Floating penstock.

Work on the two unit, 240m. head powerplant was proceeding on schedule. Installation of the 1.5km. long steel pipeline up to the intake was approaching the intake, where the pipe diameter was 5.2m. The pipe was being installed in a shallow trench excavated in the overburden, with the top of the pipe about level with the ground, covered with one meter of gravel for insulation. The trench had a half meter layer of gravel in the bottom to prevent uplift on the pipe, a 20cm. pipe with drain holes on the bottom, placed in each corner just above the gravel, and sand backfill around the pipe.

The construction engineer's staff was augmented by engineering students obtaining some practical experience, and several were assigned to pipeline inspection. The pipe contractor was very experienced, and had the work well organised. The trench had been fully excavated up to the intake. About 40m. upstream of the upper pipe can, a temporary cofferdam had been built across the trench to prevent drainage from entering the work area. The gravel bed was placed and the next task was drain pipe installation. Since this was an easy task, it was assigned to the night shift. The new student engineer noted the drain pipe being installed with the holes on the bottom, and reasoned that the water would then flow out of the holes, rendering the drain ineffective. He instructed the work crew to install the pipe with the holes on top.

Next morning the day shift was about to place a 0.25m. sand bed for the penstock, when the next student engineer noted the holes on top and reasoned that sand grains could drop into the pipe, perhaps causing a blockage. He then instructed the workers to place a strip of tarpaper over the holes - making the drains useless!. Since the drains were quickly covered with sand, the construction engineer did not notice the change during his daily inspection, nor did the students mention the change.

Several days later, there was a severe night-time thunderstorm over the project area and night shift work on the penstock was cancelled. Next morning the staff were astounded to find the upstream end of the 5.2m. pipe "floating" on the surface, with about 50 meters buckled upwards on the bottom. Excavation of the trench revealed the ineffective drains - needless to say the students got a lecture on making unauthorized changes to the construction drawings!. Other contributing factors to the accident were the temporary cofferdams placed at about 250m. intervals across the trench, the lack of stiffeners and the thin wall of the pipe. The cofferdams had not been fully removed, and hence acted as barriers to drainage water in the bottom gravel. Rainwater had flowed down the gravel layer to the first remains of a

cofferdam, and finding no relief through the drain pipes, had created sufficient uplift to buckle and float the penstock.

Fortunately only about 150 meters of pipe were affected, and about 60% of the steel in the affected pipe could be reused, reducing the cost of repairs.

Lessons Learned.

Construction drawing details should not be changed without reference to the design team. Also, in this particular case, no stiffeners were used and were added to the remaining portion of the pipe as an added safety measure against uneven distribution of uplift pressures - a necessity in all buried pipes with thin walls.