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Guidelines for inspecting used FRP equipment

Scope

This document describes how "used" fiber-reinforced plastic (FRP) tanks and vessels should be formally inspected to determine their condition, which must be known to assess fitness for continued service. Three phases of inspection are defined – external inspection when the vessel is in-service; external and internal inspections when then the vessel is removed from service. All three inspection phases must be carried out for the inspection to be considered complete. Complementary inspection with acoustic emission testing (AET) also is discussed.

This document does not discuss criteria for repair, repair methods and procedures, or criteria for assessing the fitness-for-service of FRP tanks and vessels.

These inspection guidelines also can be applied to all laminated construction FRP components, including stacks, hoods, ducts, piping and "dual laminate" equipment; i.e., FRP with an integral thermoplastic corrosion barrier. Resin-based reinforced linings, which can be heavily filled with inert materials or glass-reinforced laminates and are typically trowel or spray-applied, are not covered. However, where such linings are corrosion barriers the general principles described herein for determining their condition would apply.

Safety precautions

These guidelines describe practices and procedures involving internal and external inspection of process vessels, tanks and equipment. Prior to conducting any inspections or carrying out any actions described in this document, the user/inspector should be fully conversant with the safety policies and practices that apply to working around, on or in the specific equipment involved. These safety policies and practices should be defined and provided by the owner/operator of the equipment, who is solely responsible for ensuring the effective policies and practices meet appropriate personnel safety requirements established by local, state and federal authorities.

Basic Structure of FRP Tanks and Vessels

General structural concepts

Fiber-reinforced thermosetting organic resins are relatively new composite materials of construction called FRP, GRP or RTP, for Fiber-Reinforced, Glass-Reinforced or Reinforced Thermoset Plastic. The FRP acronym is chosen to represent all these terms in this document, because it is a widely recognized term and glass is not the only fiber reinforcing material used in equipment made from this material.

All FRP composite tanks and vessels share the same construction elements: a structural wall and a corrosion barrier.

1. The structural wall provides the shape and strength of the structure.
2. The corrosion barrier is on the process side to protect the structural wall against chemical attack. In some cases, e.g. in some mass-produced FRP pipe, the corrosion barrier can be omitted, but this is the exception not the rule.
3. The structural wall and corrosion barrier also both have laminated (or layered) construction.

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TAPPI

(CSM is available in both 0.75 and 1.5 oz/sq.ft. unit thicknesses; each providing a corresponding ply.) For especially severe service (e.g. chlorine dioxide bleach towers) the corrosion barrier thickness can be increased – up to 0.25 in. (6.35 mm) in some cases – by increasing the number of veil and mat reinforced layers. For example, a "double thickness" corrosion barrier would have 2 veil layers and 4 or 5 mat layers.

The thickness and glass content of the respective layers in any FRP component depends greatly on the form of fiber reinforcement. This can be a relatively wispy, fine veil; a CSM; a woven fabric or "roving", or continuously wound fiber threads or "filaments". CSM also can be produced from continuous strand by feeding it through a chopper gun, which chops the glass and adds the resin at the spray gun as the glass is propelled to the laminate surface.

Figure 1 shows two typical laminate designs for FRP equipment. The structural wall is always either filament wound construction or hand lay-up construction. (These construction methods are rarely used together.) Filament winding construction is suited to cylindrical shapes that can be mounted on rotating equipment for the winding operation. Hand layups can be done on molds of any shape or form. The corrosion barrier is always hand laid-up, with the inner surface on the mold (with a release sheet of Mylar.)

Filament wound laminates, with their higher glass content, usually are stronger than the same thickness of hand laidup laminates, especially in the winding direction. The angle of the helical winding should be selected to optimize the axial and hoop strengths of the component, which requires a winding angle close to 55 degrees (w.r.t. the axis) for internally pressurized, cylindrical vessels.

Despite the focus of this document on glass fiber as the reinforcing material, other fibrous materials also are used. The most common alternative is polyester fiber. As previously mentioned this is most widely used as a thin, woven, veil fabric for the inner surface, and sometimes as a heavier fiber mat for other layers. (Polyester fiber mat also is used to reinforce cure-in-place pipe liners.) Carbon fibers have a higher strength-to-weight ratio than glass and can provide electrical conductivity in a composite layer, may be used for that purpose or for their excellent chemical resistance.

Resins

The resins used in FRP equipment are organic thermosets: they cure to a hard condition by catalyzed chemical reaction and cannot be softened or reshaped by heat. The resins are mostly epoxy, epoxy vinyl-ester or polyester-based compounds and form the matrix for the reinforcing fibers (most commonly glass fibers), producing the composite structure.

The most widely used resins for FRP process tanks and vessels in pulp and paper mills are polyesters and epoxy vinyl esters. Epoxy and furan resins can also be used for composites and epoxies are widely used in mass-produced components like pipe, valves, etc.

Epoxy vinyl ester resins generally have better chemical resistance than polyesters, especially to oxidizing environments found in bleach plants. Both types of resin can be readily fabricated as FRP and they are available in fire-retardant formulations. Resin selection should be based on the extensive information on the various resins, their properties and chemical resistance available from the resin manufacturers and from other sources. The curing system is usually chosen by the fabricator, and can affect the resin performance.

Joints

An important aspect of FRP equipment construction and reliability is how joints are made; e.g., head or shell joints, nozzle and manhole inserts, baffles, etc. Joints are mostly made by fitting up the pieces, filling any gaps between them – which have definite size limits – with a resin-rich paste, then wrapping the joint with an appropriate secondary lay-up laminate. The thickness, width and structure of the secondary lay-up are prescribed by the design, as are details for protecting cut edges of joined pieces and for optimizing the durability of the joints and lay-ups.

In-service, External Infra-red Thermography (IRT) Inspection

In-service inspection of FRP equipment can be greatly enhanced with IRT. The IRT equipment should produce a scanned image of the object, using long wave IR radiation (around 10 µm) to detect temperature variations as low as 0.1°C (0.18°F).

IRT can find areas that are either warmer or cooler than the surrounding area. For equipment with warm contents, warmer zones usually indicate thinner laminate or permeation by the process liquid into the structural laminate. On the other hand, cooler zones or spots in these tanks are commonly due to dry voids, deposit build-up, or delamination air gaps/blisters. Inverted indications would exist for equipment with cooler contents.

IRT in-service inspection is strongly recommended for FRP bleach towers and pre-retention tubes (especially uninsulated vessels), chlorine dioxide and sodium chlorate storage tanks, stacks and large diameter piping.

Out-of-Service, External Walk-down and Inspection

In the same way that external in-service inspections are crucial to identifying which parts of an FRP vessel or tank warrants detailed internal inspection when the opportunity arises, detailed external inspection of the vessel or tank when it is shutdown and emptied should precede internal inspection.

It is not uncommon for flaws and problems areas to be more visible when FRP tanks are cool and empty, especially if the walls are more translucent then.

External outage inspection shall consist of close inspection of:

- attachments and structural supports,
- the base of the tank or vessel and accessible shape changes,
- all nozzles and openings.

Radiographic Inspection (RT)

RT of FRP pipe can reveal and quantify wall thinning. The RT procedure should be qualified on standards of new pipe. This inspection method can be refined for in-service inspections. The in-service, field RT inspection procedure should be qualified by mounting a reference standard on the outside of the pipe. It also may require specialized equipment to compensate for pipe vibration.

The findings from all the external inspections – IRT, in-service and out-of-service – must be used to define the scope (and urgency) of an internal inspection. In particular, suspicious features or areas from external inspections must be inspected when the vessel is internally inspected. This in turn defines what access is needed to inspect suspicious areas or features.

Internal Inspection

Preparation

Before entering an FRP vessel or tank, the inspector should:

- Become familiar with the laminate design, especially of the corrosion barrier. (In some cases — more so in recent years — cutout samples of the original fabrication might be available for direct reference.)
- Have the proper inspection tools (see **Inspection Equipment** below), equipment and lighting.
- Ensure the vessel or tank is clean and safe to enter. FRP surfaces are required to be dry for valid inspection.
- Ensure that locations indicated by external, visual and IRT inspections for internal inspection can be safely accessed.
- Be aware that the condition of the corrosion barrier is the critical issue and minimize damage to this barrier during the inspection.

- Location, distribution and number
- Nature (cracks, blisters, etc.)
- Size (maximum and average usually are sufficient)
- Depth or other useful descriptions vis-a-vis the corrosion barrier thickness.

Determining the Depth of Cracks or Deterioration

As stated before, the integrity of the corrosion barrier is the key to the durability of FRP equipment in corrosion service. The depths of cracks, blistering, buttering or other attack of the corrosion barrier must be determined. This is best done by carefully probing the depth to which the problem affects the corrosion barrier and laminate, using gentle digging, grinding or drilling.

A wide-angle router bit or special "divot" tool can reveal the relationship between the crack depth and the corrosion barrier layers. The conical, exploratory hole usually is carefully made at one or two appropriate spots, deep enough to get to the bottom of the feature or flaw. The resulting "divot" or hole should be examined at 10X magnification to determine how much of the corrosion barrier is still there, and how far below the surface the deterioration has progressed.

The condition of the corrosion barrier defines the projected service life of the equipment and when repairs should be done. Depending on the depths of cracks, blistering, buttering or other attack of the corrosion barrier and other considerations, it may be preferable simply to document and monitor these conditions rather than to immediately initiate repair of the laminate. Consultation with experienced FRP specialists can help avoid unwarranted or unnecessary repairs and ensure appropriate repair procedures are used.

Delaminations and Thickness Measurements

Delaminations are characterized by separation of the plies or layers in the laminate as in blistering, or by disbonding of the secondary overlay – especially at overlay edges. They also may occur at cut or unprotected edges and emanate from other corrosion barrier or laminate flaws. They are common around the edges of secondary overlays.

Because it leads to air spaces or hollows, delamination blistering often can be detected with oblique lighting or by tapping or sounding the surface. The edges of overlays are routinely checked by prying at them with a paint-scraper or knife.

Delaminations can arise from improper inter-layer bonding in initial fabrication or from physical damage. If the corrosion barrier is intact and well-supported, repair of the delamination may be unneeded. If the delamination grows, or is large enough to raise concerns about the durability of the corrosion barrier, it should be evaluated by the divot method or by or by removing a core sample of the entire laminate.

Ultrasonic thickness meters can be useful in determining the depth and size of delaminations, as well as in measuring full laminate thickness. As with all NDT methods, proper calibration, experienced technicians and qualified techniques are essential for meaningful, accurate results.

Magnetic thickness testing can be used to determine laminate thickness up to about 60mm (1.5in.) thick. ASTM D-4166 is a standard procedure for its use. This is a relatively simple, accurate and reliable way of measuring FRP laminate thickness, where there is access to both sides of the laminate.

Spark testing

Spark testing can be used to check the integrity of new FRP, laminate linings on conductive substrates. However, spark testing of FRP linings that have been in service is not advisable. Permeation into the resin layers in the lining by the process environment can increase its conductivity enough for holes to be burned through the lining by the spark test.