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Guidelines for inspection and nondestructive testing of cast iron paper machine dryers

Scope

This Technical Information Paper (TIP) provides guidelines for inspecting cylindrical, steam-heated pressure vessels made from gray cast iron (GCI) and used as rotating dryers in papermaking. These guidelines also apply to *unheated* GCI cylinders of the same construction. Large Yankee dryers typically used on tissue machines are not addressed in this TIP.

These guidelines are limited to inspection of the dryer pressure vessels themselves. Inspection of related steam and condensate piping, relief valves, bearings and gears, and doctoring devices is not directly covered. Nevertheless, the inspector should report unusual symptoms and conditions in those components and include that information in the inspection findings as soon as they are detected, in order to prioritize the suspect dryers for detailed inspection at the earliest opportunity in the “out of operation” mode (i.e., during a dryer shutdown).

This document complements TAPPI publication, *Guidelines for the Safe Operation of Steam Heated Paper Machine Dryers* (1). The inspection and NDT methods recommended in these guidelines generally apply to dryers made from other materials, including cast ductile iron and cast carbon steel, although dryers made from ductile materials (> 15% elongation) do not require the same degree of inspection and concern as dryers made from gray cast iron.

This TIP does not describe how to assess the significance of damage revealed by inspections. In that regard, API579-1/ASME FFS-1 “Fitness for service” (2), a post-construction code accepted by the National Board of Inspectors, provides rules for assessing fitness for service of pressure vessels, including a dryer with corrosion and wear damage. Guidelines in this TIP do not supersede local jurisdictional and regulatory requirements.

Safety precautions

Personal safety for inspectors and NDT technicians is ensured by their fully complying with paper mill procedures for equipment lockout and safe entry of confined spaces and by use of required personnel protective equipment (PPE). A dryer must be cool and adequately ventilated, as confirmed by gas testing.

Outline

These issues are discussed in more detail in following sections:

- Background information
- Damage mechanisms affecting GCI dryers
- Inspection scope planning
- Inspection frequencies
- Inspections performed in three operational modes:
 - a. Running (normal operation)
 - b. Idle (temporarily stopped)
 - c. Out-of-service/shutdown (stopped, cooled and open for internal inspection).
- Qualifications for inspection personnel and nondestructive testing (NDT) technicians
- Documentation of findings

Background information

Most GCI dryer cylinders made in North America after 1950 have been designed and manufactured in accordance with Section VIII of the ASME Boiler & Pressure Vessel Code (3). A GCI dryer has three main components: a cylindrical shell and two bolted heads, each with a journal (see Fig. 1). The tending side (TS) and drive-side (DS) heads are not exactly the same. The shell has an internal flange at each end for bolting the head. Each head has three integral elements: hub journal, dish-shaped head and flange for bolting the head to the shell. The journal may be part of the head casting or separately bolted or shrunk and made of steel or ductile iron. (Heads of a “Unicast” dryer cylinder are integrally cast with the shell.)

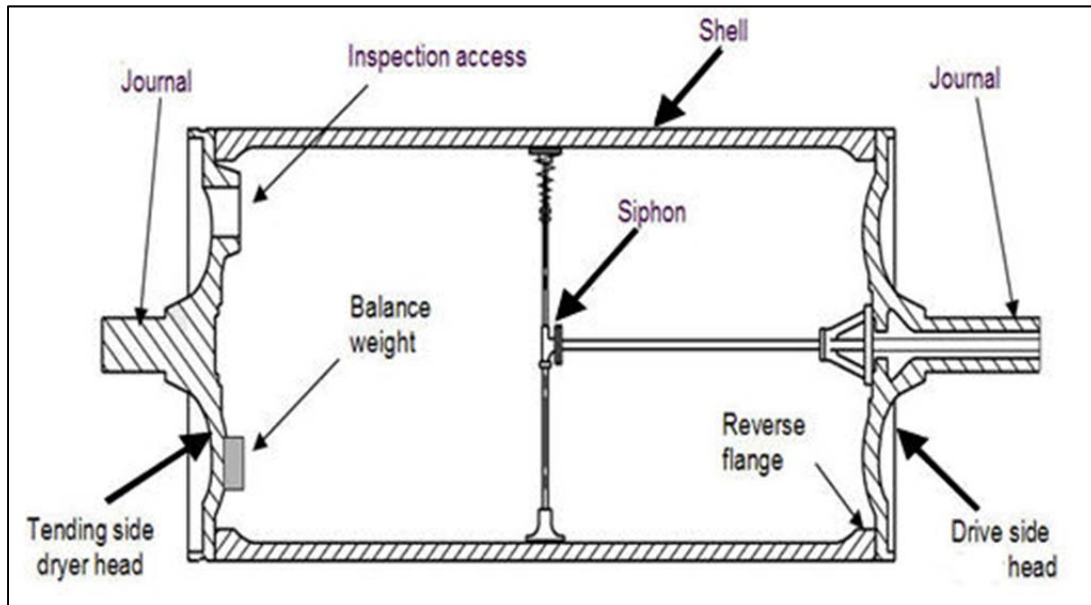


Figure 1. Dryer cross-section. The siphon can be fixed or rotate with the dryer (like this one).

Because GCI has no ductility it can fail catastrophically in a brittle manner - with no deformation from overstress. Somewhat counter-intuitively, however, the graphite flakes in the GCI microstructure give it low sensitivity to mechanical notches and thus relatively high tolerance for cracks and linear casting flaws. GCI is the only cast metal for which the ASME B&PV code allows no credit in terms of the design safety factor from volumetric flaw inspection by radiographic or ultrasonic testing.

As described later, local variations in the metallurgical microstructure of GCI castings require special precautions for acceptable ultrasonic thickness testing.

Damage mechanisms

Most catastrophic dryer failures to date resulted from an internal groove worn in the shell by loose hardware tumbling inside the dryer. Fatigue cracking in the head is another significant concern. Cracks also have been caused by severe thermal shock from spraying a hot or warm dryer with too much cold water. Uneven heating of a dryer on startup, e.g., by supplying steam to a stationary dryer, especially one with ponded water, makes cracking and distortion more likely.

The inspection methods described in this TIP typically find the following damage symptoms that could compromise a dryer's mechanical integrity:

1. Shell thinning, locally due to internal tumbling wear, or uniformly from external wear by a doctor blade.
2. Cracks in the head, especially around the journal and the manway, and in the flange.
3. Cracks or failure of the bolts joining the heads to the shell.

Internal, circumferential grooves from "tumbling wear" occur when loose hardware rolls around inside the dryer. *It is important to be alert for related symptoms of this damage mechanism, e.g., unusual noises from the dryer on 'running mode' inspections.* Localized shell thinning from condensate erosion can occur around improperly positioned fixed siphons. External wear from doctoring typically creates visible grooves and scoring.

Cracks that grow usually are from fatigue. (The cracking mechanism in GCI is difficult to identify by fractography.) Fatigue cracks, which occur where cyclic stress is locally concentrated by flaws and sharp surface shapes, mostly affect the head around the journal, around the opening, and in the flange. Internal pressure contributes to external surface fatigue cracks on heads but cracks also can occur at corners of internal ribs.

A prime inspection goal is to find fatigue cracks small enough for safe removal by grinding. API579-1/ASME FFS-1 has analytical procedures for determining the acceptable dimensions of grooves made to remove cracks and linear flaws. (Small cracks and casting flaws in GCI also may be repaired by a plugging method described in Section VIII of the ASME B&PV code.)

Carbon steel bolts joining the head to the shell are subject to stress corrosion cracking (SCC). The main cracking 'agent' is believed to be carbonate/bicarbonate ions in steam condensate. Because condensate must contact the bolt, SCC typically is associated with steam leaks around bolt holes, making steam leaks are both a potential cause and a symptom of cracked bolts. Ritualistically testing every bolt with no evidence of steam contact over a cycle of 5 or so years is of decreasing importance if no cracks are found in bolts more than 20 years old. A primary benefit of finding cracked bolts is the chance to remove them before they crack so badly they break when they are loosened. Carbonate/bicarbonate SCC is mitigated by specifying ASTM A193 B7M bolts, which deliberately have hardness <RC 25.

Inspection planning

Five essential tasks in planning dryer inspections are:

1. Establish an inspection plan that covers all the dryers.
2. Review past inspection or condition information.
3. Identify specific dryers to inspect next. Results from inspecting all the dryers from the tending and drive sides in running mode and idle mode are crucial in identifying dryers for detailed internal inspection at the next shut down. Steam leaks, thermal signs of flooding or siphon failure, and strange noises are some reasons to internally inspect a dryer at the next shutdown. Other reasons include drive or bearing problems and incidents of thermal shock from application of a cold water stream or from a fire in the dryer section.
4. Arrange for qualified inspectors, and written procedures. 'Walk-down inspections' in running mode and idle mode should be done by mill personnel trained to identify the critical symptoms and conditions listed above. Only appropriately qualified NDT technicians (see **Appendix A**) should inspect and do NDT for internal thinning, head cracks and cracked bolts. Mill personnel trained and qualified in appropriate NDT methods can do the NDT. Whenever practical, the proficiency of hired NDT technicians should be verified on a standard with known flaws, e.g., a dryer head with cracks, before they test the dryers.
5. Fully document all dryer inspections and NDT, except routine 'walk-down inspections' by machine operators of dryers in running mode and idle mode. (See **Appendix B** and **Appendix C**).

Inspection frequencies

Running mode and idle mode

Routine “walk-down inspections” of a dryer section should be done every day or two. Formal, documented visual and infrared thermography inspection in both run and idle modes, with a checklist for each dryer, should be done at least every two months.

Out-of-service (shutdown) mode

General industry practice is to comprehensively inspect an open and cool dryer at least once every five years. The interval between “out-of-service” inspections for a specific dryer should be adjusted for appropriate condition-based circumstances: cracks or other questionable conditions may warrant more frequent inspections. The default, five-year inspection interval also may be expanded if a longer inspection interval is based on engineering evaluation and risk assessment and if routine walk-down inspections do not indicate more urgent inspection is required.

Factors to consider in establishing the inspection frequency for a specific dryer include:

- What is known about the age and condition of the dryer’s principal components
- The dryer’s maintenance history, especially problems with bearings or internal components like siphons, balance weights and spoiler bars.
- Operating conditions, especially if rotational speed or dryer section pressure are increased (rerated)
- Recent dryer wash-down, sheet or felt wrap removal and fire-fighting incidents

Inspection practices

Running mode (normal operation)

The inspector should perform and record a methodical walk-down inspection on the tending and drive sides of the dryer sections, checking for the following:

- Active steam leaks
- Unusual dryer noise or motion
- Unusual dryer temperature - infrared thermography (IRT) can indicate problems with steam supply or condensate drainage
- Excessive shaking, rocking or swaying of a dryer frame; loose or cracked structural supports

NOTE: Immediately inform supervisors in papermaking and maintenance departments of suspicious conditions!

The main purpose for inspecting operating dryers in this mode is to detect early signs of problems that could affect dryer reliability, thereby identifying dryers for detailed follow-up inspection during or before the next planned machine shutdown. The inspector should record all significant observations on a formal inspection report.

Idle mode (temporarily stopped)

The main purpose for inspecting dryers in idle mode is to find early signs of problems and to identify dryers for high priority inspection. A trained operator/inspector should walk-down the tending and drive sides of an idle dryer section with good lighting looking for:

- Steam leaks, including stains and deposits especially in the bolt circle
- Missing head bolts/studs
- External corrosion, wear or impact damage
- Excessive lube oil leakage or other signs of bearing distress
- Poor condensate from the dryers (IR sensing equipment facilitates finding this)

NOTE: Immediately inform supervisors in papermaking and maintenance departments of suspicious conditions!