Q. GENERATION - HYDRO

Rattling Brook Hydro Plant Refurbishment (Clustered) - $18,242,000

PUB 11.0 NP

Has the condition of the penstock deteriorated in the last five years? Provide details.

A. **1.0 Condition of the Penstock**

The woodstave penstock at Rattling Brook is 48 years old. As early as the mid-1990s, inspection reports have noted significant deterioration in the woodstave portion of the penstock, with crushing and delamination of wood staves. In October 2003, engineering consultant SGE Acres ("Acres") was asked to assess the condition of the penstock.

Acres found the woodstave portion of the penstock to be in poor condition, with excessive deterioration of the wood and significant leakage along the springline. At that time, they recommended replacing the woodstave portion of the penstock within 2 to 4 years, noting that the leakage was expected to worsen, causing operational difficulties, increasing maintenance costs and resulting in lost production.

The deterioration includes crushed woodstaves, loss of structural integrity, excessive leakage along the springline, general decay of woodstaves, bulging of the woodstaves, organic growth, dry rot in upper woodstaves, wood decay at butt plates (approximately 17,000 steel butt plates connect the woodstave ends in the penstock) and deterioration of the wooden cradles that support the penstock above the ground. The level of deterioration is consistent along the entire length of the woodstave portion of the penstock.

In addition to the general overall deterioration of the woodstave penstock, the structural integrity of the 250-metre section downstream from the Trans-Canada Highway bridge has been compromised as a result of differential settlement. In 1995, a sudden release of water from an upstream beaver dam caused a washout of the penstock bedding in this area. The washout resulted in undermining of the penstock bedding and cradle supports. This was repaired at the time by installing wood blocking under the cradle supports. The penstock in this area continues to be supported by this wood blocking.

The 1995 washout resulted in differential settlement and twisting of the penstock in this location. This introduced stresses on the woodstave penstock that were not part of the original design. A significant leak that occurred in this area in April 2006 was most likely a result of the additional internal stress in the woodstaves caused by the differential settlement and torsional forces acting on the penstock.

Observation and monitoring of the penstock condition have shown that all of the noted conditions of deterioration have continued to worsen during the last five years.

Deterioration such as that observed in the Rattling Brook wooden penstock tends to accelerate over time as the various conditions compound in the weakening structure.

2.0 The Problem of De-watering

2.1 General

As woodstave penstocks age, general deterioration of the wood will cause leakage. For a number of years, there has been some leakage of the Rattling Brook woodstave penstock. In recent years, this leakage has become more significant, particularly following de-watering of the penstock.

Because older woodstave penstocks tend to leak if they have been de-watered for an extended period, the frequency of de-watering is minimized to the extent possible. The condition of the Rattling Brook woodstave penstock is such that the facility has been operated for some time with a view to avoiding de-watering unless it is absolutely essential. However, there are circumstances when de-watering is unavoidable.

When a leak in the penstock is too large to patch with the pipe under pressure, the penstock must be de-watered before the leak can be repaired. Similarly, if a leak were to occur in the surge tank, including the external riser, the leak could not be repaired without de-watering the penstock. In addition, the penstock at Rattling Brook would need to be de-watered if a problem developed that required inspection or repair of the turbine assembly.

In normal circumstances, the scroll case where the turbines are located can be de-watered by closing the main valves. At Rattling Brook, however, both main valves are leaking so badly that it is not possible to de-water the scroll case in this way. Consequently, if a problem develops in the turbine assembly, the only way to safely access the area is to de-water the penstock.

Because of the extent of deterioration, the likelihood that the penstock will require de-watering to repair leaks is high. Although the probability of leaks in the surge tank or problems with the turbine assembly is lower, they have occurred in the past and could happen at any time.

Since 2000, there have been four instances in which the penstock had to be either completely or partially de-watered.

2.2 2000 Surge Tank Leak

In February 2000, the entire woodstave portion of the penstock was de-watered for one day to allow for the repair of a blowout in one of the surge tank manholes. Upon re-watering, there was a significant amount of leakage along the springline. However, winter weather conditions at the time made patching of the penstock impossible, and ice continued to build up on the penstock during the remaining winter months. Fortunately, the ice caused no damage, and the leaks were repaired by the plant operators when the winter weather abated.

2.3 2003 Surge Tank Leak

In April 2003, a leak developed in the same surge tank manhole that had been repaired in 2000. In order to repair the leak, the entire woodstave portion of the penstock was de-watered for one day. At that time, the extent of leakage that was encountered did not necessitate extraordinary repair efforts.

2.4 2003 Inspection

In October 2003, the entire penstock was de-watered to allow Acres to complete their inspection and condition assessment of the penstock and surge tank, and to carry out repairs to the penstock. At that time, approximately 100 steel plates were installed along the entire length of the penstock to repair areas where excessive leakage had been noted. Upon re-watering the penstock, after approximately 6 days, significant additional leakage was encountered. The plugging of the leaks resulting from the de-watering took a crew of 6 workers approximately 4 weeks to complete.

2.5 2006 Penstock Leak

In May 2006, the uppermost 450 metres of the penstock was de-watered to repair a significant leak just downstream of the Trans-Canada Highway bridge. This section of the penstock, which is on the low-pressure end, was de-watered for less than 6 hours. However, the leakage encountered on re-watering the upper section of penstock took a crew of six workers approximately one week to repair.

2.6 Effects of De-watering

When the penstock is de-watered, the woodstaves begin to dry out. As the woodstaves dry out, they tend to shrink, especially along the springline where the structural strength of the wood has been reduced due to crushing. This shrinkage increases the tendency of the already-damaged woodstaves to leak.

In addition, de-watering puts additional stress on the penstock. When the penstock is full, internal water pressure helps the penstock to maintain its shape. When the internal pressure is reduced, the weight of the wood staves and the external pressure from the steel bands tend to distort the penstock's shape. This extra movement of the wood also contributes to leakage when the penstock is re-watered.

When the penstock is de-watered in winter, the potential for problems is even greater. Although freezing temperatures can lessen drying and shrinkage, weather conditions can change quickly. The weight of snow and ice loads can also put additional external pressure on the penstock.

More importantly, however, deep snow and icing conditions could make it impossible to repair penstock leaks. Further, if the drainage of leaking water away from the penstock is blocked by deep snow, the resulting ice around the pipe could damage the penstock even further. If this were to occur, the penstock would have to be de-watered until conditions improved.

3.0 Conclusion

The recent experience with de-waterings indicates the deterioration of the penstock is worsening. Although the most recent de-watering, in May of this year, was brief and involved the low-pressure end of the penstock, the resulting leakage was severe.

In the case of the Rattling Brook penstock, significant leakage over a period of time could result in further erosion of the penstock bedding, leading to further differential settlement of the penstock and undermining of the cradle supports. Furthermore, the volume of leaking water could wash out the road currently used for access by Newfoundland Power and local cabin owners.

If it was necessary to de-water the penstock for a week or longer in the spring, summer, and fall months, or for as little as two days in the winter, there is a serious risk of being unable to return the penstock to service.

The inability to routinely de-water the penstock for operational reasons constitutes a continuing and serious operating limitation on the penstock.