# Lessons Learned

## *Avoiding Accidents in Surge Tank Design, Operation*

Surge tanks are passive structures, added to a long pipeline to reduce waterhammer at the powerhouse. Proper design of a surge tank was first discussed in the early 1900s and has been well established for many decades. Despite this, accidents in design and operation occasionally occur, as illustrated by the following anecdotes.

### The ruptured orifice

An ore mine in a remote location was powered by a 20-MW hydro plant. As the mine expanded, the demand for power increased. Consequently, the owners added a 4-MW unit to the existing plant by tapping onto the penstock. This unit took advantage of the surplus of water from an upstream storage facility.

A few years later, the price of the ore being mined dropped, and the mine was abandoned. Subsequently, the need for the hydropower was greatly reduced. The plant was operated for many years at partial load, never exceeding 55 percent gate opening on the original 20-MW unit. Although the operators observed that the plant took longer to synchronize than in the past and that the frequency seemed to fluctuate more than it should, they could not determine why.

The next time the plant was shut down for a major overhaul, the penstock was inspected. The inspectors found the surge tank orifice plate lying in the bottom of the surge tank. Apparently, it had been blown out sometime in the past when there had been a full or near full load rejection on both units.

A subsequent investigation found that the surge tank had not been modified when the second unit was added to the penstock. The problem was solved by enlarging the orifice diameter by about 20 centimeters. The plant owners decided to accept the risk of the surge tank overflowing if a full load rejection occurred on both units coincident with a large flood over the weir spillway.

**Lesson learned:** Always check pipeline hydraulics when adding a unit to an existing penstock.

### The frozen tank

In cold climates, it is a given that surge tanks must be heated. However, in locations where winters are not too severe, heating may be considered optional. At one particular hydro plant, heaters had not been installed. The two Francis turbines operated for several years until, during a particularly severe winter, the unit governors began to hunt, with the pressure on the turbine casings rising and falling rhythmically. The pressure's frequency was found to be equal to twice the sound wave return time of the water conduit. The operators suspected that the surge tank had frozen.

An intrepid volunteer climbed the ladder on the 80-meter-high surge tank and looked down through the access manhole in the roof. He found the water surface covered with a solid sheet of ice, and the interior riser in the form of an hourglass. Nothing could be done to melt the ice, so the units continued to operate until the weather took a turn for the better. The sun's heat broke the ice bond to the tank's interior wall, and the ring of ice gradually broke up. It took a few more days before the ice in the interior riser melted.

For many years, operators had prevented the formation of ice in the surge tank by "surging" the tank (i.e., moving the turbine wicket gate controls back and forth) once or twice a day. This approach was used for the remainder of that winter to prevent a recurrence of the freezing problem. The next summer, the plant owner installed a heating system, featuring a ring welded onto the inside of the tank's exterior wall into which hot water dripped.

**Lesson learned:** In locations where frost is a problem, a surge tank heater is a requirement.

### The flammable tank

Heated surge tanks often are encased with an insulating material. On many tanks, this insulation is a frost casing of 5- to 8-centimeter-thick tongue and groove wood held in place with steel straps around the tank and riser pipe. Over the years, the effects of the sun and wind cause the timber casing to dry out and become quite flammable.

One such tank was completely destroyed when the timber frost casing caught fire from an electrical fault in the water heater controls at the base of the tank. The fire was so intense that the steel plates buckled. Because the tank was located on a hill overlooking a village, the fire was quickly spotted, and the plant staff was able to close the intake gate and drain the tank before any water was spilled. However, because there was no source of water near the tank, the fire could not be extinguished, and the tank burned to the ground.

The plant was out of service for five months while the tank was rebuilt. The new tank met current codes for earthquake safety and used a non-flammable insulation casing.

**Lesson learned:** Inspect existing plants' surge tank insulation. If it is found to be flammable, replace it immediately with a non-flammable material.

### *Overflowing surge tanks*

A large utility had built and was operating numerous hydro developments. Over the years, the company's engineers had become adept at designing dams, water control facilities, and powerhouses. However, the layout of the power plant always was contracted out to an overall equipment supplier responsible for all electromechanical equipment manufacture and installation.

At the utility's newest development, the design featured a long tunnel at the end of which a surge tank, valve house, and steel penstock led to the powerhouse containing three high-head Francis units.

The tunnel and penstock drawings showing the surge and waterhammer lines were forwarded to the equipment manufacturer as part of the design information. The manufacturer then passed the drawings on to a consultant who was coordinating purchase of all ancillary equipment such as the penstock, cranes, and piping. At that point, the consultant discovered that the top of the surge tank was about 8 meters too low, and passed the observation on to the utility.

However, the utility's engineers replied that they had checked their calculations and were confident of their design. Upon further investigation by the consultant, though, it was discovered that the utility engineers had based the surge tank height on an equation that had been reprinted in a hydraulic handbook. The problem was that, in reprinting the equation, a typographical error had occurred: the handbook's equation *subtracted* the effect of conduit friction rather than *adding* it. Discovery of this error explained why all the surge tanks the utility's engineers had designed overflowed — they had always thought this was just a normal design condition.

For the plant being built, the design was corrected by moving the surge tank about 100 meters further upstream into the mountain.

**Lesson learned:** Typographical errors occasionally happen. Therefore, when using an equation referenced to another document, it is prudent to double check accuracy by consulting the original source.

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