RUPTURE OF A DRAFT TUBE WATER COLUMN

After two years of work at the site, the large propellor unit was ready for commissioning tests. A team of engineers had been checking the instrumentation and controls for the several weeks, and with alignment and rotational checks complete, load rejection tests were about to start. The project was an extention to an existing development, where four empty bays, complete with intakes and draft tubes had been provided for future units in the 40 meter head, close-coupled intake-powerhouse complex. The engineers were justifiably proud of their achievement, having squeezed a 22% larger unit into the space provided.

Since the short penstock pipe and the draft tube were designed for a 22% smaller turbine, considerable time had been spent on predicting the hydraulic performance of the new unit, particularly on load rejection. There were concerns with respect to the waterhammer and speed rise, and also with the possibility of excessive negative pressures in the draft tube. The governor opening and closing times had been calculated to limit waterhammer to 50%, speed rise to less than 60% and the drop in pressure just below the runner to less than 0.7 bars.

Prior to undertaking the load rejection commissioning tests, engineers were assigned to closely watch the instruments recording speed, pressure rise in the casing, and pressure drop in the draft tube. The test proceedure was carefully followed, with all records of each load rejection being plotted at the end of each test. Load rejections were undertaken in 10% steps from speed-no-load on upwards. All proceeded according to plan, with test results closely matching the theoretical predictions. At 70% gate the load rejection pressure drop in the draft tube reached the maximum predicted 0.7 bars, and was the same at the 80% load off test. When 90% load was rejected, there was an extremely loud explosive sound from the region of the draft tube, the whole powerplant appeared to shake and a few seconds later the unit came to an abrupt stop! - much faster than could be attributed to application of the generator brakes.

Testing was suspended and an investigation started to find out what had gone wrong. The unit was dewatered and an inspection showed that the propellor blades had rotated to a flatter position in the trunnion, breaking the retaining pins, and the leading edge of the blades had come in contact with the throat ring, scraping off a millimeter or so of stainless steel cladding. Other than that, there was no further damage - the unit alignment was checked and was found to be unchanged, and there was no damage to the bearings. The unit blades were rotated back to the correct position, and new larger retaining pins inserted. The throat ring was ground smooth after welding over the scored surface, and testing was resumed a month later.

It was obvious that there had been a rupture of the draft tube water column, with the water separating from the runner into a pure vacuum, and then on collapse of the vacuum, impacting on the underside of the runner blades with sufficient force to shear the retaining pins and rotate the runner blades. But why had this event not been anticipated from the records of draft tube pressure?. A review of the calculations showed that the computations were based on a published paper where a computational proceedure had been developed from tests on a unit with draft tube velocities and runner submergence quite different from that at the new plant, and perhaps could not be applied to other units.

However, a detailed examination of the draft tube pressure gauge showed the real culprit - the dial bourdon gauge was callibrated in pounds per square inch, reading up to 50 psi positive pressure, and down to 15 psi negative pressure - but there was a very small brass pin installed at the bottom of the 1 in the number 10 on the negative pressure side, which prevented the needle from moving past the minus 10 psi mark, presumably to prevent the instrument from being used to measure near vacuum pressures. It was not noticed, and there was no warning on the gauge as to the allowable pressure range.

At the 70% load rejection, the gauge reached it's negative presure limit, (10/14.7 = 0.68 bar). At the next test at 80% load rejection, the gauge again read minus 10 psi and the significance of this was not noticed, the actual negative pressure must have been closer to one atmosphere. At the 90% rejection negative pressure reached one atmosphere, and the water column ruptured.

Lessons Learned.

Always check and double ckeck the instrumentation to be used in tests. Since most hydro sites are remote, instruments can loose their accuracy due to rough handling while being transported to the site. Also - remember to re-calculate the governor closing time for retrofit units, where more flow is being passed through the draft tube, it could be slower than that determined from the penstock waterhammer criterion due to restrictions on the allowable negative draft tube pressure.
