UNTESTED COMPUTER PROGRAM

George was flying out 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 why from a phone discussion with the commissioning engineer. The 8MW turbine replaced an old 4MW unit, and the penstock had also been increased in size to accommodate the higher flow. On arrival at site, George inspected the unit, and noted that all controls were electronic, using programmable logic controllers, a major change from his previous experience with a mechanical governor, where he had to re-profile a cam controlling the relief valve. 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. A detailed inspection of the controls revealed that there was no position sensor on the relief valve, nor any means of limiting the extent of 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% 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 and had discussed the effect of the relief valve in detail, mentioning the waterhammer complexity and the need for careful calculations, which today could be undertaken on a computer in seconds, whereas George had spent months calculating the waterhammer effect on his previous relief valve project. All had appeared to proceed well during execution of the work. The water-to-wire contract was awarded to a turbine manufacturer who advised that he was familiar with relief valves, and had a computer program which could solve the waterhammer problems associated with integration of the relief valve and turbine.

Waterhammer was to be limited to +/- 25%, but with the computer program, the manufacturer advised that more precise control of the relief valve could be attained, and waterhammer would be within +/- 15%. Calculations of waterhammer at 25%, 50%, 75% and full load rejection all showed on a graphical trace of pressure versus time, that waterhammer was indeed within the range claimed by the manufacturer. George looked at the output for full load rejection and noted that the relief valve discharge was about 80% of the turbine at full open, the expected valve size based on the waterhammer criteria. After the accident, discussions with the manufacturer revealed that the hydraulics of the relief valve 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, and 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% load rejection. The graphical output was identical in shape to the previous calculation! George knew this to be a physical impossibility, since the stage-discharge characteristics of turbine and valve were different. George then asked the programmer how the relief valve knew that with a 50% load rejection, the valve should only open about half-way, a question which puzzled the programmer. Further discussion elicited the response "Oh, with a half load you must use a half sized relief valve!" - end of discussion, problem solved. The programmer, with a degree in mathematics, had no concept of the engineering involved, and the manufacturer was not aware of this, hence the lack of a valve position sensor and a means of limiting relief valve opening.

The repair 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, all at the manufacturer's cost. Commissioning was delayed by several months. As for the collapsed wood stave penstock, it was repaired with the original staves and some spares at minimal cost.

Lessons Learned.

There are two lessons here. First, the usual garbage in - garbage out effect. The manufacturer had shopped around for a computer program, and had sub-contracted the waterhammer study based on the lowest cost, without determining whether the program was correct and had been used with success on other projects. Secondly, and this is a more serious problem - there were no senior engineers within the manufacturer's organization who could have spotted the defects on the equipment drawings, namely the lack of a position sensor on the relief valve, and the lack of a limit on opening at part load rejection. Also, the manufacturer's previous experience with relief valves was found to be several years in the past, at a time when none of the present staff were working for the manufacturer. The manufacturer had recently downsized, and now 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 is being 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.