Hydrostatic testing of Yankee dryers

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ABSTRACT: The hydrostatic pressure testing of a Yankee dryer is performed as a fitness-for-service test made before delivery of the Yankee. In some countries, there are also statutory requirements for on-site hydrostatic testing after the delivery, as well as periodic testing of the cylinder during its lifetime. Hydrostatic pressure testing is discussed, and the particular case of a Yankee dryer failure during on-site hydrostatic testing is described.

KEYWORDS: Drum driers (drum dryers), failure, hazards, hydraulic pressure, pressure, test methods, yankee driers (Yankee dryers).

The hydrostatic pressure test is performed by filling the dryer with water and increasing the pressure to 1.5–2.0 times the design pressure, depending on the specific pressure-vessel code. The dryer is filled and pressurized with water because the potential for explosive failure of a cracking cylinder during this test is greatly reduced with the incompressible medium.

Hydrostatic testing is a fairly relevant testing procedure for a pressure vessel that will only be exposed to an internal pressure. A Yankee dryer, on the other hand, has a much more complicated loading situation. The dryer is pressurized with hot steam and cooled on the outside of the shell by the wet sheet. This induces large thermal stresses in the shell. The Yankee dryer is also a rotating pressure vessel that is mechanically loaded from the outside with the linear load from one or two press rolls. In **Fig. 1,** the relative magnitude of these loads can be seen. In this case, the load from internal pressure is only 23% of the total load.

These facts reduce the relevancy of the hydrostatic testing of a Yankee dryer; in some cases, it may cause more harm than good.

Dryer deformation

Figure 2 illustrates the deformation of the Yankee dryer during the hydrostatic test, which means deformation from internal pressure only. This load causes a bending moment in the shell and head flange area that attempts to increase the angle between these parts at the flange interface.

Figure 3 illustrates the deformation of the Yankee dryer during operating conditions. The significant deformation here is the thermal deformation caused by the wet sheet on the shell surface. This reduces the diameter and length of the shell and causes a bending moment in the flange corner that decreases the angle between the shell and head at the flange interface.

Stress distribution

Figures 4 and 5 provide two plots of the maximum principal stress in the flange area, with the hydrostatic test condition shown in Fig. 4 and the running condition in Fig. 5. The dark areas in these plots indicate high stresses.

These plots clearly show that the stress distribution is quite different for these two scenarios. During hydrostatic testing, the high stresses are located on the inside of the shell flange and extend into a region around the first grooves for a ribbed dryer. For the operating condition, the stresses in this area are very low and mostly compressive. The high tensile stresses are, in this case, found on the outside of the shell. This is an effect of the thermal stress, caused by the temperature difference through the shell wall, that creates a bending stress in the shell with compressive stresses on the inside and tensile stresses on the outside.

The hydrostatic test requirement makes the design of the flange area more difficult, as two different load scenarios must be considered. For running conditions, the current bending forces tend to open a gap between the head and shell at the

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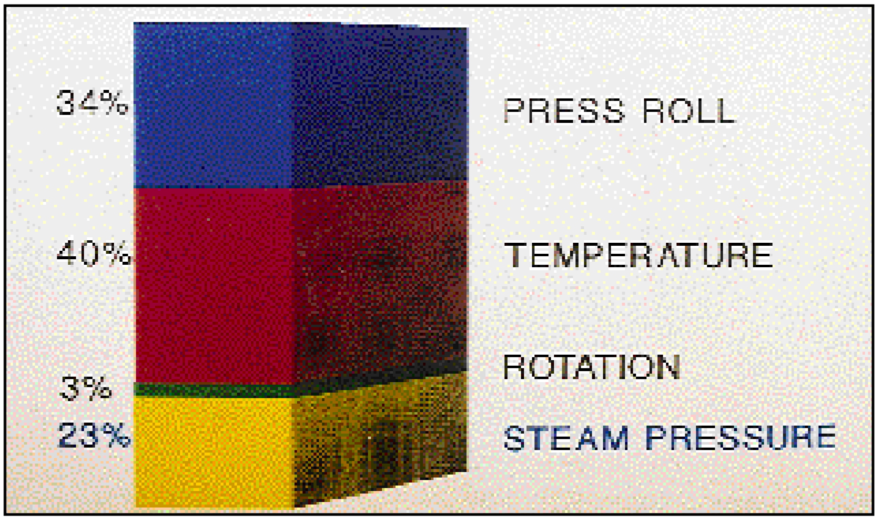
outer head radius. This will increase the risk for crevice corrosion between the shell and head flange.

The loads during hydrostatic testing are just the opposite of those for running conditions, so a design compromise must be developed that keeps the deformations within acceptable limits for both. If this is not done, a gap may develop in the spigot fit area on the inside of the flange connection at the shell-flange inner radius.

This gap will only be present during the hydrostatic test, but it may cause permanent deformation that could cause problems in the future—steam leaks, for instance.

The hydrostatic test is examining the dryer and demanding design considerations for a completely different load scenario than what the dryer will be exposed to during its operating lifetime. The primary justification for a hydrostatic examination is to establish that no major flaws exist in the materials of construction and to inspect the dryer for eventual leaks.

1. Yankee loads



On-site hydrostatic testing

The previous discussion described hydrostatic testing that is routinely performed by the manufacturer before delivery of the Yankee dryer. Some countries, such as Italy and Russia, also require an additional hydrostatic test after delivery of the Yankee to the mill. The purpose of this test is to determine whether any damage was inflicted during transportation to the mill site.

Some countries also require a hydrostatic test at regular intervals during the lifetime of the dryer. Others require a hydrostatic test even after relatively minor repair work on the dryer.

These on-site hydrostatic tests introduce some new concerns about this procedure, since mills normally do not have the same control over the testing process as the manufacturer, which does this procedure routinely.

These new concerns include:

- The enormous weight of water—upwards of 300,000 lb in large Yankees—can require structural analysis and additional structural support for the vessel.
- The Yankee cannot sustain the additional water weight through its bearings and, therefore, arrangements must be made to support this load through the heads. Without proper support of the Yankee, it can be irreparably damaged.
- Care must be taken to ensure that the water used does not carry or create deposits that may cause a nonuniform barrier to heat transfer.
- The monetary costs and downtime to perform the structural analysis, provide adequate building and Yankee support, perform the hydrostatic test, and internally clean the Yankee are considerable.

Case study

Let's look at a case study from a Yankee dryer in a Russian mill as an example of the potential danger involved with these on-site hydrostatic tests.

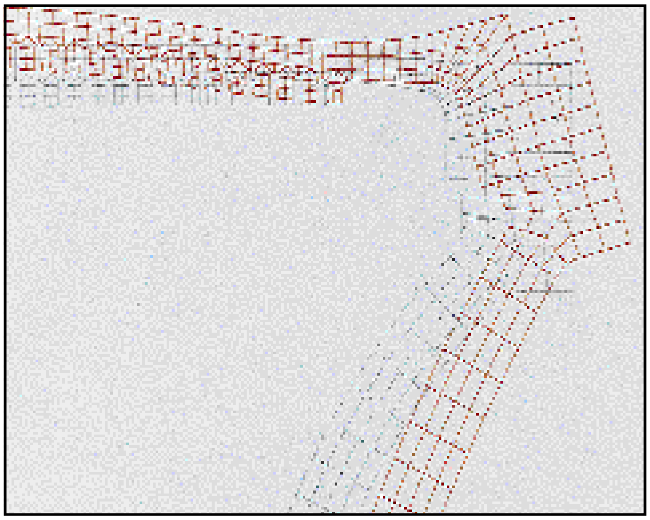
On this dryer, the mill had problems with two minor steam leaks between the head and shell flanges and was injecting sealant through predrilled holes in the head. After this repair, the Russian authorities required a new hydrostatic test.

The Yankee was manufactured in 1987. The diameter was 5000 mm (195 in.), and the shell length was 4850 mm (191 in.). The design pressure was 900 kPa (130 psi). This dryer was hydrostatically tested the first time at 1350 kPa (196 psi), which is 1.5 times design pressure, before delivery. Then, according to Russian rules, it was hydrostatically tested a second time after arrival in the mill. This was done in December 1988. In January 1993, steam leaks were sealed, and the dryer was hydrostatically tested a third time.

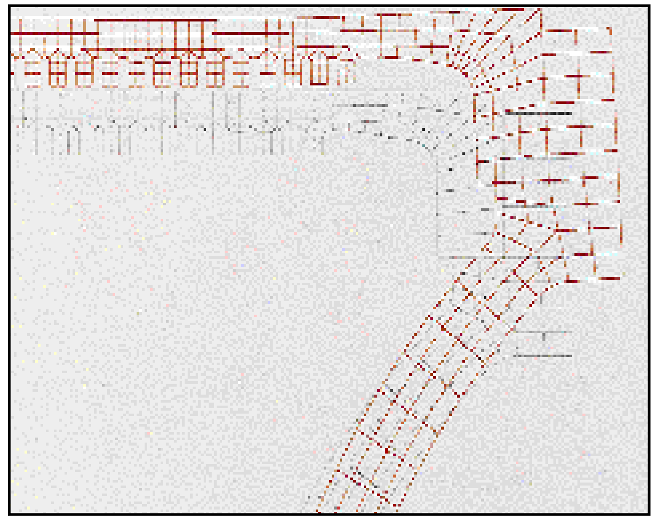
Before filling it with water, the Yankee was unloaded from its bearings and supported with cradles that were positioned underneath the shell in the flange area on the front and back sides. The water pump that was used to fill the dryer had a capacity of 730 L/min at 2100 kPa (190 gal/min at 305 psig) or 420 L/min at 3750 kPa (111 gal/min at 554 psig).

This means a pressure capacity was possible of up to 4.2 times the maximum allowable working pressure of the dryer. A manual pump was also installed in the system that, after filling, would be used to increase the pressure to its final value.

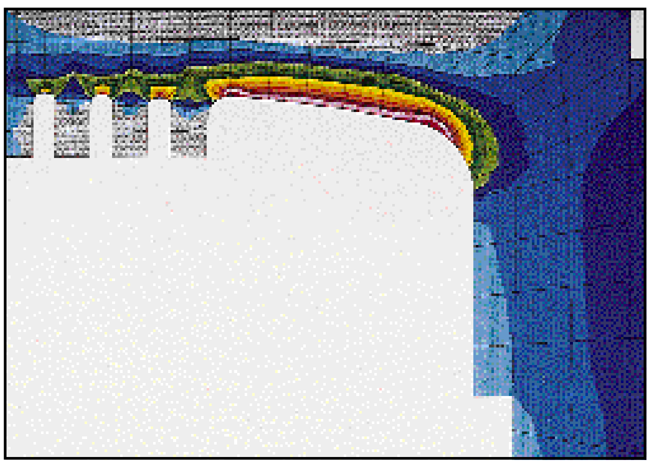
2. Deformation during hydrostatic test



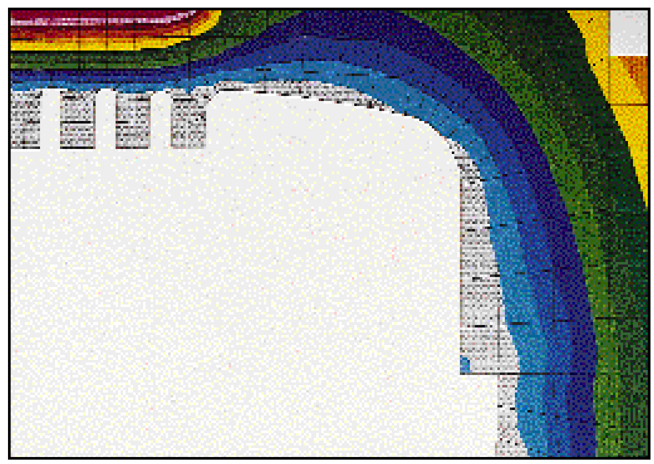
3. Deformation during operation



4. Stresses during hydrostatic test



5. Stresses during operation



The dryer was made ready for the hydrostatic test but was not filled with water because it was getting late in the day. Plans were made for the testing to be done the next day, and preparations would continue the next morning. However, during the evening, the plant employees began to fill the dryer with water to save time the next day.

The filling was initially made through the open manhole, which was located in the 12 o'clock position. At around 10 p.m., the manhole cover was closed and the filling continued. The air evacuation in this stage was done through a 10-mm-diameter hole in one of the head-to-shell bolts. About an hour later, the dryer cracked. No personnel were near the dryer at the time.

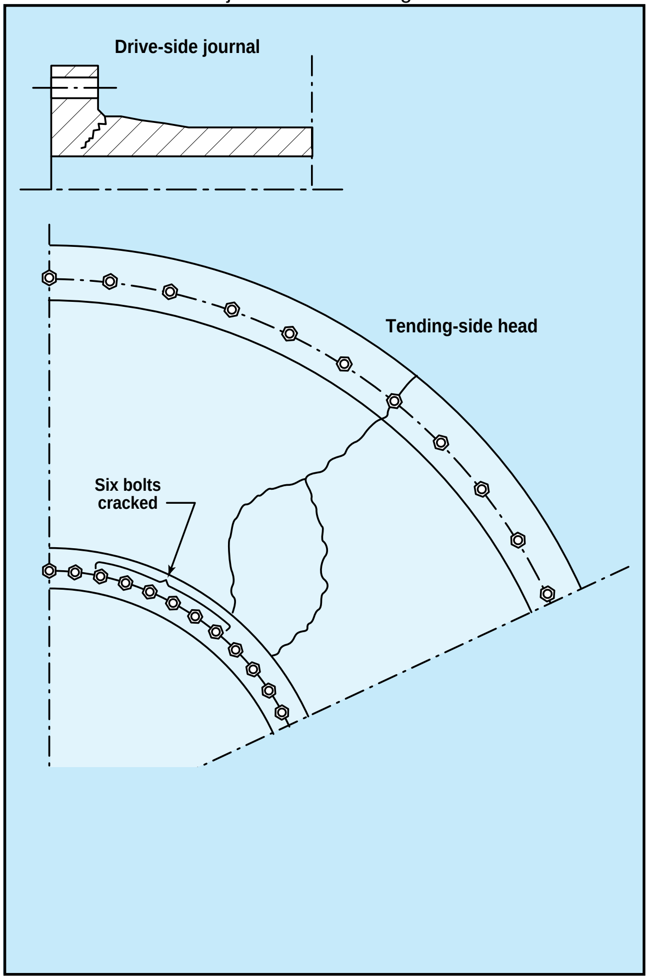
It was not known at what volume or pressure the pump was operating when the failure occurred, but a rapid pressure increase is expected when the dryer is filled and water starts to be evacuated through the 10-mm air-venting hole, or if this hole becomes plugged by some foreign material. Later calculations indicated that at about 2500 kPa (363 psi) the stresses in the dryer reach a critical level, which is also the pressure level that was expected to be created by the pump.

Here is a list of the resulting cracks in the dryer:

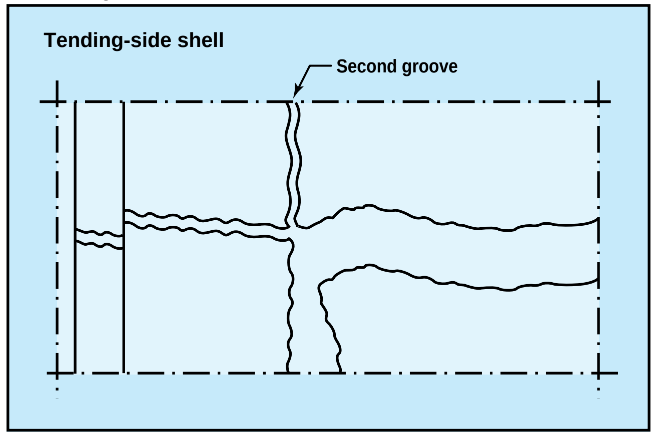
- Drive-side journal cracked at inner flange radius
- Six journal-to-head bolts broken on tending side
- Radial cracks at Bolt 135 on tending-side head
- Crack across shell at Bolt 135
- Circumferential crack in tending side at second groove
- Circumferential crack in drive side at first groove.

This list is written in the probable order in which the cracks developed. It suggests that the initial crack probably occurred in the center flange, followed by the heads being pushed

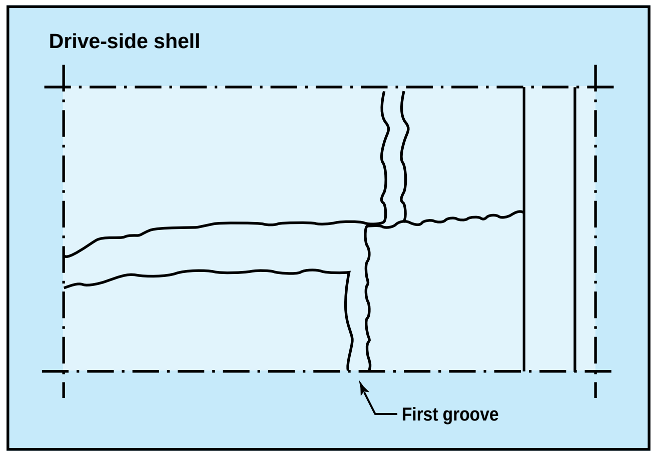
6. Cracks in drive-side journal and tending-side head



7. Tending-side cracks in shell



8. Drive-side cracks in shell



out and the breaking of the journal-to-head bolts. From this point, radial cracks progressed in the head out to the shell flange, where the axial crack started and progressed over the full width of the cylinder. From this axial crack, the two circumferential cracks were initiated. These cracks started close to the outer grooves in the shell that is, as shown earlier, one of the areas of highest stress during a hydrostatic test.

Figure 6 shows the position of the crack in the center flange, also a very highly stressed area during a hydrostatic test, and the cracks in the tending-side head.

Figures 7 and 8 show the crack pattern in the tending side and the drive side of the shell.

Summary

The case study clearly establishes the danger inherent in on-site hydrostatic testing. When we combine that danger with the costs associated with hydrostatic testing and compare them with the information gained by performing the tests, the risk and costs are far too high.

With improved calculation methods and material investigation procedures, the value of the on-site hydrostatic test has changed over the years. Global acoustic emission examination and a variety of modern and sophisticated local nondestructive testing procedures provide good alternatives to hydrostatic testing. These examinations should be performed by experienced, qualified technicians using a detailed written procedure.

For all these reasons, the Yankee Dryer Safety Committee strongly feels that in any case where a request for an on-site hydrostatic test is made, a discussion should be initiated with the involved authorities to try to substitute the hydrostatic testing with a safer and more appropriate testing method. TJ

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