CANADIAN ASSOCIATION
OF PETROLEUM PRODUCERS

BEST MANAGEMENT PRACTICE

Use of Reinforced Composite Pipe (Non-Metallic Pipelines)

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Overview

This guide is meant to provide increased awareness among designers, installers and users of non-metallic reinforced composite pipeline systems of some industry practices and lessons learned regarding reinforced composite pipelines as used by the upstream oil and gas industry. This guide is not intended to be a detailed guide or design manual on the use of these materials for pipeline applications. Significant industry literature and documentation already exists on the design, manufacturing, installation, and operation of reinforced composite pipelines. This information currently resides in pipe manufacturer's manuals and various industry standards and guides published by organizations such as ASTM International, American Petroleum Institute (API) American Water Works Association (AWWA), and International Organization for Standardization (ISO).

In Canada, the oil and gas industry pipeline code, CSA Z662-2007, has a complete chapter that is dedicated to non-metallic pipeline systems (see Clause 13.0) which also includes specific requirements for reinforced composite pipelines (see Clause 13.1).

This guide is intended to complement these existing industry documents and standards and not to replicate their contents.

Therefore, the main intention of this guide is to address the following:

- Differences between conventional steel pipe and reinforced composite pipe;
- Lessons learned and recommended best practices as gathered from Canadian industry experiences;
- Provide some guidance for designers, installers, and users who may have limited experience with reinforced composite pipelines.

Users should frequently consult the manufacturers of the pipe products in use or under consideration for use for clarification and suggestions regarding the best practices, considerations and applications of the materials in question.

In addition, pipeline operators should be aware of the applicable regulatory requirements for reinforced composite pipelines in the jurisdictions they are operating within. This guide is not intended to describe or define the application of local provincial or municipal government regulatory requirements that may apply to pipeline projects.

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1 Project Scope

The scope of this document is to provide some best practices for users of reinforced composite pipeline materials. The materials discussed within this guide include both standard individual length rigid pipe (or *stick pipe*) and flexible reinforced composite pipes (or *spoolable pipe*).

1.1 Materials

The use of the term *reinforced composite pipe* may mean different things to different people as it is often applied to many different types of non-metallic pipe. For the purpose of this document, rigid individual length reinforced composite pipe will be referred to as "stick pipe" while spoolable reinforced composite pipe will be referred to as "spoolable pipe".

Stick pipe generally refers to a fiberglass wound pipe material with an epoxy based binder.

There are two general categories of spoolable pipe: bonded Spoolable Composite Pipe (SCP) and un-bonded Reinforced Thermoplastic Pipe (RTP). RTP products are available using un-bonded reinforcement such as glass fiber, steel strip, or polymer fiber tape.

1.2 Service Application

The service applications discussed are for pipelines used by the upstream oil and gas industry located in western Canada; including oil well multiphase flow lines, gas gathering pipelines, oilfield water disposal pipelines, and oilfield water injection pipelines. Other specialized applications may also be relevant, such as large diameter pipelines for hot water supply, firewater distribution systems within plant sites or between base processing plants and remote mining sites.

1.3 Pipe Size

Pipe sizes for stick pipe can vary from NPS 2" to NPS 48"—or larger depending on the manufacturer. Spoolable pipe diameters available are NPS 2" to NPS 6". Smaller diameter pipe may be available by special order.

1.4 Pressure Ratings

Pipe pressure ratings for stick pipe will vary by diameter and wall thickness. Typically, smaller diameter pipe is available with pressure ratings up to approximately 20 mPa while larger diameter pipe, such as NPS 36", are available at much lower pressure ratings of 1.0-2.0 mPa.

For the various spoolable pipe products, different pressure rated pipe products are available, up to approximately 17.0 mPa. The pressure rating available will depend on the product and pipe diameter involved as not all spoolable pipe products are rated for the same pressure. In some cases, pipe manufacturers may be capable of producing special sized or pressure rated pipe that may not be listed in their standard product literature.

2 Review of Non-metallic Pipeline Failures

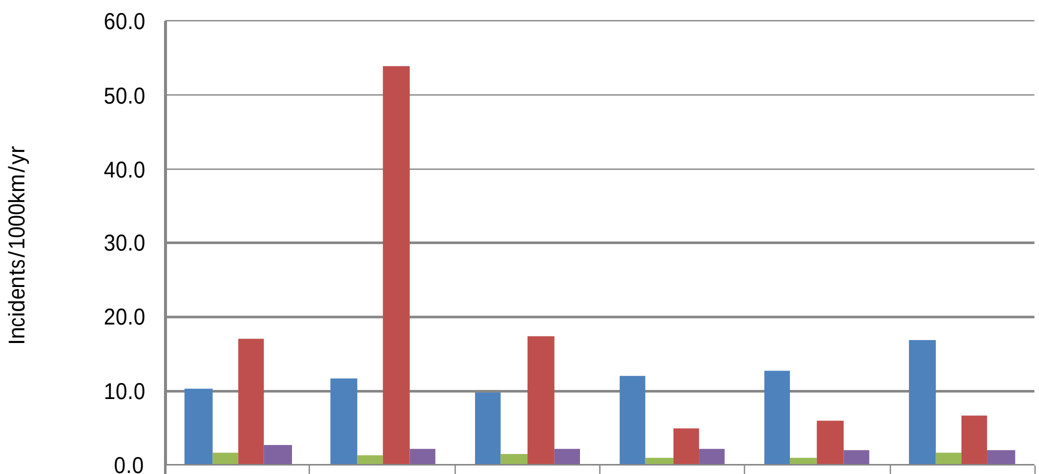
2.1 Summary

In 2007, an analysis of pipeline failure statistics was performed and presented at a pipeline symposium held in Banff, Alberta. The analysis showed a relatively high incident rate with reinforced composite pipelines—stick pipe in particular.

The incident frequency for stick pipe was higher than that of both steel pipelines and other non-metallic pipeline materials reviewed. A large percentage of the incidents involved were classified as pipe mechanical construction damage, corrosion failure of associated steel piping risers, and mechanical valve/fitting failures.

Figure 2-1 provides a summary of the incident frequencies determined by material type.

Figure 2-1 Pipeline Failure Frequency for Alberta Pipelines



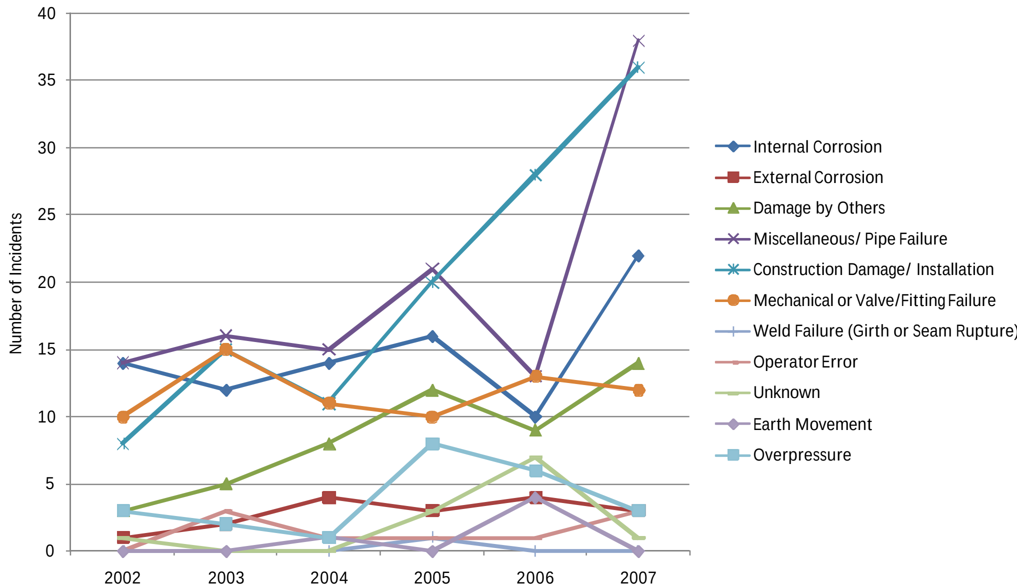
	2002	2003	2004	2005	2006	2007
Fibreglass	10.5	11.9	10.0	12.1	12.7	17.0
Polyethylene	1.8	1.3	1.7	1.1	1.2	1.9
Composite	17.3	54.0	17.4	5.1	6.0	6.6
Steel	2.8	2.4	2.4	2.4	2.0	2.0

Figure 2.2 provides a summary of reinforced composite pipeline failures in Alberta by cause in 2007. The data reveals some of the more common and reoccurring stated causes of failures, including:

- Damage resulting from installation practices;
- Corrosion of associated steel pipe risers and fittings;
- Damage by others (third party damage);
- Mechanical failures of valves or fittings;

- Miscellaneous/pipe failure;

Figure 2-2 Summary of Reinforced Composite Failures by Cause



2.2 Common Incident Causes/Potential Solutions

2.2.1 Installation Related

Installation related damage leading to pipe failures result in many forms. Most often, installation damage is unintentional and results from trying to install reinforced composite pipelines using similar techniques and installers used for steel pipelines. The reinforced composite pipe installation requirements generally do not differ from good installation practices for steel pipelines. However, reinforced composite pipe is far less forgiving than steel due to installation related deficiencies such as poor soil support, inappropriate anchoring, pipe impacts and improper backfilling practices.

In some cases, leaks caused by installation damage may be identified in the preliminary pressure test. In other cases, damage may take much longer to develop and cause a failure during operation. Two primary forms of damage that may take years to cause failure include pipe abrasion (caused by sharp objects, such as sharp rocks, rubbing against the pipe) and pipe impact (caused by dropping heavy items such as frozen backfill or large rocks over the pipe during backfilling).

A primary damage mechanism is the lack of underground pipe support. If the soil support to the pipe is not adequate or uniform, the reinforced composite pipes could be damaged due to differential pipe settling and the development of excessive axial or shear stresses in the pipe body or at connections. Such instability is occasionally created during construction when the soil is overly excavated at the pipe-ends resulting in stability issues when the soil is placed back around the pipe.

> *Note:*
> Where the reinforced composite pipeline is connected to aboveground steel headers or wellsite piping, the steel piping should be supported independently of the pipeline risers. It is not recommended that anchoring to an aboveground steel piping system be utilized.

For spoolable pipe risers, an underground structural steel support is often used to secure the riser; however, this type of support structure is not intended to support aboveground steel piping.

Another area of concern for stick pipe is *pipe joint integrity*. As a general rule pipe joints are made from either threaded mechanical connections on smaller diameter stick pipe (<12inch) or adhesive bonded bell and spigot on larger diameter pipe.

Currently there is no technology for Non-Destructive Examination (NDE) of these joints before placing them into service. Therefore, the qualifications and competencies of joining personnel—along with strict adherence to the qualified joining procedure—should be required and is a key success factor. This is a challenging area to manage for pipeline construction projects, especially for installers whose pipeline installation experience is based primarily on steel pipelines.

Similarly, each spoolable pipe product has different joining coupler designs which are mainly mechanical in nature and rely on strict adherence to installation procedures and qualified personnel. In some cases, manufacturers allow field installations of their proprietary connections by construction contractors. In such instances, the manufacturer should train installers for the use of their couplers. This approach may however present challenges to the end-user with respect to managing joint-quality and determining who is qualified to make these connections.

With spoolable pipes a great deal of care should be taken to not over-torque the pipe body during placement. This is especially important during wintertime construction when the inner liner material is stiffer and less ductile as over-torquing could cause undetected cracks to develop in the outer reinforcement structure.

> *Example of Over-Torque Damage:*
> Over-torque damage could result from attempting to stretch or force the reinforced composite pipe (with ends that already have flanges installed on them) to mate-up to the fixed risers in situations where the aboveground risers are installed before constructing the pipeline.

With spoolable pipe, kinking can occur during installation and requires careful unreeling and vigilance during construction. This is especially important if heat is applied to the pipe reel during winter construction as overheating or non-uniform heating on the reel may occur causing kinks to form where the pipe is more pliable in hotter areas and stiffer in colder areas of the reel.

Where spoolable pipes or reinforced composite pipes are installed as a liner through an existing steel carrier pipe, support of the spoolable pipe where it enters and exits that steel pipe is of primary importance. The steel carrier pipe will normally behave similar to a solid and settled area of ground. However, the area where the composite pipe exits is subject to new and varying soil settling that could lead to a failure at the entry/exit areas of the carrier pipe. Furthermore, any intermediate bell-hole excavation locations that connect two adjacent pull sections through existing carrier pipe may cause differential soil settling and excessive shear stress to develop within the spoolable pipeline.

The need for internal and external corrosion protection for metallic joining couplers used for spoolable pipes should also be provided based on the corrosiveness of the service fluid and general soil conditions. Application of protective coating and Cathodic Protection (CP) must also be considered.

2.2.2 Internal Corrosion of Steel Risers

In some cases, the use of a carbon steel pipe riser for reinforced composite pipelines is preferred. The use of steel pipe is usually to provide increased strength, damage resistance or fire resistance for the pipe riser section.

Since reinforced composite pipelines are often installed in highly corrosive service fluid, internal corrosion of the steel pipe riser should be considered a threat and mitigated.

Most often, this is accomplished by the use of internal plastic coatings that are shop-applied beforehand. At times, specialty coated and welded insert fittings are used to fabricate risers using coated pipe sections.

A couple of factors to consider for use of plastic coatings with risers are the diameter and design of the riser. The use of NPS 2” diameter pipe is not recommended since generally this is too small to internally coat successfully.

The use of an appropriate internal coating product, combined with a quality application by an experienced coating application expert is highly recommended. There are several internal pipe coating application experts available within the industry that specialize in this type of coating application and should be utilized for riser coatings. Industrial coating manufacturers should also be consulted for their recommendations of suitable internal coating materials and applicators. Using a coating with adequate temperature and chemical resistance is also of key consideration. Epoxy based coatings are most often specified in typical thickness range of 300-400 microns (12-16 mils).

Internally coated steel pipe risers should also be designed with suitable flanges or fittings that provide internal access for both weld area grinding and the coating application as coatings may fail prematurely if weld beads are left rough or if weld splatter exists. Where access for weld grinding in pipe spools is not practical, the use of alternate welding processes that develop a smoother internal weld bead, such as MIG, should be considered. NACE SP0178 provides information on preparing weld surfaces for internal coating application.

Diameter differences between reinforced composite piping and the riser piping (particularly when the riser piping diameter is smaller) should be evaluated in the coating selection step with regards to the erosion resistance properties of the coating. Where possible, gradual diameter changes should be used as more aggressive changes may lead to pre-mature coating failure (i.e. NPS 4 piping reduced down to a 2" valve assembly). Furthermore, flanged connections versus welded connections should be considered for the ease of coating smaller pipe sections and grinding weld areas for surface preparation. Cost is a factor to be considered here, as flanged connections are normally more expensive than welded connections.

The field application of internal coatings is not normally recommended due to the inability to adequately clean the steel pipe and apply uniform coatings under typically adverse field conditions. Therefore, steel pipe riser internal coating applications should be performed in a specialized coatings application shop.

It is also common to install reinforced composite pipe risers and to transition to steel pipe just above ground level with a flange. This is discussed in more detail in the design and installation sections (four and seven respectively) of this guide.

In some cases, Corrosion Resistant Alloy (CRA) piping—such as stainless steel alloys—has been used for risers; however, an appropriate alloy material should be carefully selected that is suitable for the service fluid. The alloy selection and connecting method between the alloy riser piping and the reinforced composite pipe should be discussed with the reinforced composite pipe manufacturer.

2.2.3 External Corrosion of Steel Risers

External corrosion of steel risers is also identified as a cause of failure. Where steel risers are employed in conjunction with reinforced composite pipelines, suitable external coatings such as liquid epoxy, shrink sleeves or tape wraps should be applied that are rated for the service temperature. To supplement the protective coating, spot CP should also be installed—usually with a sacrificial anode. It is recommended that the sacrificial anodes have above ground test leads to allow for anode life monitoring.

2.2.4 Third Party Damage

Damage by third parties is identified as a cause of service failures for reinforced composite pipelines. In some cases, this is a result of a lack of knowledge regarding the accurate location of underground pipelines or for not following industry recognized ground disturbance procedures.

It is important—and a CSA Z662-2007 pipeline code requirement—that all reinforced composite pipelines be installed with a suitable tracer wire to allow accurate use of pipeline location equipment. In older oil fields, pipelines may have been installed without tracer wire. In such cases, careful analysis and caution should be exercised—using information such as drawings or installation files—to best determine pipe location. Again, proper ground disturbance that avoids the use of mechanical excavation near buried facilities can help minimize this risk. Aboveground pipeline markers are also required and recommended to help increase awareness of underground pipelines and to help locate pipelines.

In cases where the location is not accurately known, there may be no choice but to perform careful hand or hydro-vacuum excavation to locate the pipeline. Use of steel probes pushed through the soil to locate pipe should be done very carefully as these can damage reinforced composite pipe if driven into the pipe wall excessively or have sharp-pointed ends.

3 Applications of Reinforced Composite Pipe

3.1 General

Reinforced composite pipeline materials for the oil and gas production industry are available for various service fluids. Services can include the following applications:

- Oil, gas, water multiphase fluid pipelines;
- Gas gathering production pipelines and fuel gas supply pipelines;
- Oilfield water injection or disposal pipelines (produced and fresh water).

In most cases, reinforced composite pipelines are initially considered and installed to provide longer-term operating benefits to the pipeline operator. Initial costs will vary given the prevailing market conditions and price fluctuations for both steel and composite materials. Regardless of the initial material and installation costs, the potential for reduced operating cost is a primary consideration in the use of reinforced composite pipe. Where possible, comparisons between reinforced composite pipe and carbon steel pipe should be based on total life cycle costs that consider initial capital costs and the operating and maintenance costs over the life of the pipeline.

Corrosion resistance—to corrosive agents such as wet carbon dioxide and sodium chloride—is one of the primary benefits of reinforced composite pipe material and an important means of reducing operating costs. Reinforced composite pipes are designed to inherently resist soil-side external corrosion whereas steel pipelines require CP installation, regular monitoring/maintenance, and the provision of an external protective coating. Further, steel pipelines generally require various measures—such as the injection of a chemical corrosion inhibitor on a continuous- or batch-basis, internal thin film organic coatings and the use of pigs to remove stagnant water—to mitigate internal corrosion. Such methods represent additional operating costs that will last over the life of the pipeline.

In some cases, reinforced composite pipe is installed to provide increased resistance to the build up of deposits such as paraffin waxes or scale on the pipe internal surface. This is a benefit derived from the smoother pipe wall and the much lower thermal conductivity of reinforced composite pipe compared to steel pipe.

Internal corrosion of carbon steel pipe in water services can lead to the significant build up of scales or fouling deposits. Such build up may have a significant effect on pump pressure drop performance through the pipeline and lead to increased power consumption or decreased injection-well performance.

The internal surface of reinforced composite pipe is only slightly smoother than new steel pipe; however, the surface finish of new steel can degrade and become much rougher over time due to corrosion and/or scale build up.

Table 3-1 provides some of the typical published values of surface roughness and the Hazen Williams flow coefficient for reinforced composite pipes compared to carbon steel pipe. The typical values given in Table 3-1 are for general information only. For surface roughness values for individual pipe products the pipe manufacturer's product specifications should be consulted and their specified values used for individual project evaluations.

Table 3-1 Typical Values of Surface Roughness of Composite and Carbon Steel Pipes

Material	**Surface Roughness, mm**	**Hazen Williams Flow Factors**
Steel Pipe, new	0.040	130-140
Steel Pipe, lightly rusted	0.400	100
Steel Pipe, very rusted or scaled	3.400	60-80
Composite Pipe	0.005	150

3.1.1 Slip-in Liners

Reinforced composite pipe is also commonly installed as a slip-in liner inside an existing steel carrier pipeline that has failed due to corrosion. This approach can offer environmental advantages given the smaller footprint it creates—as excavations are only required at the ends of pipeline sections where the reinforced composite pipe is installed. Also, the existing pipeline right-of-way can be utilized further minimizing land-owner impact.

However, in the event of the reinforced composite pipe failing inside a damaged carrier pipe, knowledge of the slope of the land and/or locations of breaks in the carrier pipe are important to determine where any fluid may come to surface. Further, the removal of the slip-liner and spilled product within the carrier pipe may become a difficult task. A review of bell-hole locations chosen for slip-liner applications and any known missing sections of the carrier pipe should be documented in the event of a failure of the slip-liner. Use of GPS coordinates is recommended to keep track of the bell-holes or missing sections of carrier pipe.

3.2 Material Selection Analysis

The final selection of suitable pipeline materials requires extensive analysis on a project-by-project basis and is well beyond the scope of this document. A thorough understanding of the intended service conditions—including the expected normal operating conditions and also any upset conditions that could exist—is required. Future field development plans also need to be considered as are any planned changes in service conditions—such as increased temperature, static and cyclic pressure, or H_2S levels—that could change or occur in the future development of the field. These new conditions may not be suitable or may present increased risk for the use of reinforced composite pipeline materials. Design life is another critical parameter in determining the strength and type of material selected. More detailed coverage of the design aspects of using reinforced composite pipe for pipelines is covered in Section 4.

Some key conditions that should be understood when selecting pipeline materials include:

Steady State Conditions:

- Service fluid compositions — such as corrosive products, sand, wax, etc;
- Operating flow rates;
- Operating pressure range including the amplitude and frequency of pressure cycles;
- Operating temperatures;
- Pumping conditions including pump start/stop parameters;
- Pump pulsation control.

Upset Operating Conditions

- Transient flow
- Start-up/ shut down characteristics (e.g. valve closure timing, electrical grid power bumps)
- Pigging requirements (due to liquid or wax load up);

Where routine high-cyclic pressure operation is possible for the pipeline in question, this aspect should be carefully considered and discussed with the pipe manufacturer prior to material selection. Associated operating conditions—such as pigging requirements, hot-oiling, and the use of additive chemicals or well stimulation chemical exposures—must also be understood and included in the materials analysis.

The pipeline terrain conditions must also be understood and should include awareness of

- general soil conditions
- existence of muskeg sections
- water crossings
- general rock content conditions
- overall soil stability characteristics

3.3 Selection Guideline

A recommended selection guideline table is provided in Appendix A for information only and is based on the manufacturer's published product specifications.

For the selection of reinforced composite pipes in particular, strict attention should be given to the combination of service pressure and temperature including upset operating conditions. Each pipeline environment includes a unique combination of temperature, pressure, stress and chemical factors and should also be considered. The combined effects of these factors on the reinforced composite pipe should be determined based on the manufacturer's recommendations—and additional testing if required—in the selection of a suitable material.

Reinforced composite pipe manufacturers usually qualify their products based on long-term tests using water at various stress levels and temperature conditions. However, prudent pipeline design may warrant that some de-rating factors be applied as determined on a project-by-project basis by the project design engineer. Therefore the service conditions, installation conditions, and design factors should be discussed and considered for each situation with the pipe manufacturer's technical staff.

CSA Z662-2007 outlines the minimum service fluid design factors that are specified to determine the pipeline design pressure (refer to Table 4-2 in Section 4 of this guide for an overview of the minimum service fluid factors).

4 Design

4.1 General

As stated previously in Section 3, reinforced composite pipeline design requires a thorough understanding of the intended service conditions on a per project basis that includes the expected normal operating conditions and any associated or upset conditions. Projects undertaken without due care and awareness of the differences in material properties compared to steel are not likely to succeed. Therefore, short- and long-term success requires extra attention be paid to several aspects at the pipeline design stage—several of which are highlighted in this section.

Success with reinforced composite pipelines usually involves aspects of design that go beyond a simple review of pipe pressure rating to include the following:

- Selection of a suitable pipe product;
- Availability of experienced construction contractors;
- Assessment of soil conditions to ensure provision of adequate pipe support and prevent pipe damage;
- Riser material and design configuration;
- Metallic coupler material selection;
- Selection, qualification, and use of a competent pipeline installation contractor.

Throughout the design process it is recommended that the pipe manufacturer be involved to provide technical assistance and provide input based on their experiences with the products.

Some key design parameters that should be considered include determining

- an accurate service fluid composition;
- operating pressure range including the amplitude and frequency of pressure cycles;
- operating temperatures;
- upset operating conditions;
- pump operation conditions including pump start/stop effects;
- pump pulsation control;
- fluid hammer conditions and their effects;
- pipe risers or lateral branch connections.

Operating conditions should also be understood and included in the design analysis. Discussion with the pipe manufacturer's technical staff can provide guidelines and is also strongly recommended. Several of these conditions include

- pigging
- hot-oiling
- additive chemicals

- well stimulation chemicals

The effects of additive chemicals such as *sulphur solvents* or *acidic well stimulation chemicals* may prove harmful to the pipe material and must be carefully considered. In cases where the chemical exposure period is very short duration, the harmful affects of chemicals may be reduced.

As well, the *pipeline terrain conditions* should be understood and include a review of:

- general soil stability;
- existence of muskeg sections;
- road, water or railway crossings;
- general rock conditions;
- overall soil characteristics.

In terms of appropriate soil conditions for reinforced composites, industry standards—such as ASTM D 3839 and AWWA M45—can provide guidance. The pipe manufacturer's technical manuals will also include information on required soil conditions, compaction, and other design information.

Unlike steel pipe, stick composite pipe is anisotropic, therefore its mechanical properties—such as tensile strength or modulus of elasticity—are directionally orientated (as a result of the fibre reinforcement winding orientation). As a result, stick composite pipe has a unique modulus of elasticity for hoop and axial orientations with the pipe having a much higher hoop strength than axial strength. This anisotropy must be considered when designing road or water crossings using horizontal directional drilling (HDD) techniques which require pulling the pipe through the bore using winches.

Table 4-1 provides a comparison of pipe properties for a typical stick composite pipe as compared to a typical standard carbon steel pipe. Data within Table 4-1 is provided for information and comparison purposes only as it contains approximate values that should not be used for design purposes. Only the pipe manufacturer's specified mechanical property values should be used for design purposes.

Table 4-1- Stick Composite Pipe Physical Properties Comparison to Carbon Steel Pipe

Property	**Rigid Composite**	**Steel , Grade 240**
Tensile Strength, mPa	138	240
Design Stress, mPa	138	240

Property	Rigid Composite	Steel , Grade 240
Modulus of Elasticity, GPa	Axial- 14 Hoop- 23	207
Coefficient of Thermal Expansion, mm/mm/^{0}C	1.6 x 10^{-5}	1.4 x 10^{-5}

***Note 1**: Values in Table 4-1 are typical only that are provided for comparison and are not intended to be used for pipeline design.*

4.2 Design Pressure

Reinforced composite pipeline design generally starts with determining the maximum allowed design pressure which is based on the manufacturer's Maximum Pressure Rating (MPR); or, the maximum operating temperature for the pipeline. This is the qualified pressure rating based on the manufacturing standards specified in CSA Z662-2007. Section 6 of this guide discusses pipe qualification methodology in more detail.

The pipeline designer should consult and use the manufacturer's published design information to the extent available but should also determine any unique circumstances for the project, such as:

- highly cyclic pressures
- temperature excursions
- pigging

In some cases, additional design factors may be warranted and should be applied on a project-by-project basis.

Once the reinforced composite pipe MPR is known, application of the service fluid factors is applied to determine the maximum pipeline design pressure allowed. Table 4-2 gives the minimum service fluid factors as specified in CSA Z662-2007. Additional design factors may be warranted—as determined by the project engineer—and applied in addition to the minimum service fluid factors specified by CSA Z662-2007.

Equation 1 provides a recommended basis to determine pipeline design pressure for reinforced composite pipelines.

$$\text{Design Pressure} = MPR \times F_{fluid} \times F_{project} \qquad \text{(Equation 1)}$$

where:

MPR= maximum pressure rating

F_{fluid} *= service fluid factor, CSA Z662*

$F_{project}$ *= additional project design factor where determined by Project Engineer*

Table 4-2 CSA Z662 Service Fluid Factors (F_{fluid})

Pipe Type	Category	Gas	Multiphase. LVP liquids	Oilfield Water
Stick Pipe	Stick Composite	0.67	0.80	1.0
Spoolable Pipes	SCP	0.67	0.80	1.0
	RTP Type 1	0.67	0.80	1.0
	RTP Type 2	0.67	0.80	1.0
	RTP Type 3	0.67	0.80	1.0

In pipelines where continuous and routine pressure cycling exists—such as that caused by water injection pump start/stops—an extra design factor of 0.50 shall be applied. CSA Z662-2007 defines severe cyclic as pressure cycles in excess of ±20% of the normal operating pressure. The pipe manufacturer should be consulted to assist in defining appropriate precautions and measures that may alleviate or minimize this concern.

> *Recommendation:*
> The installation and regular monitoring of pulsation dampeners is recommended to protect pipelines from excessive pulsation pressures downstream of pumps—in particular downstream of positive displacement pumps. Some pipe manufacturers also specify a minimum length of steel pipe between the pump discharge and the start of the reinforced composite pipe. Other measures for reducing the severity of surge pressures at the design stage, include slow-acting valves and Variable Frequency Drive (VFD) controlled pumps.

For some spoolable pipe products, the service fluid factor specified in CSA Z662-2007 may already be included in the manufacturer's MPR—designers should determine if this is the case for the pipe product involved.

The pressure test requirements following field installation must also be considered when determining a suitable pipe product and MPR. Test pressure can be calculated using the following equation—as specified in CSA Z662-2007:

Test Pressure = Design Pressure X 1.25 *(Equation 2)*

Generally, reinforced composite pipes should not be pressure tested above their specified MPR unless approved in writing by the pipe manufacturer. The pipeline designer should review this aspect with the pipe manufacturer and consider this when selecting a suitable reinforced composite pipe product.

4.3 Design Temperature

Design temperature is based on the pipeline service fluid conditions and any upset conditions that may prevail. Once determined, the temperature can be compared to the various pipeline temperature ratings published by pipe manufacturers. It should be noted that reinforced composite pipes—including stick and spoolable pipes—have varied maximum service temperature ratings which should be determined on a product basis. The designer should also take into account that service fluid temperatures in an oilfield may significantly increase over time due to changes such as increasing water cuts or the introduction of high volume downhole pumping.

The effect of elevated temperature on the MPR should also be determined during the design stage. In some cases, the MPR may have been qualified by the manufacturer at the rated temperature or at a lower temperature (i.e. 65^{o}C or 23^{o}C) and a higher rated temperature determined by the manufacturer by extrapolation of the lower temperature testing results.

Some manufacturers have published de-rated MPR values for the maximum temperature rating for instances where the maximum temperature rating exceeds the pipe's qualification testing temperature. For example, if a pipe manufacturer publishes a pipe MPR at 65^{o}C they may still allow applications up to a higher temperature, such as 90^{o}C at reduced MPR's. Therefore, the MPR at the maximum temperature should be determined and used for the pipeline design.

Most spoolable pipe products utilize a High Density Polyethylene (HDPE) Grade PE 3608 inner liner material for their standard design pipes for which manufacturers have published upper temperature ratings of 60^{o}C. In some cases, where alternate liner materials are used—such as bi-modal PE 4710 Grade HDPE or Cross-linked Polyethylene (PEX)—slightly higher temperature ratings may be indicated by the manufacturer. The pipe's maximum temperature rating and the proposed pipeline's maximum operating temperature should be reviewed and verified with the pipe manufacturer.

For stick pipes, various upper temperature ratings (from 65^{o}C-104^{o}C) are available that are based on the type of epoxy resin that is utilized and qualified for the pipe manufacturing. This aspect is covered in more detail in Section 5.

> *Recommendation:*
> It is recommended that the maximum pipe temperature rating for the specific pipeline service fluid involved is verified. The manufacturer's maximum pipe temperature ratings may be service fluid based. Do not assume that the manufacturer's specified temperature rating is suitable for all service fluids.

The Minimum Allowable Operating Temperature (MAOT) for all HDPE is -20^{o}C. This is an essential design criteria for applications where winter construction or operation, as well as start-up Joule Thomson effects, can significantly lower the MAOT of spoolable composite risers.

4.3.1 Thermal End Load

The development of forces due to thermal expansion of stick composite pipe is less than the forces developed by steel pipe of the same diameter. This is due to the relatively low axial modulus of elasticity compared to steel pipe. See Table 4-1.

A standard equation used for the calculation of thermal end-load of pipe is given by:

P = • E A • T *(Equation 3)*

Where:

P= End load

• =*Coefficient of thermal expansion*

E= Modulus of elasticity

A= Cross sectional area

• *T= temperature change*

As Equation 3 demonstrates, because stick composite pipe carries a lower value of the axial modulus of elasticity (i.e. 1:15) compared to steel, the end-loads developed due to temperature changes will also be much lower than loads developed by steel pipe of the same diameter.

4.4 Fluid Velocity

Reinforced composite pipes are used in normal fluid flow pipelines with liquid velocities up to 8 m/s. Velocity restrictions are usually based on the potential for pipe wear due to very high flow rates. The combined effect of fluid flow rate and the concentration and type of solids loading present should also be considered as each case will be unique.

Specialty pipes may be available that employ special inner resin surfaces or liners of polyurethane and other similar materials which are designed to provide increased abrasion resistance.

4.5 Pipeline Risers

4.5.1 Risers for Stick Composite Pipe

Pipeline risers for stick composite pipelines should be carefully designed and installed as they may experience significantly higher stress accumulations at the end points of the pipeline. Examples of this include stress build up due to operating temperature cycles, pipe operating service pressure and cycles, service fluid surges, pigging, and soil settling around and below the riser pipe area.

For stick composite pipelines, different riser designs have been implemented such as the use of

- steel pipe risers that transition to the stick composite pipe in the pipeline trench, usually at the bottom of the riser;
- stick composite pipe riser that is transitioned to steel piping just above ground level, usually with a flanged connection.

CSA Z662-2007 has specific requirements for reinforced composite pipelines risers. Steel risers must be supported so that no damaging load is applied to the reinforced composite pipe.

Where the transition to steel piping is aboveground, CSA Z662-2007 specifies that

- adequate support must be provided to the steel piping and that support from the composite riser is not relied upon;
- the use of a flange or coupling is specified;
- thermal expansion and soil settling stresses must be considered;
- protection from weather (such as solar heating or ultraviolet damage) be in place;
- protection from unintended contact is specified.

> *Recommendation:*
> Corrosion failure of steel risers due to internal corrosion has been a significant cause of pipeline failures as reinforced composite pipelines are often installed in very corrosive fluid services as an alternative to plain carbon steel pipe. When installing a carbon steel riser, internal corrosion protection should be considered which is usually accomplished by applying an internal plastic coating. External corrosion protection should also be considered and is usually provided by applying a suitable external coating system in combination with a CP system.

The differences in material weight and settlement need to be considered where stick composite pipe is transitioned to a steel flange belowground. This is important as the composite flange and/or adjacent composite pipe could be damaged and possibly fail by differential settling between the two connected materials.

As stated in CSA Z662-2007, steel risers on reinforced composite pipelines shall be supported so that no damaging load is induced on the reinforced composite pipe. This includes situations where unstable soils exist as the reinforced composite pipeline cannot be expected to provide support to a heavy steel riser pipe section and steel flange.

Recommendation:
Internal plastic coated risers can have limited life expectancy in corrosive services and should be included in pipeline inspection and integrity management programs. CP effectiveness for steel pipe risers should also be monitored.

Where the riser is constructed from stick composite piping, extra measures should be taken to lower risks of damage and possible failure. These measures should be considered by the pipeline designer and discussed with both the pipe manufacturer and the installation contractor.

Such measures to consider include but are not limited to the following examples:

- For stick composite pipe risers, heavier wall pipe for the riser section should be used. For example, if the pipeline is constructed with a 7000 kPa rated pipe product, consider constructing the riser pipe sections with higher wall thickness pipe and fittings. For short riser pipe sections the incremental cost of the higher rated composite pipe and fittings should be minimal. The use of heavier wall pipe will result in a smaller internal diameter. If the pipeline is to be pigged, the use of a suitable pig which can pass through the different bore diameters without damaging the pipe is required.
- When using elbow fittings, 90-degree elbows are generally used at risers. In some cases, 45 degree elbows may be installed. The use of elbows is not recommended if the lines are designed to be pigged. Elbows may further limit future aboveground remote camera inspection surveys or the ability to insert coiled tubing units in the event of blockages.
- Allowable restraints and supports for the bottom transition fitting and riser pipe are often specified by the pipe manufacturer (i.e. the use of sand-bagging or select fill such as sand).
- Pipeline riser areas are often large over-excavated areas, usually much more so than for the pipeline ditch. Re-establishing acceptable soil compaction and stability both in the pipeline ditch leading up to the riser and in the area immediately surrounding the riser is therefore recommended. This may be accomplished by means such as select soil placement and compaction.

Figure 4-1 Pipeline Riser showing use of Sand Bagging for Support and Thrust Blocking. Composite Riser Extends above Grade to Flange Transition to Steel Piping *(Photo used courtesy of Western Fiberglass Pipe Sales Ltd)*

4.5.2 Spoolable Composite Pipeline Risers

For spoolable pipeline risers, either steel risers or bringing the composite pipe above ground and transitioning to steel pipe have been used. Many of the same concerns expressed in 4.5.1 for stick composite pipe risers also apply to the spoolable pipe risers.

Spoolable composite pipes by nature are designed to bend and be flexible and are expected to be somewhat more tolerant of typical stresses developed at pipeline risers than stick composite pipe. Despite this, the riser design for spoolable pipe still requires due consideration of soil stability and pipe support as stated above for stick pipe.

Some spoolable pipe manufacturers recommend and supply a steel support structure to be installed for spoolable pipe risers. This structure is designed to cradle and support the pipe through the riser section. If available, this option should be considered to help restrain and support the spoolable riser pipe section. In particular, when dealing with ground vibration effects from oilfield pumps that could lead to soil settling after compaction/backfill (regardless if cyclic service effects have been taken into account), steel support structures are recommended.

In some cases, steel pipe risers are used where severe water hammer or pressure cycle fluctuations are expected. In these situations the pipe manufacturer's technical staff should always be consulted to review the design including the transition connection to the spoolable pipe. Consideration of the extra support required for a heavier steel pipe riser and flange are required to ensure no damaging stress is placed upon the spoolable pipe.

4.5.3 Spoolable Composite Pipeline Couplers

Metallic couplers are used for transitioning spoolable pipe to steel piping or for inter-connection of spoolable pipe. The couplers are not a standard industry design as each pipe manufacturer supplies their own couplers. Manufacturers will often install the couplers or in some cases train and certify other companies to install their couplers. The couplers are not interchangeable from one type of spoolable pipe to another, however flange designs are available from most manufacturers that may allow connecting two different spoolable composite. When flanged designs are used, consideration should be given to the issues associated with buried flange installation such as bolt tensioning preservation in conditions affected by thermal expansion and soil settlement loads.

For the design of spoolable pipelines, the coupler material must be considered in terms of both internal and external corrosion resistance. This is typically accomplished through discussion with the pipe/coupler manufacturer. Options available typically include use of plastic coatings, CRA or metallic coatings such as Electroless Nickel Coating (ENC). More information on coupler material selection is presented in section 5.2

Figure 4-2 Spoolable Pipe Metallic Coupler Installation
(*Photograph courtesy of Wellstream International Limited)*

4.6 Fluid Hammer

Fluid hammer in a piping system is caused by sudden starts or stops of flow. This can create high-pressure surges which can damage piping—including steel piping. This should be considered when designing pipe systems especially where stick composite pipelines are involved. Fluid hammer has been known to cause pipeline failures that often manifest themselves at changes of direction within the pipe—such as at elbow or tee fittings used for lateral pipe connections or risers.

Some of the common causes of high surge conditions are fast acting valves or quick pump start up. In these cases, the use of VFD or slower acting valves—such as piston check valves or slow operating control valve actuators—are recommended to minimize pressure surge conditions. Within their design manuals, pipe manufacturers publish guidelines and fluid hammer constants to enable users to consider and calculate the effects of fluid hammer. The surge pressure conditions should also be determined and included within the pipeline's design pressure.

5 Material Selection

5.1 Reinforced Composite Pipe Materials

5.1.1 Stick Composite Pipe Products

The materials used for stick composite pipe are a combination of a reinforcement structure composed of glass fibre and thermosetting resin—most often an epoxy resin for oilfield pipe. The end-user is not normally involved with the specification of these raw materials but should be aware of some of the general properties affected by the raw materials.

E-Glass (a general purpose glass fibre) is generally used for reinforcement glass; however, in some cases C-Glass is used to increase chemical resistance. Glass fibres are considered strong materials as they have a typical tensile strength value of approximately 3,400 MPa at 23^{o}C and have a modulus of elasticity of approximately 70 GPa.

As stated in Section 4.0, the resin matrix used to produce stick pipe can vary from each pipe manufacturer. In general, most stick composite oilfield pipe is manufactured from epoxy-based resins. However, using different types of epoxy curing agents will affect the pipe's chemical resistance and temperature ratings. The temperature ratings for common epoxy resins are as follows:

- Anhydride cured epoxy: 65^{o}C
- Aliphatic amine cured epoxy: 93^{o}C
- Aromatic amine cured epoxy: 104^{o}C

> *Recommendation:*
> Although pipe manufacturers publish the chemical resistance of their products within their product literature, it is recommended that discussions be held with manufacturers as the maximum temperature ratings published may not apply to all fluid environments. In some cases, specific testing may be necessary to qualify stick pipe products before their selection is made.

5.1.2 Spoolable Pipe Products

Spoolable pipe products are characterized by having a thermoplastic inner liner pipe. The most common liner material used is HDPE Grade PE 3608 or Grade PE 4710. Both of these liner materials have the same general chemical resistance and may be affected by the absorption of liquid hydrocarbons. Generally, the physical absorption of hydrocarbons is known to affect HDPE mechanical properties such as tensile strength and modulus of elasticity. Water on the other hand, is known to have little effect on the properties of HDPE.

HDPE liners can also allow a small amount of gas permeation through the pipe wall. In some cases, spoolable pipe products include a small vent hole in the metallic couplings to allow gases that have permeated through the inner liner to migrate to the vent hole. Where elevated service temperatures are required, the use of the alternate PEX or Polyamide (PA) inner liner materials—sometimes installed by manufacturers— may be considered.

HDPE Grade 4710 liners are stated to have slightly improved property retention, crack resistance, arrest resistant properties and higher temperatures mechanical properties compared to standard HDPE Grade 3608. While PE 4710 Grade is becoming increasingly popular due to its improved mechanical properties, attention should be given to fusion welding. This is necessary due to the slightly different melt flow characteristics compared to standard PE 3608 Grade material—additional guidelines may be required to be developed for quality control.

The reinforcement structure applied over the inner liner generally includes windings of glass fibre strands—similar to stick composite pipe. These are added and built up in layers that are designed to provide the required axial and hoop strength properties. Some spoolable pipe products use glass fibers encased in a thermosetting epoxy resin with the reinforcement structure bonded to the inner liner. Others use dry glass fibre strands wound over the liner with no epoxy resin matrix—in these cases the reinforced dry glass structural layers are not bonded to the inner liner. Currently, there are spoolable pipe products that use carbon steel strips and aramid fiber windings over the inner liner rather than glass fibre reinforcement. The use of steel strips for reinforcement is also employed.

Whatever the reinforcement method employed for spoolable pipes, the temperature and chemical resistances are strongly linked to those of the inner liner material, since the strength of either glass fibre or steel strip reinforcements should not be significantly affected by normal pipeline operating temperatures. As well, the pipeline service fluid is isolated by the inner liner and does not directly contact the reinforcement layers other than through gas permeation. The effects of permeated gases (such as CO_2, H_2S and water vapour) on the reinforcement structure materials and pipe's long-term integrity should also be considered and discussed with the pipe manufacturer.

The chemical resistance of inner liner material within spoolable pipe is an important consideration. Adverse effects, for instance, could be caused by the use of strong hydrocarbon solvents in pipes with a standard HDPE liner and should therefore be avoided. In general, the effects of water on HDPE—within the pipe's temperature rating limit— should be minimal. Testing may be necessary to qualify spoolable pipe products before final selection is made.

5.2 Material Selection for Metallic Couplings (Spoolable Pipe)

Normally, pipe manufacturers supply metallic couplers for their pipe products—which are often made in-house by the manufacturer. The standard coupler material is plain carbon steel. End-users should consider and determine if standard carbon steel couplers will provide adequate service life in the service fluid before specifying an appropriate material.

Available material options include organic protective coatings such as thin fluor-polymers—or Poly-Tetra-Fluoro-Ethylene (PTFE). Some manufacturers offer their steel couplers with an ENC while in some cases the entire coupler can be made from CRA such as stainless steel, duplex or nickel alloys. Where highly corrosive service fluids—such as oilfield brines—are present, the use of some thin metallic or plastic protective coatings may not provide adequate corrosion protection therefore solid CRA couplers may need to be considered.

The selection of coupler material must be done with consideration of the service conditions. The use of bimetallic materials (CRA mandrels welded to carbon steel sleeves or ENC) in water or brine service has to be carefully evaluated to avoid dissimilar metal corrosion. The use of non-metallic (plastic) coatings must take into account operating conditions such as produced sand or presence of chemicals that may affect the coating. Similar to metallic riser design, when plastic coatings are used in piggable lines, the selection of the correct pigging procedures must be specified. This involves selection of the right pig geometry and durometer hardness that would perform well and at the same time maintain the integrity of the coating.

External corrosion of the couplers is usually achieved through the use of external coatings, ranging from polyethylene sleeves or tape to liquid epoxies and viscoelastic mastics. It is recommended that external coatings are used on all coupler materials, even those that are not normally affected by external corrosion. For additional protection, spot cathodic protection can be achieved through the use of magnesium sacrificial anodes specially designed and sized to offer the required protection to the coupler. Monitoring of the sacrificial anode output and life can be done using test wires brought aboveground. The use of CP test stations must take into account practical issues such as accessibility and protection against accidental damage.

To date, service failures from the corrosion of metallic couplers for spoolable pipelines have not been reported as a significant problem—although the operating history of these products is relatively short.

5.3 Materials for Risers

5.3.1 Reinforced Composite Pipe Risers

As discussed in Section 4.0, various material options are available for pipeline risers. It is generally recommended that composite pipe be extended to just above grade before transitioning to metallic pipe as this provides a more corrosion resistant material than carbon steel pipe risers. Spoolable pipe manufacturers can provide a structural steel support structure for the underground riser section.

When using a composite riser design for stick composite pipelines, it is recommended to construct the riser section from a stronger composite pipe material than is used for the pipeline itself. Transitioning back to the standard composite pipe in the pipeline ditch should follow. Manufacturers can normally provide prefabricated heavier walled riser sections.

The use of composite riser materials must also take into account any material limitations associated with cold temperature effects such as fast crack propagation. Joule Thomson effects at start-up are common in rich gas applications or those with a high content of CO_2, and the pipeline risers close to the wells will be affected by the sudden temperature drops.

5.3.2 Metallic Pipe Risers

Measures to prevent internal corrosion may be required should the operator wish to install a steel pipe riser—which can be accomplished by applying internal plastic coatings. Coating selection and application must be done by an experienced coating applicator—preferably inside a specialty coating shop environment—as quality application is a primary requirement. Onsite field application of internal coatings is not normally recommended due to poor working conditions and the need for specialized shop equipment to properly apply internal pipe coatings.

External corrosion protection of the steel riser should also be considered and is usually provided by the application of a suitable external coating system such as liquid epoxy, heat shrink sleeves or tape wraps and by installing a CP system—as specified by CSA Z662-2007. Both the internal and external coatings selected must be rated for the service environment in terms of operating temperature, pressure and chemical resistance.

CRA fittings and pipe have also been used to fabricate risers for reinforced composite pipelines. In such cases, the alloy material and connection to the composite pipe must be carefully selected based on their corrosion resistance to the service environment. Alloys, such as stainless steel, have been used but some grades are known to be more sensitive to chloride stress cracking due to the high chloride concentration present in most oilfield waters.

In some cases, specialty pre-coated weldable steel insert fittings have also been used to fabricate a steel riser pipe section.

6 Material Qualification

6.1 Design Stress/Pressure- Stick Pipe

CSA Z662-2007 specifies that stick composite pipe be qualified and manufactured in accordance with API 15HR requirements. The standard pressure rating should also be determined in accordance with API 15HR using the 20 year Long-Term Hydrostatic Strength (LTHS) value. The LTHS values can be determined using the test procedures of ASTM D 2992 which are specified by API 15HR.

Each pipe manufacturer performs the ASTM D 2992 testing to determine pipe failure pressures/stress at various time intervals. Testing procedures tend to be lengthy as failure points of up to 10,000 hours are required for the qualification. Typically, testing is performed using 65^{o}C water; however, some manufacturers perform testing at other temperatures in addition to 65^{o}C.

To calculate design stress values, pipe manufacturers plot the failure stresses versus time on a semi-logarithmic graph. From there, the failure stress graph is extrapolated beyond the 10,000-hour data point to 20 years (175,200 hours). The predicted stress at 20 years is then determined by this extrapolation which provides the hoop stress or LTHS used to determine the pressure rating. API 15HR also specifies a 0.67 design factor be applied to the calculated pressure ratings. Design stress values can be found in the pipe manufacturer's design manuals.

It must be remembered that the design stress used to determine the pipe pressure rating is pipe hoop stress and does not consider other shear and axial stresses that may be present due to soil loading and settlement and thermal expansion stresses. In part, these are offset by the design factors in API 15HR and service fluid factors in CSA Z662-2007.

6.2 Design Stress/Pressure- Spoolable Pipe

CSA Z662-2007 specifies that glass fibre reinforced spoolable pipe be qualified and manufactured to API 15S while steel strip reinforced spoolable pipe be qualified and manufactured to meet API 17J. For Spoolable Composite Pipes (SCP) and Reinforced Thermoplastic Pipes (RTP)—with the exception of steel reinforced flexible pipe—the MPR is based on the Long-Term Hydrostatic Pressure (LTHP) testing of pipe samples in accordance with the industry standard test method, ASTM D 2292—which is the same test method used for stick pipe. Once the testing is completed, the LTHP is calculated in accordance with ASTM D 2992—which involves extrapolation of the test data to determine the LTHP at 20 years (175,200 hours).

For steel reinforced pipe, CSA Z662-2007 specifies that API 17J be used for qualification and manufacturing. The pressure rating methodology is based differently than specified in either API 15HR or 15S in that an analytical approach using analysis of each pipe layer strength is applied.

6.3 Additional Qualification Tests

In some cases, additional pipe qualification may be requested for certain applications. These should be discussed with the pipe manufacturer and follow the recommendations of the relevant manufacturing standard.

Some examples where additional qualification may be requested include:

- Effects of permeation on the pipe properties for gas or multiphase services;
- Minimum bend radius;
- Axial load capability;
- External pressure/overburden;
- Impact resistance at specified temperatures;
- Slow or rapid crack propagation resistance;
- High-cyclic pressure services;
- Service life over 20 years.

7 Installation

7.1 General

As seen on the pipeline failure data discussed in Section 2, installation damage is a leading cause of pipeline failure. Therefore, the installation techniques for reinforced composite pipelines, as well as consideration of the differences in the types of pipe being used, are critical for success.

7.1.1 Spoolable Pipe Installations

When installing spoolable pipe, either plough-in or open ditch construction installation methods may be utilized. To help determine which method to use, discussions with the pipe manufacturer and experienced local installation contractors should be held.

Some of the key aspects that should be considered for a plough-in installation include

- Terrain, soil and rock conditions;
- Number of pipeline crossing required;
- Expected weather conditions.

In general, plough-in pipeline installations are carried out in fairly level terrain with relatively stable soil conditions and low rock content soils. In some cases, wintertime plough-in construction may be possible but should be considered carefully since the stiffness of spoolable pipe products will increase significantly during low-temperatures thus increasing the probability of pipe damage. Where possible, the installation of rigid or spoolable composite pipes during extreme cold weather conditions should be avoided due to the increased risk of pipe damage.

> *Recommendation:*
> Generally, reinforced composite pipeline installation is halted or reduced when ambient air temperature drops below approximately -20^{o}C. It is recommended however, that consultation with the pipe manufacturer be conducted to determine the product's low-temperature limit.

7.1.2 Stick Pipe Installations

When stick composite pipe is being installed, the only method is conventional open ditch construction or as a slip-in liner. Where reinforced composite pipes are installed as slip-in liners in steel carrier pipes the use of wireline pull-in methods are commonly used. In these cases, the wireline unit should be equipped with an accurate weight indicator and odometer to monitor conditions and positioning during the pulling-in operation.

Push/pull technology is also being used to install liners and can offer the advantage of not applying torque to the liner pipe. This may be a factor in long pull lengths using wireline where tensile loading of the braided wireline results in excessive torque to the liner pipe. To prevent this, a swivel connection device may be employed between the wireline and the pipe pulling head.

In general, stick pipe properties are not as affected by low-temperatures as spoolable pipe; however, the risk of damage due to frozen soil or adverse joining conditions remains a concern.

Figure 7-1 Typical Spoolable Reinforced Thermoplastic Pipe (RTP) Plough-In Installation Method *(Photograph courtesy of Flexpipe Systems)*

7.2 Pipe Transportation, Handling

The transportation and handling guidelines published by pipe manufacturers should be consulted as this aspect of pipe installation requires stringent attention.

7.2.1 Stick Pipe

Pipe transportation is usually performed using flat bed trailers which provide full-length support to the pipe—having any pipe hang over the end of the trailer is not recommended. Wooden supports (dunnage) or cradles should be positioned below the pipe and between the stacked rows of pipe to provide support and separation. Usually, the minimum number of rows is specified in the manufacturer's literature and may vary depending on the pipe diameter.

Pipe tie-downs using synthetic fabric straps should be positioned at the support points or as approved by the pipe manufacturer. Typically a minimum of 4 tie-downs are installed. Chain tie downs are not acceptable. During transportation, pipe-ends should be covered by thread protectors or plastic bags to prevent damage or contamination of the connection surfaces.

> *Recommendation:*
> Pipe used in pipeline construction projects will often be located at a nearby pipe distributor's storage yard—having been previously shipped there from the manufacturer. It is recommended that a local distributor be used to transport pipe to the project site for stringing or storage. The local pipe distributor will typically have equipped trailers and experienced personnel dedicated for transporting and unloading reinforced composite pipes.

Some key inspection checks that should be reviewed when transporting stick pipe include:

- Load shifting or missing supports;
- Use of specified tie down straps;
- Use of over-tightened straps and excessive bending of pipe loads;
- Signs of wear or damage to the pipe at tie-down points;
- Missing pipe-end protection at connections;
- Examining for signs of visual damage, impact damage, and abrasion damage.

Transportation methods may vary depending on the nature of the project—such as the use of shipping containers for international overseas projects.

Reviews of where the pipe is being unloaded and stored at the construction site should be carried out to check for the truck unloading method, pipe storage rack configuration, and ultraviolet protection requirements. In the event that the pipe will be stored for an extended period (several months or more) tarps should be used to protect the pipe from ultraviolet discoloration and surface oxidation effects.

Where stick pipe has been strung along the pipeline right-of-way, the pipe may be placed upon wooden skids, plastic pylons, or short pieces of plastic pipe to protect it from rocks or other objects in the area.

Figure 7-2 Typical Wooden Cradle Supports and Tie Down for Large Diameter Pipe Transport; *(Photograph courtesy of Fiber Glass Systems and Fiberglass Solutions Inc)*

7.2.2 Spoolable Pipe

Many of the transportation and handling methods for spoolable pipe differ from that of stick pipe. For instance, spoolable pipe is shipped on large shipping reels that is carried on trailers. Further, after arriving to the construction site, the pipe reel is unloaded and kept on the shipping reels until installation begins.

Some key inspection checks that should be reviewed when transporting spoolable pipe include:

- Proper securing of the pipe reels to the trailer to prevent pipe damage;
- Pipe reel covers are in place to prevent rock impact damage caused by passing vehicles (if specified);
- Examining for signs of visual damage, pipe kinks or impact damage;
- Ensuring proper reel unloading methods and careful placement of pipe reels onto the site's ground surface that is free of rocks or other objects that could damage the pipe;
- Inspection of empty pipe reel surfaces for any abnormalities that may have damaged the pipe.

Heating of the pipe reel may be necessary prior to unreeling spoolable pipe during winter construction—refer to Section 2.2.1. for more information on the proper heating techniques for spoolable pipe. Spoolable pipe products, unlike stick pipe, rely on a thermoplastic inner liner material—normally HDPE. Thermoplastic materials are very sensitive to temperature and at low ambient temperatures will become much stiffer and less ductile. The heating procedure should be done carefully and in accordance with the manufacturer's procedure. If the pipe reel is heated unevenly resulting in hot and cold areas, this can result in significant variations in the pipes stiffness and pipe kinking damage can occur during unreeling.

Figure 7-3 Spoolable Pipe Transport on Reel Trailer
(Photograph courtesy of Wellstream International Limited)

7.3 Pipe Installation

Pipe manufacturers provide installation instructions that should be followed to successfully install both stick pipe and spoolable pipes. Normally, the manufacturers can provide a field service technician to help train and qualify the installation crew and inspectors in the proper handling, joining, and installation techniques.

Should any suspected damage on the pipe be evident, a representative for the manufacturer can provide pipe inspection and assessment assistance. The representative's services should also be utilized during installation pre-bidding meetings, installation planning meetings, and onsite during field construction.

7.3.1 Pipeline Trench Preparation

In general, the pipeline ditch bottom should provide continuous and stable support for the pipe. In the event that soil conditions are too soft, unstable or rocky, it may be necessary to over-excavate the area followed by the placement of bedding materials in the ditch bottom. The depth of bedding in most situations should be a minimum of 150 mm. The pipe should be supported by a uniform flat ditch bottom to avoid creating poorly supported spans which could overstress the pipe once backfill soil is placed in the ditch. After being placed into the ditch, additional bedding material may be required to fill around the pipe and provide a more stable soil cover. In some cases, native soil may be acceptable for bedding and initial cover but will require assessment as site conditions may vary.

Where soils conditions are unstable, additional measures are often required to stabilize the pipeline ditch. Where the right-of-way conditions have muskeg or ample moisture, the use of geo-textile can be placed below the pipe to minimize sinking. Geo-textile may also be put over the pipe to help stabilize the ditch backfill material. Where unstable ditch conditions are present, the use of steel pipe casings with end seals may be required as the use of geo-textile may not be adequate.

Aside from the pipe manufacturer's installation manuals, industry standards such as ASTM D3839, AWWA M45, and AWWA C950 provide information on pipeline trench preparation and backfilling requirements for composite pipes.

During cold weather periods, unfrozen clean soil or sand should be initially placed in the ditch—backfill containing frozen soil should not be used. Also, if any free water is present, the ditch should be pumped out and inspected for the presence of voids beneath the pipe. Any voids that are discovered should be filled with soil (if required) before backfilling the pipe with dry soil.

Figure 7-4 Large Diameter Rigid Composite Pipe; Placement of Select Fill Bedding. *(Photograph used courtesy of Fiber Glass Systems and Fiberglass Solutions Inc)*

7.3.2 Road and River Crossings

Road or river bored crossings are cased as specified by regulatory requirements. Plastic centralizers should be fixed on the carrier pipe to provide abrasion protection during pipe insertion through the steel casing while end-seals should be installed to prevent water entry into the casing end. If possible, an additional abrasion protective coating should be used on the external liner of the pipe.

When installing through horizontal directionally drilled crossings, the first meter of pipe attached to the pulling head should be removed and thoroughly examined to check for tensile or torque stress overload damage. The reinforced composite carrier pipe should be additionally protected at the exit ends of the casing to prevent high shear stress due to soil settling and from any sharp edges at the cut end of the steel casing. The soil at the casing exit ends can be stabilized through means such as compaction and sand bagging to minimize pipe settling and the development of high shear stress to the carrier pipe at the casing exits.

It is also good installation practice to provide a suitable straight length of pipe before and after the casing exit and before a bend or elbow fitting is installed. Directional changes—if located too close to the casing exit—may result in damage if the composite pipe becomes pushed against the wall or the end of the steel casing. In some cases, this has resulted in damage and service failures of composite pipelines.

7.4 Thrust Blocks and Anchors

The requirements for thrust blocks and anchors should be carefully determined for composite pipe projects for both stick and spoolable pipelines. The end-user must discuss this with the pipe manufacturer to determine if they are required with the thrust block design. Generally, high pressure pipelines have an increased requirement for thrust blocks than lower pressure pipelines (which require less or possibly no thrust blocks). Thrust blocks can take many different shapes including concrete blocks and sand bagging (an effective and widely used alternate to concrete blocks) and may be required for both elbow and tee fittings as recommended by the pipe manufacturer.

> *Note:*
> Clamping pipes to steel piles at the bottom of the pipeline ditch may not be an acceptable approach for anchoring non-metallic pipelines. Consulting the pipe manufacturer before employing this method is advised.

Regardless of the design of thrust blocks, the user should be aware that the improper use of thrust blocks can lead to early pipe failure due to excessive point-loads or shear stress development. This is often due to pipe and soil settling and stress or strain caused by the operating temperature and pressure. For most oilfield pipelines, using sand bagging at the risers may provide adequate support and thrust restraint. This is especially true immediately after construction when freshly placed soils may have low compaction around risers and the pipeline.

Overall, thrust blocks and anchors cannot be simply designed and installed as they would be for a similar steel pipeline. If possible, it may be useful to seek out the advice of local operators or installation contractors who have experience dealing with composite pipeline construction in similar soil conditions.

7.5 Slip-in Liners

Installing reinforced composite pipe as a slip-in liner inside an existing steel pipeline is commonly performed using both stick and spoolable pipes. It should be noted that pull lengths can vary based on pipe diameter, terrain and the product being installed.

Several risks involved with slip-in liners that should be assessed include the condition of the steel carrier pipe, the potential for liner damage due to surface roughness, and the existence of excessive internal weld penetrations or grapes.

Where liners are installed inside possibly rough surface carrier pipes—such as cement lined steel pipe—the risk of erosion damage to the liner may be increased especially if the pipeline is in high-pulsating or vibrating service. Thorough pigging of any debris that may exist in the carrier pipe before lining is also very important and key to lowering the risk of damage to the liner.

The diameter difference between the liner's outside diameter and the steel pipe's inside diameter should be reviewed to ensure adequate clearance exists. The reduced diameter at weld penetrations, as well as the thermal expansion of the liner should also be considered before selecting the liner diameter. The rule of thumb for minimum clearance between OD of the liner pipe and ID of the carrier pipe is considered to be a minimum ½" diameter.

Typically, the liner installation involves preparing the steel pipe by pigging to ensure it is free of significant deposits and liquids. After initial pigging and cleaning, a wireline cable should be pulled inside the carrier by a pig. It is good practice to then pull a short section of the liner pipe (of 2-3 meters) to allow for inspection of any potential damage—such as significant scratches or gouges. Elbow fittings should also be removed to provide room for the liners prior to installation. Additional line preparations may also be required to locate and remove any sections of damaged steel pipe, elbow fittings or welds that may be damaging the liner.

Once the liner has been pulled inside the steel pipe, observations of the liner exiting the far end of the steel pipe will indicate if any damage to the liner has occurred. Installing seals at the steel casing ends to prevent the entry of water into the annulus space—which could freeze and damage the liner piper—is useful for preventing damage.

Where liners exit the steel carrier pipe, the liner should be well supported by placement of stable soil with compaction or sand bagging to prevent excessive settlement and excessive shear stress development on the liner at the edge of the fixed steel casing. Use of GPS to locate these points for future maintenance or inspection is recommended.

Figure 7-5 Spoolable Composite Pipe (SCP) - Unreeling Pipe for Placement in Pipeline Trench. *(Photo used courtesy of Fiberspar LinePipe Canada Ltd)*

7.6 Metallic Tracer Wire

It is a CSA Z662-2007 requirement for reinforced composite pipelines that a corrosion resistant tracer wire (such as 14 guage standard single strand coated copper wire) be installed alongside the pipe within the ditch to allow for detection by pipeline location equipment. This step is especially critical to ensure the accuracy of future excavations—that may be required for maintenance, foreign pipeline crossings, and adjacent pipeline construction.

Following construction, the tracer wire-ends should be brought to the surface in a conduit and marked and secured to provide for easy access and use in the future.

> *Note:*
> Tracer wire is not required where steel strip reinforced spoolable pipe is installed electrically continuous from one pipeline spool to the next as the pipe's steel reinforcement will provide the required response to line location instruments.

Pipeline locator tools can be connected to either the steel pipe or the steel strip reinforced spoolable pipe. Where a non-conductive pipe—such as stick composite—is used for the riser, a tracer wire should be installed along the riser section and connected to the steel strip reinforced spoolable pipe.

In addition to tracer wires, the use of GPS locator records for spoolable pipe couplers is highly recommended.

8 Pipe Joining

8.1 Stick Composite Pipe

It is strongly recommended that the joining personnel's qualifications and experience specifically related to non-metallic materials be considered in the selection of the installation contractor. At the front end of projects, training and qualification of personnel should be carried out by the pipe manufacturer, well before production joining for the pipeline kicks off. It is also very important that Inspectors are fully aware of the joining procedure and inspection and test plan requirements that pertain.

> *Note:*
> Each pipe product carries unique joining requirements therefore the previous experience personnel may have with one product may not mean they are necessarily qualified for joining all pipe products. Unique requirements for joining fittings to pipes and risers should be covered in pre-job training and qualification.

Several areas that must be covered in the inspection plan are the approved thread compounds, approved make-up tools, and thread makeup procedure. Normally, threaded pipe is made to a specified thread position rather than a specified torque value.

Larger diameter stick pipe connections usually require an adhesive bonded connection. Again, project personnel training and qualification by the pipe manufacturer's representative are necessary. The bonder qualification methodology specified in ASME B31.3, Chapter VII has been utilized for some large diameter composite pipeline projects with good success.

The minimum joining procedure for adhesive bonded pipe joints should include:

- Adhesive type and mixing, and handling requirements;
- Cleaning and preparation of the connection surfaces for joining;
- Field tapering of pipe-ends if required (pipe joints are factory tapered);
- Application of adhesive;
- Pipe stabbing, using hydraulic come-along for joint make-up and preventing joint backing out after stabbing (prior to the adhesive curing period);
- Adhesive curing requirements and the use of auxiliary heating blankets;
- Inspection and acceptability criteria;
- Provision of suitable protection or shelters for pipe joining for adverse weather conditions such as rain or low temperatures.

Figure 8-1 Provision of Shelters for Joining Composite Pipe; *(Photograph courtesy of Fiber Glass Systems and Fiberglass Solutions Inc)*

8.2 Spoolable Pipe

Joining spoolable pipe relies on the installation of metallic couplings (to connect pipe lengths) and fittings (to provide a flange transition at the pipeline end points) to connect to aboveground piping.

Each spoolable pipe product has unique connections and often these require installation by the manufacturer's representative or in some cases third party contractors certified by the manufacturer. Joining personnel should be qualified before the start-up of any spoolable pipe project.

The CSA Z662-2007 requirements specified above for stick composite pipe also apply to spoolable pipe. It is also very important that inspectors are fully aware of the joining procedure, inspection and test plan requirements that pertain.

Where internal corrosion is a concern, additional protective coatings or use of CRA couplings are possible considerations. Generally, spoolable pipe manufacturers offer their couplings with a protective coating or in a range of CRA materials.

CSA Z662-2007 requires steel portions of non-metallic pipeline systems to have external corrosion protection. This includes external coating along with CP for underground steel couplings, transitions and risers. The CP design should be discussed with the manufacturer to determine the options for external coatings and CP anodes. The use of CP may not be required where CRAs are used; however, the application of a tape wrap is generally advised for protection against any harmful soil contaminants such as chloride.

Figure 8-2 Metallic Coupler Joining Sections of Spoolable Pipe
(Photograph courtesy of Wellstream International Ltd)

9 Pressure Testing

9.1 New Construction

Following construction, the pipeline must be pressure tested to verify integrity and prove that no joint leaks exist as per CSA Z662-2007 requirements. For instance, the specified test pressure should be 125% of the design pressure for the pipeline (NOTE: There are no additional sour service pressure testing requirements related to non-metallic piping). Further, the minimum test duration is eight hours when testing with water or 24 hours for pneumatic tests—pneumatic tests are limited to a maximum test pressure of 2,900 KPa. These preliminary pressure tests are used to verify joining procedure and quality as the construction proceeds.

> *Recommendation:*
> Pneumatic preliminary leak testing is not recommended due to safety concerns related to the high potential energy involved and associated harm that may be caused by a joint failure.

In most cases, the pipeline is tested with the joints exposed. This approach allows for the pipe joints to be visually inspected for any leaks and repaired before the pipeline is backfilled. Where the preliminary leak test is successful, the test fluid is left in the pipe during backfilling, followed by a second final pressure test.

For preliminary leak tests, the pipe body should be restrained in the ditch to resist lifting. This is often accomplished by placing soil plugs in the centre area of each pipe while leaving the joints exposed for leak assessment.

Soft pigs approved by the pipe manufacturer may be used when filling the pipeline with pressure test fluids. The use of freeze point depressants during winter construction is also acceptable if approved by the manufacturer and local regulatory bodies.

As for any pipeline pressure test, the pressure should be raised in increments with several hold points before setting at the test pressure. Non-metallic pipe materials will react differently than steel to stress and temperature variations. A stabilization period may also be required before starting the pressure test if the test fluid and pipe temperatures differ significantly.

The pipe manufacturer's pressure testing procedure should be consulted and applied during the development of the pressure test procedure for pipeline projects.

9.2 Pressure Testing Repairs

In accordance with CSA Z662-2007, pressure testing is required for any repairs performed on existing pipelines. Testing must be performed over a four-hour duration (at minimum) at the highest available operating pressure. This is meant to allow for routine repairs to be pressure tested using service fluid under operating pressure.

10 Operation

10.1 General

In general, the operation of a reinforced composite pipeline is similar to the operation of a conventional steel pipeline system. However, several differences exist that operation and maintenance personnel should be made aware of to ensure the pipeline is not operated outside its design limits. To increase awareness, field signage can be used to highlight the locations of reinforced composite pipelines.

Instruments such as pressure or temperature sensors are not normally installed or mounted directly on non-metallic pipe but are incorporated into steel piping or wellhead facilities located at ends of the pipeline.

10.2 Pressure

The pressure control, limiting and relieving systems of reinforced composite pipelines are similar to those used for steel pipelines. However, composite pipes carry a greater sensitivity to pressure cycles and as such have additional design factors specified at the design stage.

In CSA Z662-2007 there is a requirement to apply an additional design factor of 0.5 when severe pressure cycles exist—in general when then the operating pressure cycles are greater than ±20% of the normal operating pressure. During their life-spans, all pipelines will experience some degree of pressure cycles at start-up or shutdown—which normally do not present great concern. However, when reinforced composite pipelines are operated with pressure cycles on a daily basis, the initial design pressure should be de-rated by the 0.5 factor. An example of where the design pressure must be de-rated would be a situation in which water injection pumps are stopped and started several times per day and the pipeline pressure is allowed to cycle outside the ±20% criteria. Pipeline operators should be made aware of this increased sensitivity and be vigilant whenever severe pressure cycling conditions exist. The pipe manufacturer should also be contacted for further advice on the acceptability of cyclic pressure operation.

Other aspects to monitor include any pressure surges or pump pulsation conditions that may damage composite pipe over time. In most cases, pulsation dampeners are installed downstream of pumps. The effectiveness of the pulsation dampeners should be monitored and their units maintained as recommended by the manufacturer.

10.3 Temperature

Maintaining reinforced composite pipelines within the specified operating temperature is very important during operation. In general, excessive temperature is one of the leading causes of advanced plastics degradation—which is made more complex by the variety of available pipe products and the different maximum rated operated temperatures associated with each.

The temperature rating of stick composite pipe—which can vary from 65°C to 100°C or higher—is primarily based on the type of resin used. The effect of temperature on the design pressure should also be considered. For example, some composite pipes will have a specified pressure rating at 65°C and a reduced rating at a higher temperature such as 90°C. Operations personnel must therefore be made aware of the design basis that was actually used rather than relying on the manufacturer's maximum temperature rating.

The temperature rating for spoolable pipes is mainly based on the inner liner material—most often HDPE Grade PE 3608. Most spoolable pipe manufacturers restrict pipe with a standard HDPE liner to 60°C; however slightly higher temperature ratings up to 80°C may be allowed depending on service fluid conditions. Alternate liner materials—such as PEX, PA and bi-modal HDPE (PE 4710)—may be installed and also affect the temperature rating. The pipe manufacturer should be consulted when any uncertainty exists regarding the pipe's temperature rating.

Using hot oiling to remove wax deposits should be performed very carefully and staying well within the pipeline's design temperature.

Low temperature operation must also be carefully considered due to the relatively high glass transition temperature of HDPE. Where exposure to low temperature is possible, for example during winter start up or under Joule Thomson effects, careful consideration must be given to the increased brittleness of the pipe. Any accidental mechanical impact to the pipe must be avoided.

10.4 Pigging

Pigging is possible in non-metallic pipelines; however, they should be restricted to softer rubber cups (80 or 60 durometer) or foam styles without any metal components. Most pig suppliers or pig manufacturers have product lines that are suitable for reinforced composite pipelines.

An important factor to consider when selecting a pig is the different internal pipe diameters that exist for various reinforced composite pipe products. Do not assume that a NPS 3" pig sized for a steel pipeline is suitable for a NPS 3" composite pipe product as the internal diameters may vary significantly and resulting damage to the composite pipe can occur.

When selecting pig styles or sizes, consideration should be given to the restrictions introduced by the heavier wall risers and the couplings. The pig selection must take into account the pigging requirements for specific lines. Slug removal may require higher pushing pressures then what foam pigs can withstand. Similarly, the presence of sand can significantly reduce the life of the pigs and also jeopardize the integrity of the pipe when the sand particles are trapped between the pig and the pipe wall. To avoid these issues, pig criteria such as a maximum cup oversize, specific durometer and specialized multi cup design should be evaluated.

In all cases, the reinforced composite pipe manufacturer should be consulted for pigging procedures and approved pig products. Ball style pigs or pigs with metal bodies **should not be used.**

10.5 Chemicals

As stated in Sections 4 and 5, the use of chemical additives must be carefully considered before introduction to the pipeline. Chemicals known to be harmful include

- methanol
- strong solvents
- acids (including spent acid flow back)
- corrosion inhibitors
- scale inhibitors
- sulphur solvents

The effect of chemicals on stick composite pipe may be different than the effect on spoolable pipes since different materials are involved. In most cases, the effect of additive chemicals may be minimal if the chemical is only a spot treatment and exposure to the pipe is very short (i.e. a few seconds). Possible chemical carryover from chemical injection at upstream facilities and wells must also be considered.

11 Reinforced Composite Pipelines Repairs

11.1 Stick Pipe Repairs

In general, the repair of a high-pressure composite pipe that utilizes threaded connections will involve the installation of a flange set. This is accomplished by removing the damaged pipe as a cylinder with cut back to the undamaged pipe provided. In some cases, the field installation of a thread by molding can be accomplished on each end of the pipe and threaded flanges.

After cutting, the entire threaded pipe joint may be removed—in some cases by unthreading each of the cut pipe-ends. Following this, a pre-fabricated pipe joint—designed to replace a full pipe joint including a flange set—can be installed.

If lower pressure pipe is involved with adhesive bonded connections, the use of bonded repair collars with a replacement short pipe section may be employed.

Using GPS to record the location of the pipe repair areas is recommended. Tracer wire must be continuous through the repair site.

Pipe manufacturers provide detailed repair methods in their manuals and should be consulted whenever a repair is required for their product.

11.2 Spoolable Pipe Repairs

Spoolable pipeline repairs normally involve cutting a section of pipe—typically three-four meters in length or as specified by the manufacturer. At this point, all damaged pipe should be removed.

> *Note:*
> Damaged pipe layers may have been exposed to pipeline service fluid with some ingress into the adjacent pipe. In these instances, additional pipe length may be required to be cut back to ensure full removal of the service fluid.

Once the repair length has been removed, pipe couplers can be installed on each cut end and the new pipe repair section installed into the couplers.

> *Recommendation:*
> The repair couplers for each spoolable pipe product are unique and cannot be interchanged between different pipe products or pipe of different pressure ratings. As such, it is recommended that the pipe manufacturer's field service crews be on site for all repairs and in some cases to conduct the repairs themselves.

As with stick pipe repairs, the use of GPS to locate pipe repair areas is recommended. Tracer wire must be continuous throughout the repair site.

11.3 Excavation for Repairs

Any excavation of reinforced composite pipe requires extra care to avoid further damage to the pipe. When excavating, the use of probes must be done carefully to prevent damage to the pipe below. Use of probes is acceptable but they should not have sharp ends and should be pushed into the soil carefully.

Hydro-vacuum excavation is commonly used but can also damage pipe by erosion if not done carefully. To avoid damage, the hydro-vacuum contractor should be notified that the pipe material is not steel. In some cases, the use of a multi-nozzle head with dispersing flow—as opposed to oscillating and rotating flow—may be used to avoid mechanical erosion of the pipe. Maintaining a lower water pressure and temperature—than that used for steel—are other measures to be considered and discussed with the hydro-vacuum contractor before this excavation method is used.

12 Monitoring

12.1 Leak Detection

Leak detection methods such as fluid balance, pressure monitoring, and right-of-way patrols are generally no different than standard methods employed for steel pipelines. Infrared pipeline leak detection methods using airborne surveillance would also be expected to function similarly for non-metallic pipelines as for steel pipelines. However, sound transmission in non-metallic pipe will be at a different velocity than steel. As such, leak detection methods using acoustic transmission will need to be reviewed with the leak detection manufacturer to determine its suitability for non-metallic pipe.

Routine pipeline right-of-way surveillance should also be performed looking for any of the usual anomalies such as washed out areas, soil slumps, and evidence of fluid leaks.

12.2 Cathodic Protection (CP)

External corrosion protection is required where steel couplings or steel pipe risers are installed in combination with reinforced composite pipelines—which is typically accomplished by providing an external coating as previously discussed.

CP is also required and is usually accomplished by installing a sacrificial anode designed to last throughout the project. The ability to monitor the CP performance may not always be possible for underground couplers; however, can be accomplished by installing test leads from the steel equipment and anode. This issue requires operator consideration through discussion with the pipe supplier and local regulators regarding the need for CP and ongoing monitoring.

12.3 Pressure Cycles

As previously discussed, excessive pressure cycles and temperature may be damaging to reinforced composite pipelines. CSA Z662-2007 specifies pressure cycle ranges and requires their consideration for pipeline design pressure. Operators should therefore periodically perform and review operational pressure cycles and temperatures.

13 Maintenance and Inspection

13.1 Non-destructive Testing

The options for inspecting and monitoring reinforced composite pipe are more limited than that of steel pipe. In some cases, radiography has been used to examine stick pipe to identify any signs of delaminating of the pipe wall.

For spoolable pipe, bell-holes may be installed at metallic coupling sites—especially if they contain a valve or tee fitting—which would allow for periodic radiography or ultrasonic inspection of the couplings.

Evissive Microwave Transmission (EMT) is a new NDE technology that is being explored for the examination of reinforced composite pipe. Consultation with experts familiar with this technology may assist in determining condition of in-service pipe without the need to perform cut-outs.

13.2 Pressure Testing

To verify the integrity of a reinforced composite pipeline the use of a pressure test may be considered depending on the situation. When pressure testing in service pipelines, it is prudent to maintain the pressure test at or below the pipeline design pressure. In some cases, the test may be performed using the pipeline service fluid; however, the associated risks must be fully evaluated on a case-by-case basis by the pipeline operator. Usually, if the pipeline service fluid contains a significant vapour phase it will likely not be suitable for pressure testing due to the lack of accuracy and sensitivity to small leaks.

13.3 Pipeline Risers

Pipeline risers may provide an accessible location to perform inspection. If the riser end can be opened, visual inspections may be possible using lights or reflective mirrors to view the pipe's internals. A boroscope optical instrument can also be used at risers to view the pipe's internal surfaces and provide an assessment of the surface condition.

13.4 Pipe Cutouts

Any pipe sections that have to be removed should be sent for analysis of its properties and appearance—analyses can be provided by pipe manufacturers or independent laboratories. Lab analysis should provide an indication of how the pipe is standing up to the service environment.

13.5 Integrity Management

Similar to steel pipeline systems, the integrity management of reinforced composite pipeline systems must be addressed by pipeline operators. However, the methodology for prioritizing inspections and risk ranking of pipelines must be approached somewhat differently.

For baseline information, factors based on the failure statistics for composite pipelines as well as knowledge of the general failure mechanisms experienced can be used. Local area operating history may also be incorporated into integrity management planning.

In general, reinforced composite pipelines are more vulnerable to mechanical damage caused by excessive soil induced stresses. Therefore, in geographic areas where poor soil stability, very wet soil conditions, and muskeg are present, pipe damage may pose a greater risk than in areas where flat and drier terrain is present. Often this damage will manifest itself near risers where greater soil disturbance and over-excavation may have occurred during the pipeline installation. Operating factors that increase the risk of pipe deterioration for reinforced composite pipelines include:

- high temperature operation;
- cyclic pressure services;
- the presence of a small margin difference (i.e. <10%) between the operating pressure and the manufacturer's MPR.

Generally, low-pressure rated stick pipe with thinner walls may be more vulnerable to damage than high-pressure thick walled pipe.

Spoolable pipes—due to their inherent flexibility—are generally less prone to mechanical damage than more rigid stick pipe.

Where steel pipe segments for risers or couplers are present, corrosion of the steel pipe sections must be considered for integrity management. In terms of temperature, the margin between the pipe maximum temperature rating and the actual operating temperature of the pipeline can be considered. A larger margin would tend to lessen risk of premature pipe degradation for the same pipe in a given set of service conditions.

The presence of routinely occurring pressure cycles in a pipeline system can lead to premature pipe degradation. This mode of operation should be reviewed with the pipe manufacturer as the effect on the pipe's integrity may vary based on the particular pipe involved and the overall severity of the pressure cycles (amplitude/frequency). Often, where Positive Displacement (PD) water injection pumps are involved—that regularly cycle on and off—severe pressure cycles in the pipeline system may exist that can lead to the premature degradation of reinforced composite pipes. Both stick and spoolable pipe types may be vulnerable to high-cyclic pressure services due to reinforcement fiber or laminate damage. Operators should review and discuss any high-cyclic pressure operation of reinforced composite pipelines with the pipe manufacturer as the effect may vary depending on the pipe product and the operating circumstances involved.

Consideration to electrical power bumps in an operation region should also be weighed during the design and material selection phases of the project.

The remaining life of a pipe that has experienced cyclic service is difficult to determine and often times requires a combination of destructive testing and risk analysis to evaluate probability for future failures (terrain, production being carried, environmental clean-up and habitat concerns, etc.). Remaining life assessments can involve burst testing adjacent pipe samples in coordination with failure analysis of the individual fiber glass layers and epoxy resins. Consideration can be given to applying additional service factors to the maximum pressure rating of the pipe after a failure has occurred. This approach may be justified as the remaining life on the non-metallic pipe that has undergone an excursion will be different then the remaining life determined through the Long-Term Hydrostatic Strength (LTHS) values originally calculated in material qualification test procedures, using ASTM D 2992 and "normal" operating parameters.

14 References

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Appendix A Abbreviations and Acronyms

A.1 Abbreviations and Acronyms

Acronym	Description
CP	Cathodic Protection
CRA	Corrosion Resistant Alloys
ENC	Electroless Nickel
HDPE	High Density Polyethylene
LTHS	Long-Term Hydrostatic Strength
MPR	Maximum Pressure Rating
MAOT	Maxiumum Allowable Operating Temperature
NDE	Non-destructive Examination
PA	Polyamide
PD	Positive Displacement
PEX	Cross-linked Polyethylene
PTFE	Poly-Tetra-Fluro-Ethylene
RTP	Reinforced Thermoplastic Pipe
SCP	Spoolable Composite Pipe
VFD	Variable Frequency Drive

Appendix B Material Selection Guide

B.1 Reinforced Composite Pipe Options- Temperature (T)/Diameter (D)/Pressure (P) Manufacturers Ratings Guideline

Green= Product Available Red= Product Not Available

Pipe Type	Pipe Description	T <60C	T>60C T< 80C	T <90C	T <105C	D • NPS 4	D • NPS 6	D >NPS 6	P < 5.0 mPa	P>5.0 mPa P<10.3 mPa (ANSI 600)	P>10.3 mPa P<15.5 mPa (ANSI 900)	P>15.5 mPa P<17.2 mPa	P>17.2 mPa P<20.6 mPa
Spoolable Composite Pipe, (SCP) Reinforced Thermoplastic Pipe, (RTP)	RTP- Dry Fiber with PE 3408/3608 HDPE Liner	Green	Red	Red	Red	Green	Red	Red	Green	Green Note 4	Red	Red	Red
	RTP- Dry Fiber with PE 4710 HDPE Liner	Green	Green	Red	Red	Green	Red	Red	Green	Green Note 4	Red	Red	Red
	SCP- Bonded Glass Fiber to PE3408/3608 HDPE Liner	Green	Red	Red	Red	Green	Green	Red	Green	Green Note 4	Green Note 5	Green Note 5	Red
	SCP- Bonded Glass Fiber to PE4710 HDPE Liner	Green	Green	Red	Red	Green	Green	Red	Green	Green Note 4	Green Note 5	Green Note 5	Red
	RTP- Steel Strip with PE3408/3608 HDPE Liner	Green	Red	Red	Red	Green	Green	Red	Green	Green Note 4	Green Note 6	Red	Red
	RTP- Steel Strip with PE4710 HDPE Liner	Green	Green	Red	Red	Green	Green	Red	Green	Green Note 4	Green Note 6	Red	Red
Composite Pipe (Stick Pipe)	Bonded glass fiber, epoxy resin matrix	Green Note 1	Green Note 1	Green Note 1	Green Note 2	Green Note 3	Green Note 3	Green Note 3	Green Note 3	Green Note 3 Note 4	Green Note 3	Green Note 3	Green Note 3

Note 1 & 2: Temperature rating is based on the epoxy resin type used for manufacturing, not all rigid composite pipes are rated for the same service temperature, check with pipe manufacturer.

Note 3: Pipe diameter may limit available pressure ratings; generally larger diameter pipes will have lower pressure ratings availability.

Note 4: For gas gathering pipelines the maximum design pressure is restricted to 9.93 mPa by CSA Z662-2007 and maximum H_2S content in the gas is 50 kPa partial pressure. Local regulator may have more stringent requirements.

Note 5: Bonded glass reinforced pipe (SCP) available in NPS 2-6 to 10.34 mPa pressure rating, NPS 2,3,4 to 15.5 mPa pressure rating, and NPS 2-3 to 17.24 mPa pressure rating.

Note 6: Steel strip reinforced pipe (RTP) available in NPS 6" to 10.3 mPa pressure. Available to 15.5 mPa in NPS 2-4 diameters only.