after installation is completed.

The ends of the repairs, where they extend on to base metal, as a minimum shall be overlapped on the main pipeline coating to prevent corrosion to the pipe at this location.

7.2.6 Inspection and Maintenance of Repair

If considered necessary, the repair should be inspected on a regular basis to ensure the integrity of the repair and that it is operating within the assumptions used in the design of repair (i.e. base pipeline corrosion concerns, the defect size is less than

assumed in design) (see Clause 10). It may be appropriate to complete a baseline inspection immediately after application against which future inspections can be compared and changes identified.

At the end of the repair design lifetime, either the spool onto which the repair is situated should be removed, the repair removed, or the repair design lifetime revalidated (see 10.5).

8 Qualification and Design

8.1 Repair Feasibility Assessment

The following factors shall be considered by the owner and repair system supplier when assessing the feasibility of designing and installing a repair system:

- assessment of the nature and location of the defects;
- design and operating conditions for the substrate and contents (including pressure, temperature, sizes and combinations thereof);
- repair design lifetime;
- geometry of the substrate being repaired (pipe or fittings);
- hazards associated with system service;
- availability of personnel with the necessary skills;
- ease with which it is practicable to execute surface preparation operations;
- performance under upset and major incident situations, including impact, abrasion, fire, explosion, collision and environmental loading;
- operational measures, including related NIGC hot and cold work permits, gas testing and fire protection requirements to ensure safety in the vicinity of the repair area;
- failure modes;
- inspectability (both visual and non-destructive) and maintenance of the repair;
- repair system materials.

The information and data describing any hazards shall be included in the method statement (see 9.2) to be used on site.

A structured hazard identification method (e.g. Job Hazard Assessment (JHA) or Process Hazard Assessment (PHA)) shall be applied and summarized in the method statement. The analysis shall address flammability, resin handling, ventilation, thermal limits, pressurized environments, and proximity hazards.

The objective of the assessment shall be to establish the class of the repair, which determines the detail of the design method to be carried out, together with the requirements for supporting documentation. This also determines the design margin or factor of safety to be used in the design.

Guidance on performing the assessment can be obtained from INSO 23273.

Note: This Standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices, and determine the applicability of regulatory limitations prior to use.

8.2 Design Pressure and Repair Class

All repairs on pipelines shall be classified as repair class 3 according to ISO 24817.

Design pressure shall be limited to repair designed in compliance with this standard and of a thickness equivalent to $< D/12$.

The qualified upper pressure limit is a function of defect type (internal, external or through-wall), defect dimensions (depth and extent), pipe diameter, design temperature and repair design lifetime.

This upper pressure limit is derived for a given set of conditions by calculations in accordance with this standard using the qualification test data from either Annex C and Annex D of ISO 24817 for Type A and Type B defects, respectively.

8.3 Repair Design Lifetime

The repair design lifetime (in years) of the repair system shall be defined by the owner in the repair data sheet (Annex A). It may be limited by the defect type and service conditions, e.g. internal or external corrosion, dent, gouge etc.

The minimum design lifetime of the repair shall be two years.

Short design lifetimes (two years) may be appropriate to those situations where the repair is required to survive until the next shutdown.

Long design lifetimes (up to 20 years) may be appropriate to those situations where the repair is required to reinstate the substrate to its original design lifetime or to extend its design life for a specified period.

Note1: If long term performance data are not available (regression testing and representative test coupons as per Annex E of ISO 24817), the repair shall be a temporary repair not longer than 2 years.

Note2: For long term performance conducting performance test data as per annex E ISO 24817 is mandatory.

Note 3: Permanent repair means not more than 20 years. After 20 years the pipe section shall be replaced.

8.4 Required Data

8.4.1 Background

The following data shall be supplied for each repair application. The detail to which these requirements are fulfilled is determined by the output of the repair feasibility assessment. Original equipment design data, maintenance and operational histories shall be provided by the owner and material qualification data shall be provided by the repair system supplier. The availability of relevant data shall feature as part of the repair feasibility assessment.

8.4.2 Original Equipment Design Data

Original equipment design data is required, consisting of the following:

- a) relevant pipeline conditions including, material specification, wall thickness, and pressure and temperature ratings;
- b) specification of all operating mechanical loads not included in the above, including upset conditions;
- c) regulatory requirements, e.g. fire performance and HSE requirements in compliance with NIGC related documents, fire performance testing as ISO 14692 or ASTM E84. Also, documented evidence of resin compatibility with expected thermal exposure is mandatory.

8.4.3 Maintenance and Operational Histories

Maintenance and operational histories are required, consisting of the following:

- a) documentation of any changes in service conditions, including pressure, temperature, percentage of metal loss on pipeline wall thickness;
- b) past service conditions (if available);
- c) summary of all alterations and past repairs local to the substrate of concern (if available);
- d) inspection reports detailing the nature and extent of damage to be repaired.

8.4.4 Service Condition Data

Service condition data are required, consisting of the following:

- a) repair design lifetime requirements/expectations;
- b) required design and operating pressures (internal and external)/temperatures;
- c) expected future service conditions;
- d) if applicable, maximum allowable working pressure (MAOP) as calculated according to the requirements of ASME B31G, API 579, or another applicable standard. This shall be carried out considering the current position and any possible further degradation in the future, as per Annex A.

8.4.5 Repair system qualification data

The documentation and qualification data related to repair systems that shall be provided for the repair system are as follow:

Note: Details of the qualification data to be provided are given in Annex B of ISO 24817.

a) Material documentation and data

This shall include a statement of the resins and reinforcements used and any standards to which they are supplied. Basic data on material compatibility with the working environment shall also be available.

Note: Attention shall be given to Carbon fiber-reinforced plastic (CFRP) laminates and the potential for bimetallic (galvanic) corrosion of the substrate and difference between thermal characteristics of different fibers.

b) Surface preparation

The durability of a bonded assembly under applied load is determined to a large extent by the quality of the surface preparation used. Details of the surface preparation procedure and how it is to be implemented shall be provided as used in the qualification tests. (see 9.4.3)

Note1: The surface preparation shall be at least equal to SA 2 ½ as per ISO 8501-1.

Note2: The surface roughness shall be recommended by installer and accepted by owner.

c) Short-term test data

These shall include tensile strength and modulus in both the hoop and axial directions and the strength of the (adhesive) bond between the repair laminate and the substrate.

d) Long-term lap shear durability test data

These shall include the strength of the adhesive bond between the repair laminate and substrate, and optionally the ultimate tensile strain of the repair laminate. Long-term is defined as greater than or equal to 1000 h where the sample has been exposed to a water environment and a temperature greater than or equal to the design temperature. Above a temperature of 100 °C, the environment can be dry.

Table 2 lists the data required to comply with repair system requirements. Annex B of the latest edition of ISO 24817 contains the full details of the qualification data requirements.

Table 2 Qualification Test Requirements

Short term repairs (2 years maximum)			
	Material property	Test method	Comments
Mechanical properties	Young's modulus	ISO 527-1, ISO 527-4 (or ASTM D3039)	
	Poisson's ratio	ISO 527-1, ISO 527-4 (or ASTM D3039)	
	Shear modulus	ASTM D5379	
	Thermal expansion coefficient	ISO 11359-2 (or ASTM D696)	
	Glass transition temperature of resin and heat distortion temperature of resin cured at relevant temperatures	ISO 11357-2 (or ISO 75-3, ASTM D6604, ASTM E1640, ASTM E831), ASTM E2092	
	Glass transition temperature of resin after water absorption		For buried pipelines in vicinity of water or humid environment
	Barcol or shore hardness	ISO 868 or EN 59 (or ASTM D2583)	
Compliance assessment	Delamination and absence of bonding of composite repair to the pipe	UT A-Scan, Multiprobes or other qualified methods	Adapted probes and probe-shoes shall be selected
Adhesion strength	Lap shear	EN 1465 (or ASTM D3165)	
	Pull off test on steel	Annex B	
	Pull off test on coating	Annex B	
Cathodic disbondment		Annex B	
Performance data	Energy release rate	Annex D of ISO 24817	
	Short term pipe survival test	Annex C of ISO 24817	
	Impact survival	Annex F of ISO 24817	
	Degradation factor	Annex G of ISO 24817	
	Pipe spool axial strength test	Annex B	
	Additional requirements for long term repairs		
Performance data	Long term strength: • Regression testing • AND representative coupon testing	Annex E of ISO 24817	
Note: "cold" mechanical sampling methods shall be used to avoid downgrading composite properties			

8.4.6 Conditions for sample preparation for qualification tests

All samples preparation and qualification tests shall be performed in air environment.

8.5 Design Methodology

8.5.1 Overview

There are two design cases.

a) Defect type A (non-through-wall defect) design case

The defect is within the substrate, not through-wall and not expected to become through-wall within the repair design lifetime of the repair system, requiring structural reinforcement only. One of the following three design methods shall be used to determine the repair laminate thickness, t_{design} :

1) include allowance for the substrate, where yielding of the component may or may not be included (Designing based on substrate load sharing):

Use of this design method is appropriate if the contribution of the substrate is to be included in the calculation for load-carrying capability;

2) exclude allowance for the substrate (Designing based on repair laminate allowable strains):

Use of this design method is appropriate if the contribution of the substrate is to be ignored in the calculation for load-carrying capability and if short-term material properties are to be used;

3) long-term performance test data (Designing based on repair-allowable stresses determined by performance testing)

Use of this design method is appropriate if performance-based test data as per Annex E of the latest edition of ISO 24817 are available.

b) Defect type B (through-wall defect) design case

The substrate requires structural reinforcement and filling of through-wall defects. For substrates with active internal corrosion, the repair laminate shall be designed on the assumption that a through-wall defect will occur if the remaining wall thickness at the end of service life is expected to be less than 20 percent of original component wall thickness.

Design method for defect type A and B as per ISO 24817 can be carried out and then the greater repair thickness from each case (A or B) shall be taken as the repair laminate thickness, t_{design} .

All additional requirements mention in clause 8.5.5 shall be considered for each design case and applied where appropriate, with the largest thickness being taken as the repair laminate thickness, t_{design} .

The flowchart presented in figure 1 of ISO 24817 provides an overview of the above described design process.

Note1 : The equation (1) provided in clause 8.5.4 shall be considered.

Note 2: Whenever, the remaining wall thickness of pipe or fitting is less than 80% of its original wall thickness, the defect shall be considered to be a through wall defect (type B defect) which shall be discussed on a case by case basis.

Also, A derogation request shall be issued. It shall include a proper risk assessment.

Note 3: Further informative guidance on the repair design process is given in Annex K of ISO 24817. Within this Annex, two worked examples (for a Type A and Type B defect) are provided.

8.5.2 Environmental Compatibility

The suitability for use of the repair system in the service environment shall be based on the following considerations. The service environment is the one that contacts the repair laminate. It may be either the external or internal environment.

The qualification of the repair system (8.4.5) demonstrates that the repair system is compatible with aqueous (wet) and hydrocarbon environments at the qualification test temperature. In general, thermoset resins are compatible with a wide range of environments, but consideration shall be given when the environment is strongly acidic ($\text{pH} < 3.5$), strongly alkaline ($\text{pH} > 11$), highly saline or is a strong solvent, e.g. methanol, glycol, benzene and toluene in concentration greater than 25%.

Resistance to UV degradation and weathering (where appropriate) shall be provided by data from the resin supplier.

Note: For aboveground pipelines protecting of repair system against UV is mandatory. When the environmental compatibility of the repair system is unknown, then the repair system supplier shall provide one of the following to demonstrate compatibility:

- environmental compatibility data or experience of previous applications from the resin supplier, demonstrating that the environment is no more aggressive than aqueous or hydrocarbon environments at the design temperature;
- if no compatibility data from the resin supplier is available, then specific environmental testing is required. One of the following test procedures, ISO 10952, ASTM D543, ASTM D3681 or equivalent, comparing the exposure of the specific environment and aqueous environment to the repair laminate at the design temperature shall be performed.

The repair system shall be considered compatible to the specific environment if the test results from the specific environment are no worse than for the aqueous environment. When particulate erosion is the cause of the degradation process of the substrate and the repair laminate is in contact with the eroding medium, then the repair laminate can suffer material loss. The repair system supplier shall demonstrate the survival of the repair system for the specified repair design lifetime assuming a conservative estimate of the loss of laminate material. Without experimental data on the erosion rate, a maximum repair design lifetime of no more than two years is recommended. Alternatively, a metal plate can be placed over the affected area prior to application of the repair laminate to minimize material loss (of the laminate), wherein the design of the repair the dimensions of the plate are taken as the size of the defect.

8.5.3 Design Temperature Effects

The thermal properties of the repair system shall satisfy the requirements given in Table 3. The value of T_g or HDT used shall be determined in Annex B of ISO 24817 for a repair system cured at a temperature no greater than the design temperature of the repair, T_d . The cure schedule (time and temperature profile) required to achieve this shall be specified using DSC instrument as per ASTM E1356. The temperature limit of a repair system shall be defined with reference to T_g unless the repair system does not show this transition in which case the temperature limit shall be defined with reference to HDT. Repairs that are applied to systems that are depressurized and drained may be heated (post-cured) to give the required value of T_g or HDT. The heating cycle used shall have been demonstrated to achieve the required value of T_g or HDT during qualification testing.

Table 3 Thermal Property Requirements for Repair Systems

Defect type A limit	Defect type B limit
$T_g \geq T_d + 20\text{ }^\circ\text{C}$ $\text{HDT} \geq T_d + 15\text{ }^\circ\text{C}$	$T_g \geq T_d + 30\text{ }^\circ\text{C}$ $\text{HDT} \geq T_d + 20\text{ }^\circ\text{C}$

Hardness can give an indication of cure and, where measured, shall be no less than 90 percent of the minimum obtained from repair system qualification in accordance with Table 2.

Note1: Hardness alone shall not be relied upon to demonstrate cure; reference shall also be made to the cure schedule.

For a repair system where the defect within the substrate is not through-wall, the temperature limit can be relaxed to T_g less 20°C or HDT less 15°C. T_g or HDT shall be measured in accordance with Table 2.

Table 4 summarizes the upper temperature limit of the repair when cured to as specified in Clause 8.

Table 4 Service Temperature Limits for Repair Systems

Defect type A limit T_m	Defect type B limit T_m
$T_g - 20^\circ\text{C}$ HDT – 15 °C	$T_g - 30^\circ\text{C}$ HDT – 20°C

Note2: The temperature de-rating factors to account for elevated design temperature application shall be selected from related tables of the last edition of ISO 24817.

Note 3: Other temperature de-rating factors for designing repairs of defects type A and B shall be derived from related tables of ISO 24817.

8.5.4 Design of Repairs

8.5.4.1 Design Methodology Selection Procedure

Determining the minimum thickness and axial extent of the repair laminate for different defect types shall be conducted using appropriate equations given in the last edition of ISO 24817.

At the first stage of the composite repair system design, in order to assure that further plastic straining of the substrate will not occur and the appropriate design method is chosen, the remaining substrate wall thickness obtained from FFS (using advanced NDE) as per API 579/ASME FFS conforming to NIGC-PAM-PR-02 shall be determined, and then using equation(1) the maximum stress which can be sustained by substrate(S) shall be calculated and compared with minimum yield stress of the main pipe.

$$S = \frac{p_s D}{2F t_a} \quad (1)$$

Where

p_s : maximum allowable working pressure, psig

D: original outside diameter of pipe, in.

F: design factor obtained from ASME B31.8

t_a : remaining wall thickness of substrate obtained from FFS

Considering the calculated substrate stress the following procedure shall be adopted:

1) if S is less than the minimum yield stress (S_y) of component, the design methodology of defect type B shall be used.

2) if S is greater than or equal to the minimum yield stress of component (regarding to pipeline grade), the design methodology of defect type A shall be used.

8.5.4.2 Design Parameters

Following parameters shall be used in related design equations:

a) For defect type A when the design temperature is different from the installation temperature, allowable strains for composite laminates as a function of repair design lifetime are as follows:

**Table 5 Allowable strains for composite laminates as a function of repair design lifetime
(With a service factor for safety equivalent to 0,67)**

For $E_a > 0,5 E_c$	$\epsilon_{c0} = 0.003061 \times 10^{-0.0044 t_{\text{lifetime}}}$ $\epsilon_{a0} = 0.003061 \times 10^{-0.0044 t_{\text{lifetime}}}$
For $E_a < 0,5 E_c$	$\epsilon_{c0} = 0.003061 \times 10^{-0.0044 t_{\text{lifetime}}}$ $\epsilon_{a0} = 0.001$

b) The value of service de-rating factor f_{perf} shall be set to:

for 1000 hour data: $f_{\text{perf}} = 0,612 \times 10^{-0,0043 t_{\text{lifetime}}}$ (2)

for Design life data: $f_{\text{perf}} = 0,76 \times 10^{-0,00273 t_{\text{lifetime}}}$ (3)

c) The value of the service factor, f_{leak} , shall be set to:

$f_{\text{leak}} = 0.666 \times 10^{-0.01584(t_{\text{lifetime}} - 1)}$ (4)

where t_{lifetime} is the repair design lifetime, expressed in years.

d) If long-term performance test data is available in accordance with Annex E of ISO 24817, then the service factor, f_{leak} , shall be calculated using:

$f_{\text{leak}} = 0.666 f_D$ (5)

where f_D is the degradation factor [defined in Formula (G.4) of ISO 24817].

8.5.5 Optional Design Considerations

8.5.5.1 Impact

The repair system supplier shall demonstrate that the repair to a through-wall defect (type B defect) is capable of withstanding a low-velocity 5 J impact representative of a dropped tool. The demonstration test shall be carried out in accordance with the procedure described in Annex F of ISO 24817.

This test shall be used to define the minimum repair thickness when the repair is exposed to the possibility of third-party impacts (see 8.5.5.10).

8.5.5.2 Live Repairs

Live repair on gas transmission pipelines shall not be performed above 70% of the operating pressure when the defect was discovered ($p_{\text{discovery}}$):

$p_{\text{live}} \leq 70\% p_{\text{discovery}}$ (of the defect) (6)

8.5.5.3 Fire Performance

The requirements for fire performance shall be identified by the owner in the repair feasibility assessment. Flame spread and smoke generation shall also be considered in the assessment. Due account shall be taken of the response of the repair system. In many cases, additional fire protection is not necessary, as the substrate may still be able to perform satisfactorily during the short duration of a fire event. However, conduction from the metal substrate can cause the temperature of the repair laminate to exceed its design temperature, limiting the performance of the repair system.

Strategies for achieving fire performance include the following:

- application of additional repair material such that enough basic composite laminate will remain intact for the duration of the fire event;
- application of intumescent external coatings;
- use of resin formulations with specific fire-retardant properties.

Further guidance on the design and testing of composite laminates for fire performance is contained in ISO 14692.

Additional advices on the fire test performance properties of repair laminates, smoke index, flame spread index and fuel contribution index is contained in ASTM E84.

Note: Fire performance shall be compliant with pipeline owner requirements. This fire performance can be achieved by implementing a top coat.

8.5.5.4 Cathodic Disbondment

For repairs to substrates that are cathodically protected, it may be required to demonstrate that the repair will not disbond due to the cathodic protection system.

ASTM G8 shall be used to demonstrate that the repair system is not susceptible to disbondment under an imposed electrical current.

Supplier shall demonstrate that the repair will not disbond due to cathodic protection system.

Note: Further consideration of requirements shall be met as per IGS-C-TP-014-1.

8.5.5.5 Electrical Conductivity

It is likely that the properties of the substrate will satisfy electrical conductivity requirements.

Electrical conductivity testing shall be carried out in accordance with ISO 14692.

8.5.5.6 External Loads

The minimum repair thickness, $t_{\min}$ (expressed in millimetres), to resist soil loads to prevent collapse of a buried repaired substrate shall be determined as per equation in clause 7.5.9.7 of ISO 24817.

8.5.5.7 Dent and/or Gouge Type Defects

All gouges shall be removed by grinding. The remaining dent and, if relevant, the remaining wall thickness after gouge removal shall be assessed by the relevant defect assessment code or standard to determine the MAOP, p_s . The design of the repair shall follow 8.5.4.

8.5.5.8 Delamination or Blister Type Defects

The design of the repair for delamination or blister type defects (within the substrate) shall follow 8.5.4, i.e. it shall be assumed that the repair system withstands the applied load with no allowance for the remaining strength of the pipe substrate.

8.5.5.9 Repair of Other Components

Qualification of the repair system for other components shall be as defined in section B.7 of annex B of latest edition of ISO 24817.

Note: Composite repair over existing repair clamps and patches shall not be permitted.

8.5.5.9.1 Piping System Components

The following piping system components are considered:

- bends;
- tees;
- reducers;
- flanges.

The repair design procedure for each piping system component is a comparative approach based on the equivalent straight pipe component (same diameter and thickness). The repair design process is to calculate the thickness of the repair for an equivalent straight pipe section followed by a further calculation for the repair thickness increase factor, which accounts for the stress intensification due to the geometry of the component.

The first step in the design approach is to calculate the thickness of the repair for the equivalent pipe section of the component as described in 8.5.4, $t_{\text{design, straight pipe}}$ (expressed in millimetres). This repair thickness includes both the repair strength calculation, as well as the leak sealing calculation, if appropriate. The second step is to calculate the repair thickness increase factor based on the stress intensity factor corresponding to the piping system component, $f_{\text{th, stress}}$.

The design repair thickness, $t_{\text{design, component}}$ (expressed in millimetres), is given by Formula (6):

$$t_{\text{design, component}} = t_{\text{design, straight pipe}} f_{\text{th, stress}} \quad (6)$$

Table 6 presents repair thickness increase factors, $f_{\text{th, stress}}$, for each piping component.

Table 6 Repair thickness increase factors for piping system components

Piping system component	Repair thickness increase factor
	$f_{\text{th, stress}}$
Bend	1.2
Tee	2
Reducer	1.1
Flange	1.1

The axial length of the repair shall be calculated from 8.5.4.

For tees, the main diameter is defined as that pipe that contains the defect. This pipe diameter shall be used to calculate the repair thickness from the equivalent straight pipe section. The repair thickness increase factor is then applied to this repair thickness.

The axial length of repair shall be based on the (larger) dimension of the piping system component and applies to both the axial length of repair along the main body and branch (where appropriate).

For the repair of tees, the maximum allowable design pressure, p (expressed in megapascals), for the repair laminate design thickness, $t_{\text{design, component}}$ (expressed in millimetres), shall be adopted to related equation given in the last edition of ISO 24817.

Note: For composite repairs on bend, tee, reducer, etc. a finite element calculation shall be issued to confirm the design requirements as follows:

- Stresses in the repair laminate shall not exceed 1/6 the ultimate tensile stress of the laminate
- Stresses in the substrate shall not exceed 95% specified minimum yield stress (SMYS) of the base material.

8.5.5.10 Design Output

The outputs of the design calculations for the repair system are the following:

- thickness of the repair laminate, t_{design} , expressed in millimetres and number of layers, n ;
- total axial repair length, l , expressed in millimetres;
- axial extent of repair, l_{over} , expressed in millimetres;
- cure schedule required, expressed in minutes or hours at temperature in degree of Celsius.

The design thickness of the repair shall be expressed as number of layers, n , for installation purposes, in accordance with Formula (7):

$$n = \frac{t_{\text{design}}}{t_{\text{layer}}} \quad (7)$$

where t_{layer} is the thickness of an individual layer of repair laminate, expressed in millimetres.

The minimum design thickness for the repair laminate is given by

- type A repairs. The greater thickness of either two layers or 2 mm whichever is the greater, and
- type B repairs. That qualified by testing as described in 8.5.5.1. Where the potential for external third-party accidental impacts are agreed by the owner to be unlikely the minimum thickness requirement may be relaxed to the greater of two layers or 2 mm.

8.5.5.11 Additional Repair Design Considerations

The repair system shall be designed to ensure a continuous protection against corrosion between the repair and the existing coating.

The composite repair system is applied on the prepared steel surface (bare steel) which may require to remove the existing external coating. In that case, after composite repair is installed and fully cured, the anti-corrosion protection of the remaining bare steel area shall be performed as follows:

- edges of the composite repair shall be beveled in order to avoid any possible water retention and infiltration. This is particularly important for repair on risers, in vertical position.
- for paint and corrosion coating application, design proposal shall be submitted to company for approval, as this will be a case by case evaluation.
- for above ground pipelines painting system shall be applied according to IGS-O-CH-042 as shown in figure 2.
- for buried pipelines, if adhesion and disbondment with existing coating is qualified for long term, composite repair system or three-ply co-extruded plastic tape regarding to

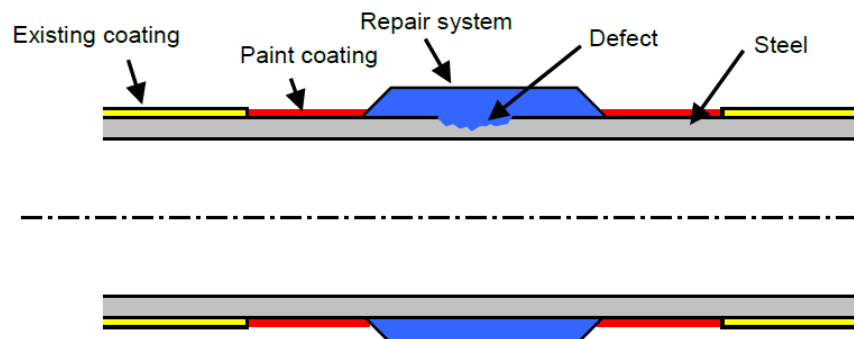


Figure 2 Anti-corrosion protection system for above ground pipelines

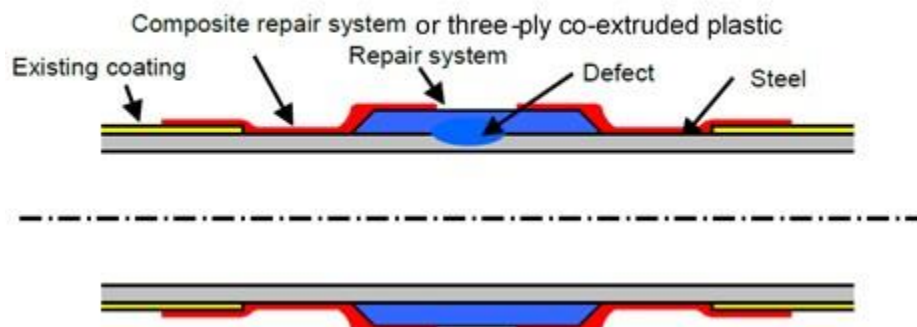


Figure 3 Anti-corrosion protection system for buried pipeline

existing coating as per IGS-C-TP-014-1 or IGS-C-TP-014-2 can be applied for anti-corrosion purposes, if adhesion and disbondment with existing coating and applied composite repair is qualified for long term as figure 3.

Note 1: The minimum overlapping on each side of the repair shall be 100 mm.

Note 2: Durability of bonding between dissimilar materials shall be evaluated

8.6 Re-Qualification of the Repair System

8.6.1 Overview

If a change or modification to the repair system has occurred, then the testing specified in 8.6.2 and 8.6.3 shall be completed.

If the modified repair system is found to be of lower performance than the original repair system, then it shall be treated as a new system and validated according to 8.4.5.

If the modified repair system is found to be of higher performance than the original repair system, then it may be treated as a new system and validated according to 8.4.5, or the qualification data from the original repair system may be used.

8.6.2 For Type A Defect Repairs

Re-qualification tests shall include the testing specified in part 2 of the annex B of ISO 24817.

If the repair system has been validated according to part 6 of the annex B of ISO 24817, then the repair system shall be subject to the survival testing specified in part 2.1 of the annex E of ISO 24817 E.2.1.

8.6.3 For Type B Defect Repairs

Re-qualification tests shall include the testing specified in part 2 and 3 of the annex B of ISO 24817.

Note that only three tests are required and results shall be compared with γ_{LCL} of the original repair system, as per part 4 of the annex D of ISO 24817D.4.

Essential variables for repair system qualification are as follow:

1. Resin composition
2. Resin supplier
3. Hardener composition
4. Hardener supplier
5. Fiber type (glass, aramid, etc.)
6. Fiber supplier
7. Fiber tape manufacturing process
8. Fiber tape densities in longitudinal and transverse direction
9. Pipe surface preparation tool
10. Pipe surface heating prior to repair (temperature and time)
11. Post-curing process (temperature and time).

Whenever one of the previously listed essential variable change, the repair system shall be re-qualified.

8.7 Composite Repair Design Key Issues

A few of the important questions to be addressed in the process of designing a composite repair which shall be checked by owner are listed in the bullets that follow:

- What is the elastic modulus and short-term tensile strength of the composite material system? Factors that affect performance of the composite material include fiber type, matrix material (i.e. resin), and fiber orientation.

- Has an appropriate filler material (i.e. load transfer material) been selected? Has this material been subjected to the required testing regime to ensure that it can withstand the anticipated loading conditions?
- Is material property, including filler and composite fiber material, data available as a function of temperature? Having data on the matrix resin alone is not sufficient for applications where conditions exceed room temperatures (tensile test data is typically obtained at room temperature).
- Has the repair been subjected to the full battery of loads to which it will experience in service? If so, has an appropriate safety factor been applied to ensure that a long-term solution has been achieved?
- What documentation has been provided from the composite manufacturer/supplier? Do they have a certificate from NIGC demonstrating their compliance with ISO 24817 and clause 8-4 of this standard?
- What Quality Assurance methods are in place to ensure that what has been designed is being delivered to the pipeline's owner? Does the manufacturer/supplier have a method for traceability and tracking products?
- Are there any chemical compatibility issues with the composite materials (e.g. external environment or fluids that may come in contact with the repair)?

9 Installation

9.1 Storage Conditions

Storage of material shall comply with the repair system supplier's instructions. SDS sheets shall be retained for reference. All materials shall be stored and controlled according to national safety regulations and NIGC HSE department's relative procedures.

All materials shall be clearly labelled with relevant health and safety data, batch number, expiry date and any other relevant technical information.

Control of the temperature during storage shall be maintained. (Shelf lives can be reduced significantly if temperatures are allowed to exceed those specified by the repair system supplier.)

Reinforcements shall be stored to ensure that condensation due either to storage of material below the dew point or on movement between areas at different temperatures does not occur.

Shelf lives quoted by the repair system supplier shall be observed.

Disposal of time-expired material shall be carried out in compliance with local regulations and according to repair system supplier's instructions.

9.2 Documentation Prior to Repair Application

9.2.1 Method Statement

Each repair shall be covered by a method statement which is often generic in nature that describes the main procedures to be carried out prior to and during repair system application.

Typically, the method statement provided by the repair system supplier includes the following information:

a) Health and safety, comprising

1) list of materials to be handled including copies of SDS sheets and NIGC HSE department statements by ensuring that the SDS includes detailed Occupational Exposure Limits (OELs), flashpoint, and reactivity under UV or curing temperature conditions.

- 2) details of protective measures to be adopted, and
- 3) list of hazards associated with pipeline or equipment to be repaired and equipment in the vicinity of the repair site with protective measures;

Note: HSE documentation shall include proximity risk maps for repair locations, risk of flammable vapor accumulation, and handling instructions for resin/hardener systems with low flashpoints. SDS must be site-specific, recent, and aligned with the materials' actual curing profiles.

b) Quality assurance, comprising

- 1) generic overall QA plan, and
- 2) generic details of hold/inspection points in the repair application procedure (see 9.4);

c) Installation procedure, including generic overview of installation procedure;

d) Environmental, including information on disposal of unused material.

9.2.2 Work Pack

Each repair shall also be covered by a work pack which is specific and relates directly to the procedures to be performed prior to and during repair system application.

a) Scope of work, including specific details of the design conditions and status of the component requiring repair;

b) Health and safety, including SDS and following IPS-G-SF-130 and IPS-G-SF-870 for the materials to be used and related NIGC HSE department statements;

c) Risk assessment, including details of tool box talk with site personnel;

Note: The risk assessment shall follow a standardized matrix format and be updated before repair starts. It must include human factors, environmental risks, and emergency mitigation steps. Toolbox talk shall be documented and signed by all on-site workers.

d) Repair details, including drawing of planned repair, thickness, and dimensions of repair and cure schedule;

e) Installer qualification level, defining whether a supervisor is required for the specific application;

f) Specific installation instructions, including any amendments to the generic installation instructions provided in the method statement. These instructions shall include

- 1) acceptable environmental conditions of site at time of repair,
- 2) material storage,
- 3) surface preparation,
- 4) resin system mixing,
- 5) laminate lay-up for the component geometry,
- 6) laminate consolidation procedure (fiber wetting),
- 7) cure schedule as defined in 8.5.3, and
- 8) key hold points.

Further details of these requirements are listed in Annex J of ISO 24817. The key hold points to be observed during repair system installation are summarized in Table 7.

- Quality assurance, comprising and specific amendments to the generic QA plan provided in the method statement, e.g. details of any materials tests to be carried out, if specified by the owner (as per Annex B of the latest edition of ISO 24817).

- Installer certification, comprising a named list of the installers and their individual qualification certifications.

In addition to above mentioned items, in any case a quality control plan (QCP) or inspection and test plan (ITP) shall be issued by the pipeline owner's engineering department for any repair. Requirements listed in table 8 shall be at least considered.

Table 7 Hold Points During Installation of a Repair System

Hold point	Conducted by	Checked and approved by
Method Statement	Installer	Company review
Repair design (calculation note)		Shall be checked by engineering department of the owner
Materials Preparation - reinforcement - resin		Shall be witnessed by inspection department of the owner or delegated third party. Repair system shall be the one selected and use for designing the repair.
Environmental conditions - relative humidity - dew point - component surface temperature		Shall be witnessed by inspection department of the owner or delegated third party
Surface Preparation - inspection - surface profile test - mechanical test (stipple test) - Cleanliness of the surface		
Resin+ hardener mix: according to manufacturer document		
Fiber tape impregnation		
Filler Profile		
Stage check on reinforcement fiber or cloth orientation		
Overlap between two consecutive turns		
Tests on Repair Laminate - cure (and post-cure) through hardness test or time-temperature measurements taken from the repair - thickness - repair axial extent and tape length - absence of disbonding (UT) - external inspection (see Table 10)		Shall be approved by inspection department of the owner or delegated third party. Curing time shall be recorded and pressure shall not be increased back to the nominal before the curing time is achieved and curing is confirmed by shore hardness measurements
Preparation of samples in field conditions for company: - Resin + hardener - Impregnated fiber tape		Shall recover samples for validation tests: glass transition temperature and tensile performance of the fibers
QA records		Company review
Pressure Test		Shall be witnessed by inspection department of the owner or delegated third party.

9.3 Installer Qualifications

Personnel involved in the installation of a repair system shall be trained and qualified in accordance with Annex I of ISO 24817.

9.4 Installation Procedure

The repair system supplier shall provide full installation instructions. There are two phases involved in obtaining an acceptable result.

The first phase involves properly documenting the condition of the pipeline being repaired. Sand-blasting is often required to properly prepare the surface of the pipe so that minimal additional work is required by the applicator before the repair is made. The second phase involves actual application of the composite repair.

It is also imperative that the recommended installation techniques provided by each manufacturer be followed. The only composite repair systems that should be used are those manufactured by companies with certified training programs where hands-on installation classes are required for certified installers.

9.4.1 Phase One: Examination and Documentation of the Pipe to be Repaired

1. The region to be repaired shall be inspected by owner to assess the precise dimensions and nature of the defects. If necessary, confirm using an appropriate NDE technique, such as magnetic particle.
2. The level of corrosion in terms of depth and length shall be determined by supervisor delegated by the owner of the repair system. It is assumed that prior to making the decision to make a repair that previous measurements have been made.
3. Provide measurement results of the anomaly to the repair provider to determine the appropriate composite repair design.

9.4.2 Phase Two: Make the Repair

1. Determine (or confirm) the appropriate composite repair thickness based on the measured corrosion damage and expected operating/design conditions. The length of the composite repair should extend at least 50 mm beyond the extent of the corrosion damage in the longitudinal direction. Section 7.5.8 of ISO 24817, provides additional guidance on repair length.
2. Before installation of the composite material, ensure that the surface has been properly prepared (see 9.4.3).
3. For mechanical damage and dents additional steps may be required before the installation of the repair system, including grinding to remove stress risers.
4. Prepare the work surface where all mixing and preparation of the composite materials is to take place.
5. Mix the filler material (typically a two-part epoxy putty). Fill the damaged region of the pipe with the filler material. Trowel the surface of the filler material to ensure that its surface is contoured with the outside surface of the pipe. Rigid repair systems require additional care to fill all potential voids (ex. areas along a SAW weld cap) when applying the filler material.
6. Mixing the resin to coat the outside surface of the pipe (typically a two-part epoxy or other resin systems) shall be checked by supervisor delegated by the owner of the repair system. Thoroughly cover the repair region of the pipe, extending as appropriate beyond the extent of the corrosion damage.
7. The proper number of composite layers shall be applied on the pipe as per related design documentation (see 8.5.4). The composite material should be pulled tight during installation to ensure that no wrinkles or bubbles are present. Proper overlap should be maintained. Continue wrapping until all designated layers are installed. It is essential that

the manufacturer's recommendations be followed as prescribed, especially with regards to orientation of the fibers, overlapping, and staggering techniques of the fiber mat.

8. Once all of the composite layers have been installed, the exposed edges and ends of the composite repair should be sealed as per section 8.5.5.11.

9. It is recommended that certified/qualified personnel remain on-site until a sufficient level of the curing has occurred. This includes monitoring for sag on the bottom portion of the repair during a horizontal application or slide on a vertical application.

10. The final inspection and documentation of the installation shall be complete before the repair is re-coated or the ditch is back filled. Allow the composite materials to cure to an acceptable level before re-coating or backfilling.

9.4.3 Surface Preparation

Prepare the repair area surface by abrasive blasting, hand tool cleaning, or power tool cleaning. The preferred surface preparation is abrasive blasting as it prepares the pipe to a near white metal finish SA 2 ½ as per ISO 8501 (should be specified by manufacturer). ISO 8501, ISO 8502 and ISO 8503 provide methods of assessing these factors and ISO 8504 provides guidance on the preparation methods that are available for cleaning steel substrates. For hand tool and power tool cleaning, remove all loose dirt and debris, rust, and other contaminants that reduce adhesion. A roughened, clean surface is necessary to properly install any composite repair system and ensure that corrosion does not develop beneath the repair. The area prepared for the composite installation must extend at least 50 mm beyond the extent of the corrosion defect (specific details can be found in 7.5.8 of ISO 24817).

Note: The time period between the completion of the surface preparation stage and the application of the repair laminate should be as short as possible but no longer than 4 h.

9.5 Repair Completion Documentation

The following documentation shall be provided by the repair system installer to the owner on completion of the repair. All records should be retained by both the owner and repair system installer for the duration of the repair design lifetime.

a) Repair details, comprising

- 1) repair reference number,
- 2) location of repair.

b) Repair design, comprising details of laminate lay-up:

- 1) design data (Annex A) and calculations;
- 2) repair sketch;
- 3) number of layers;
- 4) repair area covered including axial extent;
- 5) orientation of individual layers of reinforcement (this may be presented as a written description or a drawing incorporating standard details such as overlap and taper dimensions and length information).

c) Material records, comprising

- 1) repair system supplied,
- 2) resin type and quantity,
- 3) reinforcement type and quantity,
- 4) batch number of materials.

d) Repair application, comprising

- 1) details of surface preparation procedure, including method of application, equipment used and inspection and testing method,
- 2) details of actual defect size and location,

- 3) details of the environmental conditions including dew point temperature, ambient temperature, substrate temperature and relative humidity and any relevant limitations,
- 4) details of the filler used to achieve a smooth outer profile prior to the application of the laminate,
- 5) details of time limitations between stages of the repair, e.g. between surface preparation and lamination,
- 6) details of the mixing of the resin and hardener,
- 7) details of lay-up procedure including orientation of the repair laminate, including also if the repair laminate was applied in stages,
- 8) details of curing schedule and comparison with specified cure schedule

e) Quality control records, comprising

- 1) repair reference number,
- 2) visual inspection report,
- 3) thickness measurement,
- 4) repair axial extent measurement,
- 5) curing details (time, temperature) and if performed post curing details, temperature and time,
- 6) personnel (installer) applying the repair system,
- 7) Barcol or Shore hardness measurement (if carried out),
- 8) DSC measurement as per ASTM E1356 (if carried out),
- 9) bond strength measurement (if carried out),
- 10) Inspection and NDT results (if carried out).

f) Independent inspection, comprising test report (if carried out).

g) Service inspection, comprising details of service inspection intervals and repair condition monitoring guidance (Clause 10).

9.6 Live Repairs

Repairs to defects that are not through-wall within live substrates may be performed, provided that the associated hazards are fully considered in the repair feasibility assessment (clause 8.1) for the operation. This shall include any hazards to surrounding live equipment in addition to that being repaired.

Repairs to defects that are through-wall within live substrates may be performed provided that no leakage exists in substrate.

Post-curing using elevated temperature heating should not be undertaken on live pipes unless it can be demonstrated that the required post cure temperature can be achieved within the repair laminate.

9.7 Repair of Piping Components

Guidance for the surface preparation of piping components is the same as for repairs on straight pipe (see Annex J of ISO 24817).

The axial profile of the repair laminate in the transition from the main pipe body to the component causing the protuberance should be at least tapered with taper dimension of 3 (axial direction) to 1 (radial direction). The precise details of the repair, e.g. repair laminate lay-up and orientation relative to piping components, shall be provided by the repair system supplier. The arrangements at the edges of the repair, e.g. tapering and profiling onto raised faces, shall also be provided by the repair system supplier.

9.8 Environmental Considerations

Only repair materials that allow for satisfactory disposal according to prevailing environmental regulations shall be used as described in 9.2.1.

Information and procedures for disposing of unused chemicals, resins and waste shall be provided by the repair system supplier. Incineration in the open air shall not be performed.

9.9 Repair Marking

For transmission pipelines with pigging ability, a marking system (e.g. ferrous element or metal banding) shall be inserted in the repair system in order to allow clear location identification by intelligent pig during inspection runs. The marking system shall be placed in such manner that it does not affect the repair performance.

In addition to above mentioned marking, the UTM coordinates of the repair point shall be recorded.

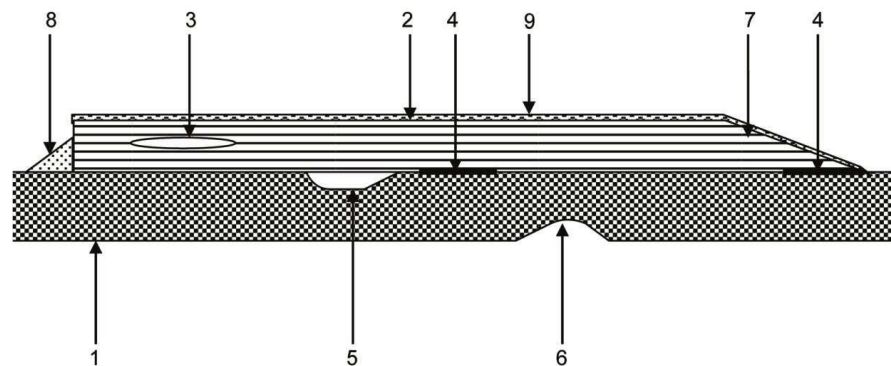
10 Testing and Inspection

10.1 General

All testing and inspections shall be conducted as per the latest edition of ISO 24817 considering the following issues:

- inspection of the repair laminate;
- inspection of the bond between the repair laminate and the substrate;
- inspection of the substrate underneath the repair laminate;
- system should not influence or prevent any internal inspections (e.g. from pigging inspection tools) that are performed on the pipeline.

The basic structure of a repair system in this context is considered in Figure 4.



Key

- 1 substrate, pipe wall
- 2 repair laminate
- 3 internal laminate defect
- 4 interface delamination de-bond
- 5 external defects (with filler)
- 6 internal defect
- 7 taper of laminate (extends beyond overlay lover)
- 8 adhesive fillet
- 9 resin rich surface layer

Figure 4 Schematic of a repair system

10.2 Allowable Defects for the Repair System

The defect types and respective allowable limits for the different sections of the repair system are given in Table 8 prior to application of the repair and in Table 9 for after installation of the repair and in service.

The defects that are listed for the repair laminate and resin-rich layer are likely to arise during installation, as opposed to being caused as a result of deterioration in service. As a result, process control and monitoring of the repair material as it is being applied is the primary means of assuring good quality. The information given in Table 9 is typical of that used for composite process equipment, e.g. Glass-reinforced plastics (GRP) piping (see ISO 14692).

The defects that are listed for the interface between the repair laminate and the substrate refer primarily to the loss of adhesion. As with the repair laminate, the defects listed for the interface are generated during initial application. In the majority of cases, deterioration during service manifests itself as an interfacial delamination.

Table 8 Quality assurance checks for the substrate prior to application of the repair

Repair section	Defect	Allowable Limits
Substrate prior to repair application	Check substrate material is that for which the repair has been designed	
	Changes in geometry	Repair area to be free of sharp changes in geometry (all radii > 5 mm) or sharp geometry to be faired-in
	Surface preparation	In accordance with repair system specification
		Axial length to be in accordance with design
	Surface temperature	In accordance with repair design
	Defect	Dimensions do not exceed those for which the repair has been designed
		Defect nature to be that for which the repair has been designed
	Location of repair	Axial extent and positioning to be in accordance with design

**Table 9 Inspection requirements for the repair laminate
after installation and in service**

Repair section	Defect	Allowable Limits
Interface between pipe and repair at the ends of the repair, including adhesive fillets	Delamination (cracks between the pipe and the repair)	None allowed Tap test may help identify presence of delamination
Surface of repair (Resin-rich layer)	Cracks	None (check adhesive fillets)
	Foreign matter and, blisters	Maximum 10 mm in width, 1,5 mm in height
	Pits	Maximum 25 mm in diameter, 1,5 mm in depth No limit for depths shallower than 1 mm
	Wrinkles	No step changes in thickness in height greater than the lower of 1,0 mm or 20 % of the repair laminate design thickness
	Pin holes	None deeper than resin-rich layer
	Resin color	Uniform
	Dry spots	None
	Finishing materials	None (should be fully removed before inspection is completed)
Repair laminate	Fiber orientation	As specified in design
	Un-impregnated/dry fiber	None
	Exposed cut edges/fiber	None
	Foreign matter	None
	Axial extent and positioning of the repair	As specified in the design Does not extend beyond prepared surface
	Impact damage	None
	Delamination within laminate	None allowed Tap test may help identify presence of delamination

The defects that are listed for the substrate relate to those that have been repaired and to possible continued degradation of the wall thickness after repair due to internal corrosion or erosion. Monitoring of the remaining wall thickness may be required to ensure that the repair system continues to operate within the original design assumptions.

Note: Inspection and monitoring of repaired pipeline after installation shall be conducted by owner. It is recommended the inspection may be conducted for the first year of installation. Decision for further inspection may be made by the owner if required.

10.3 Repair of Defects Within the Repair System

Repairs containing defects that exceed the limits in table 9 and table 10 shall be removed and another repair system applied. However, on agreement with the owner, local removal of the damaged area and reapplication of the repair system materials to this area are allowable if the repair system supplier can demonstrate that this will restore the full performance of the repair.

Dry areas in the resin-rich surface layer should be repaired by abrading and cleaning the affected area and then wetting out with more resin.

10.4 Inspection Methods

10.4.1 General

The repair system supplier should provide guidance on techniques and methods for inspecting the repair system. Further guidance could be provided by inspection third-party companies. Inspection techniques may be applied immediately after the repair system application as a base line measurement or during the repair design lifetime. In most cases, the requirement is not to inspect the composite laminate, but to inspect the defect within the substrate with the overall aim of demonstrating the integrity of the complete system, i.e. substrate and repair.

10.4.2 Tap Test

The tap test may be utilized to identify delamination and voids in the cured laminate that sound hollow in comparison with a solid area. In the tap test, the surface of the structure is tapped by hand using a hard-blunt object such as a tapping hammer (less than 60 g), sounding wand, or a coin. This method is often used as the first inspection method, which may be followed by other nondestructive evaluation (NDE) techniques.

10.5 Repair System Maintenance and Remedial Options

10.5.1 Overview

The appropriate maintenance and replacement strategy for repair systems is a function of the type of original defect in the substrate. A risk assessment shall be completed to determine the appropriate strategy and shall consider the guidance given in this sub clause. Annex L of ISO 24817 provides informative guidance on how to manage the overall integrity of repair system applications.

10.5.2 Condition of the Repair - Visual Inspection

Visual inspection of the repair laminate for defects in accordance with Table 10 is recommended as part of the maintenance strategy. If defects are located, then further assessment shall be made in conjunction with the repair system supplier. The frequency of inspection should be determined in accordance with the risk assessment.

Where the pipe is coated, then in addition to the inspection detailed above, the inspector shall confirm that an additional coating covering the ends of the repair is present and in good condition.

If no coating over the ends of the repair is present and the pipe substrate is in good condition, then a coating should be installed. If corrosion is visible at the ends of the repairs, then the fitness for purpose of the repairs shall be considered by a reassessment of the design requirement.

Note: Pictorial guidance of defects after installation and in-service as well as coating requirements at ends of the repair are provided in tables 17 and 18 of ISO 24817.

10.5.3 Condition of the Pipe Substrate

10.5.3.1 External Defects

For external defects, it is assumed that further deterioration of the defect is stopped on application of the repair laminate. Therefore, the maintenance strategy should be to ensure that the repair laminate remains intact, i.e. the repair laminate is not damaged or partially delaminated from the substrate.

Inspection of the pipe beneath the repair shall be considered for all repairs. Radiography and eddy current techniques have been successful in interrogating the pipe beneath the repair; further advice can generally be obtained from the repair system supplier and third-party inspection companies.

It is recommended that a baseline inspection is completed after installation of the repair because it is much simpler to identify changes than to interpret the information gained by subsequent inspections.

For repairs with design lifetimes greater than two years, consideration should be given to confirming that internal corrosion has not commenced. If internal corrosion is determined as active, then a suitable strategy to mitigate the threat should be determined (e.g. change in process conditions, use of inhibitors or reduced life of repair, etc.).

10.5.3.2 Internal or Through-Wall Defects

For internal corrosion or through-wall defects, further deterioration or growth of the defect may continue despite application of the repair laminate. Therefore, in addition to the requirements set out in 10.5.3.1, the maintenance strategy should ensure that the internal defect does not grow to a size greater than assumed in the design or that the repair laminate does not delaminate from the substrate.

Therefore, information of the acceptable defect size determined by design shall be retained and be readily available.

The frequency of inspection should be determined in accordance with the risk assessment.

Inspection of the pipe beneath the repair shall be considered for all repairs the objective being to demonstrate the defect in the pipe remains within the acceptable limit determined by design. Again, radiography and eddy current techniques have been successful in interrogating the pipe beneath the repair; further advice can generally be obtained from the repair system supplier and specialist inspection companies. It is recommended that a baseline inspection is completed after installation of the repair because it is much simpler to identify changes than to interpret the information gained by subsequent inspection.

10.5.4 Remedial Options

If the assessment determines that replacement is required, then the only remedial option which can be considered is the removal of the repair (e.g. through ultra-high-pressure water jetting) and replacement.

Note: All safety requirements of water jet machines as per INSO 23200-1 shall be considered.

10.5.5 Extension (Revalidation) of Repair Design Lifetime

The decision to extend the repair design lifetime shall be documented along with supporting records which shall be retained for future reference (records shall include the risk assessment, original and any revised design assessments and the original installation documentation for the repair).

To revalidate the lifetime of a repair, the design and installation details shall be available (these shall include records of the surface preparation of the substrate and the design and cure of the repair met the original specifications) and the installation records sufficient to demonstrate the repair was installed in full compliance with the repair supplier's procedures. It is recommended that repair design lifetimes are only revalidated up to a maximum of 20 years (from the time the repair was installed). Revalidation of the repair design lifetime is performed by redesigning the repair based on the required lifetime and the most up to date inspection data on the defect of concern. This redesign may result in a thicker repair than currently installed which implies that extra layers of repair material shall be added to the existing repair.

For revalidation of lifetimes greater than 20 years, only a moderate lifetime extension is recommended, i.e. increments of no more than five years. It is further recommended that the repair and the substrate underlying the repair are fully inspected before considering revalidation.

Note: Extension of repair design lifetime shall be considered only in the case a sacrificial wrapping has been installed at the time of the repair and close to the repair locations. This sacrificial wrapping shall be submitted to the same temperature, loads and environmental conditions than the repair.

The purpose of this sacrificial wrapping is to perform tests periodically and determine the ageing behavior of the composite repair system.

Glass Temperature Transition (T_g) and absence of any delamination (UT methods) within the composite block or at the interface between composite block and the pipe, shall be assessed as a minimum. T_g will then be compared with T_g at the time of qualification or production test sample, using the same measurement method. In case of ageing, limit of extension shall be within the abovementioned range.

10.5.6 Future Modifications

It is not permitted to modify existing repair. Anytime the repair design has to be changed, the existing repair shall be removed and a new one shall be implemented by the repair system supplier.

11 System Testing

System pressure testing should be specified by the owner if required or as recommended by the relevant design standard for the substrate.

All repairs shall be cured in accordance with the repair system supplier instructions before system testing.

The repaired system shall be flushed with an appropriate medium prior to testing.

The recommended procedure for hydro-testing is as follows. The hydro-test should be performed at 1.5 times the design pressure for a period of at least 60 min, during which any changes in pressure and temperature shall be recorded. No leakage is permitted.

All supports and anchors shall be in place prior to pressure testing.

If the test pressure exceeds the pressure for which the repair system has been designed, then this higher pressure shall be considered as a separate design case. For the purposes of the design calculation, the hydro-test condition shall be treated as an occasional load.

Further guidance on system testing can be found in ASME PCC-2 Article 5.1 or other relevant documents.

12 Shipment, Packing and Packaging

Shipment, packing and packaging shall be according to the material (including resin, fiber etc.) supplier documents and recommendations.

13 Decommissioning

Reference should be made to the risk assessment prior to decommissioning of a repair system. If necessary, a separate risk assessment should be carried out.

The removal of repair material may be achieved by mechanical means (e.g. high-pressure water jetting regarding safety requirements as per INSO 23200-1). Procedures should be put in place to contain any dust that may be generated.

Care should be taken to avoid damage to adjacent equipment that is to remain in service.

Annex A (normative)

Design Data Sheet

Customer details	
Contact	
Company	
Address	
Telephone	

Component details		
Year of construction		
Location of defect		
UTM coordinates of defect		
Pipeline class location		
Buried	Yes ☐ No ☐	
Quantity (number of)		
Component reference		
Component specification		
Material/Grade		
Pipe type production	Seamless ☐ Welded (Longitudinal ☐ /Spiral ☐)	
External diameter (mm/in)		
Original wall thickness (mm)		
Minimum remaining wall thickness(mm)		
Pipe contents	Natural gas ☐	
Design temperature (°C)	Minimum:	Maximum:
Operating temperature (°C)	Minimum:	Maximum:
Pipe coating (existing)		

Repair class and lifetime				
Repair class	Class 3 as per ISO 24817			
Repair design lifetime(years)				
Other data				
Loading	Operating	Design	Test	Comments
Pressure rating (MPa)				
Axial Load (kN)				
Bending moment (Nm)				
Shear load (kN)				
Torsion (Nm)				
Other loads (N)				

Details of defect area:

Repair specification			
Type of defect			
Nature of defect			
Current size	Area (mm ²):	Depth (mm):	
Projected size	Area (mm ²):	Depth (mm):	
Cause	Corrosion ☐	Erosion ☐	Note:

Effect	External ☐	Internal ☐	Note:
	Perforated ☐		
MAOP (MPa)	(output of defect assessment see part 4)		

Anticipated conditions during implementation of repair		
Pipe temperature (°C)	Minimum:	Maximum:
Ambient temperature (°C)	Minimum:	Maximum:
Pipe pressure (Psi)		
Pipe contents		
Humidity (%)		
External environment		
Constraints		

Equipment to be provided by client for installation (surface prep., etc.):

-
-
-

Other information:

Prepared by:

Date:

Annex B (Normative)

Additional Qualification Tests

B.1 Pull off test on steel

The objective of the test is to evaluate the adhesion of the composite repair system by determining the tensile pull off force before detaching from the steel, before and after ageing in hot water. Breaking points, demonstrated by fractured surfaces, occur along the weakest plane within the system consisting of the dolly, the adhesive, primer coating and composite layers.

B.1.1 Preparation

The composite repair system shall be applied on three prepared steel surfaces (flat or pipe section of approx. 200mm x 200mm which will constitute a test sample).

two test samples shall not be subject to ageing.

One test sample shall be subject to ageing, immersed in hot deionized water with unprotected edges during 28 days at the maximum design temperature of the composite repair system +20°C. The sample will be allowed to cool down before the pull off test.

B.1.2 Test procedure

The pull off test shall be performed at two locations per sample (6 tests in total) in accordance with ISO 4624.

B.1.3 Acceptance criteria

The failure shall occur in the composite system, with a minimum value of 5 MPa for the sample with no ageing and 50% of the average value obtained for the sample with ageing.

B.2 Pull off test on coating

For anti-corrosion protection continuity purposes required in location 2, the test defined in M.1 shall be performed on the composite system applied on the same coating as the pipe to be repaired.

The failure shall occur in the composite system, with a minimum value of 3 MPa before ageing and 50% of the average value before ageing, once ageing has been undertaken.

B.3 Cathodic disbondment test

Cathodic disbondment test shall be required in location 2 and 3. The objective of this test is to assess the resistance of composite repair system to disbonding when exposed to cathodic protection.

B.3.1 Preparation

The composite repair system shall be applied on 2 prepared steel surfaces (flat or pipe section of approx. 100 mm x 100 mm which will constitute a test sample).

B.3.2 Test procedure

The test shall be performed according to ISO 21809-1 Annex H.

1 sample shall be exposed during 2 days at 65°C or the maximum design temperature of the composite repair system + 20°C, whichever is the lowest.

1 sample shall be exposed during 28 days at the maximum design temperature of the composite repair system +20°C.

The test samples shall be polarized to -1500 mV with respect to the calomel reference electrode. For temperature check, thermocouple shall be positioned inside the cell at contact to the steel.

For interpretation of test result, the following procedure shall be followed:

- Once the test is finished, abrade the composite system top layers, until only the first layer is visible on the whole area under the cell during the test

- Make twelve radial incision using a sharp knife through the composite system down to the steel, extending outwards from holiday for a distance of at least 40 mm. Make the incision approximately 30° angle of each other's.
- Insert the knife point into the center portion of the holiday down to the metal substrate. Using a gentle levering action, peel away slowly a radial section of coating continuing until firm action is encountered. Record distance up to which coating is disbonded (and not discoloration of the steel)
- Repeat with each segment
- Calculate the average of the twelve measurements. Record the value.

B.3.3 Acceptance criteria

The measured disbonding radius shall not exceed:

- 3 mm on the sample exposed during 2 days at 65°C
- 5 mm on the sample exposed during 28 days at the maximum design temperature of the composite repair system +20°C.

B.4 Pipe spool axial strength test

When the remaining steel cross-sectional area at defect location is not sufficient to withstand true wall axial loads, the composite repair system shall be qualified for axial strength.

B.4.1 Preparation

The test spool shall be cut in 2 segments. The composite repair system shall be applied on the 2 segments aligned, as presented hereunder. The repair shall be designed in accordance with latest edition of ISO 24817 for minimum thickness $t_{min,a}$ and minimum axial extent l_{over} required for short term axial load resistance (i.e. non-aged mechanical properties shall be considered). The axial load to be considered shall be greater than the end cap effect at design pressure.

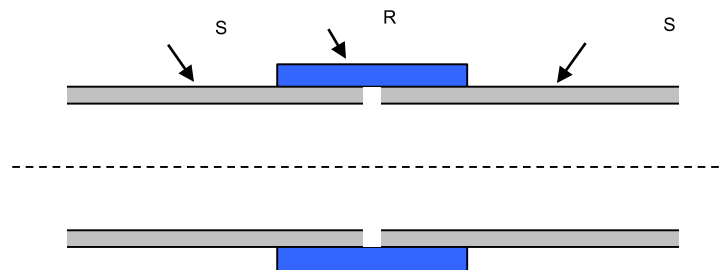


Figure B1 Sample preparation for pipe spool axial strength test

B.4.2 Test procedure

A tensile load shall be applied progressively on the spool, until the failure occurs. The failure mode may be either a circumferential rupture in the composite system, or a lap shear failure between the composite system and the steel.

B.4.3 Acceptance criteria

The failure shall be a circumferential rupture in the composite system, not a lap shear failure. The tension at failure shall be above the calculated axial load considered for the design of the composite repair system.