Hot Water Heater Failures — Assessing a Common Residential Risk

D.R. Turriff and M.N. Bailey

When was the last time you inspected your hot water heater? These large cylindrical units are commonly referred to as water ‘tanks’, and are often hidden in basement closets and ignored until a cold shower or growing water puddle reminds you of their startling importance. Failures such as slow leaks can go undetected, and water heater claim severities can be high. In this article, we review the basic structure of hot water heaters, provide guidance for gathering evidence in heater failure claims, and examine a failure case study that highlights common defects.

According to a recent review of US homeowners’ insurance claims, water heater failures constitute one of the top five sources of residential water losses.¹ The results of the study showed that out of 700 tank failures, the majority (69%) were due to the tanks slowly leaking or suddenly bursting via rust and corrosion issues (see Figure 1). The age at failure ranged widely from 1-30 years (average of 10.7 years). We will explore different factors affecting this broad failure range.

Anatomy of hot water heaters and how they work

In North America, most homes utilize one of two distinct tank-type heaters: electric or gas-fired. Here, we will focus on electric heaters (Figure 2). Cold water enters through the top of the tank and travels down to the bottom through a dip tube. Electric elements inside the tank heat the water to a temperature controlled by an adjustable thermostat found on the tank’s exterior. Colder, denser water remains near the tank bottom and hotter, less dense water rises to the top of the tank, where it is drawn off by the outlet pipe to supply household demands (sinks, showers, appliances, etc.).

---

¹ Institute for Business and Home Safety (IBHS) data regarding hot water heater failures. Obtained with permission from [1].
Figure 2. Schematic of an electric hot water tank and tank wall cross-section

The steel tank often contains a horizontal, circumferential lap weld joining the lower portion of the cylindrical tank to the upper portion of the tank, with some overlap at the joint (see detail a in Figure 2). The tank is surrounded with an insulation layer that is enclosed in a thin, painted metal outer shell, or jacket. To impede corrosion, the interior surface of many steel tanks is lined with a thin protective coating consisting of an organic or glass/enamel-based material.1-3

As an additional corrosion protection mechanism, one or more metal rods (referred to as anodes) are installed inside the tank. The anodes consist of a steel core wire surrounded by an aluminum or magnesium alloy. This alloy is designed to preferentially corrode or dissolve over time instead of the tank wall, which is why the rod is referred to as a sacrificial anode.4

Background - water heater issues to be aware of

A recent consumer-based study examined the interiors of 18 different heaters and, not-surprisingly, found that more expensive heaters often had larger heating elements, thicker insulation, and larger protective anode rods, which correlated to longer warranty periods.2

Unfortunately, many homeowners aren’t aware of the anode rods within their heaters or the fact they should be periodically inspected to monitor their intended gradual degradation over time. In water heater corrosion failure investigations, removal and examination of the rod can reveal if it has been inspected and/or replaced.

Figure 3 shows the cross-section of a new anode (left) compared to anodes with increasing degrees of degradation (right). As the anode surface area decreases, it becomes less effective as a sacrificial protection system for ‘drawing’ corrosion away from the steel tank. The rate of anode corrosion can be elevated when water softeners are used due to the higher salt concentrations generated by the softening process.1,2 Generally, once half of the anode is consumed or when the steel core wire is exposed, the anode becomes ineffective and should be replaced.1

The Canadian Standards Association (CSA) code B139ON-06 provides some basic guidelines for proper installation of hot water heaters but does not provide specific inspection or maintenance requirements. The code does state that homeowners should follow the manufacturer’s instructions, which typically recommend annual anode inspections depending on the tank model.1 In other words, it is the owner’s responsibility to monitor and maintain the anode.

Gathering evidence promptly

When dealing with water losses such as water tank corrosion failures, it is important to collect installation, inspection, and maintenance records (if any), as well as manufacturer documentation. Photographs should be taken of the tank, connected plumbing and any signs of the leak. The evidence (usually the whole tank) should be secured for further investigation. It is important to collect this material promptly while it is still available and un-altered since an expert may be required to perform a detailed analysis at a later date to identify the failure mechanism.

A case study

MEA Forensic has examined numerous heaters where water had gradually leaked via a small hole in the steel tank wall and down into the inner shell/jacket space (see example in Figure 4). Once the jacket and insulation were stripped, extensive corrosion damage of the steel tank was revealed. The heater’s single anode was also badly deteriorated.

Figure 3. Anode rod cross-sections showing different stages of consumption: left-new, right-degraded.

Figure 4. Defective hot water tank. Significant tank wall corrosion is apparent once the outer shell and insulation are removed.
To identify important root/contributing causes and to clarify the failure mechanism, the sample was mounted and polished for metallographic examination at higher magnifications using an optical microscope. Figure 6 shows a mosaic optical micrograph of the weld microstructure as well as the structure of the tank walls, which consist of ferritic steel containing minor imperfections (e.g., dark pores, inclusions, impurities). From the left image, it is clear that the tapered corrosion hole penetrated through the lower tank wall very close to the weld, thus explaining the water leak.

**Maintenance defects**

When considering the degraded condition of the anode and the significant corrosion deposit observed near the crevice opening (Figure 5c), this failure is consistent with gradual under-deposit pitting corrosion of the tank wall near the weld crevice/gap. This leak likely initiated at a slow rate and could have been avoided with periodic anode inspections and replacement, thus constituting a maintenance failure.

**Manufacturing defects**

Product or manufacturing defects can also be contributing factors to a tank failure. According to leading tank manufacturers, the glass-based coating placed on the interior tank surface can contain imperfections due to manufacturing issues. These imperfections (e.g., pores visible within the dark coating in Figure 6 inset) have been known to form at discontinuities such as welds. They can impede coating performance and longevity by eventually leading to delamination and the early onset of corrosion and leaks.

**Installation defects**

Other potential contributing factors to the loss are the timeline between first leak detection and water shut-off, and the presence/location of water drains or basins at the site. These issues are not causes of the tank failure, but they are important in terms of mitigating water damage such as prolonged water accumulation and mold growth. In the case of missing or defective water drainage or shut-off valves near the tank, there may be an installation component to the claim.

**Summary**

Determining the cause of failure requires straightforward evidence gathering, careful examination of the evidence (destructive and non-destructive), and proper interpretation of the results by an appropriately qualified metallurgist or materials engineer. If an expert is required, it is important to be aware of their qualifications and how they can contribute to the investigation team.

**References:**
PRACTICE GROUPS

Transportation
MEA Forensic’s Transportation Group applies engineering and scientific principles to identify the causes and factors contributing to transportation crashes and losses.

Injury
Our Injury Biomechanics Group combines knowledge of injury/impact biomechanics, anatomy, and human performance to determine how injuries are caused and prevented.

Product
Our Product Group blends a thorough knowledge of material behavior, product design, failure analysis, and human factors to determine how and why a loss or injury occurred.

Property
Our Property Group’s strong knowledge of mechanical, materials, and civil engineering helps clients uncover the chain of events or conditions leading to a property loss.

Aviation
Our Aviation Group brings together mechanical engineers, material scientists and experienced pilots to investigate the causes of airplane and helicopter accidents and incidents.