A Discussion of Water Heater Design

An Analysis of Tank-Type Water Heaters & Commercial Water Heaters

The Laars Approach To Heating Water

In 1953, after seven years of intensive development and field testing, Laars introduced a totally new volume water heater with remarkable performance.

Laars engineers were confident they had achieved real breakthroughs in solving the three most common problems in storage-type water heaters:

1. Failure due to scaling problems.
2. Failure due to corrosion problems.
3. Continuing decrease in operating efficiencies over the life of the water heater.

Since 1953 many thousands of Laars volume water heaters have put these claims to the test. The results have proven the engineers correct. Severe water conditions were overcome with pre-engineered pumps to provide the proper water flow through the heat exchanger to prevent scaling, corrosion, and maintain efficiency.

Scale Problems

Mechanism of Scale Formation

The formation of scale in water heaters is the most common cause of heating equipment failure. There is a direct correlation between water temperature and scale formation; the higher the water temperature, the greater the scale problem.

An observation has been made that scale seems to harden and become more difficult to clean as time passes. It seemed as though it was "fusing" to vessel walls with a process that, in time, behaved like firing porcelain or glass. This is in error. Actually, the initial soft, porous scale traps undissolved particles of substances such as clay and silicates. These are, of course, difficult to clean, and the problem becomes increasingly severe on neglected systems.

Let's see what happens in a tank-type water heater:

- As the water is heated up, the calcium and magnesium salts precipitate out and fall to the bottom.
- The hotter the water, the more salts precipitate out.
- The water is hottest at the surface that is being directly heated.
- Therefore, you get the thickest layers on those surfaces that are directly heated.

In electric water heaters, the elements themselves get the thickest layers of scale, or lime.

Problems result because the scale (or lime) acts like an insulating material. If you want to know if your tank-type water heater at home has a layer of lime, turn the heater off for an hour. Water will seep into the cracks of the lime layer. Then turn the heater back on. Some of the water will be trapped between the tank wall and the insulating layer of lime and form steam. This will result in a "crackling" noise coming from your heater.

If you hear a crackling noise, that is the least of your problems. First of all, you are wasting gas or electricity. There is another major problem: Since lime does form an insulating layer, it insulates the metal tank from the cooling water. Therefore, the metal starts getting hotter and hotter as the layer of lime builds up. Surface temperatures on the metal on the water side of the tank can be as much as three times greater when two inches of lime have accumulated. This excessively high temperature weakens the metal and shortens tank life. Sooner or later, the tank develops a leak—the

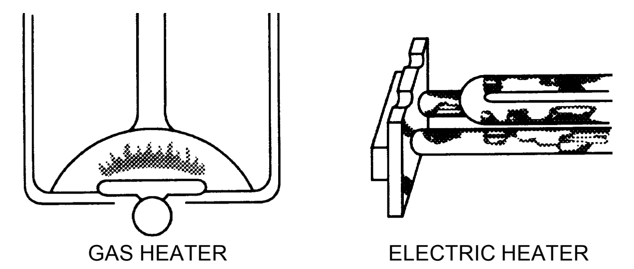
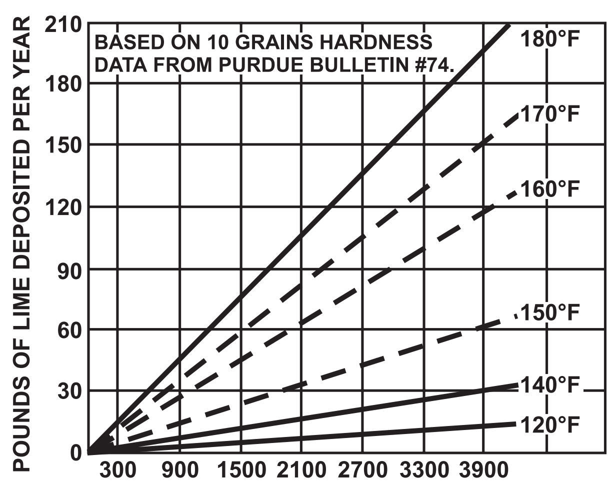


Figure 1. Scale formation in gas and electric storage water heaters.

metal has failed from overheating. In an electric water heater the elements "burn out."

The liming problems with commercial high-capacity, tank-type heaters is identical to those in domestic water heaters. In services such as restaurants, where 180°F is required, the problems are far more severe because the amount of liming is a function of the water temperature. The greater the temperature, the greater the liming problem.



Relationship between lime deposits and water temperature — developed by Purdue University. The chart is based on 10 grains of hardness. For any other hardness, multiply the "Pounds of Lime Deposited per Year" data by the new grain hardness converted by a multiple of 10. For example, 20 grain hardness = 2 times the data. (1 grain hardness = 17.1 ppm hardness.)

Figure 2. Pounds of lime deposited vs. temperature and water usage.

A very important fact shown in Figure 2 is that almost 7 times more lime is deposited when the water temperature is 180°F as opposed to 140°F. The factor of 7 translates into a very short life expectancy for tank-type heaters in services that require sanitizing (180°F) water temperatures.

Prevention of Scale Formation

There are only two common ways of preventing scale formation:

1. Installation of water softener or water treatment device to remove the calcium and magnesium bicarbonate from the water prior to heating.
2. Mechanical scrubbing of the surfaces to prevent or remove scale build-up.

In the case of tank-type water heaters, the only way to avoid liming is by using a water softener. However, where large amounts of water are used, or where water softener maintenance is a problem, even a water softener isn't the total answer (restaurants are notorious for not maintaining equipment - they have more important problems than worrying about the mechanical equipment). You still end up with DISPOSABLE water heaters.

Laars volume water heaters are designed so all the heating surfaces are mechanically scrubbed automatically to prevent lime formation. The design is based on a relatively simple premise: Adequate water velocities are maintained over all heated surfaces to prevent the build-up of lime (see Figure 3).

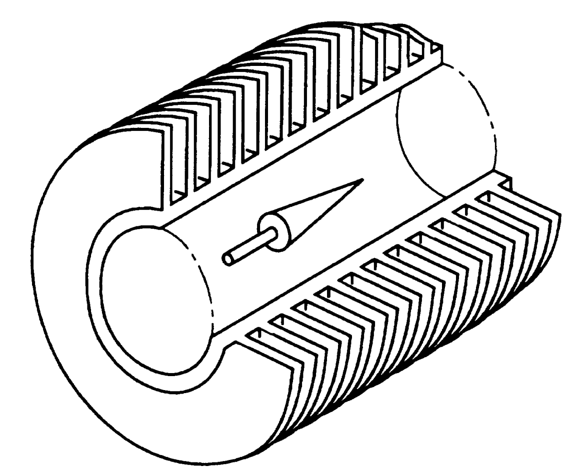


Figure 3. Copper tubing with adequate water velocities to prevent lime build-up.

As lime would form on the surface, the water would simultaneously erode it away. However, this requires a fairly delicate balance.

If the velocity is too low for the amount of lime being formed, a layer will still build up. Therefore, the harder the water is, the higher the velocity which must be maintained.

Laars has divided the hardness into three categories:

0 -130 ppm (0-7.5 grains) soft

130 - 300 ppm (7.5-17 grains) normal

300+ - hard

On Laars pump-mounted volume water heaters (Model PW), a completely engineered package is available which is designed to operate lime-free when ordered for the water hardness category in the area.

Corrosion Problems

Mechanisms of Corrosion

Corrosion on the inside (water side) of the tank is the other common cause of failure of tank-type water heaters. Water is the closest thing there is to a “universal solvent.” Almost everything corrodes in water. Only the degree of corrosion over a period of time varies depending on a number of factors.

Before the mechanism of corrosion is discussed, it would be helpful to give some definitions:

Corrosion — Destruction of a substance by reaction with its environment.

Electrode — An electric current conductor with either a positive charge (see Cathode) or a negative charge (see Anode).

Cathode — In a corrosion process, the positively charged electrode having the lesser tendency to go into solution.

Anode — In a corrosion process, the negatively charged electrode having the greater tendency to go into solution.

Electrolyte — A solution through which an electric current can be made to flow. Water is an electrolyte.

Electrolytic — Corrosion of a metal in the presence of an Corrosion electrolyte.

Galvanic — Corrosion resulting from the contact of two Corrosion dissimilar metals in an electrolyte.

All metals contain positively charged ions and negatively charged electrons. Some of the positive ions will go into solution, causing the metal to become negatively charged (It should be noted that all metals become negatively charged to a certain extent in the presence of an electrolyte - such as water). Anode (negative charge) and cathode (positive charge) areas exist in the same piece of metal. As the negative charge on the surface of the metal increases, due to the migration of positively charged ions, it becomes more difficult for positively charged ions to leave (opposite charged particles attract), and corrosion is inhibited. However, based on the same principal of opposites attract, there is a tendency for the more negatively charged surface electrons (anode) to flow through the electrolyte to the positively charged surface (cathode). The negative charge on the anode is decreased, causing it to lose some more positive ions, which means corrosion at the anode can continue. Meanwhile, the negative charge at the cathode has not decreased because the electrons have flowed from the anode to the cathode inhibiting further cathodic corrosion.

Methods of Corrosion Protection

Cathodic Protection

The most common method of protecting tanks is by providing a magnesium or zinc anode rod inside the tank. This alleviates the galvanic corrosion process. Various metals develop different potential volts before corrosion stops (see Figure 4). The idea is to use a metal for the anode which develops a greater potential (negative charge) than the metal of the tank itself.

As mentioned previously, the more negatively charged area of metal will supply electrons to the more positively charged area. Therefore, the anode will supply electrons to the tank jacket. The corrosion process is transferred from the tank to the zinc or magnesium anode, and is accelerated if the metal is heated. Since the anode is designed to be the sacrificed metal, it must be checked regularly to see if there is complete deterioration.

Metal or Alloy	Potential, Volts
Magnesium	—1.73
Magnesium containing 4% Al	—1.68
Zinc	—1.10
Aluminum containing 4% Zn	—1.02
Aluminum containing 4% Mg	—0.87
Aluminum	— .84
Cadmium	— .82
Aluminum containing 4% Cu	— .69
Iron	— .63
Lead	— .55
Iron containing 5% Cr	— .50
Tin	— .49
Iron containing 12% Cr	— .27
Copper containing 30% Zn (70-30 brass)	— .25
Copper	— .20
Stainless steel (18% Cr + 8% Ni)	— .15
Copper containing 10% Sn	— .15
Monel	— .10
Copper containing 5% Sn	— .08
Silver	— .08
Nickel	—0.07

Figure 4. Metal or alloy potential volts.

Coatings for tank surfaces

Cathodic protection is not the total answer. An enormous and cost prohibitive anode must be used to protect an uncoated steel tank. Therefore, tanks are coated with non-metallic substances such as vitreous enamel (glass-lined), or with metals which are less susceptible to corrosion, such as copper or nickel. Cathodic protection is used in conjunction with the coating, because no coating is perfect. For example, small cracks in the enamel provide points where corrosion can start. Therefore, the coatings are used not to protect all of the steel in the tank, but to reduce exposed surfaces so an anode of reasonable size can be used. Neither the coating or the anode contribute anything toward scale prevention. If the anode is allowed to get too small (consumed by the corrosion process), the protection is lost and the tank can develop a leak.

Laars volume water heaters do not need cathodic protection. The heat exchanger is totally copper, and copper is one of the most corrosion resistant metals available. Protection is not dependent on someone inspecting and replacing anode rods. Separate storage tanks still need cathodic protection, but corrosion problems in unheated tanks are a magnitude lower than those encountered in directly heated tanks.

Operation Efficiency

Higher fuel costs in the past years have led to governmental agencies setting higher efficiency standards. Laars boilers meet or exceed the efficiencies now required.

When comparing Laars boilers to tank-type heaters when they are new, efficiencies are close. The difference becomes evident as weeks of operation go by. Research has proven that 1/8" of scale build-up can reduce heat transfer by as much as 25%. If not cleaned, the scale continues to build up, further decreasing the efficiency. Decreasing the efficiency 25% results in an increase of 33% in fuel costs.

It is not uncommon for restaurants to spend several thousand dollars per year to maintain their hot water requirements. Industrial processes, laundromats, hotels, athletic clubs, etc., often have large fuel bills. In many installations, there is an economic advantage to replacing an old tank-type water heater before it fails with a Laars volume water heater.

Summary

Laars volume water heaters are designed to last many years. Tank-type water heaters are “disposable” pieces of equipment frequently replaced.

Laars volume water heaters are designed to operate scale-free, even when used in hard water areas. Tank-type water heaters can operate scale-free only if all the calcium and magnesium carbonate are removed from the water prior to letting the water enter the tank. Water softeners are only partially successful in removing all scale-forming properties, and are often inoperable due to lack of proper service and maintenance attention.

Laars volume water heaters do not need cathodic protection, and are not susceptible to corrosion in potable water. Tank-type water heaters depend on coatings on the tank walls PLUS cathodic protection to prevent corrosion failures. If the anode is not checked and/or replaced at regular intervals, corrosion protection is lost.

Laars volume water heaters have a high recovery efficiency when new, and the efficiency remains high over the years. Tank-type water heaters may have high efficiency when new, but efficiency decreases drastically as the inside surfaces start to accumulate a layer of scale.

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