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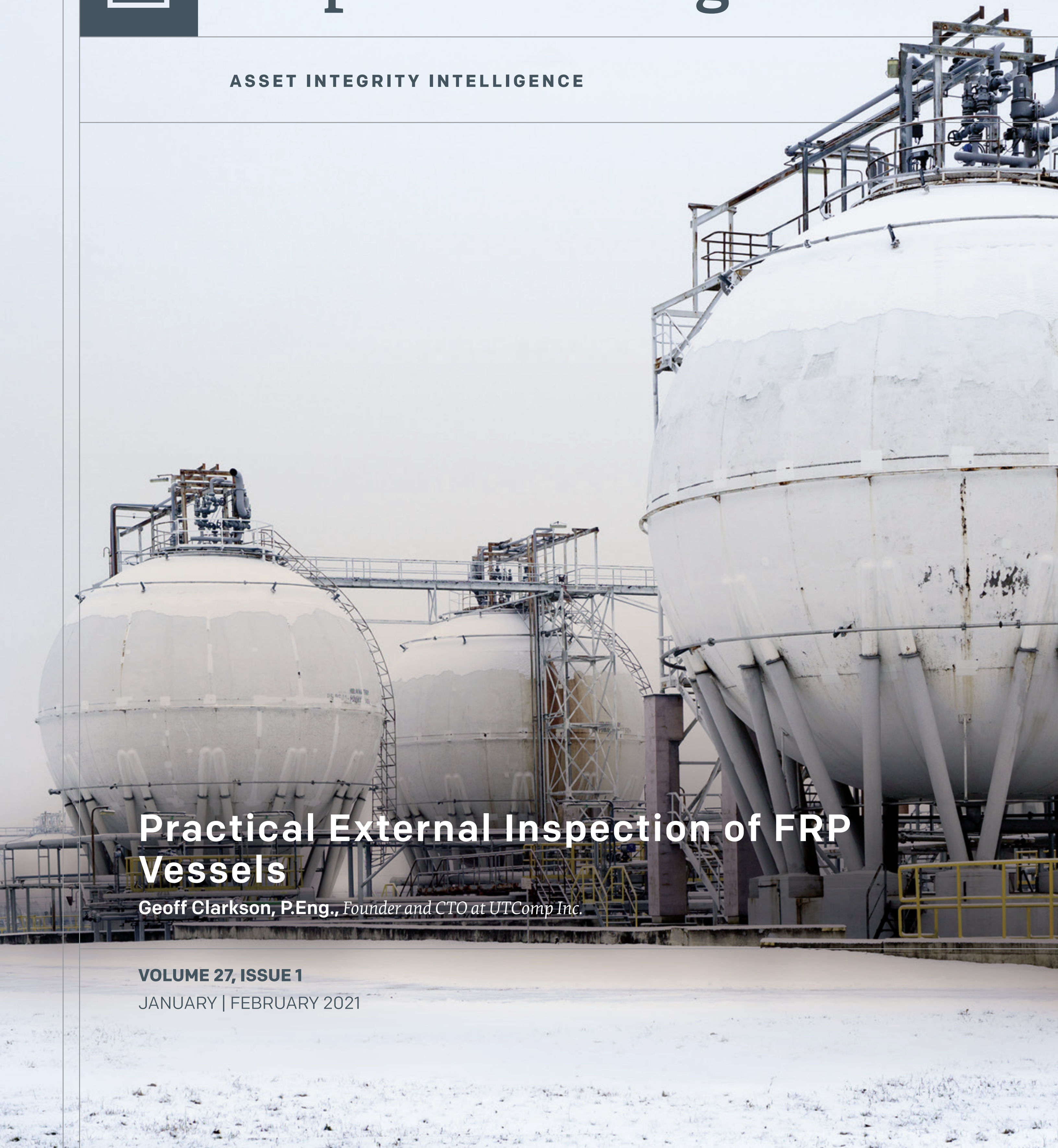

Practical External Inspection of FRP Vessels

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Introduction

For the purposes of this article, vessels include storage tanks, chemical reactors, scrubbers, and other containers for storage or processing of chemicals. Since usage of Fiber Reinforced Polymer (FRP) for vessels and piping in the chemical processing industry (CPI) started in the 1950s, many users have experienced reliability problems. In response to this, there has been significant work to establish standards and codes for FRP vessel design.[1-5] They have contributed significantly to increased reliability of FRP equipment.

Even with these increases in reliability, some vessel failures still occur, some of which could have been prevented or mitigated by following a systematic external inspection program. This article provides a systematic process/program for these external inspections that serves to increase reliability.

If corrective action is recommended, it can be identified at one or more of the stages in the process, including analysis of the cause, evaluation, and engineering of possible solutions, design, and execution. This work is usually unique to each situation and is beyond the scope of this article.

Behavior of FRP Material

Fiber reinforced polymers are used in many corrosive applications because the polymers provide superior corrosion protection to many metal alloys. Unlike metals, FRP used for most industrial applications is not ductile – it cannot be bent and it does not form ductile fatigue cracks. When overloaded, it behaves as a brittle material. FRP materials also undergo changes while they are in service from stresses and chemical attack. The standards and codes used to design FRP equipment recognize this and use design factors to increase the thickness of the FRP to beyond what is required for long term service.

It is also very important to note that the tensile strength of FRP can be tailored to match how the design stresses are applied. For example, if the only stress expected by the designer is hoop stress – such as for an open-top tank, then the FRP in the shell could be designed and built with very little strength in the vertical direction, since it wouldn't be necessary. But if a cover is attached to the tank and the tank is overfilled so that liquid contacts the cover, the tank will now be under pressure and the shell may be overstressed in the vertical direction where the hoop strength does not apply. An example of what can happen is shown in **Figure 1**, where a storage tank with a cover was overfilled and the tank shell failed because of the vertical stress that was much greater than the design. It is important to note that this failure occurred because the vessel was subjected to loads that were not included in the design requirements, even though there were no flaws detected in the material.

Figure 1. One consequence of over-filling

In many cases, the author has found that many defects identified using this systematic approach have existed from the time of installation or fabrication and have not yet been corrected. Please note that most of the items described below can result in loss of containment and probably interruption of operations. Code-level design documents provide guidance on this issue at the design stage, but standard-level documents may not provide for overfill protection.[1-5]

External Inspection Overview

Codes and standards that are typically used for design of FRP vessels limit their inspections to those required for the design and manufacture. No guidance is provided for fitness for service inspections or inspections after commissioning of the equipment. The American Petroleum Institute (API) has several inspection codes for vessels, that focus on steel or metallic vessels. No explicit coverage is provided for FRP vessels. The external inspections described here are modeled on API 653, with some additional items of relevance to FRP.[6]

In most cases, external inspections should be completed while equipment is operating so that corrective action can be determined and planned for outages.

Systematic external inspection is grouped into four major categories. The categories and what they include are listed below:

1. Support Structure: Structural support of the vessel such as the concrete pad or steel structure and any anchors.

2. External Condition: The condition of the outer surfaces associated with the vessel, including insulation, cladding, vessel shell and roof, and paint and coatings.

3. External Components: The presence and condition of overflows, pressure relief, vacuum relief, venting, external attachments, and seal pots.

4. Pipe and Nozzle Connections: All flanges and connections to them.

For each category, inspection can be organized using a systematic and logical approach. In a number of cases, software can be used to automatically evaluate the situation and provide recommendations based on a simple "Yes" or "No" questionnaire. This can be combined with notes and photos to improve analysis and documentation. Furthermore, software can be used to evaluate complex situations more objectively.

For each of these categories, we will identify items for inspection. Examples and photos are also provided to illustrate the types of situations where corrective actions are required or not required. The examples provided do not include all possible situations that could occur. If the inspector finds a situation where it is not clear if corrective action should be required, it is recommended that the correct choice is to require corrective action so that other members of the team can help to assess whether there is a defect and then take appropriate action.

Category: Support Structure

Item	No Corrective Action Required	Requires Corrective Action
• Settling or deformation. • Damage to support steel or concrete.	• Concrete or steel is level. No cracks. • No significant corrosion. • No material loss. • No deformation.	• Concrete or steel is not level, significant cracks, corrosion causing material loss, pieces broken out of base, coatings perforated.

Figure 2. Support that does not require corrective action.

Figure 3. Support that requires corrective action.

Item	No Corrective Action Required	Requires Corrective Action
• Hold-down anchors are in place. • Corrosion of anchors.	• Vessel was not designed for anchors. • Bolts, nuts and anchor plates are snug. • Corrosion has not rendered threads unusable or reduced thickness more than 5%.	• Anchors not in place or fastened. • Significant corrosion that has reduced the capacity to less than required. • Loose bolts, nuts, anchor plates.

Figure 4. Anchors and hold-downs that do not require corrective action.

Figure 5. Anchors and hold-downs that require corrective action.

Category: External Condition

Item	No Corrective Action Required	Corrective Action Required
• For insulated equipment, the condition of cladding or presence of leaks.	• Surface is undamaged, no cracks or signs of leakage.	• Any cracks or evidence of leaks from behind the cladding. This could show as leaks where cladding sections meet.
• There is damage to the exterior surface. Cracks or leaks are present in the FRP of the shell or heads.	• The surface is hard and relatively smooth. No cracks or leaks are present. The FRP does not flake off of the surface.	• Cracks are visible in the outer surface of the FRP. • There are signs or evidence of leaks from inside the equipment.

Figure 6. Intact FRP surfaces where no corrective action is required. Note that flaking of paint from the outer surface is normally considered to be superficial.

Figure 7. External surfaces that have been damaged; corrective action is required.

Figure 8. Cracks and leaks in the outer surface that require corrective action.

Category: External Condition

Item	No Corrective Action Required	Corrective Action Required
• Body flanges connecting vessel sections.	• No cracks in the flange.	• Cracks in the flange.

Figure 9. Body flange where corrective action is required.

Item	No Corrective Action Required	Corrective Action Required
• Fiber bloom and exposed reinforcement	• No exposed fibers. • If fibers are exposed and they are not straight.	• Exposed straight glass or reinforcement fibers.

Figure 10. Reinforcement where no corrective action is required.

Figure 11. Exposed reinforcement where corrective action is required.

Category: External Components

From the example of **Figure 1**, a very common item that causes loss is related to overflows, pressure relief and vacuum relief.

Item	No Corrective Action Required	Corrective Action Required
Overflow.	• Open top tank with or without a pipe for the overflow. • Overflow is attached below the roof and does not have a high point above the roof attachment.	• No overflow on the side of the tank. • Tank is vented with vertical or gooseneck vent on the roof with no side overflow

Figure 12. Overflows where no corrective action is required.

Figure 13. Tank with no overflow; corrective action is required. Note the staining from overfill spills out of the top nozzle. While this tank has not yet failed, every overfilling event creates a new risk of failure.

In some cases, tank overflows include traps or seal pots. If the liquid in the seal pot or trap could freeze, or if the tank contains a slurry that could plug the seal pot, it will prevent the overflow from functioning, with the same possible result as in **Figure 1**.

Some tanks are intended to be pressurized and have pressure relief and vacuum protection instead of overflows.

Item	No Corrective Action Required	Corrective Action Required
• Pressure relief or vacuum breaker on the vessel.	• Pressure relief and/or overflow is present and operation can be verified.	• Not present or operation cannot be verified.
• Ladder supports, overflow supports, etc.	• Attached and secure.	• Damaged.

Figure 14. Combined vacuum breaker and pressure relief. Operation can be verified by confirming that the internal disks lift.

Category: Pipe and Nozzle Connections

Flange damage and cracks are the most common failures for FRP vessels.

Item	No Corrective Action Required	Requires Corrective Action
All pipe stub-ins and attachments have a reinforcing pad on the outside surface.	Reinforcing pad is visible and 3 inches to 6 inches larger than the nozzle.	No reinforcing pad is visible.

Figure 15. Reinforcing pad (repad) where corrective action is not required.

Category: Pipe and Nozzle Connections

Item	No Corrective Action Required	Requires Corrective Action
Cracks are present on the backs of any flanges on nozzles. Include body flanges on the vessel.	• No cracks are visible. • Any visible cracking is narrower than a knife blade (0.25mm or 0.010″) or is only present in the paint.	• Cracks are present where a knife blade can be inserted. • Stains or leaks at visible cracks. • Discontinuities are visible within unpainted FRP.

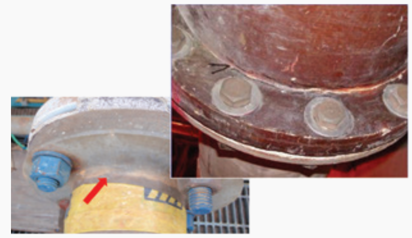

Figure 16. Flange cracks where corrective action is required.

Item	No Corrective Action Required	Requires Corrective Action
• FRP flanges are correctly bolted and mated to the correct flange type.	• Flat faced to flat faced; or, • Lap joint to lap joint or raised face; or, • Correct spacer between flat face and other flanges.	• Any arrangement where the FRP flange faces are not fully in contact with compressed gasket.

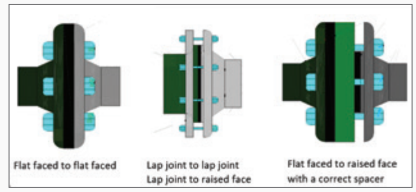

Figure 17. Acceptable FRP flange arrangements that do not require corrective action. Note that lap joint flanges are sometimes described as Vanstone flanges.

Item	No Corrective Action Required	Requires Corrective Action
• Valves and pipes are supported close to the flange.	• Supports are installed for valve on tank nozzles. Pipe connections are supported near the tank nozzle. • Drain nozzle flanges are not in contact with concrete	• Supports are not in place or not providing support.

Figure 18. Unsupported valve that requires corrective action.

Completing the Inspections

The inspections outlined above are normally completed by personnel after a modest amount of training. By using a systematic questionnaire, the results can be analyzed very quickly to identify situations where vessel reliability might be reduced because of avoidable and repairable factors. In some cases, using a computer program can enable fast and accurate analysis and record keeping. This approach has been shown to provide increased reliability for FRP vessels in many applications and areas. ■

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

REFERENCES

1. ASTM, "Standard Specification for Contact-Molded Glass-Fiber-Reinforced Thermoset Resin Corrosion Resistant Tanks," ASTM International, West Conshocken, Pa.
2. ASTM, "Standard Specification for Filament-Wound Glass-Fiber-Reinforced Thermoset Resin Corrosion-Resistant Tanks," ASTM international, West Conshohocken, PA, 2010.
3. ISO, "EN 13121 GRP Tanks and Vessels for use above ground," BSI.
4. ASME, "ASME RTP-1 Reinforced Thermoset Plastic Corrosion-Resistant Equipment," ASME, NY.
5. ASME, "BPVC Section X-Fiber-Reinforced Plastic Pressure Vessels," ASME, NY.
6. American Petroleum Institute, Tank Inspection, Repair, Alteration and Reconstruction, Designation API 653, Washington, DC: API Publishing Services, 2009.

CONTRIBUTING AUTHOR

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Geoff is the CTO and Founder of UTComp, Inc. His innovative company works globally to help eliminate uncertainty about the condition of FRP assets during production, delivery and in-service, allowing their remaining life to be determined. Geoff completed his engineering degree at the University of Waterloo, Canada in 1982, specializing in Systems Design Engineering. His decades of experience have helped him lead the way in the successful establishment of ultrasonic testing and fitness for service engineering for FRP composites. Geoff is a Member of the Order of Honour of Professional Engineers Ontario and a Fellow of Engineers Canada.