In The Matter of the Public Utilities Act, R.S.N.L. 1990, c. 1990, c. P-42

And

In The Matter of the 2007 Capital Budget Application filed by Newfoundland Power Inc.

## INFORMATION REQUESTS

To: Newfoundland Power Inc.
55 Kenmount Road
P.O. Box 8910 St. John's, NL A1B 3P6

Attention: Mr. Peter Alteen/Gerard Hayes

CA-1-NP Please provide reliability and availability data for Ratting Brook over the past 10 years, and expected figures going forward following the refurbishment (page 2 of 65, Schedule B, Volume I).

CA-2-NP Will SGE Acres be allowed to bid on any components of the refurbishment given their involvement in the original assessment of Rattling Brook (Appendix B and C, Volume II)?

CA-3-NP Will Newfoundland Power Inc.'s staff carry out any of the work identified as part of the Rattling Brook refurbishment?

CA-4-NP What is the age of the steel section of the penstock? Has it ever been coated to reduce corrosion (page 3, Volume II)?

CA-5-NP What percentage loss in thickness of the penstock and surge tank is considered significant (Thickness Measurements, Appendix C of Appendix B, Volume II)?

CA-6-NP Why was only a 15-year inflow sequence used in the analysis of optimum penstock size rather than the full hydraulic record (page 2, Appendix C, Volume II)?

CA-7-NP What is the basis for the energy values of $0.071 and $0.093/kWh used in the economic analysis of penstock diameters (page 2, Appendix C, Volume II)?

CA-8-NP Why is there excessive vegetation on the downstream face of Rattling Lake Dam? Is control of such growth part of Newfoundland Power Inc.'s normal maintenance practices (Figure 4, Attachment A, Appendix D, Volume II)?

CA-9-NP It is stated that it will be necessary to change the voltage of the existing plant station service transformer to satisfy the voltage requirements of the new equipment and increase transformer capacity to accommodate the additional load (page E-1, Appendix E, Volume II). Why is station service load increasing? Please indicate where the additional station service load is factored in to the Feasibility Analysis of the Rattling Brook refurbishment in Appendix H.

CA-10-NP It is stated that Rattling Brook is a "critical black start plant". Please provide a copy of the relevant black start procedure indicating the role of Rattling Brook. In addition, please provide a list of occasions when Rattling Brook was used for black start purposes and identify the occasions when it failed to provide black start service owing to the lack of redundancy in the station service supply (page E-1, Appendix E, Volume II).

CA-11-NP Please provide details of the butterfly valve replacement benefit/cost assessment (page F-1, Appendix F, Volume II).

CA-12-NP What is the date of the Feasibility Analysis in Appendix H, Volume II?

CA-13-NP The capital costs of Rattling Brook refurbishment are estimated to be $20.9 million, and the levelized cost over 50 years, including capital and operation and maintenance costs, is estimated to be 2.9 cents/kWh (Appendix H). This translates to a capital cost of $1482/kW (or $7207/incremental kW). Please provide comparable figures for new hydro and wind generation, and energy conservation initiatives, in the Province.

CA-14-NP What is the annual impact on Newfoundland Power Inc.'s retail rates resulting from the Rattling Brook refurbishment for the years 2007 through 2016?

CA-15-NP What is the annual impact on Newfoundland Power Inc.'s retail rates resulting from the proposed capital expenditures in the 2007 Capital Budget (other than the Rattling Brook Refurbishment) for the years 2007 through 2016?

CA-16-NP What components of the Rattling Brook refurbishment could be left until the major overhaul in 2012?

CA-17-NP What are the estimated costs of maintaining the status quo at Rattling Brook for another five years?

CA-18-NP In the attached paper by Robert Meyers and Ralph Carpenter entitled "Victoria Dam Penstock - A Second Generation Wooden Penstock Replaced with 114-Inch Spiral-Welded Steel Pipe" the authors state that in 2001 the Upper Peninsula Power Company (Michigan, U.S.A.) replaced a 6050 linear foot (1.8 km) wooden penstock with a spiral welded steel penstock of 2.9 m in diameter for slightly more than $5,000,000 U.S. Please explain how if at all the design and installation methods used for the Michigan project differs from that contemplated by Newfoundland Power Inc. in the proposed penstock replacement (which is estimated to cost approximately $11.7 million) and please further detail the estimated cost of the penstock replacement on the assumption that the design and installation methods used in the Michigan project were employed in the project at hand?

CA-19-NP With reference to the Meyers and Carpenter paper referenced in CA-18, to what extent, if any, has Newfoundland Power Inc. investigated whether the design and installation methods used in the Michigan penstock project would be suitable for the Rattling Brook penstock project?

CA-20-NP At the present time is Newfoundland Power Inc. in a position to advise the Board whether the design and installation methods used in the Michigan penstock project would be suitable for the Rattling Brook penstock project and, if so, please provide the basis for this position?

CA-21-NP If Newfoundland Power Inc. is not in a position at the present time to advise the Board whether the design and installation methods used in the Michigan penstock project would be suitable for the Rattling Brook penstock project, on what basis does it seek immediate approval to expend approximately 11.7 million on the Rattling Brook penstock in the manner as contemplated?

CA-22-NP Did Newfoundland Power Inc. investigate and consider using the design and installation methods employed in the aforesaid Michigan penstock project when undertaking the recent replacement of the New Chelsea penstock? If so, was it pursued, and if not, why not?

CA-23-NP Who will have responsibility for the design work in relation to the penstock as proposed for Rattling Brook and does that entity or entities, as the case may be, have experience and expertise in relation to the design as used in the aforesaid Michigan project?

CA-24-NP What firms are considered probable bidders for the installation of the Rattling Brook penstock as proposed in the Capital Budget Application and which of these firms, if any, have experience and expertise in relation to the installation methods used in the aforesaid Michigan project?

CA-25-NP In the opinion of Newfoundland Power Inc., would it be beyond the ability of probable bidders of the Rattling Brook penstock as proposed to carry out a successful installation using the methods employed in the Michigan project?

CA-26-NP Please provide details as to how the cost of the materials for the replacement penstock as proposed has varied, if at all, for the period 2001 to 2006 inclusive?

CA-27-NP Please provide for the years 2002 to 2006:

i) the particulars of maintenance costs in relation to this plant, with details in relation to the penstock and the surge tank;

ii) maintenance logs;

iii) inspection reports/assessments; and

iv) outage reports in relation to outages that can be attributed to items that are the subject of the proposed capital expenditures.

CA-28-NP The cost benefit analysis that was provided in relation to the Rattling Brook Refurbishment is an evaluation of two alternatives - proceeding with the proposed capital expenditures vs. not operating the plant. Provide a cost benefit analysis assuming the continued operation of the plant without the work and with this work, setting out details of the savings associated with the increased capacity and the costs associated with the carrying charges.

CA-29-NP The Acres report says that the Rattling Brook penstock should be replaced in the near future. Please provide clarity as to what was reasonably intended with the wording "the near future".

CA-30-NP Acres says without repairs in "the near future" they expect that the leakage problems would worsen causing operational difficulties and increasing maintenance costs. Detail the operational difficulties and projected maintenance cost increases and the likelihood that this may happen.

CA-31-NP Provide details of consequences of deferring the Rattling Brook Refurbishment project for 1, 2, 3, 4, or 5 years?

CA-32-NP Is there a risk of a catastrophic loss if the penstock replacement is not completed in the next 1, 2, 3, 4, or 5 years? Please provide the basis for the response in light of the Acres Report's making no reference to the risk of catastrophic loss in connection with the existing penstock.

CA-33-NP Identify aspects of the Rattling Brook penstock project that require urgent attention and therefore must be dealt with in 2007, specifying the portions or percentage of the penstock that must be repaired. Identify among the remaining items any that can be deferred until 2008, 2009 or 2010 or later.

CA-34-NP Provide a cost benefit analysis that allows the urgent requirements to be dealt with in 2007 and delays the remaining until 2008, 2009 or 2010 or later depending on the attention required. Include the costs that will be incurred, as well as the opportunity costs of delaying the expansion of the capacity of the penstock.

CA-35-NP Has Newfoundland Power Inc. solicited the assistance and advice of experts specifically on woodstave penstocks to determine the remaining life and possible maintenance that would extend the service life of the penstock?

CA-36-NP Please provide details as to the scope and extent of patching/repairing work undertaken on the penstock in the last three (3) years and please indicate how areas of the penstock that were patched/repaired with steel plate are presently functioning. For example, what is the situation presently in the areas depicted in photos No.s 14 and 15 of the Acres photographs?

CA-37-NP Please comment on the type of penstock leaks that can be plugged or patched without necessarily de-watering the penstock and please provide an estimate as to the number of man hours and anticipated cost of attending to the leaks along the penstock that are amenable to such plugging or patching in this manner?

CA-38-NP Before embarking upon a replacement penstock, would not Newfoundland Power Inc. consider it financially prudent to seek expertise from an established woodstave pipe engineering and supply firm to evaluate the Rattling Brook penstock in order to determine whether the existing penstock may be refurbished to extend its life? (Please see attached paper from the Summer 2002 edition of the Canadian Dam Association Bulletin entitled, "Life Extension of a Wood Stave Penstock at Nipissing Generating Station of Ontario Power Generation Inc."

CA-39-NP Please provide the study of Newfoundland Power hydro generation showing that all expenditures on individual hydro facilities over the remaining life of each plant are justified on the basis of the replacement value of energy; i.e. as opposed to retiring plant (page 4 of 65, Schedule B).

CA-40-NP What are the contributors to the 15% annual increase in the Rebuild Distribution Lines category forecast for the period 2007 through 2011 versus the five-year historical period ending 2006 (page 33 of 65, Schedule B)?

CA-41-NP What is the cause of the significant increase in the Relocate/Replace Distribution Lines for Third Parties in 2006 (page 36 of 65, Schedule B)?

CA-42-NP What is the cause of the significant increase in the Additions to Real Property cost category in the 2008 to 2011 time frame over historical levels (page 42 of 65, Schedule B)?

CA-43-NP What guidelines are used by other Canadian utilities for replacement of heavy fleet and passenger vehicles (page 48 of 65, Schedule B)?

CA-44-NP What is Newfoundland Power Inc.'s target SAIDI and how is this target tied to the value customers place on reliability (2007 Capital Budget Plan, Graph 2, page 2)?

CA-45-NP Please provide a description of Newfoundland Power Inc.'s industry best practice maintenance program for its distribution assets (2007 Capital Budget Plan, Graph 2, page 16).

CA-46 -NP Please provide the Distribution Reliability Initiative (2007 Capital Budget Plan, Graph 2, pages 16/17).

CA-47-NP Please provide resumes for Gary L. Murray, Sean LaCour, Glenn Samms, Trina L. Troke, Trina Cormier.

CA-48-NP Please provide resumes for the principal authors of the reports on 2007 Application Enhancements, 2007 System Upgrades and 2007 Shared Server Infrastructure.

CA-49-NP How does Newfoundland Power Inc. integrate its capital program with its other costs? For example, a distribution automation capital project may result in reduced operating and maintenance costs. How much money will be eliminated from Newfoundland Power Inc.'s other budgets as a result of its proposed 2007 capital program?

CA-50-NP What is the expected improvement in customer service and reliability as a result of the proposed 2007 capital program?

CA-51-NP What are the repercussions of delaying the Ten-Year Substation Refurbishment and Modernization Capital Plan by five years (2007 Capital Budget Plan, Graph 2, page B-1)?

**DATED AT** St. John's, in the Province of Newfoundland and Labrador, this 12th day of July, 2006.

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# Victoria Dam Penstock – A second Generation Wooden Penstock Replaced With 114-Inch Spiral-Welded Steel Pipe

Robert Meyers[1] and Ralph Carpenter[2], M.ASCE


## Abstract

*The Upper Peninsula Power Company (UPPCO), owner and operator of the Victoria Hydro facility located near Rockland, Michigan, was faced with the responsibility of having to replace a second-generation wooden penstock. This 6,050-linear foot (1.8 km) deteriorated Douglas fir penstock, installed in 1959, replaced the original wooden penstock that was built in 1930. UPPCO and their engineer, Montgomery-Watson-Harza, evaluated several materials for the new 114-inch (2.9 m) penstock, including wood, fiberglass, concrete, and roll-and-welded steel before deciding on spiral-weld steel pipe. This paper will discuss the process that determined the technical and economical viability of spiral-welded steel pipe manufactured by American SpiralWeld Pipe Company, LLC., in a new state of the art facility located in Columbia, South Carolina. It will also discuss the installation and performance of the new penstock.*


## Introduction

The Ontonagan River has its headwaters in the Ottawa National Forest where nearly 400-inches (10 m) of snowmelt and rainfall runoff collect in a watershed of approximately 800-miles$^2$ (2,072 km$^2$). The wild and scenic waters of the river wind approximately157-miles (253 km) through the Upper Peninsula (UP) of western Michigan to Lake Superior. In 1931 the Ontonagan was forever changed with the completion of Victoria Dam. The multi-arch buttress designed dam had reinforced concrete walls that varied from 4-feet (1.2 m) at the base to 2-feet (0.6 m) at an elevation of 118-feet (36 m) above the original riverbed holding back the waters that form Victoria Reservoir. It was the vision of brothers Frank and Al Spees to harness the water of the Ontonagan at Victoria Reservoir to generate electricity for the mining industry in this region of the UP. From Victoria Dam, to the power generating station, the waters of Victoria Reservoir flowed through a 6,050-feet (1,844 m) redwood-stave penstock where the force of the water is focused on the blades of 65-inch (1.65 m) diameter cast steel turbines generating enough power to serve 8,000 modern day households. The harsh extremes of the areas' climate would eventually take a toll on Victoria Dam and the wood-stave penstock. The dam needed replacing in 1991 and the penstock would see two (2) replacements, the first in 1959 with a Douglas fir wood stave penstock of the same diameter, and the second in 2001 with a new 114-inch (2.9 m) spiral-welded steel penstock.

## Wood Stave Penstocks – 1930 and 1959

Constructed in 1930, along with Victoria Dam, the original 120-inch (3 m) penstock dropped 214-feet (65.2 m) from the dam to the powerhouse which are separated by a distance of 6,050-feet (1.8 km). In constructing the wood stave penstock, it is estimated that if each redwood

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stave were laid end-to-end the line of timber would stretch almost 85-miles (137 km). Designed for a flow velocity of 800 cfs (22.7 cu-m/s) and a pressure of approximately 93-psi (641 kPa), the penstock resisted this internal pressure with approximately 72,000 iron bands that encircled the penstock every 10-inches (256 mm). Over 600 formed-concrete saddles provided support for the exposed penstock; foundations for these saddles were supported with a minimum of two (2) 12-feet to 16-feet (3.7- 4.9 m) cedar post friction piles that were driven into the native clay soils.

Stewardship for the Victoria hydroelectric facilities changed hands in 1947 when three small electric generating companies, including Copper District Power Company, the original owners of Victoria Dam, penstock, and powerhouse, were consolidated into the Upper Peninsula Power Company (UPPCO). After almost 30 years of service, exposure to the extreme climatic variation of the UP, where, for example, the temperatures vary from –40°F (-40°C) in the winter to 110°F (43.3°C) in the summer, the original redwood penstock was in desperate need of replacement. The penstock experienced a failure in February 1959. During the repair, the entire penstock was evaluated for replacement. During the spring and summer of 1959, UPPCO contracted with Stone and Webster to design and construct the replacement for the original redwood penstock. The design parameters remained the same--flows to the powerhouse required approximately 800-cfs (22.7 cu-m/s) at a static head of approximately 214-feet (65.2 m) or 93-psi (641 kPa). Designed for a service life of approximately 30-years, Stone and Webster decided that this second generation penstock would be of wood-stave construction using Douglas fir and would utilize the same formed-concrete saddles as the original 1930 penstock. Based on a 30-year service life, the 1959 Douglas fir, 120-inch (3 m) wood-stave penstock would be scheduled for replacement in 1989, see Figure No. 1. Oh, the "best-laid plans o' mice an' men[i]."

Suffering from the same deteriorating symptoms as the original 1930 penstock, the 1959 Douglas fir did, in fact, need to be replaced in 1989. However, this same year the Federal Energy Regulatory Commission (FERC) directed UPPCO to replace Victoria Dam. FERC determined that due to severe freeze-thaw cyclic cracking, some of which had been epoxy grout injected and were holding up very well, the dam had deteriorated beyond repair. In 1990, Stone and Webster designed a new roller compacted concrete dam to be constructed immediately down stream from the existing dam. Construction began in April 1991 and eight (8) months later, in December 1991, at a cost of approximately $9 million, the new dam was completed. UPPCO lacked the funding to replace both the dam and the penstock during this same period; therefore, during dam construction several wood staves of the existing (1959) penstock were replaced.

Maintenance of 1959 penstock was extremely problematic during the winter, with the period from January through March being the worst months. The penstock leaks were so severe that maintenance crews could not drive on the service road that ran next to the line due to severe icing. Attempts were made again in 1998 to extend the life of the line by installing an additional 500 steel bands, 250 steel plates, and replaced numerous deteriorated wood staves in a conscious effort to tighten up the line. The 120-inch (3 m) penstock had a total of 72,000 bands installed on the line of which two-thirds or approximately 4,000-feet (1,219 m) had all of the tightening shoes located on the same "clock" position on the circumference of the penstock. The original design was to have the shoe positions staggered as they were in the remaining 2,000-feet (610 m) section. By locating the shoes in the same "clock" position on the penstock exterior, stress concentration points resulted and a more rampant deterioration occurred. The 2000-feet section where the shoes had been staggered during the construction in 1959 performed substantially better. The penstock was deteriorated from the inside with added loss from the Kelsey butt joints missing and outside from dry rot. FERC, in a 1998 inspection, requested that UPPCO do a dry walk through of the penstock to determine the condition of the interior. Dewatered inspection was averted by soliciting the assistance of several experts on wood stave penstocks to determine the remaining life and possible maintenance that would extend the service life of the penstock. The continuing maintenance proved to be a futile effort and in 2000 UPPCO determined that extending the life of the existing penstock was not cost effective and that it would be replaced, see Figure No. 2.

**Planning for Replacement**

In 1999, several of the "key" design personnel that were intimately involved in the design of the existing 120-inch, 1959 penstock, had left their previous design and construction firm and were now part of the Hydropower Group at Montgomery – Watson – Harza Engineers (MWH). UPPCO was convinced that due to their comfort level with the original design team members, their engineering skill, service longevity with UPPCO as a client, and their experience with penstocks designed in accordance with ASCE Manual No. 79, Section 12 – Installation[ii], that UPPCO would retain MWH to prepare the design documents for the new penstock.

The strength of the UPPCO and MWH design team was the vast experience of the team members and their ability to "think out of the box" as it related to concepts for the design and construction of the replacement penstock. The team looked at various alternate materials including, prestressed concrete cylinder pipe, designed per the requirement of C301; fiberglass pipe, designed per the requirements of AWWA C950; spiral-welded steel pipe, designed per ASCE Manual No. 79 and AWWA M11, and manufactured per AWWA C200; wood stave pipe per manufacturer requirements; and finally a cured-in-place liner that utilized the existing penstock structure as a form. UPPCO's decision to purchase spiral-welded steel pipe for the new penstock was based on the following brief summary of each of the alternative pipe materials:

- Fiberglass Pipe (C950)
  - Pipe reliability in the harsh climate of the UP was questionable.
  - FRP pipe and RPMP pipe both had no commonly used method for joint restraint, and thermo expansion was determined to be a potential problem.
  - FRP and RPMP are not easily fixed if penetrated by the hunting rifle of choice in the UP, a 30/30.
  - Manufacturers' delivery scheme amounted to a continuous delivery when UPPCO required delivery on demand.

- Prestressed Concrete Cylinder Pipe (E301)
  - Embedded cylinder pipe, E301 is extremely heavy and would require increased capacity of handling and installation equipment.
  - E301 pipe is only available in 20-foot (6.1 m) joint lengths.
  - Concrete coating is suspect when exposed to freeze-thaw cycles.
  - E301 pipe is not easily fixed if penetrated by the hunting rifle of choice in the UP, a 30/30.
  - Manufacturers' delivery scheme amounted to a continuous delivery when UPPCO required delivery on demand.

- Wood Stave Pipe
  - Time required for installation was not feasible.
  - Installation manpower was not available in the area.

- o Limited service life of 30 years.

- Cured-in-Place Liner
  - Would require a structurally sound penstock, therefore, repairs of substantial sections of the existing penstock would be required.
  - The volume and sources for the steam or hot water necessary to cure the lining was questionable.
  - Never considered a real viable alternative.

- Spiral-Welded Steel Pipe
  - Long joints up to 54.5-feet (16.6 m), manufactured and 100% hydrostatically tested in accordance with AWWA C200, was available from the new, state-of-the-art facility of American SpiralWeld Pipe (ASWP), Columbia, South Carolina.
  - Lap-welded joint configuration, see Figure No. 3.
  - External polyurethane coating for the steel pipe alternative has an excellent UV resistance and not adversely affected by the freeze-thaw cycle.
  - Spiral-welded steel pipe is easily repaired if penetrated by the hunting rifle of choice in the UP, a 30/30.
  - Manufacturers' delivery scheme allowed for delivery on demand as required by UPPCO.
  - Spiral-welded steel pipe furnished by ASWP was the material of choice for the "Green Mile[iii]."

Details of the design, manufacture, and installation of the spiral-welded steel penstock will be provided later in this paper.

Direct-bury of the penstock was evaluated by the team as an alternate to an exposed, above ground installation scenario. By reviewing original photos of the 120-inch (3 m) penstock (1930), it was verified that the 600 formed-concrete saddles were supported on foundations supported with a minimum of two (2) 12-feet to 16-feet (3.7- 4.9 m) cedar post friction piles that were driven into the native clay soils. The design team determined that it would be prohibitively expensive (approximately $200,000 to $600,000) to remove these piles and that their removal would disturb the insitu clay soil resulting in soil foundation destabilization.

The first of two (2) critical elements of the team's planning effort addressed an alternate method of joining spiral-welded steel pipe sections. FERC approval of the penstock construction plans would require that UPPCO and MWH follow the requirements of ASCE Manual No. 79. Section 12 – Installation of this manual of standard practice states that the butt-welded joint configuration is the preferred method for joining sections of steel pipe. MWH personnel knew that the most economical joint configuration for spiral-welded steel pipe was the lap-welded joint. Utilization of the lap-welded joint configuration would eventually result in a savings of approximately $400,000 on the construction of the new penstock. Estimated savings were based on the observations that lap-welded joints assemble quicker, are less susceptible to misalignment difficulties, and require a less expensive joint air test to assure joint weld integrity. Parenthetically, butt-welded joints require additional testing to assure joint weld integrity, and require more difficult butt welds.

The final critical element of the Team's planning effort was a unique, and truly, "out of the box" bedding installation technique. This pipe bedding technique eliminated the need for formed-concrete saddles by utilizing a shaped bedding of compacted crushed rock. Concrete thrust blocks would be used at major changes in alignment to restrain the continuously welded steel penstock.

Both of the critical elements were demonstrated in 1988 with the emergency replacement of a 1,600-feet (488 m) section of a 60-inch (1524 mm) wood stave penstock at another UPPCO facility. UPPCO maintenance personnel knew of an abandoned 60-inch (1524 mm) steel penstock owned by Cleveland Clifts, Inc., a mining and hydropower company. This penstock began at Carp Hydro-Electric Dam and was 5-miles (8 km) in length. The line had been constructed in 1911 using 30-feet (9.1 m) length of 60-inch (1524 mm) "Lock-Bar" steel pipe manufactured in Germany, see Figure No. 4. The pipe was tapered from one end to the other and each section was forced fit and riveted to the previously laid pipe. UPPCO's contractor cut off the riveted end of the pipe and shipped it to the project site. The assembly of the joint was made by stabbing the small end of the Lok-Bar pipe into the larger end forming a pseudo lap-welded joint that was then fillet welded. This replacement section was laid on top of the ground with bedding made of crushed rock shaped to the contour of the replacement pipe. It was this "out of the box" Team thought process that produced a successful emergency installation that would eventually prove to be paramount in convincing FERC that the proposed shaped bedding and the lap-weld joint configuration for the new 114-inch (2.9 m) replacement Victoria penstock would be successful.

With time quickly passing, the team, again thinking "outside the box", decided to arrange a meeting directly with FERC staff in Washington, DC, and including the regional FERC staff from Chicago, to review any potential concerns with variations from FERC standard design protocol. The critical variations that UPPCO was proposing included the exposed surface installation method using a shaped bedding system that utilizes compacted crushed rock with a geotextile overlay for pipe coating protection, and the lap-weld joint configuration. This process normally would take at least 6 months if UPPCO had to work out the details first with FERC's regional office in Chicago who in-turn had to submit the same information to Washington for final review and authorization. UPPCO and MWH were well prepared for questions from FERC's staff with documentation that supported the proven design – installation scenarios. FERC approval of a new 114-inch (2.9 m) spiral-welded steel penstock as represented by the preliminary design was approved.

**Spiral-Welded Steel Pipe – Design and Manufacture**

The UPPCO and MWH design for the steel pipe maximized the inherent advantages of the material and the manufacturing processes available at the state-of-the-art facility of American SpiralWeld Pipe Company, LLC. located in Columbia, South Carolina, see Figure No. 5. The parameters for the new penstock were as follows:

| | |
|---|---|
| Pipe Size: | 114-inch (2.9 m) |
| Pipe Wall Thickness: | 0.448-inch (11.4 mm) |
| Pipe Joint Length: | 54.5-feet (16.6 m) |
| Joint Configuration: | Lap-weld joint; interior structural weld, exterior seal weld; interior joint test ports. |
| Pipe Coating: | 40 mils (1.02 mm) Polyurethane, Madison Chemical – Corropipe II (Aqua-Green). |
| Pipe Lining: | Bare interior. |

American SpiralWeld Pipe Company, LLC. (ASWP) is a subsidiary of American Cast Iron Pipe Company, an internationally recognized leader in the production of ductile iron pipe and one of the "100 Best Companies to Work for in America[iv]". ASWP began production in August 2000 in a new facility located approximately 8-miles (12.9 km) from the center of Columbia, South Carolina. In early 2001 several UPPCO and MWH Team members visited the facility to verify the capacity of ASWP to produce the size, quantity, and quality of spiral-welded steel pipe that would be needed for the new penstock and review ASWP's ability to deliver within the critical time frame established for completion of the project.

The 114-inch (2.9 m), 0.448-inch (11.4 mm) wall spiral-welded steel pipe was produced on a helical or spiral weld-seam pipe mill, see Figure No. 6. The process uses coiled steel with thicknesses up to 1-inch (25.4 mm) that is first uncoiled, flattened, and then reformed and double-submerged arc welded to produce a helical weld-seam pipe of varying diameters. Pipe diameter is a function of the width of coil and the forming angle, which is the angle measured from the center axis of the in-feeding uncoiled steel sheet to the center axis of the pipe out-feed table. This forming angle is calculated using the following formula:

$$\text{Cosine } \Delta = \frac{\text{Coil Width}}{\text{Pipe Circumference}}$$

After forming the spiral weld-seam pipe, one end of the pipe cylinder is expanded to form a tight-fitting bell socket approximately 5-inches (127 mm) in depth. The bell expander (Figure No. 7) uses hydraulic pressure to radially displace the steel cylinder resulting in an increase in the circumference at the bell end. The bell end of the steel cylinder is expanded beyond its' elastic limit such that when the hydraulic pressure is relieved, the steel will relax to form a bell where the inside circumference is equivalent to the circumference of the outside of the spigot end of the steel cylinder, plus or minus 1%. Maintaining this dimensional tolerance assures a tight fitting, lap-welded joint that requires a minimal amount of gap centering and weldment.

With the lap-welded bell formed, the pipe is then hydrostatically tested to a pressure ($P_{ht}$) that induces a stress into the steel cylinder equivalent to 75% of the specified minimum yield of the material, see the formula below. Each and every 54.5-feet (16.6 m) pipe section that makes up the Victoria penstock was factory tested to a pressure of 248 psi (1.71 mPa) prior to shipment. The hydrostatic test press at ASWP (Figure No. 8) is capable of withstanding 6,000,000-lbs (26,690 kN) of end thrust resulting from internal pressures as high as 3,500 psi (24.1 mPa).

$$P_{ht} = \frac{\text{Wall thickness x [2 x (0.75 x Specified Minimum Yield)]}}{\text{Pipe Outside Diameter}}$$

The final manufacturing process was the surface blast and application of the 40 mils (1.02 mm) polyurethane to the pipe's exterior surface after which internal supports or stulling were installed to support the pipe during transportation and installation at the project site, see Figure No. 10.

**Installation**

Delivery of the large diameter, 114-inch (2.9 m) penstock pipe required special low flatbed trailers and special permitting due to the necessary clearance required. With only a few exceptions, the trucks, carrying one piece each, followed the 1233-mile (1984 km) route to the UPPCO project site. UPPCO and ASWP personnel worked closely to coordinate shipment to the limited staging area at the project site.

UPPCO and MWH team members set up the request for proposals, dividing the primary responsibilities into civil construction and mechanical construction. Responsibilities of the civil contractor included the following high-level tasks: surveying, preparation of shaped compacted crushed rock bedding, and site stabilization. Defined responsibilities of the mechanical contractor included pipe unloading and storage, pipe laying, joint welding and testing, and final closure of the penstock. UPPCO competitively bid the construction of the penstock, receiving proposals from 3 mechanical contractors (7 – mechanicals received a RFP) and proposals from 2 civil contractors (4 – civils received a RFP). Reviewing the proposals in great detail, UPPCO contracted with Moyle Construction, Houghton, Michigan, for the civil work and AZCO Integrated Construction, Appleton, Wisconsin, for the mechanical work. Removal of the existing penstock was handled under a separate demolition contract.

Construction began in July 2001 with the demolition of the 1959 wood stave penstock and formed concrete saddles. The demolition went much quicker than the original construction; the line was completely removed within the first week of construction. The team's critical path required that Moyle and AZCO, each with two (2) crews, begin simultaneously at the dam and at the powerhouse, working toward the middle.

The first shipment arrived in Victoria on July 9th, 2001, with the first joint being laid on the prepared bedding shortly thereafter in late July 2001, see Figure No. 11. Assembly of the lap-welded joints went very well. The joints assembled easily after the appropriate technique of laying the lap-welded joint pipe was embraced. Lap-welded joint steel pipe is laid spigot ahead (actually steel plain ends ahead). With the pipe spigot exposed in the trench (internal stulling remaining in place to maintain joint roundness), the next pipe section is secured with non-abrasive straps to a spreader bar and lifted into the trench. Positioning the pipe at a slight angle downward toward the bell end, the top inside of the bell is tack welded to the top outside of the spigot at the appropriate distance from the pipe end. As the opposite end of the pipe is lowered, the top of the bell, acting as a mechanical hinge, will deform around the spigot end to complete the assembly.

Next the pipe laying crew allowed the welding crew access to the pipe for welding of the inside structural weld and outside seal weld. The inside welder is responsible for equalizing any gap remaining in the joint by using shims at equal intervals around the joint to assure that the gap does not accumulate in an area around the joint circumference. AZCO welding crews used wire feed welding equipment that is quicker and more efficient than "stick" welding. After completing the inside and outside fillet welds, the inside welder removes a ¼-inch (6.35 mm) threaded plug from a tapped hole located mid-way between the inside and outside weld and connects an air hose and pressure gauge for testing the integrity of the completed joint. UPPCO and MWH had specified that this air test of 80 psi (0.83 mPa) be satisfactorily completed on all 120 joints. The final step in completing the joint was the application of the 40 mil (1.02 mm) polyurethane coating to the joint areas.

The last 114-inch (2.9 m) pipe closing section was laid complete in November 2001 (Figure No. 12), completing the penstock slightly ahead of schedule and under the $6,000,000 budget at slightly more than $5,000,000.

## Observations and Conclusions

The success of this project was a direct result of the strength and the ability of the team to "think out of the box" for solutions to problems and issues that, had they been arbitrarily accepted, would have raised the project cost substantially. Also contributing was the decision by UPPCO to remain loyal to the engineering personnel at Montgomery-Watson-Harza who provided the design and construction services for many of UPPCO's facilities. Contributors to the successful completion of the construction of the 6,050-linear feet (1.8 km), 114-inch (2.9 m) penstock included American SpiralWeld Pipe, Moyle Construction, and AZCO Integrated Construction.

After approximately 15 months and 1½ winter seasons of operation the penstock's performance is excellent. Surge testing in late 2001 did not challenge the 114-inch (2.9 m) Green Mile (Figure No. 13).

Other specific observations include the following:

- Facilitating the approval meeting at FERC headquarters in Washington, DC.
- Lap-welded joints for ASWP spiral-welded steel pipe in lieu of butt-welded joints. Joint tolerance was tight, minimizing joint gap equalization and weldments.
- Testing the lap-welded joint configuration with 80 psi (0.83 mPa) compressed air.
- Pipe foundation using a shaped compacted crush rock bedding with geotextile stabilizer.
- Two (2) lay directions maximized pipe-laying production.
- Pipe storage area could have been larger.
- Single access road was problematic, required extensive coordination.
- Crushed rock embedment was too close to service road causing slope erosion.

Figures Nos. 1 through 13

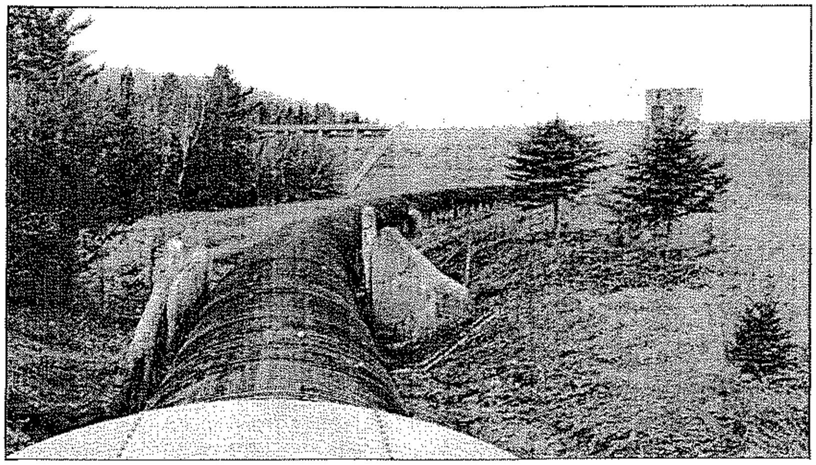


Figure No. 1: Victoria Dam (Built in 1991) and Wood Stave Penstock (Built in 1959)

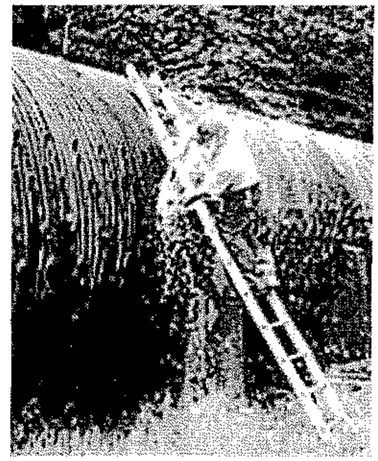


Figure No. 2: Maintenance of Wood Stave Penstock (Built in 1959)

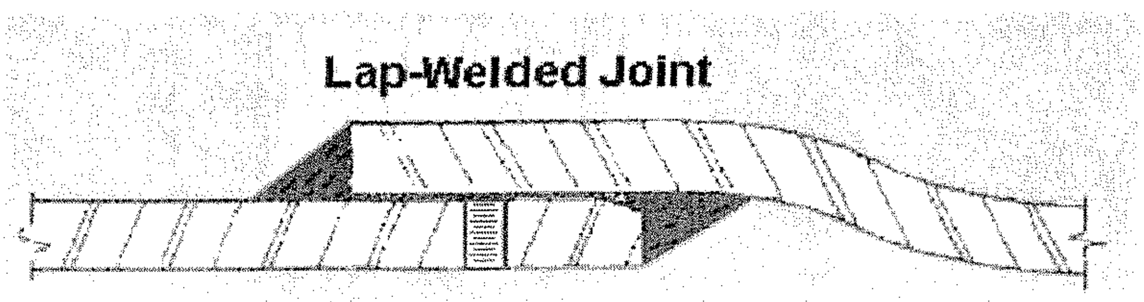



**Figure No. 3:** Lap-Weld joint for steel pipe, shown with inside and outside fillet welds and with air test port.

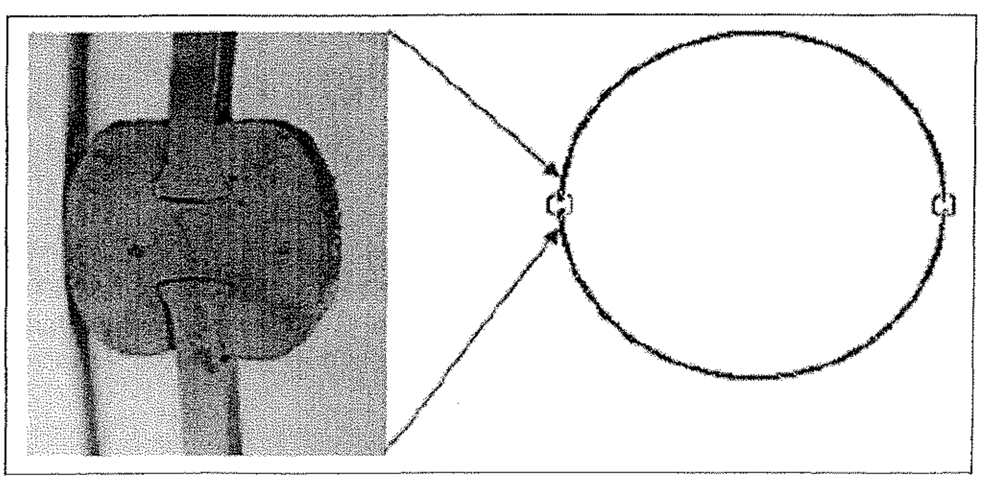


**Figure No. 4:** Lock-Bar steel pipe connection, circa 1911.

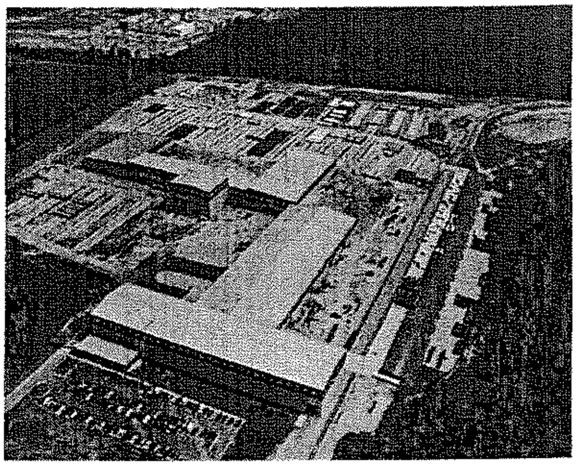


**Figure No. 5:** American SpiralWeld Pipe (ASWP) plant in Columbia, SC.

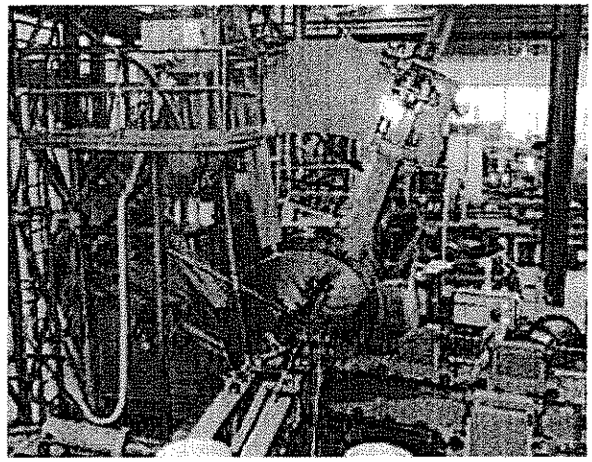


**Figure No. 6:** ASWP Spiral Pipe Mill No. 2.

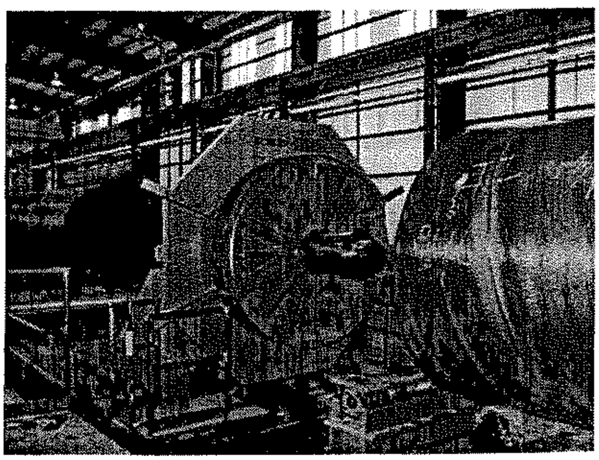


**Figure No. 7:** ASWP Hydraulic Expander.

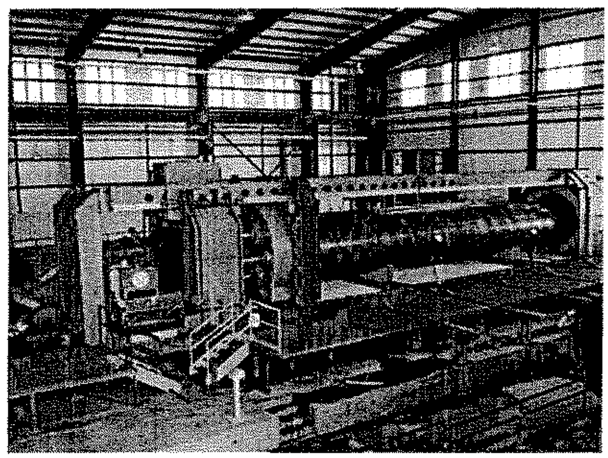


**Figure No. 8:** ASWP Hydrostatic Test Press.

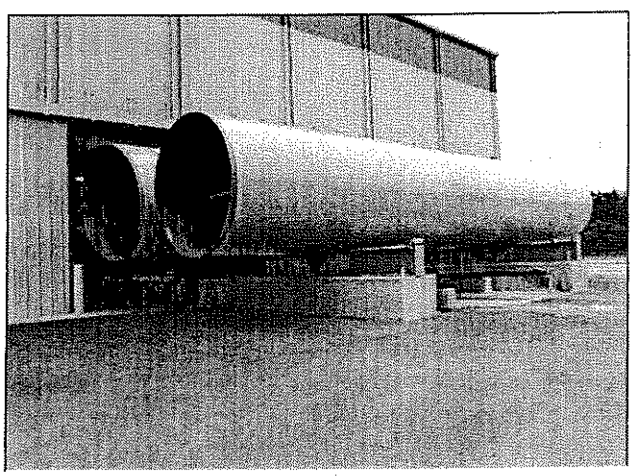


**Figure No. 9:** Newly completed 114-inch (2.9 m) UPPCO penstock pipe at ASWP.

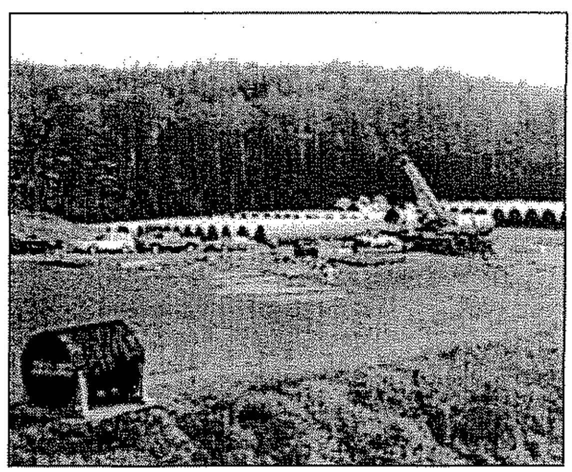


**Figure No. 10:** Pipe staging area at Victoria (center); display section of the 1959 Douglas Fir penstock (bottom left).

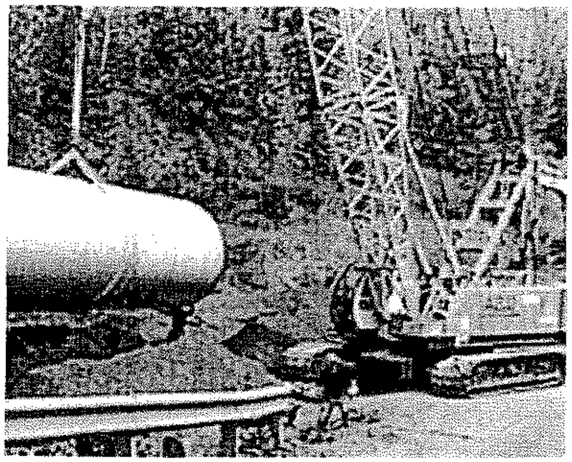


**Figure No. 11:** Installation of new penstock on compacted, shaped crushed rock bedding.

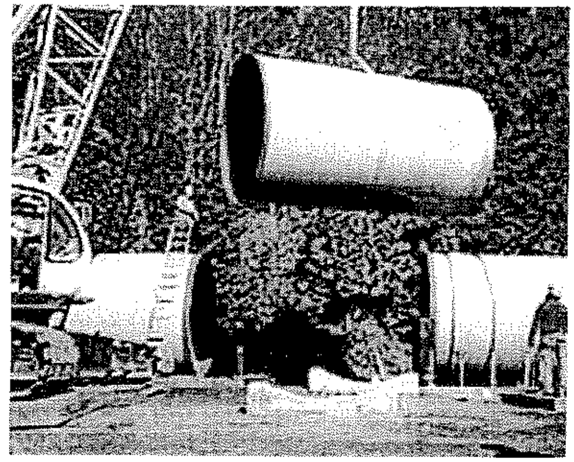


**Figure No. 12:** Installation crews make final closure in the center of the 6,050-feet (1.8 km) penstock.

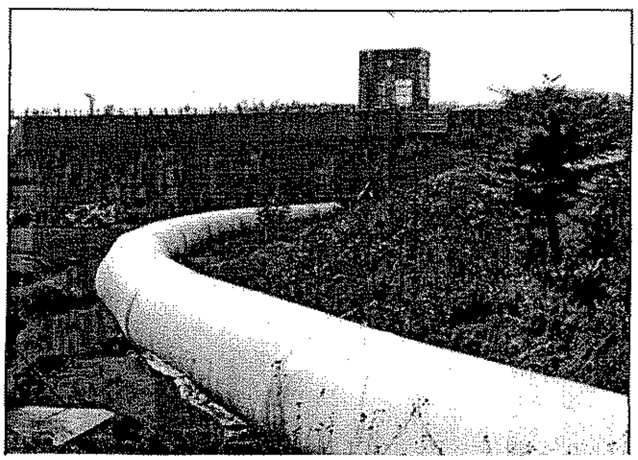
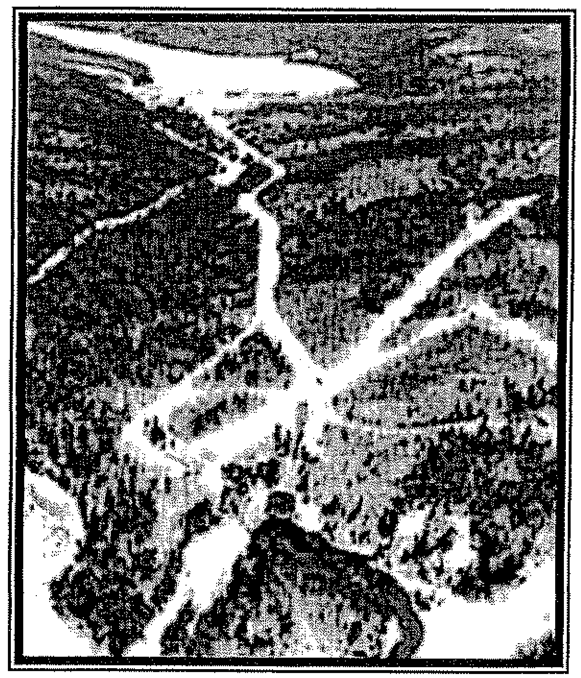


**Figure No. 13:** New Spiral-Welded steel penstock, the "Green Mile" at Victoria Dam.



**Victoria Dam and Reservoir (top); Penstock alignment (vertical-center); Power House (bottom-center)**

[i] Burns, Robert, "To a Mouse", (1759 – 1796).
[ii] American Society of Civil Engineers, "Steel Penstocks – ASCE Manuals and Reports on Engineering Practice No. 79", April 1982 .
[iii] Janet Wolfe, UPPCO, "Build for the Future – A History of Victoria Hydro", Video, 2002.
[iv] *Fortune* Magazine, "The 100 Best Companies to Work for in America", 1998, 1999, 2000, 2001, 2002, and 2003.

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**Paper No. 174**

## Victoria Dam Penstock – A second Generation Wooden Penstock Replaced With 114-Inch Spiral-Welded Steel Pipe

Bio-Sketches of Authors
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Robert J. Meyers – Co-Author

Robert "Bob" Meyers is Supervisor of Hydros for the Upper Peninsula Power Company (UPPCO), he has 28 years of experience with a background in power production, operations, maintenance, engineering, construction, and labor relations. Bob has additional experience in the management of facilities including coal-fired generating stations, hydroelectric plants, and gas turbine sites. He has broad industry knowledge including compliance and regulatory issues in the power generation business. Bob is a graduate of Michigan Technological University where he received a BS degree in mechanical engineering. Bob also has previous experience with QC, layout, design review and site management on three (3) penstock projects and involved in all company Part 12 Engineering Inspections.

Ralph Carpenter – Co-Author

Ralph Carpenter has been in the pipe industry for 25 years serving in capacities as pipe designer, engineering supervisor, sales engineer sales manager, and in his current capacity as marketing specialist for American SpiralWeld Pipe and American Ductile Iron Pipe. During his industry tenure Ralph has designed, managed, marketed, and sold projects associated with the power industry including penstocks, make-up water lines, and cooling water lines. Ralph is a graduate of SUNY College at Buffalo, a member of AWWA, WEF, and ASCE. He is a resident of Birmingham, Alabama.

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CANADIAN DAM ASSOCIATION

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# Bulletin

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## Conference Highlights, Itinerary, Registration Forms

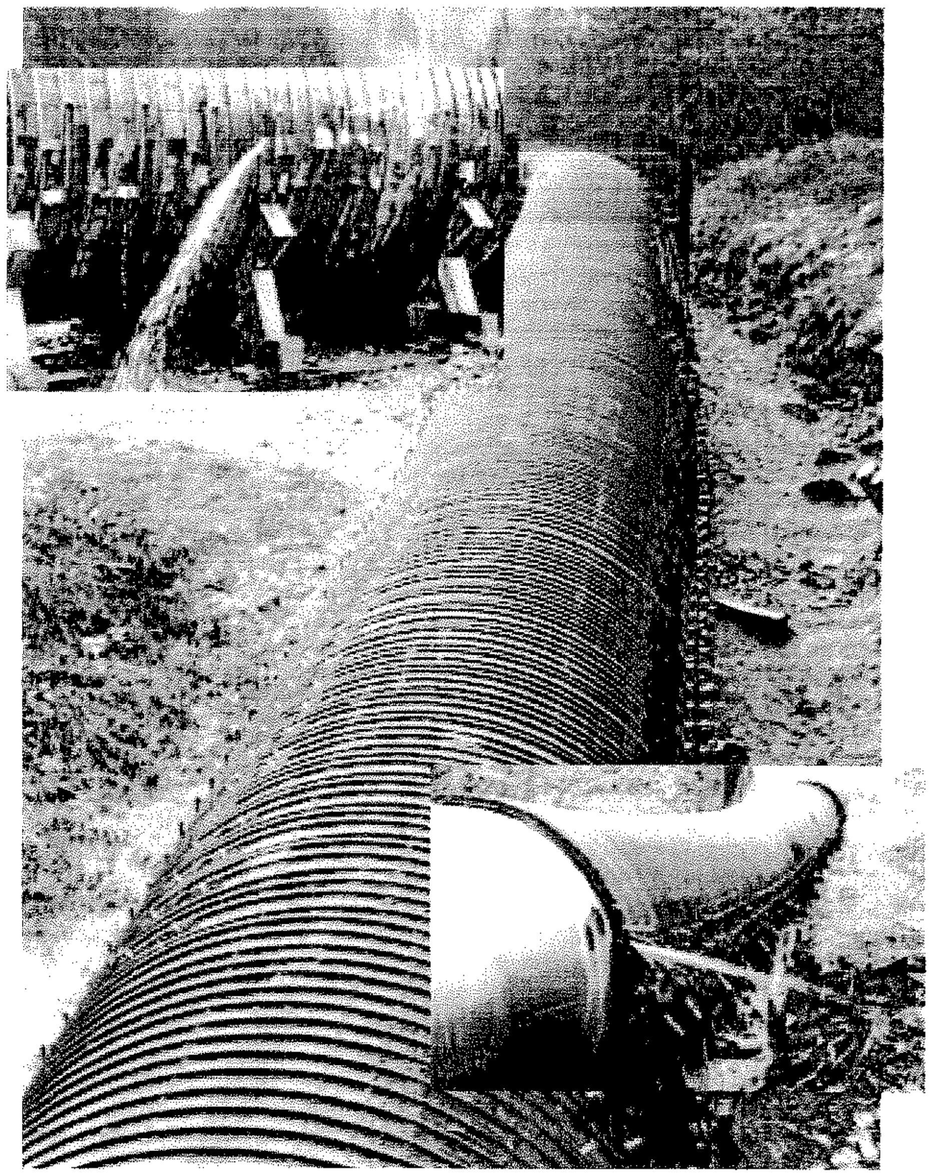
## Nipissing Generating Station

# CONFERENCE ISSUE

# Life Extension of a Wood Stave Penstock

## at Nipissing Generating Station of Ontario Power Generation Inc.

*By Phil Stevens, Project Manager-OPG Evergreen Energy, Iskander Boulos, OPG-Project Engineer, Terry Stinson, CANBAR INC. -Vice-president & General Manager*



Ontario Power Generation (OPG) and predecessor Ontario Hydro have operated the Nipissing Generating Station, built in 1909. The Station has two generating units currently producing up to 2.0 MW of electricity. The Generating Station is supplied via a single 2.13m (84") ID wood stave penstock, approximately 0.63-km (2080 feet) in length from the dam to the surge tank.

The original penstock had been replaced about fifty years ago in 1953, and was recently beginning to show its age. Although total quantity of leakage was not deemed significant, there were numerous leaks particularly towards the bottom (higher head) portion of the penstock. The penstock had a history of a partial collapse and distortion at some locations. Integrity of the penstock was of concern.

Ontario Power Generation now faced the question of how to deal with this aging penstock. Being a small station, the level of energy production required a cost-effective solution to ensure that the station remained viable. Two alternatives were evaluated:

(a) to replace the full penstock with a new wood stave or steel pipe, or
(b) to refurbish the existing penstock to extend its life.

Ontario Power Generation worked with Canbar Inc., a long established wood stave pipe engineering and Supply Company, to evaluate the penstock. Canbar found the metal banding, which is installed around the penstock to hold the wooden staves in place, to be in good condition and suitable for continued service. Interestingly, most of the metal bands had been reused during the pentock replacement in 1953 from the original 1909 pipe (over ninety years old). The OPG maintenance group had developed a tie-down system to prevent slipping of the bands at the hold down shoes that provided additional integrity. As well, the OPG maintenance group installed support structures at critical locations to reduce horizontal "swelling" of the penstock.

Canbar's analysis pointed to the beginning of wood stave deterioration in several locations. Some wood stave crushing/angle shear had occurred as well as some limited delamination. There were some spongy areas. These observations are typical and are to be expected in wood pipes of this age. Overall, the wood stave wall was judged to be still in sound, serviceable condition. It is important to note that once stave crushing has started, it will compound as efforts are made to tighten up on the banding to reduce leaks, leading to further crushing. Unless something is done, this is the beginning of the end for the penstock.

In this case, it was felt that steps could be taken to stabilize the pipe wall and extend the penstock life. The existing crushed staves had to be stabilized or replaced.

When Ontario Power Generation compared the cost of replacement versus stabilization and refurbishment, the difference was dramatic. Replacing the penstock was going to be a $2 million dollar range job. Refurbishing the existing penstock wall would cost less than 20 percent of this amount, and was expected to add another fifteen years to the penstock operating life. Discounted Cash Flow Analysis clearly favoured refurbishment/life extension.

The penstock was dewatered for five weeks in August/September 2001 to allow the technical personnel from Canbar, supported by a trades crew from Aecon Construction, to perform the repairs. Both internal and external Canbar designed steel patching was installed to stabilize weak/failing staves and prevent further wall deterioration. Some cradles were repaired and some staves were fully replaced. The Ontario Power Generation Project Management group coordinated the project with support from the OPG Technical Services Group.

The Nipissing penstock now has a new lease on life. All serious leakage has been eliminated; some minor weeping still remains. Routine maintenance is now expected to keep this penstock in service for many years to come. ■