Lesson Learned
The Untested Computer Program

George was flying to the hydro site at the urgent request of the owner. The wood stave penstock had collapsed on the first test of the new turbine, and George could not determine the cause from a telephone discussion with the commissioning engineer. The 8-MW turbine had replaced an old 4-MW unit. In addition, the project's penstock had been increased in size to accommodate the higher flow.

Upon his arrival, George inspected the unit. He noted that all controls were electronic, using programmable logic controllers - a major change from the last time he had worked on the detailed analysis of relief valve-turbine hydraulics. (See "Lessons Learned: The Mahogany Governor Cam," *HRW*, December 2003, page 29.) Nevertheless, there had to be a servomotor and pressure tank with valves to move the wicket gates and relief valve, and here he was in familiar territory.

From his detailed inspection, George discovered there was neither a position sensor on the relief valve, nor any means of limiting the extent of the relief valve opening on load rejection at small wicket gate openings. Something was seriously wrong!

On the first test, the relief valve had fully opened on a load rejection from only 20 percent load, and the penstock had collapsed from negative pressure induced by the sudden increase in flow.

When George had taken on the project, he assigned the work to an experienced turbine engineer. He had discussed in detail with the engineer the effect of the relief valve, mentioning the waterhammer complexity and the need for careful calculations. Today, those calculations could be undertaken on a computer in seconds; however, George had spent months calculating the waterhammer effect when he had worked on a relief valve on another project. (See "Lessons Learned: The Mahogany Governor Cam," HRW, December 2003, page 29.)

All had appeared to proceed well during execution of the work. The water-to-wire contract was awarded to a turbine manufacturer that advised that it was familiar with relief valves and had a computer program that could solve the waterhammer problems associated with integration of the relief valve and turbine.

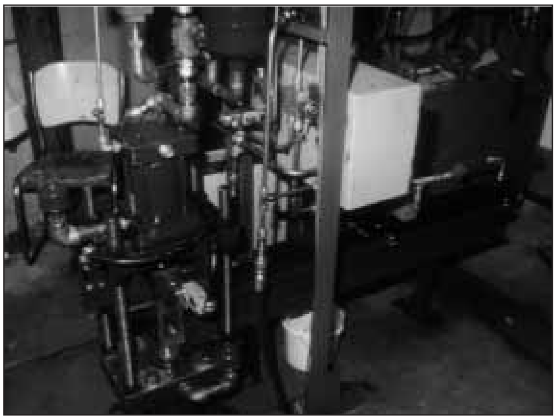
Waterhammer was to be limited to +/-25 percent, but, with the computer program, the manufacturer advised that more precise control could be attained. Waterhammer would be within +/-15 percent. Calculations of waterhammer at 25 percent, 50 percent, 75 percent, and full load rejection - all showed on a graphical trace of pressure versus time - proved that waterhammer was indeed within the range the manufacturer claimed. George looked at the output for full load rejection and noted that the relief valve discharge was about 80 percent of the turbine at full open (which was the expected valve size based on the waterhammer criteria).

After the accident, discussions with the manufacturer revealed that the relief valve hydraulics had been subcontracted to a graduate in mathematics who had written a waterhammer program. George obtained a copy of the computer output and perused it in detail. He could not find any instructions in the input for valve or turbine characteristics. This raised his suspicions.

A meeting with the programmer was arranged. At the meeting, the programmer sat down at the computer, entered the data, and produced the waterhammer-time profile for a full load rejection. George asked for the exercise to be repeated with a 50 percent load rejection. The graphical output was identical in shape to the previous calculation! George knew this to be a physical impossibility, because the stage-discharge characteristics of turbine and valve were different. George then asked the programmer how the relief valve knew that, with a 50 percent load rejection, the valve should only open about halfway. This question puzzled the programmer Further discussion elicited the response: "Oh, with a half load you must use a half-sized relief valve!"

The programmer, with a degree in mathematics, had no concept of the engineering involved. However, the manufacturer was not aware of this deficiency, hence the lack of a valve position sensor and a means of limiting relief valve opening.

The repair - paid for by the manufacturer - was expensive and included a cam positioner to physically limit relief valve opening based on the extent of wicket gate opening at start of load rejection. Commissioning was delayed by several months. As for the collapsed wood stave penstock, it was repaired at minimal cost with the original staves and some spares



relief valve controls

Lesson learned

This story points out two lessons. First, the "garbage in-garbage out" theory is a good one. The manufacturer had shopped around for a computer program, subcontracting the waterhammer study based on the lowest cost - without determining whether the program was correct and had been used with success on other projects.

Second, there were no senior engineers within the manufacturer's organization who could have spotted the defects on the equipment drawings. Also, the manufacturer's "previous experience" with relief valves had occurred several years ago and had involved engineers who no longer worked for the company. None of the present staff had experience with relief valves. The manufacturer had recently downsized; as a result, all drawings were done with computer-aided design and most of the engineering calculations were computerized. Don't misunderstand me - I have nothing but praise for computers. This article was written on one! But, sometimes, young engineers lack an intuitive feel for the correct answer - hence the mistake. Nowadays, it is important to have engineering work reviewed by an experienced engineer, especially where there is reliance on a computer- generated design.

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