

Protecting Stored Water

In Hazards of Stored Water (p. 52) we considered what harm stored water could do. Now we're going to consider what harm can be done *to* stored water and how to avoid it. (Note: For freeze protection see p. 74.)

Earthquake Resistant Storage

In designing for earthquake resistance, it is important to recall that:

- ❖ inlet or outlet pipes are as or more likely to break than the tank itself
- ❖ raised storage, tower or rooftop, is much more likely to fail
- ❖ properly engineered storage is much less likely to fail

Earthquakes can generate a variety of motions—back and forth, up and down. Rhythmic movement can amplify if it coincides with the resonant frequency of the structure or sloshing water in the tank. The most violent motions the earth can generate are all but impossible to engineer structures for. Many building codes call for structures to resist an acceleration of 0.2 gravities (but accelerations of 1–2 gravities have been recorded). Imagine the plane of the earth tilting until it and the tank are sloped 20%. Would the tank fall or slide over? Perhaps it needs to be anchored.

Fire Resistant Storage

In a fire, the most likely failure points for a water storage system are the pieces that can burn. The most secure installation would not have plastic outlet pipe, rubber seals or couplings, wooden supports, or delicate steel supports surrounded by fuel, or depend on unprotected electronic controls. Water inside a tank can carry heat away, often enough to save the walls from burning. In the 1990 Painted Cave Fire—106°F, 8% humidity, 50 mph winds—400 houses burned in a few hours.^m The sides of our old redwood water tank burned down to the water level, where the burning stopped. New water couldn't get into the tank, however, because the wooden truss work that supported the galvanized inlet line burned away, and the unsupported pipe broke.

Hurricane Resistant Storage

Tanks are vulnerable to wind when they are empty or nearly so. A full water tank, made of any material, is so heavy it is not likely to be affected by wind, except indirectly by flying debris or falling trees puncturing the side or breaking an outlet. Lightweight tanks definitely need to be anchored against high winds in areas that experience them.

Lightning Grounding

Steel tank installations without cathodic protection need to be grounded in accordance with local electrical and fire codes. Use a zinc grounding rod where the tank touches the earth, not a copper rod.

Roots and Trees

Probing, swelling roots, swaying branches, and falling trees can wreak havoc on water systems. One of the sadder but necessary maintenance tasks is to rip out tree seedlings that are too close to tanks.

Toxic Leakage or Leaching

Aquifers can be threatened by toxins from underground gasoline tanks, dry cleaners, agricultural poisons and nitrates, or saltwater intrusion driven by over pumping (see Aquifers, p. 16). **Water stored in tanks** is pretty much immune to contamination of this sort from outside; the concerns are contamination of the source water, and leaching from the tank (see How Water Quality Changes in Storage, p. 9, and Tank Materials, p. 39).

The Hazard of Permeation

Permeation is the diffusion of chemicals through the wall of the container or pipe and



Almost all water tanks survived the 2008 Tea Fire in Santa Barbara, CA, somewhat worse for the wear, but still watertight. Several ferrocement tanks did well.

Flammable Storage for Automatic Fire Control?

A neighbor used a generator to pump water from his cheap, plastic tank. One day, the generator caught fire. The fire spread to the adjacent plastic tank. When the tank burned through, the water rushed out and put out the fire on both the generator and the tank!

^mMetric: 41°C, 80 kph wind.

into the water. Permeation can be an issue with aromatic toxins (gasoline, kerosene, pesticides, and the like) and plastic pipes or containers. For example, if you store emergency water in polyethylene containers (such as milk jugs) next to gasoline cans, paint thinner, and pesticides, the fumes can permeate through the plastic and contaminate the water. A municipal PVC water main passing through an industrial waste plume can absorb toxins by the same route. Permeation of toxins can be avoided by using an impervious material (metal, glass) to contain the water, keeping toxins well away, or best—keeping toxins out of your life entirely. Thick-walled plastic containers (such as 55 gal drums) are significantly less permeable than thin-walled ones.

Armed Marauders

If you are worried about hordes of barbarians stealing your water after the disaster, your best bet is to hide it underground, or disguise it (e.g., as a ferrocement boulder).

Children, Vandals, Unauthorized Access

One desert community I know occasionally found passing motorists skinny-dipping inside their potable water tanks. Fences and locks provide some security against this sort of thing. You can remove valve handles, lock valves in position, or enclose valves in locked boxes to reduce the chance of accidental or malicious adjustments.

IT Publications has this to say about children and water systems:

“Children should be considered to be compulsive saboteurs of the system. Although they do not do so deliberately, their curiosity leads to much damage and repetition of work. Open pipe ends, exposed pipeline, fresh masonry all will attract attention, with frustrating results.”¹⁶

Systems for Firefighting

One of the most valuable uses for stored water is to prevent or limit fires, saving people and property. In places where fire safety is an issue, the firefighting performance requirements (legally mandated or owner preferred) often drive the design. Typically, the amount of storage, the pipe sizes, and pressure will be *much* higher.

Besides a hydrant and water storage set aside just for firefighting, there may be requirements for wide, gently sloped, paved access with a huge turnaround at your house. It may be cheaper to go beyond the water system requirements (even as expensive as plumbing is) in trade for slack on the road requirements, if the fire marshal is willing. From an integrated design perspective, this is almost always worth it.

Speaking of integrated design, ideas about fire safety best practices for wildland interface areas are very much in flux, stirred in part by experience in Australia and Southern California.

Fire Safety Plan

Left on its own, your home has to be *totally* impervious to fire (or lucky) to survive. The biggest factor for the survival of houses is the presence of people to defend them.

In Australia, following a particularly deadly fire season in 1983, researchers examined 100 years of fire data. More than 90% of the houses lost were never exposed to direct flame or radiant heat. They were ignited by blowing embers. Most deaths were from late evacuation. There were almost no deaths among people actively defending their homes.

In response, Australia pioneered a **“prepare, stay and defend, OR get out early”** policy in the early 1990s. Since then, more than 90% of structures defended by able-bodied people survived, because the owners were there to put out spot fires from raining embers before and after the flame front passed. Some districts in California are considering this approach. It remains to be seen how, or if, the February 2009 fires will affect this trend.

The first-person accounts from fire disasters are harrowing and informative.

In Santa Barbara's Tea Fire, 800 students sheltered safely in the windowless, concrete gym in a well-cleared area of Westmont College. This was planned in advance; they'd had a drill less than month before. There were no special provisions for air supply.

In Australia, one family survived the recent inferno in a homebrew fire bunker at-

Climate Disruption Exacerbating Fires

A few days after the 2008 Tea Fire in Santa Barbara, California, Governor Schwarzenegger acknowledged that because of global climate disruption, Central and Southern California now have an extended fire season stretching from late February through December, instead of late June through mid-October (January and February are flood season, if we're lucky). California spent nearly a billion dollars on fire suppression in 2008, as well as half of US Forest Service firefighting dollars.

Australia had fires far worse than any in history, with larger loss of life, in February of 2009.

tached to a water tank. The \$1,000 fireproof door heated up so much before they got in that it wouldn't shut all the way; flames licked in. There was no mention of special provision for air supply.

Five friends had seconds' notice before their shop and vehicles were engulfed in flame. They jumped into waist-deep water in an old concrete water tank. They stuffed wet shirts in the cracks in the walls, took turns boosting each other up to the hatch for (smoky) outside air, and survived.

Some people evacuated early, but miles away their escape was cut off by another fire. Some stayed, fought, and didn't make it.

Our home has been threatened by fire three times in the past two years. To be willing to stay (or if we're trapped), I'd want at least one totally fireproof structure we could hide out in for the 5–30 minutes it takes the flame front to pass.

There are unanswered questions about thermal resistance, thermal mass, insulation, and air supply. There does not appear to have been much research or testing. Analysis of the tragedy unfolding in Australia as we go to press will likely help others survive future conflagrations.

Cob (monolithic adobe fibercomposite) is a material which is more fire-resistant than concrete, because it conducts heat more slowly. It is also earthquake and termite resistant, and exceptionally owner-builder friendly. A cob cottage with a ferrocement roof and metal shutters over metal dual-glazed windows and doors is a structure which could potentially resist the most intense firestorm, and still be pleasant to live in. Small cob cottages are reportedly used traditionally to safeguard family treasures in Japanese wooden villages.

Water tanks seem to survive fire very well compared to other structures. Could a ferrocement rainwater harvesting tank near the house do triple duty as an invincible (if claustrophobic) fire-safe haven? It seems that a higher roof to ensure head space with air inside the tank, and a pressure tank with fresh air supply, could make it so. The cost would be very low and security high compared to any alternative.

Buried, cast concrete septic tanks as low cost, high security underground fire bunkers are being promoted in Australia (probably better to have it double as a root cellar rather than a septic tank). In the old days, people in Australian lumber camps had dugouts with timber roofs as fire shelters, fed by the inches of fresh air rushing along the surface of the earth to feed the fire.

Lots of people living in flammable brush is inherently dangerous. The least dangerous way of managing this is an open question.

Whatever your fire safety plan, research it well, prepare, and practice for it; the stakes are quite high.

Water System Design For Fire

In most fire emergency situations, well power is off, and/or the flow demand is so much greater than the supply that storage is essential to cover it. For example, the incoming supply might be 10 gpm, while the fire department can go through several thousand gallons in 15 minutes.^m However, incoming water may make a crucial difference in reality—especially if the reality is that your tanks are low to start with, or get drained wetting things down before the fire even gets there.

Armoring the water supply system, as described in Fire-Resistant Storage (p. 77), will increase the likelihood that at least *some* water is being added to the system even as you are rapidly draining it. **If you don't have an entirely gravity powered system, stored water may be your only supply,** as fire often knocks out the power grid before the

Current Southern California Wildland Interface Fire Safety Approach:

- ❖ *Mechanical clearing around flammable homes and landscapes*
- ❖ *Big, wide, costly, and ecologically devastating evacuation/access roads*
- ❖ *Water systems that often fail in a fire*
- ❖ *Expensive but flammable construction*
- ❖ *Protection of homes only by overwhelmed professionals*
- ❖ *Dense fuel that has frequently burned clear the past 15,000 years, but has built up unprecedented levels from 80 years of fire suppression*
- ❖ *A state insurance system for high fire areas that may go bankrupt due to climate change-induced increase in fire, even though it currently is paying out only half the cost of rebuilding*

The more economical and ecological approach I think we may eventually be forced to adopt:

- ❖ *Fire-safe landscaping, most clearing by frequent, less intense fires*
- ❖ *Human-scale roads*
- ❖ *More robust water systems*
- ❖ *A mix of structures that are passively and actively fire-armored to protect residents in a full scale firestorm, and inexpensive structures that burn clean*
- ❖ *Protection of structures primarily by residents*
- ❖ *Maintenance of low fuel levels through frequent fires*
- ❖ *Increasing reliance on self-insurance*

—oasisdesign.net/shelter/fire

^m*Metric: Incoming supply is 40 lpm, fire department can use tens of thousands of liters in 15 minutes.*

flames arrive. A battery bank and electric pump, a gas pump, or a generator and electric pump can keep water flowing/pressurized in this instance (don't plan on your generator or gas pump working in an emergency unless you maintain it).

In general, I prefer fire emergency hardware, especially pumps, that are incorporated into the regular system. I plan to use the fire emergency pump to pressurize the rainwater supply to our house. Besides the efficiency of the item doing double duty, it's much more likely to work when a fire comes if it is something that is regularly used.

When plumbing your pool or spa, hook things up so that you can use the pool's own filter pump to power a fire hose. Some people also include a gas pump (or generator) in the pool plumbing for firefighting. This may require different-sized lines and/or pump for adequate flow and pressure. Make sure the pump inlet is near the bottom of the pool, so the system can access most of the water. If you use a gas pump for irrigation, you might as well use it for fire, too.

Water elements for fire safety (besides the idea of using a water tank as fire-safe haven, mentioned earlier) are of three classes: systems to support fire hoses, automatic fire sprinklers (interior and/or exterior), and water to refill fire trucks:

Water for Fire Hoses

To operate fire hoses, you will need:

- ❖ **Stored water with high pressure (gravity preferred)**—At the hydrant, pressure should be 40–100 psi (275–700 kPa).
- ❖ **A decent-sized line**—For good dynamic pressure at high flow. For instance, a high-pressure 2" line can barely supply two 1-1/2" hoses at the same time, while a 3" line at the same pressure could supply three hoses, with better flow for each hose.*
- ❖ **Fire hoses**—Stored onsite, convenient to hydrants.
- ❖ **A pump**—To make up for low pressure and/or an inadequately sized line.
- ❖ **A foam injection system**—See Foam, p. 81.

Even one fire hose places an extreme demand on system hardware. Accommodating this can double the resources required to build your storage and distribution plumbing—all for something that hopefully will never get used. Is it worth it? It is a form of insurance, one that you'll have to judge how much to purchase.

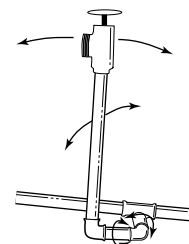
The difference between a 3/4" garden hose and a 1-1/2" fire hose is truly phenomenal. Likewise the difference between 40 and 100 psi of water pressure. You'll need a powerful water delivery capability to have a chance against the considerable power of a house fire or wildfire. When we are burning brush piles, occasionally a gust of wind drives the flames skyward on a windrow of 50 truckloads of tinder-dry brush. In seconds it can go from feeling like a nice campfire to having your clothes ironed with you in them. A moment's burst from a 1-1/2" fire hose (with 60 psi of pressure) puts it right down. A garden hose going full-blast would do essentially nothing; it would just take a bit longer for it to get so hot that you had to back off. If we were to let the whole thing get fully engaged and roaring, with wall-to-wall two-story-high flames, we could probably put it completely out in a few minutes with two fire hoses.

On the other hand, a fully engaged firestorm in Southern California chaparral, whipped by freeway-speed, hot, dry wind is beyond the capability of *any* fire hose to suppress. That's when you 1) pay your insurance diligently and get out early or 2) build a fireproof bunker and stay and defend against embers (p. 79).

Some other things to think about are the location of fire hose standpipes (small hydrants) and how they are plumbed. The hydrants should be near structures, but not so near that it would be too hot to hook up hoses if the structure were burning.

The plumbing needs to be secure. I've seen hydrants that were made by connecting a hip-high vertical length of steel pipe directly to a tee in an underground PVC pipe. Imagine a panicked person pulling hard for a bit more hose they desperately need to keep their home from burning down. Pulling, that is, on a long steel lever with a brittle connection to a delicate plastic pipe. If it breaks, they've got a tough decision—turn off the water, or watch the tank empty uselessly, in each case while the house burns.

FIGURE 27: SWING JOINT ATTACHMENT FOR A SMALL HYDRANT



Hydrant can be pulled or knocked over without breaking the main. Use plenty of Teflon paste on the threads and wrap the outside with pipe wrap tape.

*Flow is proportional to pipe diameter squared times two thirds; 230' (70 m) of head provides 100 psi (700 kPa), ideal for fire hoses.

One solution is to encase the steel in enough concrete at ground level so that the steel will bend before the plastic underneath breaks. A better solution is to put two 90° bends at right angles, so the standpipe can be pulled or knocked over without stressing the plastic pipe (Figure 27).

Water for Fire Sprinklers

Water system features for fire sprinklers:

- ❖ Stored water with adequate gravity pressure (or a booster pump), and a line size engineered for adequate flow. ($\frac{3}{4}$ " at 100 psi to 1- $\frac{1}{2}$ " at 40 psi for a residence.)^m
- ❖ A mechanism for triggering the sprinklers at the right time, such as heat-sensitive sprinkler heads. I've also heard of heat-sensitive wires that trigger a valve.
- ❖ Roof-wetting systems on a home with a roof rainwater harvesting system can be plumbed to recycle the water running down the gutters, so it takes much longer to run the tank dry.

Indoor fire sprinklers may or may not stop a house fire, but they will virtually always slow and cool it enough so residents can escape.³³ There is a detailed code for interior fire sprinklers.

For exterior sprinklers—designed to keep a wildfire from incinerating your home—the design is up to you. The common roof-wetting design is a high-pressure irrigation sprinkler or two.

Here's my (untried) design idea for rooftop sprinklers: Place copper pipes along the roof ridgelines, with small holes drilled in them for the water to jet (or drool) over the roof. It seems that the water would get used much more efficiently, and that you'd cover the whole roof even if the pressure were really low (as it will be if your neighbors are all wetting things down in a panic). What's more, if you've got a roof rainwater harvesting system, the water would virtually all go back into your tank, so you could just turn the pump on and leave the water to circulate. The same type of system (pipe with holes) could be installed under the eaves to protect eaves and windows as well, although it wouldn't recycle. A flowing sheet of water over tempered, dual glazed windows is an effective fire wall (if you try one of these, let me know how it turns out).

Water for Fire Trucks

Fire trucks don't carry that much water—usually no more than 800 gal (3 m^3). Dedicated tanker trucks can carry a few thousand gallons ($10\text{--}15\text{ m}^3$). Sources for refilling trucks include:

- ❖ stored water with gravity pressure, a large diameter line, and the right hydrant fitting (a 4" hydrant right by the tank is common)
- ❖ a pond, swimming pool, hot tub, or river, pumped out with a suction hose

Foam

Injecting Type A firefighting foam or gel greatly increases the effectiveness of water for fighting fires. The wet foam sticks, smothering fire on something burning, or insulating and reflecting heat from something you're trying to protect.

If your plan is to wet things down and evacuate early, foam is much more effective than water alone. Instead of running off, it sticks (for 20 minutes to a few hours). Turn your house into a big marshmallow and go (or duck into your fire bunker).

A neighbor of ours did this with his house and big wooden deck. He watched the flames cavitate under the deck, but it didn't catch fire—quite impressive.

This house was brick with a tile roof. The owner had his own gravity flow water supply feeding a 1 1/2" fire hose. He stayed and sprayed down the exposed rafter tails with fire retardant gel until his hair was singed from the heat of the advancing wall of flame. Despite his doing everything right, the house burned anyway, probably from the underside of the roll roofing under the tiles on the eaves catching fire. Cars sprayed with foam survived untouched.



Could "stay and defend" have saved this house? Having a fire-safe bunker would have enabled the owner to find out with an acceptable level of risk (and could have saved his neighbors months in the burn unit). Note that the half-full plastic tank survived the fast moving firestorm.

^mMetric: Line sizes range from 2 cm at 700 kPa to 4 cm at 275 kPa.