Material Integrity Solutions, Inc.

PROJECT BULLETIN

NL-15

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# Penstock Reliability & Remaining Life Valuation of a Hydro Electric Power Plant

## BACKGROUND

Hydro-electric generation is one of the oldest and most cost effective means of power generation around the world. A typical hydro plant consists of a reservoir at a higher elevation, a turbine-generator, and a water conduit - which is referred to as a penstock (*Fig. 1*).

A large penstock of a major hydro power plant suffered an over-pressurization event which lead to cracking and leakage at several locations. Because of safety and reliability concerns with this penstock, the plant owner - a major utility - commissioned MIS to provide an engineering evaluation of this event and determine its structural adequacy for future operation.

*Figure 1: Photo of a typical penstock system*

## DISCUSSION

The penstock was comprised of two miles of various diameter and thickness piping. About half of the penstock was riveted and the remainder "lapwelded" (longitudinally seam forged welded) construction (*Fig. 2*). During the over-pressurization event, cracking and leakage occurred at a number of locations including a cast iron manhole and a cast iron venturi, which lead to the shut down of the unit and raised concerns about the safety and long-term reliability of the penstock.

MIS conducted a detailed evaluation of this penstock to determine its tolerance to fracture and to estimate its remaining life. In this work, parts of the pressure history during the over-pressurization event was considered as the "proof test" and used to estimate the maximum size of flaws that could exist in the penstock. Different flaw geometries were considered for these calculations. This work also included:

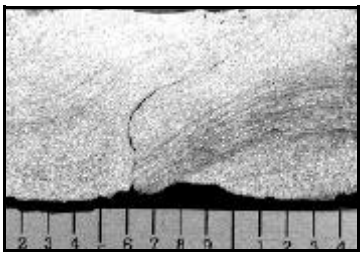

*Figure 2: Cross section of a lap-weld showing a large existing flaw*

- Review of operating records and classification of operating practices.
- Stress analyses for all sections of the penstock under all operating conditions such as slow and fast valve closures.
- Material testing to determine mechanical and fracture properties of the penstock - including $J_{IC}$ (elasto-plastic fracture toughness) testing (*Fig. 3*).
- Fracture mechanics analyses to determine critical flaw sizes, crack growth under fatigue loading caused by normal plant operation, and remaining life analysis.

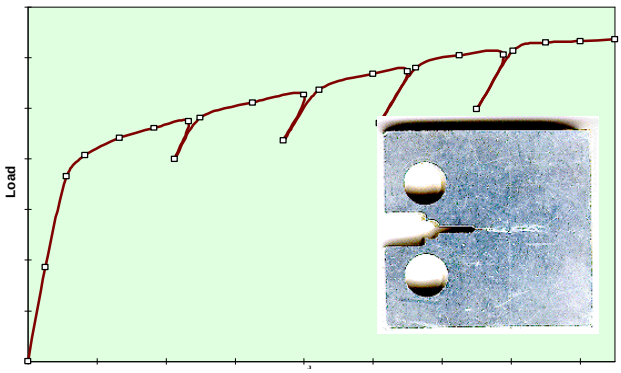


*Figure 3: Compact tension specimen for fracture toughness*

## CONCLUSION

MIS determined that the penstock in its current condition could operate safely. We also estimated the penstock's remaining life and established an inspection program to assure continued reliable and safe operation of this unit.