Penstock low pressure alarm.

George, the on-call operator for several hydro plants on a river system, was enjoying some fishing, when his cell phone rang, and he was asked to check on the White Bay plant, which had just gone off line. After some 50 years of uneventful operation, White Bay had recently been renovated with remote controls and a new wood stave pipeline between the intake and surge tank. The powerhouse contained two Francis units, each equipped with a butterfly valve. The SCADA system was quite basic, with only power, wicket gate opening and headwater level being indicated on the screen at the remote control center, and no fault indication apart from a unit off-line warning.

At the plant, George entered the building, accessed the local terminal and found that the turbine had dropped off line due to low penstock water pressure. However, at the turbine, the penstock pressure gauge indicated full reservoir pressure, and all other gauges were normal. Puzzled, he then drove alongside the wood stave pipe up to the intake where there was a large concrete building. The upstream wall of the building dropped down into the headwater about 2 meters ahead of the racks, providing shelter for rack cleaners. Inside, there were two bulkhead gates with manual rack and pinion hoists. The windowless building was locked, and there was no sign of entry. George walked around, but did not bother to go in since the door lock was old, and the key had to be jiggled around to open the lock, a time consuming process. Again everything appeared normal. George thought that perhaps the shutdown was due to a fault in the SCADA, since there were thunderstorms in the region.

George called the control center on his cell phone and advised that he had re-set the low pressure alarm, that the penstock pressure gauge indicated full pressure, with everything in the powerhouse and around the intake being normal, and that he could not find anything wrong. He suggested that the unit be put back on line, and this was initiated.

As he was driving back to the powerhouse alongside the pipeline, he noticed the wood stave pipe start to collapse, and within a few seconds, some top staves at a vertical bend were sucked inwards, and water started to spew out of the pipe. The flow increased rapidly, and began to wash out the gravel road. George reversed direction and raced back to the intake. On entering the building, he found that one of the gates was fully closed, and the other was about half closed. Since the bulkhead gates were not designed to close against flow, he could not do anything, other than call for help.

Once help arrived, the flow was shut off by first blocking the racks with some old mattresses, and then closing the gate. Damage was fortunately limited to about 30 meters of collapsed pipe, and some erosion of the intake access road. The plant was off for several weeks while repairs were undertaken. But what had happened?

Reconstructing the sequence of events, it was realized that someone had entered the intake house, and had released the dogged gates. The first gate closed fully, since there would have been little differential pressure, and the second gate then dropped until friction from the water pressure overcame the gate weight. The second gate canted sideways and became stuck in the guides. Since there was no signs of forced entry to the building, the only access must have been by swimming in under the upstream wall. At this point, whoever entered must have realized that the only way out was back under the headwall, swimming against the flow, and this would have been difficult, hence the gates were released. It is fortunate that the swimmer did not become trapped against the racks when swimming in.

With the units operating at near full load, the partially closed gate would increase conduit losses, water level in the surge tank would drop, gradually reducing pressure at the turbine, initiating the shut down. When off line, the penstock and surge tank would fill, and pressure would return to normal. At the intake, the only indication of anything wrong, would have been the height of the gate stems, the tops of which would have indicated closed or partially closed gates. Since George had not entered the intake building, he had not noticed the closed gates. On re-starting, the operator set the units to operate at near full load. The negative surge, combined with the high loss through the intake was enough to cause the hydraulic grade line to drop below the top of the pipe at a vertical bend just upstream of the surge tank, initiating the collapse.

Lessons learned.

When a unit shuts down due to a fault, a thorough investigation of the reason for the fault should be undertaken, even if it requires some additional time. Another lesson from this incident is that all intakes should have gates capable of closing against flow. At White Bay, the second flow control method is the butterfly valve, hence the intake could be equipped with bulkhead gates at lower cost. However, accidents and burst pipes do occur, hence prudent design would call for gates capable of closing against flow. Many utilities are now recognizing the deficiencies in old bulkhead intake gates, and are retrofitting intakes with roller gates capable of closing against full turbine flow.
