HUNTING IMPULSE TURBINE

George was having a relaxed lunch with Lucio at the camp cookhouse. They were discussing the innovations Lucio had added to the high head 28MW impulse powered hydro project in the Andes mountains. The new peaking plant was the fifth in a series developed on the same river. The upstream plants were generating at a steady base load, but pondage was added at the new plant in the form of a small forebay excavated into the steep sloped mountainside. For every cubic meter of pondage, over one cubic meter of rock had to be excavated, hence the pondage was expensive. The project included a long unpressurized tunnel from the tailrace of the upstream plant, which discharged into the headpond. The 11m. of storage in the headpond was just enough to provide water during the daily peak.

Lucio, the project resident engineer, had the bright idea to split the headpond in two, with a wall across the pond to form an intake tank into which the tunnel discharged. The tank contained less than 10% of the headpond volume. The dividing wall had an overflow into the main headpond and a bottom culvert with a swinging flap gate opening into the tank. When the headpond was empty, the tunnel flow would quickly fill up the tank, adding 3% to the head on the turbines, before flowing over the dividing wall to slowly fill the headpond. An added benefit was the wood cover to the tank, which prevented rocks, which were continually falling down the mountainside, from entering the tank. Rocks falling into the main portion of the headpond were removed when the headpond was empty, whilst keeping the plant in operation with flow through the intake tank.

Another of Lucio's innovations, was to move the powerhouse over 100m. downstream from the penstock centerline. Lucio had the foresight, based on his experience with living in the valley, to realize that the straight penstock climbing the 45 degree bare rock mountainside, would result in many rock falls from anchor block and pier excavations. When George arrived at the site to assist in the commissioning, he was astounded to observe a large concrete "ski jump" at the bottom of the penstock gulley, just above the road to the powerhouse. On questioning Lucio as to the function of the structure, since it was not shown on drawings, Lucio advised that rock slides from the penstock excavation had been severe and were continually blocking the access road to the powerhouse. Since rocks rolling down the mountainside attained a high velocity, Lucio had built a flip bucket to direct the rocks over the road to the river beyond. It worked very well.

After lunch, George and Lucio were walking down to the powerplant where the operators were going to water up and run unit #1 for the first time. Suddenly all the operators in the plant came rushing out. Lucio immediately ran down into the plant with George following. Inside the plant, the penstock pressure gauge was rising and falling steadily between a pressure of zero and about 600m., twice the static pressure on the turbines. Every time the gauge reached maximum pressure, there was a loud bang from the turbine manifold pipe. Lucio immediately shut down the rotating turbine by closing the turbine rotary valve. The other turbine was still in the commissioning stage, and not yet ready to operate.

What had gone wrong?. Clearly, the governor had lost control of the unit, but how?. The governor was similar to others on the upstream plants, with one exception, the return motion cable from the spear jet valves was a new design, consisting of a long race of small ball bearings which in effect formed a highly flexible rod, which transmitted each spear valve position back to the governor. Other governors on the system had a wire return motion cable, kept under tension by either a weight or a spring. However, the cable stretched. The new design was intended to eliminate stretch. Detailed examination of the ball race indicated that it had a small amount of lost motion, sufficient to confuse the governor as to the precise opening on the spear valves.

In an impulse unit the speed-no-load spear valve opening is in the region of only 3%, and a very small change in valve opening will cause a large change in runner speed, hence precise control is essential. For this, the governor needs to know the exact valve opening. With a small amount of slack in the ball race, the governor started to hunt, at a frequency which apparently equaled the sound wave return time in the penstock, resulting in a 100% waterhammer. Fortunately, the penstock was designed to withstand a 100% waterhammer at a stress of 95% yield. Examination of the penstock found no damage to the pipe, but all the anchor blocks were split at the top, where the concrete is thinnest. The cracks were caulked, the only repair required. As for the governor, the ball race was replaced with a wire cable, and operated successfully.

Lesson Learned.

If technology is to advance, innovations are required, and someone will be have to be the quinea pig for the first application. For the civil work innovations, they were simple, and well thought out by an engineer with many years of practical experience. On the other hand, the ball race was developed by design engineers with little or no field experience. The concept had been extensively questioned by the consultant at the proposal stage, and assurances were given that it had worked well at the factory - but it had never been tested in a governor connected to an operating turbine. If a new design is being tried out for the first time on your project, be prepared for some bugs to be worked out.