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Developing Inspection and Test Plans for Fiberglass Pipe and Duct Systems

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Introduction

The Fiberglass Reinforced Plastics Institute (FRPI) has just published its first standard practice for fiberglass aboveground pipe and duct system inspection. These procedures were cloned from recognized procedures for fiberglass aboveground storage tank inspection discussed in the July/August 2024 Inspectioneering Journal article "Fiberglass Storage Tank Inspection Procedures Gain Traction in the US" [1]. This new pipe and duct system practice enables the development and implementation of inspection and test plans for these systems, often transferring hazardous substances, such as chlorine dioxide liquid and gas. Please refer to **Figure 1**.

Figure 1. Chlorine dioxide piping.

The FRPI inspection procedures were developed to be consistent with the American Petroleum Institute (API) Standard 570 Piping Inspection Code: In-service Inspection, Rating, Repair, Alteration of Piping Systems [2]. API 570 was introduced in 1993 to help establish requirements and guidelines needed to maintain the safety and mechanical integrity of commissioned pipe systems. Like API 570, FRPI procedures help with asset management and cost optimization. Additionally, they provide the ability to identify and lower the risk of environmental and safety incidents through improved inspection effectiveness, consistency, and equipment reliability.

This article highlights typical challenges with developing inspection and test plans (ITPs) for fiberglass pipe and duct systems. Means for overcoming the challenges are then introduced, with an ITP case history presented to show a basic plan at work.

Planning Challenges

The fiberglass pipe and duct system industry in the United States is a 70-year-old fragmented niche business that is remarkably smaller than the 165-year-old steel industry. Inspection codes and standards for fiberglass pipe and duct systems have been previously nonexistent, causing commercial challenges that have led to asset integrity issues for owner-operators over decades. This long-term absence of procedures has been problematic; a sense of acceptance has set in, and these matters have cost the industry hundreds of millions of dollars in lost opportunity.

Finding someone to inspect fiberglass pipe and duct systems has generally not been a challenge for owner-operators. The bigger problem has been obtaining inspection results of consistent quality from the inspector community. The root cause of this problem is seeded in the fact that the industry has not had fiberglass inspection procedures available. The absence of standardized procedures and acceptance criteria has caused inspection companies to independently develop private practices that may work for some, but have often proved inconsistent from inspector to inspector and caused hardship for owner-operators.

The list of ITP development challenges for pipe and duct system owner-operators and other stakeholders is too long to cover in one article. Noteworthy problems are disclosed in the following sections addressing design basis selection, materials traceability assessment, installation shortcomings, and repair deviations.

Challenge #1 – Design Basis

Determining the basis of fiberglass pipe and duct design is central to ITP development. In the fiberglass industry, there are nine primary standards for mechanical design, which draw in a second layer of reference standards governing material design and dimensions. These standards allow for dozens of alternative designs for a given pipe or duct size based on four alternative standards for fiberglass major component manufacturing methods. The primary categories of pipe and duct products that these dozens of designs fall under can be categorized as mass-produced distributed products (MPDPs) and custom-engineered products (CEPs).

The nine primary standards are recognized and generally accepted good engineering practices (RAGAGEP) that establish the material and mechanical basis of design. The following is a list of these standards, with MPDP and CEP categories shown:

- ASTM D6041 contact-molded pipe and fittings (CEP) [3]
- ASTM D3982 contact molded duct (CEP) [4]
- ASTM D5421 contact molded flanges (CEP) [5]
- ASTM D2996 filament-wound pipe (MPDP) [6]
- ASTM D2997 centrifugally cast pipe (MPDP) [7]
- ASTM D4024 machine made flanges (MPDP) [8]
- ASME B31.1 Power Piping (MPDP) [9]
- ASME B31.3 Process Piping (MPDP) [10]
- ASME NM.2 glass-fiber-RTR piping systems (CEP) [11]

Note: The standard NBS PS15-69 contact-molded process equipment (CEP) design basis for pipe and duct systems is obsolete and no longer in general use by leading equipment manufacturers [12]. This standard was last updated on November 15, 1969. There are a remarkable number of circuits that were installed based on this design, and this standard is still being followed for new circuits and replacement parts by several manufacturers throughout the United States.

The challenge is for owner-operators and inspectors to differentiate and identify which of these standards their circuits are constructed in accordance with. Minding design basis selection is a significant part of the ITP foundation and guides many other ITP development requirements.

Challenge #2 – Material Traceability

The nature of the fiberglass pipe and duct system design basis is the number one challenge that makes inadvertent design substitution a high-priority for investigation when developing the ITP. There are two issues at play here, the first being design confusion and the second product marking issues. Consequently, there is a high likelihood for a facility to have circuits whose complete material and mechanical design basis is unknown.

The MPDP category of the product tends to be consistently marked, given the need to identify it in the distribution channel, and has somewhat distinguishing exterior visual characteristics. The CEP category tends to be shipped with no permanent marking, and exterior visual characteristics are often indistinguishable between manufacturer brands. Once equipment is installed, only some owner-operators adequately ensure circuits are marked to readily disclose design.

The design confusion and product marking issues lead to inadvertent design basis substitution, which may sow the seeds of premature failure. Maintenance planning and procurement practices tend to fall victim to making these inadvertent substitutions. Typical substitution errors include putting in a product with a design basis per NBS PS15-69 in place of ASME B31.3, ASTM D2996 in place of ASTM D6041, or ASTM D4024 in place of D5421.

The net result of substitution errors is a facility ending up with an assortment of vintage designs within a single circuit and/or zone within a circuit. Multiple vintages with no marking are common and escalate the confusion. Please refer to **Figure 2**, where the pipe marked with a red "X" shows four different vintages of pipe in three of five circuit zones where the design of each is unknown. **Figure 3** exemplifies catastrophic inner corrosion barrier failure within two years of being placed in service due to an inadvertent substitution.

It is also important to note that for any circuits determined to have an NBS PS15-69 design basis in a process regulated under EPA 40 CFR 68 and/or OSHA 29 CFR 1910.119, the owner-operator is required to determine and document that the circuits are designed, maintained, inspected, tested, and operating in a safe manner [13,14]. While many circuits determined to fall under this design basis may be safe, some circuits may be at risk of premature failure.

The challenge is for owner-operators and inspectors to identify the suitability of the design basis for all vintages in a circuit. Minding materials traceability assessment is a significant part of the ITP foundation and guides many other ITP development requirements.

Figure 2. Single circuit with multiple pipe manufacturing vintages.

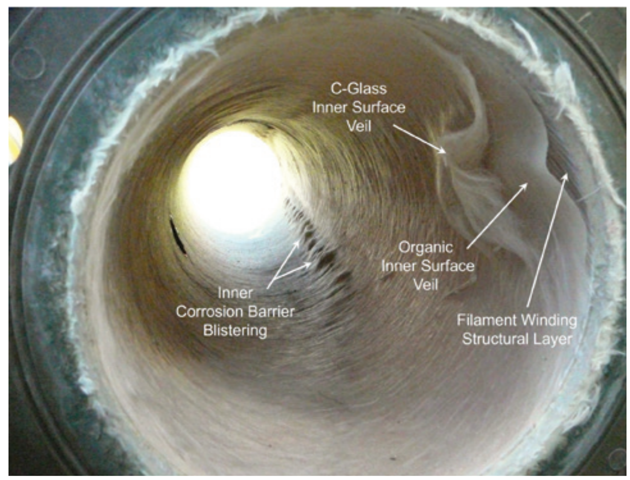

Figure 3. Pipe wall resin attack, permeation, and blistering.

Challenge #3 – Installation

The performance of a fiberglass pipe and duct system and replacement parts installation is often subject to how they were purchased, as purchase scope tends to dictate the extent of engineering and labor experience that goes into the installation. Planned larger systems are more likely to perform better given increased engineering control than parts bought on the fly to be installed during a shutdown by lesser qualified tradespeople. Areas that may have received minimal to no engineering oversight make for high-priority points of investigation when developing the ITP.

There are also two extremes when considering the extent of engineering on larger systems. On one side, a CEP category system may have undergone a full engineering review under a licensed professional engineer who was a fiberglass subject matter expert who performed pipe stress and finite element analysis based on demonstrated laminate physical properties. On the other side is an MPDP category system with manufacturer-engineered pipe or duct lengths, fittings, and joint kits purchased separately from a distributor under the direction of an owner-operator's project engineer, with no system engineering performed.

Mechanical installation success is another vulnerability. Large-diameter systems and systems with long runs tend to invite installation performance issues. Small diameters and shorter runs tend to be more forgiving. Heavy pipe and duct bearing on a poor support fit-up, misalignment, plus unqualified field installers combined with overlooked system stress are some observations inspection reports often disclose and find their way onto ITP checklists.

Poor support fit-up is more prone to occur with products manufactured per ASTM D6041, D3982, and D2996 plus ASME B1.1, B31.3, and NM.2 due to their variable thickness designs and resulting outside diameters. Systems built to these standards generally require custom support, which is seldom provided. Horizontal runs require a minimum 120-degree padded saddle bearing area, where some installations skip the saddle altogether. Please refer to **Figure 4**.

Figure 4. Improper pipe support.

Misalignment of flange connections are other issues that often find their way into inspection reports. Flanges in an all-flanged system being bolted up will not mate flat and parallel with other fixed flanges for all practical purposes. When this assembly challenge is not addressed at installation, an interlaminate delamination will occur over time due to the low tensile elongation properties of the flange (see **Figure 5**). Full-faced flanges mating with dissimilar raised-faced steel flanges and over-torquing to draw flanges together end up with circumferential hub radius, radial, circumferential bolt hole, and cross-sectional cracking most of the time (see **Figure 6**). Faulty ASTM D5421 flange construction is another culprit for these crack-type damage mechanisms.

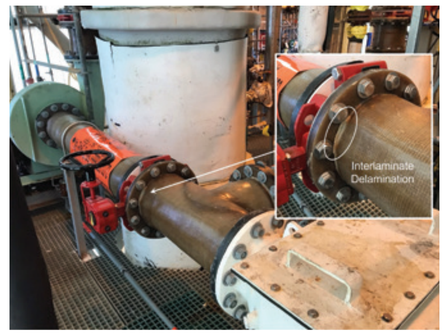

Figure 5. Flange hub radius interlaminate delamination.

Unqualified field installers struggling with the manufacturer's bonding procedure specifications are usually the cause of improper field joining. These issues tend to evolve into field joint adhesive and primary laminate secondary bond attack, with eventual leaking (refer to **Figure 7**).

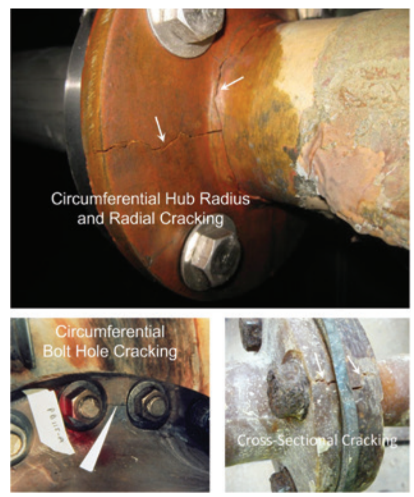

Figure 6. Flange crack damage classifications.

Overlooked system stress may occur in the design, but poor fit-up, misalignment, and unqualified field installers may also compromise the best pipe stress analysis solution. Excessive stress may relieve itself in the form of a crack or fracture, as shown in **Figure 8**.

The challenge is for owner-operators and inspectors to understand the extent of system engineering and the level of mechanical installation quality achieved. Minding installation shortcomings are a significant part of the ITP foundation and guide many other ITP development requirements.

Challenge #4 – Repair

There is a remarkable gap in the grand scheme of fiberglass pipe and duct system maintenance that raises concerns about circuit reliability. Areas that have been or are claimed to be in need of repair make for a high-priority point of investigation when developing the ITP. The gap is created by the fact that industry standards do not exist for the repair of in-operation fiberglass pipe and duct systems. ASME B31.3 and NM.2 have bonder qualification methods leaning on bond procedure specifications, but only for joints and not for repairs.

Figure 7. Secondary bond attack (adhesive and primary laminate).

Many repairs are done on the fly during a facility shutdown, where unqualified contractors get called on to affect a quick fix. The issues with these inappropriate repairs often include the lack of engineering followed by incorrect material selection, no applicable repair procedure specification, poor workmanship, and limited, if any,

Figure 8. Elbow stress fracture.

Figure 9. Inappropriate nozzle neck repair.

quality assurance (see **Figure 9**). Other factors that play into this gap are the question of repairability, a qualification scheme for field technicians, and sufficient time allowed to make the proper repair.

The challenge is for owner-operators and inspectors to know what an engineered repair does and does not look like. Minding repair deviations are a significant part of the ITP foundation and guide many other ITP development requirements.

Overcoming Challenges

The industry began developing steel pipe inspection standards in the early 1990s. In 1999, the Materials Technology Institute (MTI) and Technical Association of the Pulp and Paper Industry (TAPPI) published the first guides for in-operation fiberglass pipe and duct inspection. MTI's was titled "Field Inspection of FRP Equipment and Piping" [15]. TAPPI's was titled "Guidelines for Inspecting Used FRP Equipment," and the title was changed in 2016 to "Best Practice for Inspecting Used Fiber-reinforced Plastic (FRP) Equipment" [16]. These publications were more of an introduction to fiberglass inspection than a set of procedures to follow. Filling this gap in procedures with decades of lessons learned has been long overdue.

FRPI's new standard practice SP8330 "Fiberglass Aboveground Pipe and Duct System Inspection" [17], along with its companion standards first published in 2018, solves problems created by the historical absence of fiberglass pipe and duct inspection procedures. These practices enable inspectors to consistently follow a process for objectively determining end-of-life criteria, remaining useful life, suitability for continued service, and future inspection intervals for these systems. They also allow in-service external and out-of-service internal inspection, as dictated by owner-operator and inspector ITPs governed under SP8330.

The following sections provide key considerations when developing a fiberglass pipe and duct system ITP that addresses the planning challenges identified while following a standardized inspection process emulating applicable elements of API 570. Collectively, these considerations support a flexible top-down planning process tailored to leave the selection of nondestructive and/or destructive test methods to the planner based on the inspection purpose.

Understanding Failure Modes

Before beginning to write an ITP, it is prudent to start with an understanding of how fiberglass pipe and duct systems fail. A formal failure study was conducted in 1991 and presented at a TAPPI annual conference in a white paper titled "Safety and the Environment Versus FRP Process Equipment Standards" [18]. The leading types of failure for 368 cases reported were 32% laminate degradation and 42% secondary bonds (welds), whereas leading causes for these types were 43% poor field assembly, 13% faulty fabrication, and 12% resin selection. While results date back decades, the modes are essentially similar today. These findings underscore the importance of minding the material and mechanical design plus installation details in the ITP.

Fiberglass reinforced plastic (FRP) materials of construction, classified as thermoset plastics, fail differently than other homogeneous materials such as steel and thermoplastics. The underlying difference is that FRP is a heterogeneous material identified by designs composed of numerous combinations of matrix materials and reinforcements. The matrix materials include resin, curing agents, and various diluents that make up a polymer used to bond different organic and glass reinforcement types together by encapsulation or secondary bonds between layers. The FRP eventually fails due to a breakdown of the matrix, reinforcement, and/or polymer bonds.

Another important consideration for mode of failure is mechanical properties, including tensile elongation and coefficient of thermal expansion. FRP has anisotropic property characteristics, which exhibit a remarkably different mode of failure than isotropic steel and thermoplastic properties. While FRP Type I all mat construction and Type II alternating mat and woven roving construction each individually have the same theoretical strength in the "X" and "Y" direction, the strength of Type X filament wound construction is different in these directions and all three construction types typically vary in strength across the "Z" or layer build direction. In contrast, isotropic material properties are equal in all directions. FRP does not yield like other materials.

When writing the ITP, it is important to account for anticipating FRP failure modes considering the design basis, application, installation, and repair schemes that delineate the circuits. FRPI standard SP1030 for identification of damage mechanisms provides a classification method covering 24 terms that are to be used when describing modes of failure occurring [19]. These terms are categorized as normal aging, mechanical events, temperature events, and multiple mechanisms. They are associated with a definition, evidence photographs, cause, and pertinent discussion.

Writing the Inspection and Test Plan

FRPI SP8330 Part 2 Inspection Practice Areas includes guidance for developing the inspection procedure, selecting integrity and leak testing technologies, making determinations, and writing reports. The inspection procedure guidance requires an ITP incorporating relevant integrity and leak testing to support objective determinations around the remaining useful life, suitability for continued service, and next inspection interval for circuits inspected—all within the confines of the inspection purpose stated. Primary elements of the ITP scope to be disclosed include the following:

- Inspection purpose
- Appendix "A" Installation Inspection Checklist items
- Appendix "B" In Operation Inspection Checklist items
- Determinations to be made
- Regulatory requirements and owner guidance
- Inspection procedure RAGAGEP
- History
- Inspection and test methods
- Material and mechanical design basis
- System configuration

The ITP is intended to provide directions for assessing damage per SP1030. Part 2 *Qualifying* and Part 3 Quantifying Damage Mechanisms of SP1030 provide a procedure to identify, describe, and illustrate damage evidence observed. This procedure puts SP1010 Laminate Identification and SP1020 Visual Imperfections into action, where the damage found in a laminate and its impact on laminate performance can be assessed [20, 21]. This damage assessment is also coordinated utilizing SP1040 Integrity and Leak Testing technologies [22].

When writing the ITP, it is important to account for data collection that enables determinations to be made per SP8330. Formulas for calculating rates of degradation and time remaining are provided for when these determinations are required by the ITP, where the methodology is similar to API 570. These calculations necessitate collecting reliable prior and current thickness and/or modulus data depending on the assessment being conducted.

Reviewing History

Researching pipe and duct system circuit history is an obvious essential element of establishing the basis necessary for an appropriate ITP. The review should be reasonably easy if past ITPs were well written and executed, plus inspection reports included appropriate documentation. The reports should have included summarizes of any past:

- Authorized inspection agency reporting
- Damage identified or anticipated and corrected
- Repair organization work completed
- Operating capacity re-rating
- Changes in service

When writing the ITP, it is important to account for a thorough history review. This should also include all relevant situations that have affected the circuits since the prior ITP implementation, interviewing those with special system knowledge or expertise and bringing to light any past ITP program internal or third-party audit findings.

Selecting Inspection and Test Methods

FRPI SP1040 Part 2 *Qualifying* and Part 3 *Quantifying Integrity and Leak Testing* provide a procedure to identify advantages, disadvantages, and limitations of 15 test methods described and then engage a minimum of two appropriate methods to best satisfy the ITP established. This procedure puts SP1030 into action, which provides options for pursuing assessment of multiple mechanisms. Resin attack, permeation, blisters, glass attack, and resin-glass interface attack may lead to erosion, where each of these damage mechanisms are at the root cause of stress corrosion modulus decay. The following evaluation technologies are leading candidates for inclusion in a pipe and duct system ITP:

- Visual inspection
- Sounding
- Core specimen
- Advance Ultrasound
- Infrared Thermography
- Monitored Filament Insertion
- Microwave

Testing technologies listed in SP1040 termed Advance Ultrasound, Infrared Thermography, Monitored Filament Insertion, and Microwave have been technically argued by those deploying the testing to be nondestructive and non-intrusive methods. This means the pressure boundary is not compromised, and the system is not entered during application of the test. A brief introduction to these four emerging technologies follows.

Advanced Ultrasound. This is a patented data collection and analytical process that claims to determine the retained flexural modulus of the structural layer, laminate thickness, and corrosion barrier characteristics for determining remaining service life and next inspection interval. An article in Inspectioneering Journal titled "NDE Methods for Detecting In-Service FRP Damage" summarizes the application of this technology [23].

Infrared Thermography. This is an emerging evaluation method performed when FRP equipment is in service. It is claimed to assist with determining laminate relative thickness reduction and density variation plus the presence of cracks, delamination, and joint discontinuities. The FRPI SP1040 standard provides a description of this method, along with advantages, disadvantages, and limitations, summarizing the application of this technology.

Monitored Filament Insertion. This is a patented robotic testing means that measures laminate damage and predicts failure. It is claimed to digitally graph the degree of saturation of a laminate and facilitate a trend to failure over time. A white paper presented at the TAPPI PEERS Conference titled "Two Strategies and Four Tasks with One Goal: Reliable Fiberglass (FRP) Equipment" summarizes the application of this technology [24].

Microwave. This is an emerging volumetric technique that incorporates vector network analyzer advancements. It is claimed to detect damage mechanisms plus measure their size and location, including laminate thickness. An article in Inspectioneering

Journal titled "Advanced Microwave Inspection: Evolution of the Method" summarizes the application of this technology [25].

When writing the ITP, it is important to account for the scope and skill level of visual inspection. With about 88% of damage mechanism classifications that can simply be observed visually, an in-depth expert external and internal visual inspection of the circuits is invaluable.

Determining Material and Mechanical Design Basis

The requirement for disclosing the pipe and ductwork system basis of design in the ITP seems elementary and sounds like an obvious routine checkbox item. However, considering the challenges with identifying the system due to it being one or more of ten primary standards of design, possibly comprised of multiple vintages within a circuit or zone, maybe customized, and often insufficiently labeled, a method for determining the design basis is crucial to the determinations necessitated by the ITP. The SP8330 appendices provide checkbox items for describing the circuit application, identification of laminates per SP1010, and benchmarking visual imperfections per SP1020.

FRPI SP1010 Part 2 *Qualifying and Part 3 Quantifying Laminate Identification*. This standard practice provides a procedure to identify, describe, and illustrate the laminate design basis. The procedure puts ASTM C582 plus ASME RTP-1 Part 2 and Part 6 material standards into action, where laminates are described by classifications, composition plus visual observations of reinforcement textures and sequence, inner surface mold impressions, outer surface patterns, and polymer components [26, 27]. Recognizing and correctly characterizing laminate composition by layer is a critical element of the ITP.

FRPI SP1020 Part 2 *Qualifying and Part 3 Quantifying Visual Imperfections*. Similar to SP1010 and now focused on imperfections, this standard practice provides a procedure to identify, describe, and illustrate imperfection evidence that affects laminate performance characteristics. The procedure puts ASTM C582 plus ASME RTP-1 Part 2 and Part 6 material standards into action, where the imperfections found in a laminate and their impact on laminate performance can be assessed in consideration of its SP1010 design basis determination. Recognizing and correctly characterizing laminate quality by layer is another critical element of the ITP.

When writing the ITP, it is important to account for the steps necessary to identify the material and mechanical design basis for each vintage of pipe or duct in each circuit by zone. This identification may be easier if the vintages are readily recognizable or clearly labeled as one of the mass-produced distributed products whose design is properly documented by the product manufacturer. Conversely, if vintages are unlabeled, the SP1010 and SP1020 identification processes will need to be performed to a practical extent in order to correlate discoveries with the primary standards of design to best describe its material and mechanical basis.

Defining System Configuration

The scope of physical pipe and/or duct system inspection to be included in the ITP is a given. In writing the ITP, the following elements of the circuit configurations inspected are to be disclosed on an isometric or layout drawing and defined in the plan:

- Circuit and zone identification
- Sizes and pressure ratings
- Process chemistry and temperature exposure
- Bonded and/or flanged joints
- Mixing points
- Injection points
- Dead leg locations
- Threaded connections
- Vibration sources
- Unusual or localized degradation modes or rates
- Condition monitoring locations
- Gasket and fastener materials

When writing the ITP, it is important to account for any process design deviation variables that may affect the integrity of the pipe or duct and include the time span for such deviations. It is also necessary to identify any special pipe or duct system accessibility, preparation, and surface cleaning relative to the configuration to conduct the inspection.

Simple ITP Case History

A typical outcome of a simple visual inspection performed without a complete ITP can often lead to costly premature actions. In this case history, a chlor alkali facility decided on the fly during an outage to remove a 12-inch section of four-inch diameter pipe in hot wet chlorine gas service. They determined, based on an internal visual inspection, that the circuit from which it was removed should be replaced at their next annual shutdown at a cost in the hundreds of thousands of dollars. This preliminary decision was based on noteworthy erosion observed, where the mechanical integrity engineer's instinct was to obtain a second opinion.

An ITP was developed for the second opinion, to objectively determine the circuit's estimated remaining useful life. Relevant SP8330 Appendix "A" and "B" inspection checklist items we selected for the ITP. This included visual inspection and core specimen evaluation per SP1040, material traceability assessment following SP1010 and SP1020, plus damage mechanism classification in accordance with SP1030. A history, regulations, owner guidance, and system configuration review were also included in the ITP.

Historical documentation was reviewed, including an isometric drawing defining the system configuration, plus a procurement specification describing the material and mechanical design basis of the pipe. No prior inspection or repair reports were available. The circuit was externally inspected, where all documentation details were verified except for the pipe label that identified a different design basis. The specimen extracted was internally and externally inspected, destructively tested per ASTM D638 tensile properties and D2584 glass content, and a laminate sequence evaluation was performed per ASME RTP-1 Part 2A-400(d) and 6-930(c) protocol [28, 29].

The ITP findings were quite revealing (see **Figure 10**). The pipe specimen extracted was a Type X filament wound with a 54-degree wind angle measured as anticipated. Additionally, an organic veil was detected as the inner surface layer of the inner corrosion barrier (ICB), along with swelling, blistering, and erosion. The softened ICB, known as chlorine butter, was easily removed down to stable laminate. The total pipe wall and remaining layer thicknesses were measured with digital calipers and reasonably verified by the sequence of glass content remains following an ignition loss of cured reinforced resins test. Observations included:

PIPE WALL THICKNESS	DIMENSIONS
Undisturbed total	0.415 inches (10.5 mm)
After butter removed ("A")	0.324 inches (8.2mm)
Inner corrosion barrier ("B")	0.103 inches (2.6 mm)
Structural layer ("C")	0.135 inches (3.4 mm)
Outer corrosion barrier ("D")	0.086 inches (2.2 mm)

Other ITP findings needed for determining the four-inch diameter pipe circuit's estimated remaining useful life included identifying the original pipe wall design thickness. The actual outside diameter (OD) of the cutout specimen was measured, the inside diameter (ID) was assumed to be equal to that stated in ASTM D6041 Part 8 Dimensions and Tolerances, and the thickness was derived from the relationship between the OD and ID. This assumed original thickness appeared logical, as it met the allowed tolerance at 95% of design and swelling of 6% to 0.415 inches (10.5 mm) thick was within reason. Resulting observations were:

PIPE WALL DESIGN	DIMENSIONS
Outside Diameter (actual)	4.779 inches (121.4 mm)
Inside Diameter (assumed)	4.000 inches (101.6 mm)
Thickness ((OD - ID) / 2)	0.390 inches (9.9 mm)

To determine the circuit's estimated remaining useful life based on the ITP findings, the Type X structural layer quantified was assumed adequate based on the pipe manufacturer design recognizing the ICB as a corrosion allowance and given the ASTM D638 findings were nonconclusive. Therefore, SP8330 erosion rate and erosion time remaining calculations were prepared for the ICB based on ITP findings. With a known circuit having ten years in service and a minimum thickness of 0.221 inches (5.6 mm) allowed (structural layer plus outer corrosion barrier), an erosion rate of 6.6 mils (0.2 mm) per year and 15.6 years remaining useful life was estimated.

In conclusion, recognizing the impractical linearity implied by the calculations used to predict time to failure, this simple ITP case history led to ten-year estimated remaining useful life and five-year next inspection interval determinations. The mechanical integrity engineer was pleased to know a costly pipe system replacement was not imminent, and they had more time to engage in a deeper investigation into reported unknowns if necessary. Unknowns included long-term structural layer strength retention and localized higher rates of degradation at other points in the circuit, such as abrupt changes in flow direction, mixing, injection, and/or dead legs.

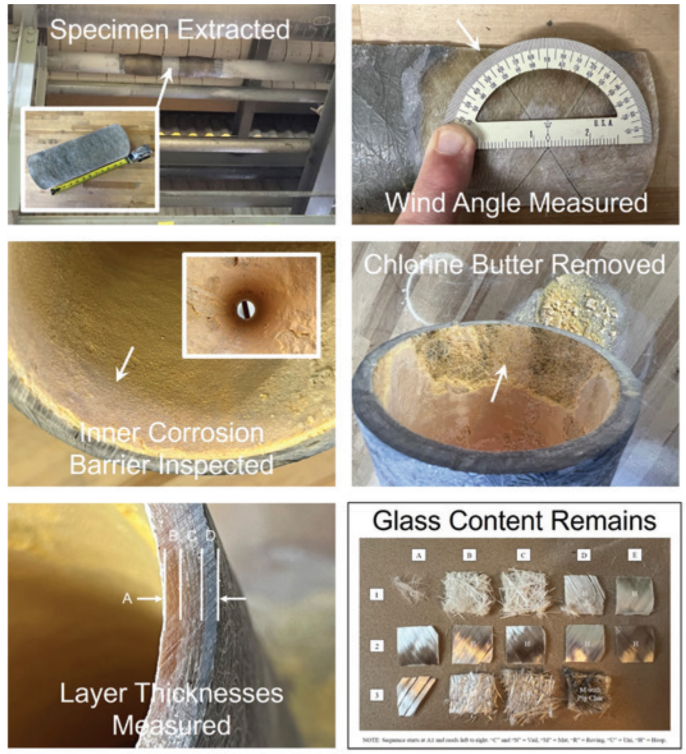

Figure 10. Basic core specimen evaluation.

Planning Limitations

The FRPI SP8330 standard practice guidance for developing an ITP covers a broad and deep body of knowledge to roll up in the planning process. However, it currently does not include qualification methods for vetting, certifying, and licensing authorized inspection agencies, inspectors, and auditing organizations. Owner-operators will still need to qualify those involved with developing, implementing, and auditing compliance with the ITP. Guarding against premature removal of pipe or duct and inadequate risky ITPs due to improper condition assessment is still necessary to mitigate vulnerability in the fiberglass industry.

Conclusion

Many technical details go into writing comprehensive inspection and test plans for fiberglass pipe and duct systems. Standards governing inspection procedures and supporting coursework are finally available, enabling challenges to be overcome in the planning process and guiding effective plan implementation. These procedures reflect a broad compilation of industry experience spanning 70 years. Regular utilization of these procedures in developing the ITP can help all owner-operators and inspectors perfect their expertise. This results in improving the consistency of mechanical integrity assessment of fiberglass circuits, plus improved system reliability, cost-effectiveness, facility safety, and environmental protection for all stakeholders. ■

For more information on this subject or the author, please email us at inquiries@inspectioneering.com.

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