A REPORT TO
THE BOARD OF COMMISSIONERS OF PUBLIC UTILITIES

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UPGRADE GENERATING UNIT 1 FORCED DRAFT FAN DUCTWORK

Holyrood Thermal Generating Station

February 2010
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APPENDIX B
1 INTRODUCTION

The Holyrood Thermal Generating Station (Holyrood) is an essential part of the Island Interconnected System, with three units providing a total capacity of 490 MW. The generating station was constructed in two stages. In 1971, Stage I was completed bringing on line two generating units, Units 1 and 2, capable of producing 150 MW each. In 1979, Stage II was completed bringing on line one additional generating unit, Unit 3, capable of producing 150 MW. In 1988 and 1989, Units 1 and 2 were up-rated to 170 MW. Holyrood (illustrated in Figure 1) represents approximately one third of Newfoundland and Labrador Hydro’s (Hydro) total Island Interconnected generating capacity.

![Holyrood Thermal Generating Station](image)

**Figure 1: Holyrood Thermal Generating Station**

The three main components of each generating unit are the boiler, turbine, and generator. The boiler servicing Unit 1 is equipped with two forced draft (FD) fans which are commonly referred to as the east and west FD fans. A FD fan is a system that provides combustion air to the boiler during operation. The fan consist of a rotating assembly, commonly referred to as an impellor, that is positioned inside a steel casing which contains both air intake and
discharge zones. The impellor is driven by a 1,500 horsepower electric motor. Each FD fan also contains air intake and discharge ductwork which is connected to the fan casing air intake and discharge zones respectively. During operation, the intake ductwork conveys ambient air to the FD fan from both inside and outside the plant. After passing through the FD fan, the discharge ductwork then conveys the air to the boiler furnace where it is mixed with the boiler fuel oil for combustion. The Unit 1 FD fan arrangement is illustrated below in Figure 2.

![Figure 2: Holyrood Unit 1 West FD Fan](image-url)
2 PROJECT DESCRIPTION

This project is required to perform modifications to the ductwork on the east and west FD fans servicing generating Unit 1 to reduce fan vibration levels and eliminate ductwork cracking. A Computational Fluid Dynamics (CFD) analysis will be completed on the fans while they are in operation in order to model the air flow characteristics inside the intake and discharge ductwork. CFD analysis is a computer modeling technique commonly used in industry to model fluid flows and analyze problems in mechanical systems by simulating the interaction of fluid flows with equipment surfaces. Based on the results of the CFD analysis, custom fabricated equipment will be installed inside the FD fan intake and discharge ductwork. These modifications will reduce flow induced vibrations and ductwork cracking. It is also anticipated that the modifications will reduce the overall pressure drop across the air handling system thereby reducing the fan power consumption. Due to safety concerns associated with performing modifications to the FD fan ductwork during the regular annual boiler outage maintenance work in the same congested work area, this project will be sole sourced to Alstom Power, the boiler service contractor because of their overall experience and familiarity with Holyrood.
3 EXISTING SYSTEM

The existing Unit 1 west FD fan system is illustrated in Figure 2. The east and west FD fan systems servicing the Unit 1 boiler are identical. During operation, the geometry of the existing FD fan ductwork causes air flow turbulence which creates vibrations on both the intake and discharge ductwork. The vibrations result in ductwork cracks which are normally repaired by Alstom Power during the annual Unit 1 outage. However, extensive ductwork cracking has the potential to cause an unscheduled outage in order to make repairs. An unscheduled unit outage during the peak winter load demand would result in a loss of 170 MW of power generation to the Island Interconnected System. This represents approximately 11 percent of Hydro's Island Interconnected System's capacity. Typical Unit 1 internal ductwork cracking and previous repairs are illustrated in Figure 3.

![Figure 3: Unit 1 FD Internal Ductwork Cracking](image)
3.1 Age of Equipment or System

The existing oil fired boiler and FD fans are 39 years old.

3.2 Major Work and/or Upgrades

Unit 1 was originally commissioned in 1971 to produce 150 MW and was up-rated to produce 170 MW in 1988. During the upgrade it was necessary to increase the capacity of the FD fans in order to increase the volumetric flow rate of combustion air to the boiler. A higher volume of combustion air was necessary to increase the boiler maximum steam flow rate required to produce the additional 20 MW. The capacity of the FD fans was increased by adding tips to the existing fan impellor blades.

3.3 Anticipated Useful life

The anticipated useful life of Unit 1 has been forecasted to extend to the year 2020, absent an infeed from Lower Churchill.

3.4 Maintenance History

FD fan maintenance is a component of the annual maintenance strategy for Unit 1. During the annual shutdown Hydro uses a boiler service contractor, Alstom Power, to perform preventative maintenance inspections and corrective maintenance repairs on the FD fans and ductwork system. The cost of maintenance for the FD fans is a component of the total maintenance cost for the whole unit. The five-year maintenance history for the Unit 1 FD fans is shown below in Table 1.
3.5 Outage Statistics

In December of 2008, there was a forced outage on Unit 1 with a one-week duration due to a failure of the intake guide vanes on the east FD fan. The intake guide vanes are stationary blades that are welded to the intake ductwork and they function to reduce the air flow turbulence prior to entering the fan. The failure of the guide vanes was attributed to high vibration levels caused by air flow turbulence on both the intake and discharge ductwork as a result of the ductwork geometry.

In addition, following the repairs completed on the intake guide vanes in December of 2008 during the forced outage, Unit 1 was de-rated to produce a maximum of 157 MW for the entire operating season that ended in May of 2009 as a result of high vibration levels on the FD fan intake and discharge ductwork caused by air flow turbulence. To address the issue, turning vanes or stationary blades were installed by Alstom Power inside the FD fan ductwork during the 2009 annual Unit 1 outage as a temporary measure to reduce the air flow turbulence and vibration levels in order for Unit 1 to operate at full capacity. This temporary measure did not address the overall deterioration of the ductwork.
3.6 Industry Experience

Flow induced vibration caused by air flow turbulence due to ductwork geometry is common in FD fan systems. The industry trend is to utilize CFD analysis techniques and perform ductwork modifications to reduce air flow turbulence as opposed to replacing the existing ductwork to correct geometry design problems. Many companies now specialize in providing solutions to reduce flow induced vibrations in fan ductwork systems and overall fan pressure loss through the use of CFD analysis techniques.

The application of CFD techniques and modifications to FD fan ductwork was completed in February of 2004 at New Brunswick Power’s 1,050 MW coal fired power plant located at Colson Cove. M&I Power Technology (M&I), a company that specializes in the application of CFD techniques to modify ductwork in order to reduce flow induced turbulence and overall fan pressure loss, was contracted by New Brunswick Power to perform modifications to the FD fan ductwork servicing one of the 350 MW coal fired units at the Colson Cove generating facility. Appendix A provides the background for the project.

3.7 Maintenance or Support Arrangements

Hydro currently has a service contract with Alstom Power to perform boiler maintenance during the annual scheduled outage. The FD fan maintenance is completed under the boiler service contract.

3.8 Vendor Recommendations

In December of 2009, Hydro had a preliminary CFD analysis completed on the Unit 1 FD fans intake and discharge ductwork systems by M&I to reduce pressure loss and flow induced vibrations in plant air flow systems. The analysis indicated that the air inside the ductwork
does not flow through at a uniform velocity. This results in high fan entry loss and poor fan blade loading. In addition, the analysis also indicated that the fans are operating at a high flow rate (165 Kg/s per fan) resulting in very high velocity magnitude in the range of 84.5 to 96.6 m/s which creates flow induced vibration. The report from M&I recommends that Hydro perform a more comprehensive CFD analysis on the FD fan systems and install aerodynamic diffusers and long turning vanes inside the ductwork to reduce both flow induced vibrations and fan pressure loss. The report outlining the findings of the analysis is included in Appendix B.

3.9 Availability of Replacement Parts

Spare parts are available for the existing Unit 1 FD fan system.

3.10 Safety Performance

There are no safety code violations with the current operation of the Unit 1 FD fans.

3.11 Environmental Performance

There are no environmental code violations with the operation of the existing Unit 1 FD fans.

3.12 Operating Regime

Holyrood operates in a seasonal regime. The full plant capacity is needed to meet the winter electrical requirements on the Island Interconnected System. The FD fan systems are an integral component of Unit 1.
4 JUSTIFICATION

The FD fans servicing Unit 1 at Holyrood have an ongoing problem with flow induced vibration on the fan intake and discharge ductwork systems. During operation, the geometry of the existing FD fan ductwork causes air flow turbulence which creates vibrations on both the intake and discharge ductwork. The vibrations cause cracks to develop in the ductwork. The cracks are normally repaired during the annual Unit 1 outage. However, the development of cracks on an on-going basis threatens the integrity of the ductwork infrastructure and reduces the reliability of Unit 1.

In December of 2008, there was a forced outage on Unit 1 due to a failure of the intake guide vanes on the East FD fan. Failure of the intake guide vanes was due to high vibration levels caused by air flow turbulence on both the intake and discharge ductwork. In addition, high vibrations levels resulted in a de-rating of Unit 1 during the 2009 operating season. To address the issue, turning vanes were installed inside the fan ductwork during the 2009 annual Unit 1 outage as a temporary measure to reduce air flow turbulence and vibration levels.

Failure of the FD fan ductwork can result in an unplanned Unit 1 outage of three to four weeks duration. An unscheduled unit outage during the peak winter load demand would result in a loss of 170 MW of power generation to the Island Interconnected System which represents approximately 11 percent of the Island Interconnected System’s capacity.

This project is required to maintain the reliability of generating Unit 1 at Holyrood.

4.1 Net Present Value

A Net Present Value (NPV) calculation was not done, however, a cost benefit analysis was completed on two alternatives over a study period of ten years. See Cost Benefit Analysis Section 4.3 for details.
4.2 Levelized Cost of Energy

The levelized cost of energy is a high level means to compare costs of developing two or more alternative generating sources. Therefore, the levelized cost of energy is not applicable to this project.

4.3 Cost Benefit Analysis

A cost benefit analysis was completed on two alternatives. The study period for the cost benefit analysis was 10 years.

**Alternative 1 - Upgrade Unit 1 FD Fan Ductwork based on Fuel Cost Savings:**

This alternative is to complete the proposed modifications to Unit 1 FD fans in order to reduce ductwork vibrations caused by flow induced turbulence and air handling system overall pressure loss. Upon completion of Alternative 1, the annual operating and maintenance (O&M) cost was estimated at $1,000 per year which would cover FD fan preventative maintenance inspections. It is anticipated that there would not be any unscheduled FD fan failures or corrective maintenance to repair ductwork cracks after completing the proposed modifications to the FD fan ductwork. The preliminary CFD analysis report completed by M&I Technology (Appendix B) indicated that the energy savings associated with each FD fan will be 16 percent after completing the proposed modifications to the ductwork. The savings for Alternative 1 were calculated using the January 2010 Nalcor Energy/NLH Thermal Fuel Oil Price Forecast for No.6, 0.7 percent sulphur fuel with a PUB approved conversion factor of 630 kWh/bbl. Using an average Unit 1 load of 80 MW and 4,520 operating hours as in 2009, the Cumulative Present Worth (CPW) for Alternative 1 is a benefit of $489,706 with a payback of six years.

A sensitivity analysis was performed on Alternative 1 using a Levelized Unit Energy Cost (LUEC). The PUB approved LUEC rate at $0.09 per kilowatt hour was used to calculate the
project saving. Using an average Unit 1 load of 80 MW and 4,520 operating hours, the CPW cost is $182,008.

Alternative 2 – Status Quo:
This alternative is to operate the FD fans under the current operating conditions without performing any modification to the ductwork. Using the maintenance history available for the Unit 1 FD fans, the annual O&M cost for this alternative is expected to be $7,000 per year to perform preventative maintenance inspections and corrective maintenance repairs. Also, based on the history of forced outages with an occurrence in 2008 and repair cost at approximately $330,000, it was assumed that an identical forced outage would occur again in 2018. Using the O&M cost indicated above, the CPW cost for Alternative 2 is $242,526.

The analysis indicates that Alternative 1 is the lower cost option. Table 2 shows the results of the cost benefit analysis.

<table>
<thead>
<tr>
<th>Table 2: Cost Benefit Analysis</th>
</tr>
</thead>
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**HRD Unit 1 FD Fan Ductwork Modifications**

<table>
<thead>
<tr>
<th>Alternative Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulative Net Present Value (CPW)</td>
</tr>
<tr>
<td>To The Year 2020</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Cumulative Net Present Value (CPW)</th>
<th>CPW Difference between Alternative and the Least Cost Alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRD Unit 1 FD fan Ductwork Modifications @ Fuel Cost</td>
<td>(489,706)</td>
<td>0</td>
</tr>
<tr>
<td>Status Quo</td>
<td>242,526</td>
<td>732,732</td>
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</table>
4.4 Legislative or Regulatory Requirements

There are no legislative or regulatory requirements to complete the proposed modification to the FD fan ductwork to reduce vibration levels and fan pressure loss.

4.5 Historical Information

There is no applicable historical information.

4.6 Forecast Customer Growth

Customer load growth is not affected by this project.

4.7 Energy Efficiency Benefits

It is anticipated that completion of the proposed project will reduce the energy consumed by the Unit 1 FD fans by 16 percent.

4.8 Losses during Construction

There are no associated losses during the construction of this project as it will be scheduled during the annual planned unit outage.

4.9 Status Quo

Status quo is not an acceptable alternative. A cost benefit analysis has shown that upgrading the FD fan ductwork will present a savings to Hydro. Also, an unscheduled failure during the peak winter load demand could result in a loss of 170 MW of power which represents approximately 11 percent of the Island Interconnected System's capacity.
4.10 Alternatives

Two alternatives were considered as discussed in the Cost Benefit Analysis Section 4.3.
5 CONCLUSION

Modifications to the Unit 1 existing FD fan ductwork systems is required to reduce flow induced vibrations caused by air flow turbulence due to the existing ductwork geometry. The modifications will also reduce the overall fan pressure drop, thereby reducing the fan power consumption by 16 percent. Using an average Unit 1 load of 80 MW and 4,250 operating hours as in 2009, a cost benefit analysis indicates that completing the proposed project is the preferred option as compared to the status quo alternative.

Failure to perform the modifications to the Unit 1 FD fan ductwork systems increases the likelihood of unscheduled downtime on the turbine and increases the risk of being unable to meet customer demands during the peak winter load requirement.

5.1 Budget Estimate

The budget estimate for this project is shown in Table 3.

<table>
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<th>Project Cost: ($ x1,000)</th>
<th>2011</th>
<th>2012</th>
<th>Beyond</th>
<th>Total</th>
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<td>Labour</td>
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<td>Consultant</td>
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<td>Contract Work</td>
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<td>619.1</td>
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<td>O/H, AFUDC &amp; Escln.</td>
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<td>Contingency</td>
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<td><strong>TOTAL</strong></td>
<td>843.0</td>
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5.2 Project Schedule

The anticipated project schedule is shown in Table 4.

Table 4: Project Milestones

<table>
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<th>Activity</th>
<th>Milestone</th>
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<tbody>
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<td>Project Kick-off Meeting</td>
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<tr>
<td>Complete Design Transmittal</td>
<td>February 2011</td>
</tr>
<tr>
<td>Develop Supply &amp; Installation Contract</td>
<td>February 2011</td>
</tr>
<tr>
<td>Issue Tender &amp; Award Contract</td>
<td>March 2011</td>
</tr>
<tr>
<td>Installation</td>
<td>July 2011</td>
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<tr>
<td>Commissioning</td>
<td>October 2011</td>
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<tr>
<td>Project Final Documentation and Closeout</td>
<td>December 2011</td>
</tr>
</tbody>
</table>
APPENDIX A

Project Background:

M&I Technology’s Solution for FD fan Inlet Duct Silencing System
For
New Brunswick Power’s Colson Cove 1,050 MW Power Plant
PROJECT BACKGROUND

M&I’s Solution for F.D. Fan Inlet Duct Silencing System
For
New Brunswick Power’s Colson Cove 1,050 MW Power Plant, Canada

N.B Power sought a solution that would reduce noise emanating from the I.D Fan. The conventional splitter type silencer solution occupies lot of space and it was not possible to accommodate it in the available space. Additionally, the pressure drop of the conventional silencer was very high to the tune of 36 mm WC and this pressure drop was resulting in overloading of the F.D Fans. Even an increase of 12 mm W.C would have adversely affected Fan performance, which in turn would have affected generation capacity.

Babcock & Wilcox, Canada which was contracted for this part of the project, approached M&I to employ its “Aero-Acoustic” technology and develop a solution that would solve this apparently conflicting requirement.

M&I’s approach integrates flow streamlining with noise attenuation. The flow across the ducting system and fan was analyzed and the effect of turbulence, flow separation, vortices, etc was determined. M&I then developed a diffusion system that streamlined flow across the inlet ducting and ensured that the flow into the Fan is uniform. This 3-dimensional diffusion system that M&I designed also acts as a silencer and absorbs noise. Additionally, the duct is lined with acoustic insulation, which contributes to noise attenuation. A streamlined flow across the duct without turbulence would reduce the flow induced vibration and this also brings down noise generation.

You would note M&I have not employed the conventional splitter type silencer and this brings down the pressure drop. Also, by streamlining the flow across the duct, it is possible to convert unproductive velocity pressure to useful static pressure. In this case M&I was able to reduce pressure drop by 26 mm W.C, as compared to conventional splitter silencer. The noise level that was guaranteed was 84 dBA at 1 m, 1 dB lower than conventional silencer.

Please refer enclosed CFD analysis and Drawing carried out at bid stage for the customer. We are glad to inform you that M&I met contractual performance guarantees as demonstrated in our CFD results. Please also refer enclosed reference letter from B&W, Canada confirming superiority of M&I’s aero-acoustic technology over conventional design.
To Whomsoever It May Concern

This is to advise that Babcock & Wilcox Canada contracted with M&I Air Systems Engineering, Mississauga, Canada for the design, engineering and supply of an Aerodynamic inlet silencer ducting system. The system will be installed on 6 nos. Forced Draft (F.D.) Fans at the 3 x 350 MW Coleson Cove Power Station (Owned and Operated by New Brunswick Power, Canada). B&W opted for the M&I design as it offered a noise attenuation solution at a very low pressure drop across the ducting system, compared to a conventional splitter type silencer solution. Performance guarantees were provided by M&I.

B&W has recently installed two systems for one of the 350 MW units (Unit #3). B&W is satisfied with design, engineering and workmanship of the silencer units. Moreover, M&I’s modular construction enabled B&W to easily retrofit the FD inlet ducting in spite of the space constraints of the existing station. Unit #3 is operating at full capacity load of 350 MW, and has met the contractual performance criteria.

Yours truly,

Babcock & Wilcox Canada

R.J. Johnston
Project Manager
M&I Power Tech.

**Conventional Design**

- Conventional splitter type silencer

**M&I's Design**

- M&I's proprietary Aeroacoustic diffusion system

High pressure drop across silencers due to non-uniform flow results in high pressure drop and uneven loading of fan blades.

Streamlined and uniform flow results in lower pressure drop.

Pressure drop savings in M&I design: 1" W.G
M&I Power Tech.

Babcock & Wilcox A/c New Brunswick Power
Colson Cove Project (1,050 MW)
FD Fan Aerodynamic Inlet Silencer Duct
Client: Heyden Power Station, E-ON, Germany

Responsibility:
Design, CFD Analysis, Engineering, Manufacturing, Supply and Supervision of Installation.

Project Background:
Heyden Power Station (An E-ON Company) awarded contract to M&I for CFD Analysis, Design, Engineering, Manufacturing, Supply and Supervision of 2 nos 950 MW units. Objective of working with M&I was to reduce draft loss of 3.5 mbar before ESP and total Draft loss reduction of 10 mbar from Economizer outlet to FD Fan discharge. Above draft saving was very important, since Heyden PS is envisaging use of different grades of Coal in place of Brown Coal. This has resulted in 10-12% higher volumetric flow in the draft system. Heyden PS had two fold problems to tackle above situation.

1) Suitability of Existing ESP Duct and Structure
2) Static Pressure Margins of ID fan

Bigger ID fan could have solved second problem but first problem was still unresolved. Except M&I solution there were no other feasible alternatives to address first issue.

M&I is offering Aero-acoustic solution for following areas of power plant:

1) SCR Inlet System (Between Ammonia Injection and SCR Catalyst)
2) Air Pre Heater Inlet System
3) ESP Inlet System
4) ESP Inlet Transition
5) Fan Suction Box
6) ID Fan Discharge Duct
7) FGD Inlet System

By leveraging Aero-acoustic technology, M&I is proposing pressure drop reduction in the plant draft system to Heyden PS. Savings are in the tune of 10 mbar to 12 mbar.

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SUMMARY OF SAVINGS OFFERED BY M&I:

<table>
<thead>
<tr>
<th>Description</th>
<th>Current Pr. Drop (mbar)</th>
<th>M&amp;I Design (mbar)</th>
<th>Pressure drop saving in (mbar)</th>
<th>++ Appx Increase in net Weight (Kgs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCR Inlet System</td>
<td>3.43</td>
<td>1.04</td>
<td>2.39</td>
<td>60 tons</td>
</tr>
<tr>
<td>Air Pre Heater Inlet System</td>
<td>1</td>
<td>0.6</td>
<td>0.4</td>
<td>10 tons</td>
</tr>
<tr>
<td>ESP Inlet System</td>
<td>3.55</td>
<td>2.05</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>ESP Transition</td>
<td>2.95</td>
<td>2.45</td>
<td>0.5</td>
<td>10 tons</td>
</tr>
<tr>
<td>ID Fan suction box</td>
<td>1.5</td>
<td>0.75</td>
<td>0.75</td>
<td>4 tons</td>
</tr>
<tr>
<td>ID Fan Discharge System</td>
<td>10.5</td>
<td>5.5</td>
<td>5.0</td>
<td>18 tons</td>
</tr>
<tr>
<td>PGD Inlet</td>
<td>3.28</td>
<td>2.28</td>
<td>1.0</td>
<td>19 tons</td>
</tr>
</tbody>
</table>
This is to advise that E.ON Kraftwerke GmbH, Trseckowstraβe 5, 30457 Hannover, Germany contracted with M&I Power Technology, Inc., Mississauga, Canada for Design, Engineering, Manufacture and Supply of aerodynamic diffusers for our 915 MW Hayden Power Station at Petershagen to reduce the plant draft loss across the following systems:

1) SCR Inlet system
2) ESP Inlet duct and transition
3) ID fan suction box
4) ID fan discharge system
5) FGD inlet system

Above plant draft loss reduction was necessary to accommodate burning of coal with less caloric value. This means more flue gas transportation to produce the same MW. Further it was also necessary to keep same or low suction pressure upstream of ESP to avoid reconstruction of the ESP casing.

We are pleased to mention here that M&I fulfilled all our expectations and contractual guarantees through an efficient diffusion system. Further M&I solution avoided installation of new ID fans. The following tangible benefits were achieved through M&I technology:

1) Reduction of 2.2 MW ID fan Power Consumption
2) 11 mbar saving in the pressure drop
M&I executed this job in time without any delay even in a narrow steel market through efficient project management and offered very good cooperation during installation of the above system.

Due to this excellent result, E-ON would recommend this technology being applied not only to other existing operating plants, but also in case of adding FGD or SCR and forthcoming new plants of their own where most advanced technology will be part of the design group to consider in order to reduce costs and raise performance. As such, M&I technology would be placed on our list of priority.

The technology itself has other salient benefits such as noise and vibration solution without utilizing large conventional silencers, since the technology addresses noise at the source.

For additional information please feel free to contact the undersigned. We wish M&I many more years of success in the future business.

Yours sincerely,

E.ON Kraftwerke GmbH

[Signature]

[Signature]

2/2
E-ON – Heyden Power Station 950 MW Each
SCR inlet, ESP inlet, ID Fan Suction box inlet, and discharge
(Under Implementation)

M&I’s OVERALL SOLUTION FOR PS HEYDEN PROJECT:
CFD Analysis at the Inlet and Outlet of SCR

Old Design

M&I Design

ATTACHMENT # 4

M&I’s OVERALL SOLUTION FOR PS HEYDEN PROJECT:
CFD Analysis at the Inlet & Outlet of SCR

Old Design

M&I Design

ATTACHMENT # 3
M&I's OVERALL SOLUTION FOR PS HEYDEN PROJECT
CFD Analysis at Air Heater Outlet to ESP Inlet

- Velocity Streamlining Profile

ATTACHMENT #11

M&I Power Technology Inc.

- Total pressure drop saving (A-B): 1.50 mbar

ATTACHMENT # 10

M&I Power Technology Inc.
Appendix A

M&I's OVERALL SOLUTION FOR PS HEYDEN PROJECT
CFD Analysis at ESP Inlet Transition

Velocity Streamlining Profile

Old Design               M&I Design

ATTACHMENT #18

M&I Power Technology Inc.

M&I's OVERALL SOLUTION FOR PS HEYDEN PROJECT
CFD Analysis at ESP Inlet Transition
Total pressure profile

Total pressure drop (A-B): 2.95 mbar

Total pressure drop (A-B): 2.45 mbar

Total pressure drop saving (A-B): 0.50 mbar

Old Design               M&I Design

ATTACHMENT #16

M&I Power Technology Inc.

Page 11
Toni Pressure Drop:
3.9 mbar

M&I Design

Total Pressure Drop: 4.45 mbar

Existing Design

CFD Analysis for PS Heyden project
ID Fan Intake System

ATTACHMENT # 23 & 24

M&I Solution

Total Pressure Dynamics

Newfoundland and Labrador Hydro

ATTACHMENT # 27

M&I Power Technology Inc.

Old Design

M&I Design

CFD Analysis for Fan Suction Box

Velocity Profile
Total pressure profile:

- Old Design
- New Design

M&I Power Technology Inc.
M&I Power Technology Inc.

Total Pressure Streamline

Current Design

M&I Solution

Total Pressure Drop reaches to 6.0 Inch WG Including 3.2" WG Silencer Section Loss

Total Pressure Drop reaches to Only 4.1 Inch WG Including 1.8" WG Silencer Section Loss

E-ON Heyden Power Stn. 950 MW Each
FGD Inlet duct @ 100% Flow of Full Load

Total pressure drop profile

Total pressure drop (A-B) : 3.28 mbar
Pressure drop saving (A-B) : 1.00 mbar

Current Design

M&I Solution

M&I Power Technology Inc.
E-ON – Heyden Power Station 950 MW Each
SCR Inlet Modification Different Option offered by M&I

CFD Analysis for PS Heyden project for
FGD inlet duct @ 100% Flow of Full Load

M&I Solution
OPTION # II

Pressure drop saving (A-B) : 0.89 mbar
Solid Model

M&I Solution
OPTION # III

Pressure drop saving (A-B) : 1.00 mbar
Solid Model
Client: Heyden Power Station, E-ON, Germany.
M&I is offering Aero-acoustic solution for SCR Inlet, Air Pre Heater System, ESP Inlet, ESP Inlet Transition, Fan Suction Box, and ID Fan Discharge Duct.
APPENDIX B

Commercial Proposal For:

FD Fan Inlet & Discharge Ductwork Modifications To Eliminate Flow Induced Vibration And Capacity Bottleneck At the Holyrood Thermal Generating Station
Techno-Commercial Proposal

For

FD Fan Inlet & Discharge Modifications to eliminate flow induced vibrations and capacity bottleneck

At

Holyrood Generating Station

Submitted to:

NEWFOUNDLAND AND LABRADOR HYDRO
St. John's, Newfoundland

M&I Power Technology, Inc.
2145 Meadowpine Blvd, Mississauga,
Ontario, Canada, L5N 6R8

02/12/2009
February 12, 2009

Newfoundland and Labrador Hydro

Holyrood Generating Station

Duff's Road, Holyrood

NL A0A 2RD

SUB: Quotation for CFD analysis & Modification to FD fan Inlet & Discharge Duct.

Dear Sirs,

At the outset I would like to thank you for the courtesy extended to our engineer Vladimir Elise. We also appreciate the opportunity to provide you with the proposal for the modifications of FD fan inlet and discharge duct to eliminate flow induced vibration problem and debottlenecking of fan capacity limitation. In view of long business relations with your esteemed organization, we had no hesitation in carrying out preliminary CFD analysis worth $10,000 free of cost to evaluate flow condition inside the FD fan inlet and discharge duct responsible for vibration and turbulence. Refer “Synopsis” segment of the proposal showing CFD results of the existing duct.

Attached is our techno-commercial proposal & general arrangement drawing showing proposed modification areas. We have diligently worked on the proposal based on the information collected by our engineer. Most of our modifications are at the strategic locations where maximum benefits exist in the above draft system. We propose modules to be retrofitted at those locations only. We are also envisaging some outside duct modifications, which can be easily carried out at site.

M&I's aerodynamic diffusers offer reduction in the vibration and FD fan performance improvement by virtue of reduction in pressure drop in inlet and discharge duct. Estimated savings are enumerated below for review:

- Expected Pressure drop Reduction/ Savings in FD fan Inlet Duct: 1.5” W.G.
- Expected Pressure drop Reduction/ Savings in FD fan Outlet Duct: 2.0” W.G
- Minimal flow induced vibrations in the ducts.
At this time we are open to help us to work together with you on this project. We now look forward to hearing from you to proceed further in the matter. In case you need further clarification, please feel free to contact me.

Thanking you and assuring you of our best services at all times.

Best regards,

Pradeep Gaur, P.Eng.
President
M&I Power Technology Inc.

M&I Power Technology Inc.
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CONTENTS

Section 1 : Introduction to M&I/Company profile
Section 2 : Synopsis
Section 3 : Scope of Work
Section 4 : Limit of Supply & Exclusion
Section 5 : Design Basis
Section 6 : Performance Parameters & Guarantees
Section 7 : Price Schedule
Section 8 : Drawing
Section 1

COMPANY PROFILE

M&I Power Technology Inc.,
2145 Meadowvale Blvd, Mississauga, ON L5N 4R8 Canada
Tel +1 (905) 673-0320/0300 Fax +1 (905) 673-5496

* All Concepts and Designs outlined in this document remain the property of M&I Power Technology and shall not be used for any purpose other than to evaluate the application of the company's technology for the addressed project.
Incorporated in 1981, M&I and its various divisions, is an applied R&D oriented company. The company's origin was in niche technologies serving primarily the HVAC industry. M&I's core competence is in Aero-acoustic Principles, which offers reduction of horsepower, noise and vibration.

M&I developed numerous products in the air movement field, especially variable and centrifugal fan systems, and has been able to improve the overall system efficiency, utilizing flow field technology. Many other associated products were developed in the field moving technology, which can be found on our website: www.miair.com.

M&I has grown steadily and profitably over the last 20 years and is represented throughout the United States, Europe and Canada through an established network of manufacturer's representatives. M&I group operates its HVAC systems through M&I Heat Transfer Products LTD and flow solutions for power and process industries (i.e. boilers, HRSG, Gas Turbine, Steel, Pellet, Cement, Aluminum, etc.) through M&I Power Technology Inc. M&I Power offers expertise in the areas of flow control, dust load reduction, furnace combustion performance analysis & optimization and efficiency improvement of rotating & stationary equipments used in Power, Cement, Steel, Pellet & other Process industries. Our website: www.miapowertechnology.com.

The engineering, manufacturing and procurement aspects of the Company are well-proven, yet flexible to meet the specific demands on a project-by-project basis. For example, engineering is done in-house or sub-contracted as needed to meet schedules and remain competitive. Alliances and relationships are formed with industrial experts, scientists, and engineers from reputed consulting firms and universities to add new approaches. Procurement is done both locally or internationally, as the Project dictates. Manufacturing is similarly flexible with core critical components being manufactured in North America and other scope competitively sub-contracted, but always under M&I Project control.

Leadership innovation and technology (with the latest advances in Computational Fluid Dynamics and 3-D engineering modeling and analysis) to solve customer problems and offer effective solutions is what drives M&I and separates it from its competition. M&I's various products are thus a secondary means to affect and satisfy this goal. M&I has been awarded 30 Patents in aero-acoustics with an additional 9 pending.

M&I's corporate goals and culture go beyond the best engineering tools and technology. The real capital of M&I is the talented personnel, which has been developed in a conducive environment, leading to excellence. M&I's goal/objective goes far beyond the traditional shipment of components and accepting warranty obligations to taking complete functional and design responsibility of all the systems that M&I manufactures and puts in beneficial use.

M&I Power Technology, Inc.
Corporate Profile

M&I Corporate Office in Minnepolis, Canada

M&I's Baghouse Fan Exhaust Silencer for St. Lawrence Cement, Canada

M&I's 3D Modeling for Furnace Combustion Process

M&I's Baghouse Fan Exhaust Silencer for B&W, Colstrip, MT

M&I's 3D Modeling for Furnace Combustion Process

M&I's Baghouse Fan Exhaust Silencer for St. Lawrence Cement, Canada

M&I's Air Intake Silencer Designing for FR/HEA, O/T

Holyrood: Upgrade Unit 1 FD Fan Ductwork
Appendix B

Newfoundland and Labrador Hydro

B7
Section 2

SYNOPSIS
SYNOPSIS

M&I has carefully analyzed FD fan inlet duct and discharge duct between fan outlet and Steam coil air heater (SCAH) to identify potential reasons for flow induced vibration and fan capacity curtailment. Based on site visit by M&I Engineer and the information collected / received from plant, M&I carried out a preliminary CFD analysis to map flow behavior inside the upstream and downstream duct of the FD fan. Based on the results of CFD findings, M&I is submitting a proposal for modification of the above segment using their state of the art aerodynamic diffusers to achieve lower pressure loss and elimination of flow stratification and turbulence. To develop an efficient manufactured solution, M&I needs to carry out an advanced CFD analysis. This activity will only be carried out after placement of the order. However preliminary analysis gave us good indication of problems in the system.

It is quite evident from the CFD pictures attached below that there are very high velocity hot spots in the certain portion of the duct combined with local flow separation in the certain areas of the duct causing flow recirculation. Drastic change in velocity distribution across duct cross section resulting in high fan entry loss and poor fan blade loading. Moreover fan is operating at very high flow rate (185 kg/sec/fan) resulting in very high velocity magnitude creating flow induced vibrations. It is very important to eradicate those high velocity hotspots through aerodynamic diffusions by bring dynamic pressure values close to area average velocities from mass average velocities. Further pressure regains needs to be achieved at fan discharge to minimize unproductive velocity pressure responsible for high backpressure and loss across steam coil air heater.

M&I’s proposal comprises of internal modifications and some external modifications to the one side of inlet and discharge duct:

M&I would propose state of the art aerodynamics diffusion system and long turning vanes to eliminate flow abnormalities like local flow separation, turbulence and eddy’s. Utmost care is given to understand flow behavior and insertion of suitable shape diffusers to achieve proper flow diffusion.

Please refer attached schematic drawing #P09-001-001 showing indicative areas (final modifications to be confirmed by detailed CFD analysis) of modifications proposed by M&I (suitable diffusers will be designed & developed to retrofit at those locations) to achieve lower draft loss and pressure drop savings. Indicative pressure drop savings to be achieved by M&I modifications are given below:

---

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RESULTS AT A GLANCE:

Expected Pressure drop Reduction/ Savings in FD fan Inlet Duct: 1.5" W.G.

Expected Pressure drop Reduction/ Savings in FD fan Outlet Duct: 2.0" W.G.

Above reduction in pressure drop will give approx. 15-16% reduction in fan horse power (if fan efficiency does not change at lower static pressure) or 8-10 kg/sec/fan (5%) more air.

Lower flow induced vibrations: Flow stratification causes flow induced vibration. M&I's aerodynamic diffusers will streamline flow inside the duct and at fan inlet and at SCAH inlet...

We also confirm high quality of manufacturing and stringent quality/inspection norms. Every aspect like transient loads, combination loads, are considered in the design criteria of the system. Our manufacturing process conforms to CSA/eqvt. standards.

Efficiency, quietness and reliability is a standard for M&I products. Our approach to the total solution to air and plant draft systems and knowledge sharing culture are the strengths of our organization.
Appendix B

I.

CFD RESULTS OF EXISTING DUCT:

- Very High Velocity Stratification Causing Flow Induced Vibrations
- High Local Flow Separation

FD Fan Discharge Duct
Holyrood: Upgrade Unit 1 FD Fan Ductwork
Appendix B

Proposed Holyrood Generating Station FD fan duct modifications.
Client: Newfoundland & Labrador Hydro, NL.
Graph 11 of 28.

- Local Flow Recirculation & Turbulence in Fan Suction Box
- Poor Fan Blade Loading
- Stratified Flow Responsible for Flow Induced Vibrations & Turbulence

Velocity

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Section 3

SCOPE OF WORK
SCOPE OF WORK

CFD Analysis, Design, Engineering and Supply of carbon steel internal diffusers (same as existing duct material)

M&I will supply diffusers & long turning vanes (internals) to be integrated inside the FD fan inlet & discharge duct. At couple of places there will be local outside duct modification, which is feasible to carry out under present circumstances. M&I will fabricate complete internal diffusers/vanes (as shown in the Dwg # P09-001-001) and partial external modifications. Broad scope includes:

- 3/16" / 1/4" thick carbon steel (same material as the existing duct) Single / double walled diffusers..and outside duct wall.
- New expansion joint near fan suction box
- Associated Frames and hardware to hold internal diffusers
- Diffusers and external wall modification is 100% seal welded
- Required hardware including bolts, nuts, washers and gaskets (wherever necessary) at interfacing point.
- Stiffeners, wherever applicable
- Inspection during manufacturing stage as per M&I standard practice.
Section 4

LIMIT OF SUPPLY AND EXCLUSION
LIMIT OF SUPPLY:

- Internal & some external modifications to existing duct an extent to meet pressure drop saving values as mentioned in the above scope of work.

EXCLUSION:

- Foundation, anchor bolts, nuts, washers and leveling hardware.
- Unloading, forwarding, and storage of equipment at job site.
- Dismantling, Installation, start-up, testing, commissioning, utilities and consumables.
- Insulation if any
- Structural support, ladder, grating.
- Plant and equipment lighting.
- Lighting arrestors and grounding system, Fire protection and detection system.
- Site leveling and grading.
- Control and Power cables, Supply of AC or DC power.
- Dampers.
- Third party inspection.
- Emission probes.
- Any statutory clearance.
- Any item not specifically mentioned in our scope
Section 5

DESIGN BASIS
DESIGN BASIS:

Design pressure:
- FD fan Downstream duct: -10/+30" WG
- Design air temperature: 40 deg C

Operational Condition at Rated load:
- Air Temperature at FD inlet: 30 deg C
- Air Flow from one FD fan: 165 kg/sec
- Duct/diffuser Corrosion allowance: 1/16"
- Maximum Velocity inside the duct: 4000 FPM

SITE DATA:
- Site location: Holyrood Generating Station, NL
- Site Elevation:
- Ambient temp: Not Available
  Maximum: Not Available
  Minimum: Not Available
- Design Relative Humidity: Not Available
- Design Ambient Pressure: 14.03 psia
- Max. Rainfall Intensity: Not Available
- Max. Wind Velocity: Not Available
- Seismic Zone Factor: Low intensity - assumed
- Ground Snow Load/Exp. Coeff.: Not Available
Design Philosophy:

While designing internal diffusers, long turning vanes and fan discharge diffuser duct, following design considerations were considered:

- Loads are considered as force applied to support structure:
  - For primary load calculations, all loads are considered separately.
  - Duct internals are designed for transient air heater upset condition.

Internal diffusers, turning vanes provided at various locations inside the FD fan duct will be thoroughly checked for structural integrity as well as retained adequately with duct walls.
Section 6

PERFORMANCE PARAMETERS
PERFORMANCE PARAMETERS & GUARANTEES:

Performance Guarantees:

- Expected flow improvement in air flow: 8-10 Kg/sec each side
- Expected Pressure drop Reduction/ Savings: 3.5" W.G.

Tolerance:
- Pressure drop: +/- 2.5%

Basis:

- Air Temperature at A/H outlet: 30 Deg C
- Total Air Flow / fan: 165 kg/sec
Section 7

PRICE SCHEDULE
PRICE SCHEDULE:

1) CFD analysis for developing solution: C$ 25,000

2) Design, engineer, manufacture & supply
   - Of internal diffusers, expansion joint,
   - External one side duct wall for FD
   - Fan inlet & discharge duct as per enclosed
   - scope of supply and dwg # P09-001-001
   - C$295,000 for 2 fans

Price Basis:

- Price includes transportation of diffusers to Holyrood site.
- Does not include dismantling, installation and commissioning
- Includes supervision of diffuser installation
- Above price is in Canadian funds

VALIDITY:

Our quotation is firm and valid for 60 days from the date of the submission.

TERMS OF PAYMENT:

25% as advance along with Purchase Order

25% payment against submission of revised CFD analysis, design and drawings.

40% against dispatch of complete system net 15 days

10% on successful completion of Erection and commissioning

DELIVERY:

To be mutually agreed upon to meet project schedule.
Section 8

Drawings