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Technical Publication

Re-Powering Paper - Coal-to-Gas Boiler Conversion

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ABSTRACT

This paper will provide a synopsis of the work involved in converting three (3) boilers at the Domtar Nekoosa Paper Mill from coal to natural gas firing. Units 1 & 2 at the facility are wall-fired steam boilers rated for 110,000 pph main steam flow each. Unit 10 was originally a stoker fired coal and bark boiler rated for 225,000 pph main steam flow. In 2014, all three boilers were converted to fire natural gas only. Riley Power Inc. and TEi Construction Services Inc. were contracted by the facility to supply engineering services, equipment, construction, and commissioning for the gas conversion.

The comprehensive conversion approach will be highlighted by detailing the interconnected project elements from the perspectives of various stakeholders, including owner project development considerations, fuel equipment design engineering, as well as construction and commissioning planning and implementation. Owner considerations discussed include fuel, maintenance, and environmental costs. Project engineering analysis includes fuel and air supply as well as combustion equipment design and arrangement. The unique construction approach will be described, including an overview of scope and scheduling between the three (3) units. Lastly, unit commissioning considerations, including equipment checkout, safe entry of gas, controls implementation, and emissions performance results will be shared.

INTRODUCTION

Setting out to convert an existing coal fired boiler to natural gas can be a daunting task that involves many facets and stakeholders. This paper will describe the process and results of converting three (3) boilers from coal to natural gas firing at the Domtar Nekoosa Paper Mill (pictured in Figure 1). It will shed light on the conversion process by providing the views and considerations from the boiler owner, engineering design and supply firm, as well as project construction and commissioning entities.

Boilers 1 and 2 were originally Combustion Engineering (CE) wall fired pulverized coal boilers and boiler 10 was originally a CE stoker boiler. Boiler 1 and 2 existing burners were arranged in a 2x2 configuration while the boiler 10 was fired by coal feeders and four (4) bark chute openings evenly spaced above the feeders. Boiler 10 was designed to burn stoker coal and wood fuel on an air cooled traveling grate. Both boilers 1 and 2 were designed to generate 110,000 pph of steam flow, while Boiler 10 had an MCR steam flow rate of 225,000 pph.

Figure 1 – Domtar Nekoosa Paper Mill

PROJECT DEVELOPMENT TO MEET REGULATIONS

With three (3) industrial power boilers firing coal, the paper mill faced a 2016 deadline to comply with the National Emission Standard for Hazardous Air Pollutants, also known as Boiler MACT (Maximum Achievable Control Technology). Plant management had to decide whether to add the environmental controls necessary to comply with MACT, or convert to natural gas, a less carbon intensive fossil fuel.

The plant first examined additional pollution abatement equipment to allow the boilers to continue operating on coal. This approach included absorbent injection systems for all three boilers, and was calculated to raise operating costs significantly and require a large capital investment. Next, the plant evaluated converting boilers 1, 2, and 10 to natural gas firing and removing a small older boiler from service. This approach was found to lower maintenance costs from pulverizers and coal delivery equipment, as well as reduce operating costs through improved plant efficiency.

Ultimately, with assistance of Domtar's Corporate Purchasing, Engineering, and Mill and Corporate Environmental Teams, the gas conversion project was developed and approved in late 2013. All environmental approvals for the project were secured from the regulatory authorities in a timely fashion. A specification was developed jointly between the Domtar and an outside engineering firm. The specification covered the mechanical, structural, electrical, and I&C engineering and design requirements, as well as equipment installation and performance guarantees requirements.

Riley Power Inc. (RPI), a Babcock Power Inc. company, competitively bid the project with a strategy for the entire project (design, supply, and installation) to be sole sourced within the Babcock Power family of companies. The offer included engineering design, equipment supply, and commissioning by RPI, with installation and commissioning support by Riley Power's associate company; TEi Construction Services (also a Babcock Power Inc. company). In the end, the mill concluded that the combination of RPI's innovative designs, equipment technology, execution strategy, and single source responsibility was the most cost effective solution for their conversion.

PROJECT ENGINEERING

The overall project involved many areas of the mill, including the power plant and four (4) boilers, controls, wood room and bark system, railroad which transported coal, and the coal distribution system within the facility. Riley Power's engineering design was limited primarily to the boiler systems and included the following:

Riley Power Scope

Units 1 & 2 (existing pulverized coal, wall fired units, 110,000 pph each):

- Design and supply of four (4) new STS® low NOx burners (Figure 2) and four (4) new OFA ports
- Supply of four (4) new gas ignitors and UV scanners
- Design and supply of new gas delivery piping and valving
- Boiler control logic and instrumentation

Unit 10 (existing coal and bark stoker boiler rated for 225,000 pph):

- Design of new refractory floor in place of existing stoker
- Design and supply of new secondary air ducting and burner windbox
- Design and supply of four (4) new STS® low NOx burners
- Supply of four (4) new gas igniters and scanners
- Supply of new cooling air blower skid and piping
- Design and supply of new gas delivery piping and valving
- Boiler control logic and instrumentation

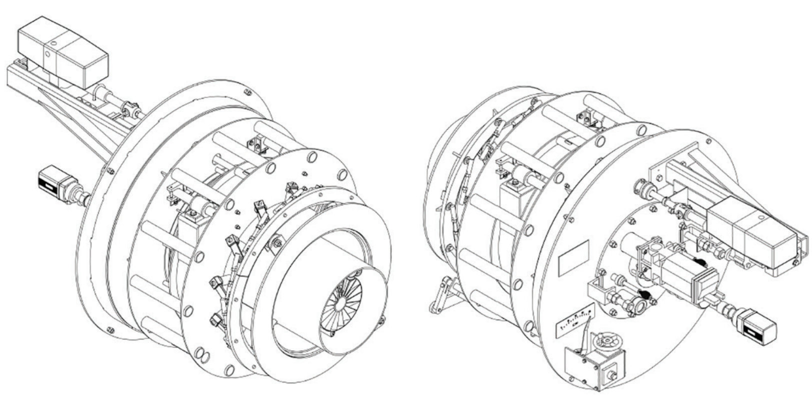

Figure 2 — RPI STS® Low NOx Natural Gas Burner

Several key and innovative features of Riley Power's design included:

- The burners supplied for units 1, 2, and 10 were all the same model. With this approach the burners, igniters, flame scanners, and burner front block and bleed valves were identical on each unit, simplifying operation, maintenance, and spare parts inventory.
- No pressure part changes were required for burner & OFA installation. The burners on unit 10 were installed in the four (4) existing bark chute tube bend openings. The burners and OFA ports on units 1 & 2 were installed in the existing coal burner openings.
- All major equipment was fabricated and shipped as pre-assembled modules in the largest size possible, for ease and speed of installation. Examples of this included the STS® Burners (Figure 3), the Unit 10 Secondary Air Ducting and Windbox (Figure 7), and the natural gas control valves and instruments for all three (3) boilers (Figure 4).

Figure 3 — STS® Burner, as Shipped

Figure 4 — Natural Gas Control Skid, all three (3) Boilers

The new windbox design for unit 10 was evaluated using CFD modeling. Turning vanes were incorporated into the design to achieve even and symmetric flow to each burner. Even flow distribution was a contributor to the excellent emissions performance (noted on page 9). The flow profile results from the CFD modeling with and without turning vanes are depicted in Figure 5.

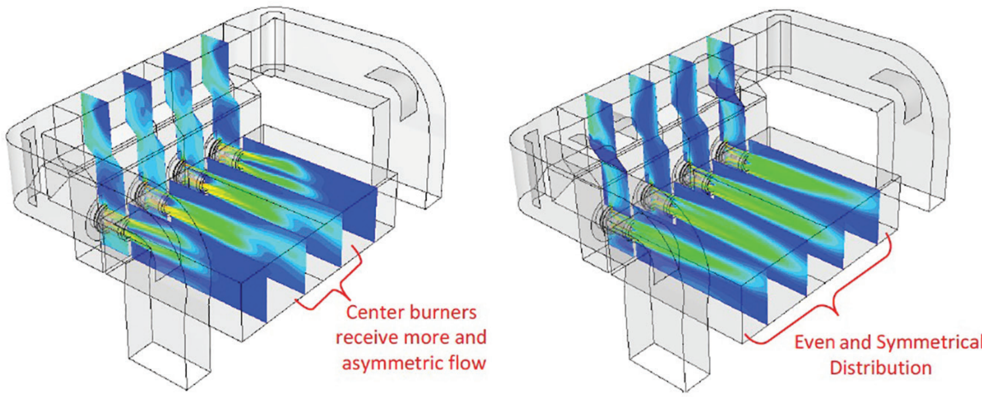

Figure 5 — CFD Model of New Windbox without (left) and with (right) Turning Vanes for Flow Distribution

Client Scope

Additional project scope the mill completed was adding a new bark handling system including a silo, with the plan to have bark product shipped to another mill for consumption in a new biomass unit. The mill also implemented a new DCS system to modernize the power plant's control system.

CONSTRUCTION EXECUTION

TEi Construction Services (TEiC) worked in collaboration with RPI to provide a D&E (Design and Erect) proposal that met the customer's objectives. The strategy was to supply a competitive proposal by maximizing modularization of equipment, allowing the projects to be completed during the planned unit outages of 2014. The team further considered what existing equipment could be re-used to minimize outage duration and construction cost. A single job foreman led the construction disciplines as the point of contact with RPI and the site. Lastly, the work was self-performed with a direct hire construction crew, working 7 days per week to minimize boiler downtime.

Boiler 10 was the first to undergo its conversion and was completed a few days early. This was quickly followed by boiler 2 and then boiler 1. The construction went smoothly and all boilers were on line and operating 21 days ahead of schedule. Another key element was that the project was completed by the mill crews and TEiC with zero first aids or incidents.

Construction Outline, Unit 10

- Schedule – Four (4) weeks, Working (1) Ten Hour Shift / Day
- Demo existing coal and bark feeder equipment and delivery systems including chutes up to the bunkers and all refractory (Figure 6).
- Install the following equipment:
  - o Modularized Windbox and Ductwork (Figure 7)
  - o Four (4) Riley Power STS® Burners, Gas Ignitors, and UV Flame Scanners (Figure 7 & 7)
  - o Four (4) Burner and Ignitor Valve Assemblies
  - o New Stoker Floor
  - o Superheat Pendants (replacement in-kind)

Figure 6 — Unit 10 Existing Bark Feed Chute and Nozzle (left), and Bark Feed Openings after Demo (right)

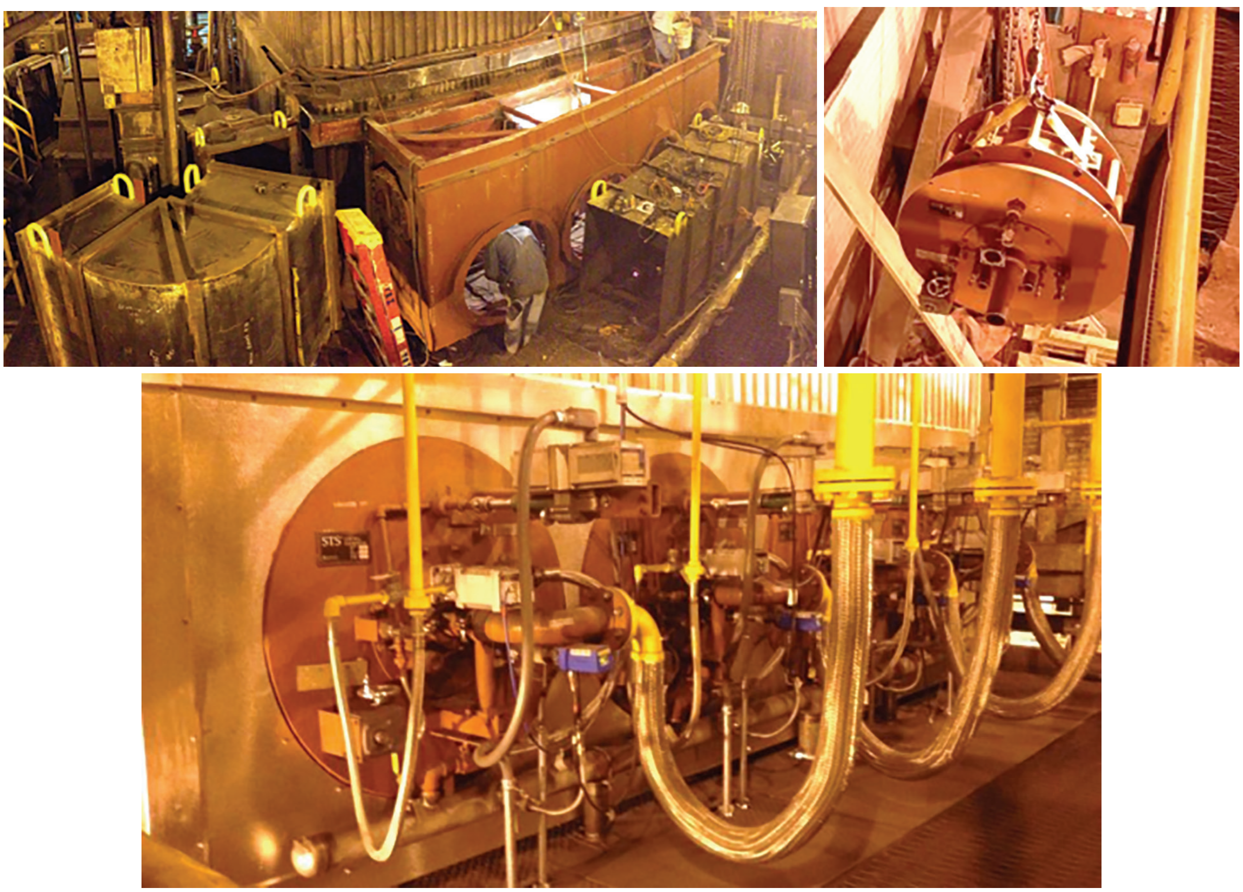

Figure 7 — Unit 10 Modular Windbox and Ductwork Installation (top left), Burner Hoisting (top right), Installed Burners (bottom)

Figure 8 — Unit 10 Burner Throat Refractory Installation

During the design phase of the project the initial plan was to remove the stoker equipment in its entirety. In reviewing this approach and in executing the strategy to re-use as much as possible, the existing structural supports were analyzed. It turned out that the existing traveling grate could remain in place and be utilized as a floor. However, the stoker steel wasn't designed to withstand the furnace temperatures without an insulating layer from the stoker coal fly ash bed. Additionally, the stoker plenum was viewed as a potential source of air in-leakage, which could impair the performance of the new gas burners. To minimize heat exposure and excess air issues the stoker grate was covered with insulation and fire brick. This approach, shown in Figure 9, reduced the demolition and material cost considerably.

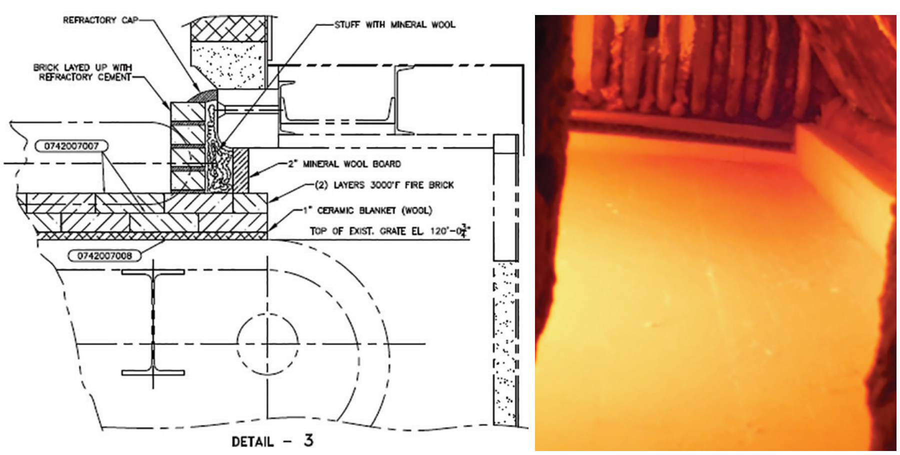

Figure 9 — Insulation and Fire Brick Installation Drawing (left) and Picture (right) on Stoker Grate

The construction approach saved enough time to allow in-kind replacement superheat pendants to be installed during the same outage duration. The SH pendants were installed through the front wall utilizing the opening created from the demolition of the coal feeder equipment.

Construction Outline, Units 1 & 2

- Schedule – Two (2) weeks / unit, Working (1) Ten Hour Shift / Day

Scope of Work, Per Unit (as shown in Figure 10):

- Demo existing four (4) coal burners and equipment (ignitors, scanners and coal piping)
- Install the following equipment utilizing the existing windbox and boiler front water wall burner opening:
  - o Two (2) Riley Power STS® Burners, Gas Ignitors, and UV Flame Scanners
  - o Two (2) OFA Ports and Shroud assemblies to be installed through the two (2) upper burner openings
  - o Two (2) Burner and Ignitor Valve Assemblies

This approach allowed for all of the work to be completed in the allotted two week schedule per unit which included the demolition and installation of the burner throat refractory.

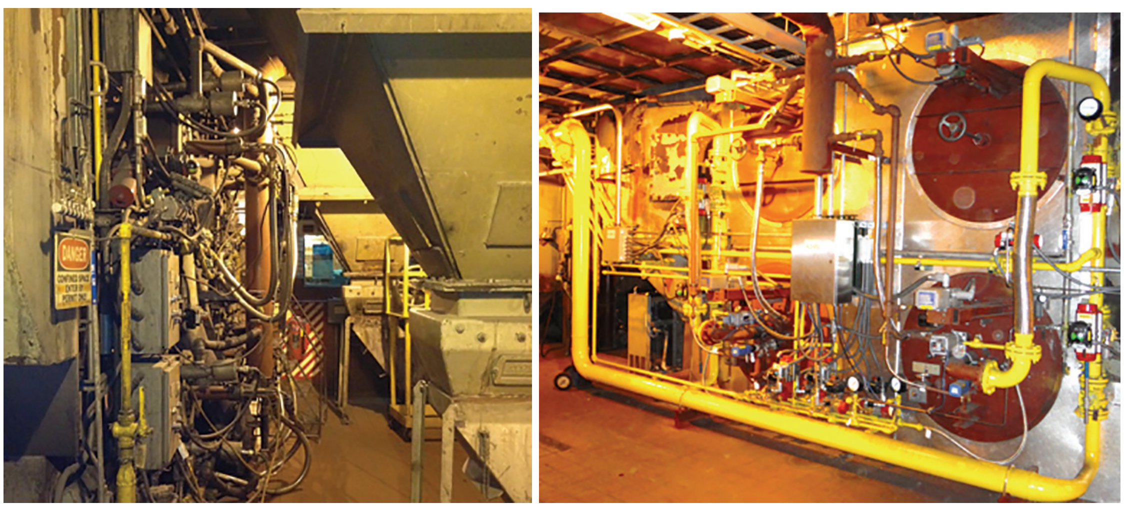

Figure 10 — Unit 1 & 2 Existing Coal Burners and Coal Chutes (left), and new STS® Burners and OFA (right)

CHECK OUT, COMMISSIONING, AND PERFORMANCE RESULTS

A Riley Power field service engineer worked with TEiC during the construction, and performed in process installation inspections. Any installation changes were handled jointly between RPI and TEiC with the RPI field service engineer acting as the go-between representative. The field service engineer further completed final mechanical installation checkout inspection and signoff.

The RPI field service engineer, mill crews, and a programmer for the customer-supplied burner management system worked together to complete loop checks, functional checks, and controls trouble shooting on all new equipment.

The natural gas piping system was designed per the latest addition of NFPA 85[1]. The installed piping system was pressure tested and leak checked per ASME B31.1[2]. Guidelines for nitrogen gas purging of the natural gas lines and for initial gas firing were subsequently developed. Nitrogen was introduced to displace the oxygen contained within the system to a reduced level, mitigating the risk of having a combustible gas mixture when introducing gas. The initial gas firing procedure was followed, which included automated and manual leak checks to ensure safe introduction of gas to the boiler.

The pressure regulators and flow control valves were set to maintain the desired light-off pressure. Successful initial light-off was achieved through careful coordination between Riley Power, the mill operation team, and the BMS programmer.

After initial light-off, the ignitors were tuned and in-service leak checks of the burner and ignitor flex hoses were conducted. The burners were placed in and out of sequence to achieve the required temperature rate increase for curing the refractory. This temperature was monitored using thermocouples installed within the refractory. Pictures of the STS® Burner flames at low, medium, and high loads are shown in Figure 11.

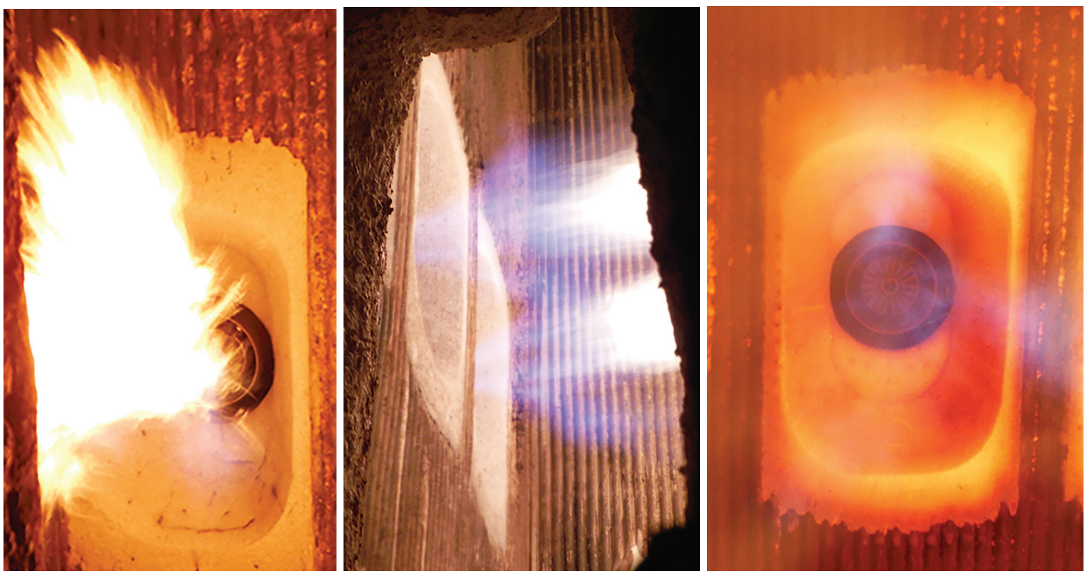

Figure 11 — Unit 10 STS® Low NOx Burner Flames at Low, Med, and High Loads

Once the refractory cure was completed, tuning of the fuel and air systems was conducted. The natural gas flow control valve remained in manual control until fuel and air control curves were developed. The boiler load was coordinated with plant operations who decided the steam loading and steam routing.

Optimization testing of the burners followed. This involved running a series of tests and collecting a complete set of DCS data, local burner settings, furnace observations, and boiler outlet emissions sampling grid. The testing took several days per unit.

All three (3) boilers were able to reach their original full load steam flow capacity at better than expected energy efficiencies. Previous studies have shown that switching from coal to natural gas will generally result in a decrease of boiler efficiency between 2-5 percentage points[3]. However, in this case, the conversions actually resulted in a net increase in boiler efficiency. Boiler 10 posted a 5% gain in boiler efficiency from baseline performance, while the boiler 1 & 2 conversions resulted in a reduction of less than 1% each. This performance was attributed in part to the construction crew's work in sealing up the boiler, to allow for very little air in-leakage and extremely low excess air operation.

The STS® burners achieved extremely low NOx and CO emissions throughout the load range, with the peak full load emissions noted in Table 1. Additionally, the burners demonstrated an impressive turndown range of greater than 15:1, leaving the mill substantial operating flexibility.

Table 1: Emissions Performance Results

Parameter	Boiler 1	Boiler 2	Boiler 10
NOx, lb/mmbtu	0.046	0.066	0.068
CO, ppmvd	2	0	2

From an environmental perspective, expected annual environmental benefits from the project are anticipated to include the following reductions estimated to be: approximately 172,000 tons of greenhouse gas emissions, 3,500 tons of SO_2, 1,000 tons of NOx, 50 tons of particulates; the elimination of mercury emissions from coal combustion and around 32,000 tons/year of boiler ash that was previously landfilled.

SUMMARY

After a boiler MACT analysis, Domtar decided that converting the Nekoosa Mill to natural gas was a more attractive option than adding the environmental controls required for continued coal operation. The new gas combustion equipment was designed and supplied to minimize the existing unit modifications and provide a straightforward installation. Installation was completed ahead of schedule with zero safety incidents. A safe an effective startup was conducted, allowing uninterrupted mill operation into the peak load season. This project demonstrates the results that can be achieved with a successful team oriented turnkey project approach.

ACKNOWLEDGMENT

The authors wish to acknowledge the significant contributions of several other individuals involved in project execution. This project would not have been the possible without the dedicated mill crews and their ability and readiness to work side by side with the TEi Construction crew during startup. Additionally, Mike Coyle, Joe Ufnal, and Yoram Schaker contributed significantly to the project in engineering and management functions. Also, Dennis Twomey and Murat Yaldizli from Riley Power provided the I&C and CFD engineering as a backbone to the project. Lastly, Jeff Brewer and Nancy Fuhrmann provided the project engineering support from the mill that pulled it all together.

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