ONTARIOPOWER GENERATION

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OPG-FORM-0075-R004*

Type 2 Business Case Summary

To be used for investments/projects meeting Type 2 criteria in OPG-STD-0076.

Project Information			
Project #:	Project # 13-83088	**Document #:**	NA44-BCS-43120-00003
Project Title:	PA LP Feedwater Heat Exchangers Replacement		
Class:	☐ OM&A ☒ Capital ☐ Capital Spare ☐ MFA ☐ CMFA ☐ Provision ☐ Others:	**Investment Type:**	Sustaining
Phase:	Execution	**Release:**	Full
Facility:	Pickering	**Target In-Service or Completion Date:**	SEP-2018

Project Overview

We recommend Gate 3 approval and the release of $9,351 k, including $1,145 k of contingency.
The estimated total project cost is $23,529 k, including $1,145 k of contingency.

The quality of the estimate for this release is Class #2, and for the total project is Class #2.

This release will fund the following scope of work:

- Design documentation and package issued as required, for replacement of Heat Exchangers (HX), 4-43120-HX1A/B and HX2A/B.
- Design close-out activities as required.
- Procurement of Unit 4 LP Feedwater HXs
- Unit 4 pre-requisite work including track installation and materials.

Unit 4 during P1841 outage:

- Replacement of asbestos insulation with non-asbestos insulation on 4-43120-HX2A/2B.
- Removal of old equipment and installation of new equipment during the unit scheduled outage.
- Commissioning of 4 new LP Feedwater HXs.

History of BCS releases and project cost estimates:
The total project cost is now estimated at $23,529k, including $1,145k of contingency, compared to $19,389 k, including $4,389 k of contingency in the previous release. The change is mainly due to significant design change for track system.

Work completed thus far:

- Technical Specifications (Rev #1) issued for the procurement of all Units (1 & 4) LP Feedwater HXs.
- Preliminary assessment and walk downs completed by Plant Design Engineering, to determine the level of design effort required to support heat exchanger replacement, including piping configuration and floor loading.
- Purchase Order has been issued for the procurement of 4 HXs (for Unit 1) based on the revised technical specification issued by Design.
- Commitment to vendor to update the purchase order for balance 4 HXs (for Unit 4) after approval of next BCS.
- Replacement of asbestos insulation with non-asbestos insulation for 4-41230-HX1A and 1B was completed during the P1641outage.
- Design documentation and package issued, for replacement of 1-43120-HX1A/B and HX2A/B.
- Update of purchase order for procurement of balance of 4 HXs (for Unit 4).
- Design close-out activities as required.

Unit 1 during P1711 Outage:

- Replacement of asbestos insulation with non-asbestos insulation on 1-43120-HX1A/1B and HX2A/2B.
- Removal of old equipment and installation of new equipment during the unit scheduled outage.
- Commissioning of 4 new LP Feedwater HXs.

*Associated with OPG-STD-0076, Developing and Documenting Business Cases

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Project Title: PA LP Feedwater Heat Exchangers Replacement, Full Execution Release

Project Overview

- The purchase order has been released for the procurement of HXs, based on the revised technical specification issued by Design. The replacement is with like for like equipment. The new equipment tube bundle material is unchanged as admiralty brass.

History of scope and schedule changes:

The previous approved release of BCS funding was $ 14,178 k, including $ 3,218 K of contingency. A PCRAF was submitted in November 2017 AISC to release the contingency funding of $ 3,218 k to complete the Unit1 installation and advance the Unit 4 pre-requisite work.

The PCRAF addressed changes to the project budget and schedule due to a change in design for the installation of the track system for Unit 1. The pre-requisite work on Unit 4 needed to commence earlier than the original schedule due to the change in design.

The current target in-service date of SEP-2018 has not changed from the previous release.

Part A: Business Need

In December 2013 and January 2014, Pickering Units 1 and 4 Low Pressure Feedwater Heat Exchanger tube bundles were 100% inspected. The inspections confirmed previously suspected tube leaks and identified significant degradation of the tubes in general. The degradation mechanism is suspected to be chemical attack from ammonia as a by-product of hydrazine decomposition. It is recommended that new material is used to mitigate the decomposition mechanism.

As a result of the inspections, tubes were plugged based on allowable wall loss criteria. Additional tubes were plugged to "cage" adjacent breached tubes. The number of tubes plugged for each HX is approaching, or at the plugging limit normally identified for heat exchangers to maintain designed heat transfer capacity. Tube plugging, or isolation, of the affected HXs affects the heat balance of the unit and degrades cycle thermal efficiency, resulting in a decreased Megawatt (MW) output. Furthermore, increased plugging accelerates HX degradation and increases risk of HX unavailability which has the potential to result in extended forced unit outage.

Replacement of LP Feedwater HXs will ensure that MW output is maintained from a LP Feedwater perspective, improve equipment reliability and will minimize the on-going inspection program requirements.

The replacement of the heat exchangers must be weighed against potential Forced Unit Outage as a result of HX unavailability, MW losses incurred due to the plugged tubes, on-going inspection program requirements (inspections must remain on all HXs with known degradation), and on-going degradation associated with the "No Project" option, as per station management decision.

The following scenarios could be expected from the "No Project" option:

1. Based on the current degradation levels and rate of degradation, an on-going inspection program of all LP Feedwater HXs would be required on a regular basis. Approximately 400 Hrs of station resources per unit are required for inspection only.
2. Based on the results of the latest inspections, there is a significant risk that further leak will develop due to wall thinning, resulting in further plugging to or beyond current limits. This would have a negative impact on thermal efficiency and increase MW losses.
3. Any additional plugging of tubes beyond the analyzed design limit may lead to increased vibration of the equipment which has the potential to affect the structural integrity of the component. If this design limit is reached, the HX would be declared unavailable and the bank would be isolated resulting in Unit de-rate. It is not recommended to operate the unit on a single bank for an extended period of time due to significantly increased risk of damage to the available heat exchangers. This would likely result in an extended forced outage for HX replacement.

The table below shows the current conditions of the LP Feedwater HXs for Unit 1 and Unit 4. Based on current design limits (15% plugging allowed), only 128 tubes are allowed to be plugged per HX.

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Part A: Business Need

Equipment	Tubes plugged
1-43120-HX1A	127
1-43120-HX1B	108
1-43120-HX2A	94
1-43120-HX2B	121
4-43120-HX1A	86
4-43120-HX1B	124
4-43120-HX2A	106
4-43120-HX2B	129

The rate of degradation has increased rapidly over the past inspections. In P1511 outage, HX1A and 1B were inspected and due to the observed degradation, the plugging increased by 78% and 29% respectively from the previous P1311 outage.

Part B: Preferred Alternative: Replacement of all LP Feedwater Heat Exchangers

Description of Preferred Alternative

The preferred alternative is to replace the entire heat exchangers with newly procured equipment. The new heat exchangers will be installed on both units during the scheduled outages.

The proposals received from vendors (against RFQ) for the supply of LP Feedwater HX units with stainless steel tubes were over dimensional in size. The over sized equipment could not be accommodated in to existing location. Kepner Tregoe (KT) Decision Analysis was initiated to select the tube material. The analysis indicated that use of brass material for the tube bundle is the optimum solution. The replacement is with like for like equipment. The new equipment tube bundle material is unchanged as admiralty brass.

Replacing the complete LP Feedwater Heat Exchangers in Units 1 & 4 will remove the uncertainty of continued operation and improve equipment reliability. Replacement will reduce the maintenance and inspection burden, with increased MW production and reduced risk of forced unit outages.

Pros:

- Improved equipment reliability.
- No Generation loss.
- Plugging evaluation is not required.
- Shorter vendor lead time compared to tube only replacement, which would require OPG to ship one old HX for reverse engineering, resulting in increased timelines.
- Vendor thermal guarantee is provided for complete heat exchanger replacement.

Cons:

- Expedited schedule for replacement.
- Significant resources required during replacement

Deliverables:	Associated Milestones (if any):	Target Date:
Design Requirements Identified	Issue Technical Specifications	Complete
Vendor assessment to manufacture new exchangers	Issue Purchase Order for Unit 1	Complete
Asbestos insulation removal on 2 LP Feedwater HXs in Unit 4	Complete asbestos insulation removal during P1641 Outage	Complete
Vendor assessment to manufacture new exchangers	Issue Purchase Order for Unit 4	Complete
Delivery of 4 LP Feedwater HXs for Unit 1	Procurement of equipment – U1	Complete

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Deliverables:	Associated Milestones (if any):	Target Date:
Installation and commissioning of 4 LP Feedwater HXs in Unit 1	P1711 Outage	Complete
Delivery of 4 LP Feedwater HXs for Unit 4	Procurement of equipment – U4	09-Feb-2018
Installation and commissioning of 4 LP Feedwater HXs in Unit 4	P1841 Outage	30-Sep -2018

Part C: Other Alternatives

Summarize all viable alternatives considered, including pros and cons, and associated risks. Other alternatives may include different means to meet the same business need, and a reduced or increased scope of work, etc.

Alternative 2: Base Case – No Project – Do nothing

If the Project is not executed, complete Heat Exchanger inspections will be required every 30 month during planned unit outages and tubes will be plugged as required. If design plugging limits are reached, the HXs will be declared unavailable, which will impact unit operation and has the potential to result in extended unit outage.

Pros:

- None

Cons:

- Continued accelerated degradation, of tube material showing high rate of chemical attack. Tube bundles likely will not meet end of station life with increased plugging limit.
- Generation loss from high tube plugging and/or HX unavailability.
- Increased burden for required inspections. Approximately 400 Hrs of station resources per unit are required for inspection only.

Excess plugging may introduce system vibration, which would result in accelerated degradation and has the potential to compromise component structural integrity, resulting in HX unavailability and potentially extended unit outage.

Alternative 3: Delay Work – Targeted replacement when required

If the project is Delayed, inspections would continue every planned outage and tubes will be plugged as required until the HXs are replaced. Given the current number of tubes plugged and observed degradation rate over the past inspections, there is a significant risk that the upcoming inspections would result in plugging requirements beyond allowable limits, with the HX deemed unavailable.

Pros:

- None

Cons:

- Continued accelerated degradation, and tube material showing high rate of chemical attack.
- Increased maintenance and inspection burden until replacement, approximately 400 Hrs per unit.
- Generation loss from high tube plugging and/or HX unavailability.

Alternative 4: Replace Tube Bundles Only

The alternate option is for the replacement of tube bundles only (internal of heat exchanger) with like for like brass material. Replacing all tube bundles in the U1 & 4 LP Heaters will remove the uncertainty of continued component operation and will improve asset management of subsequent equipment.

Pros:

- Improved reliability.
- Complete replacement of tube bundles only will reduce overall project costs.

Cons:

- There is no design documentation for existing HXs and reverse engineering would be required.
- No confirmation that internal design of U2 HXs bundles is identical to U4 HXs.
- Additional resources to remove two HXs from Unit 2 for shipment to vendor to conduct reverse engineering.
- Transportation of old bundles to vendor facility required.
- Vendor does not provide thermal guarantee on the new bundles.

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Alternative 4: Replace Tube Bundles Only

This option is has uncertainties due to lack of design documentation, vendors not able to confirm / provide performance guarantee and lastly no significant saving in field construction work.

Part D: Project Cash Flows, NPV, and OAR Approval Amount

k$	LTD	2017	2018	2019	2020	2021	2022	Future	Total
Currently Released	481	11,733	1,964						14,178
Requested Now	-		9,351						9,351
Future Required	-								
Total Project Cost	481	11,733	11,315						23,529
Ongoing Costs	-								
Grand Total	481	11,733	11,315						23,529

Estimate Class:	Class 2	**Estimate at Completion:**	$22,384 k
NPV:	N/A	**OAR Approval Amount:**	$23,529 k

Additional Information on Project Cash Flows (optional):

The contingency amount of $3,218k included in the previous release was withdrawn by the project in response to the design scope change.

Part E: Financial Evaluation

k$	Preferred Alternative	Base Case	Delay Work	Alternative 4	
Project Cost	23,529	NA	NA	NA	
NPV	NA	NA	NA	NA	
Other (e.g., IRR)	NA	NA	NA	NA	

Summary of Financial Model Key Assumptions or Key Findings:

Part F: Risk Assessment

Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation Probability	Post-Mitigation Impact
Cost	There is a risk for track system design as incompetent and require changes during installation. There is a risk that alignment of nozzle between new equipment and existing piping will be a challenge and require more time.	U1 design OPEX had been incorporated in U4 design change. Secondly, the OPEX has been realized in the pre-requisite work for Unit 4, hence, the risk is reduced to minimum. The laser measurement is performed on the old equipment to mitigate the misalignment of nozzle location. OPEX from Unit 1 installation will be considered during installation.	Low	Low
Scope	There is a risk that additional scope may be required due to potential discovery issues during execution.	Team consisting of all key stakeholders reviewed the scope for replacement of LP Feedwater HXs. The OPEX from Unit 1 installation are incorporated into Design package. Multiple walk downs have been performed by the team and their inputs were incorporated into the current project estimates.	Low	Low
Schedule	The P014 Cranes may be unavailable to project team at critical execution	Coordination meetings will be conducted between all stakeholders	Medium	Medium

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Part F: Risk Assessment

Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
			Probability	Impact
	milestones due to insufficient planning and coordination before and during P1841 Outage, which may lead to schedule delays and increased cost.	related to P014 Crane usage during P1841 Outage to identify interferences, schedule overlaps, and mitigation plans. Everyday coordination meeting/discussion will be required during the execution period to avoid any delay to either Turbine crew or LP FW crew.		
Resources	There is a risk that insufficient resources are available to complete replacement of HXs in the outage window.	Contract staff is budgeted and issuance of Purchase Order (PO) will be expedited to secure qualified resources.	Low	Low
Quality/ Performance	There is a risk that vendor quality is poor for the equipment supplied.	Approved Supplier List (ASL) process is being followed. Proposed vendor is in approved ASL list and has previously supplied equipment to OPG. Components Engineering and Design will identify required tests, inspections and vendor oversight to mitigate risk.	Low	Low
Technical	There is a risk that heat exchanger will not meet performance requirements.	Technical Specification and performance data were provided to the vendor. Components Engineering and Design will identify required tests to ensure critical attributes are met.	Low	Low

Part G: Post Implementation Review (PIR) Plan

☐ It is determined appropriate that only a Project Closure Report (PCR) is needed as the PIR for this project, due to its straight forward deliverables, which do not require any measures other than confirmation of completion or delivery.

Type of PIR Report	Target In-Service or Completion Date	Target PIR Completion Date
Simplified PIR	SEP-2018	MAR-2019

Measurable Parameter	Current Baseline	Target Result	How will it be measured?	Who will measure it? (person/group)
Thermal Performance	0.85 MWhr Generation loss as a result of HX performance	No MWhr Generation loss as a result of HX performance	Health Report	Performance Engineering

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Approvals			
	Signature	**Comments**	**Date**
The recommended alternative, including the identified ongoing costs, if any, represents the best option to meet the validated business need.			
Recommended by (Project Sponsor): Randy Lockwood SVP Pickering			Feb 9, 2018
I concur with the business decision as documented in this BCS.			
Finance Approval: John Blazanin VP Nuclear Finance per OPG-STD-0076			March 6/2018
I confirm that this project, including the identified ongoing costs, if any, will address the business need, is of sufficient priority to proceed, and provides value for money.			
Approved by: Glenn Jager President OPG Nuclear & CNO per OAR 1.1			9 MAR 2018

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Appendix A: Summary of Estimate										
Project Number:	Project # 13-83088									
Project Title:	PA LP Feedwater Heat Exchangers Replacement									
k$	**LTD**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**Future**	**Total**	**%**
OPG Project Management	32	58	100						190	1
OPG Engineering (including Design)	20	37	50						107	0
OPG Procured Materials		3,065	3,050						6,115	26
OPG Other	18	954	840						1,812	8
Design Contract(s)										
Construction Contract(s)	403	7,186	5,730						13,319	57
EPC Contract(s)										
Consultants										
Other Contracts/Costs										
Interest	8	433	400						841	4
Subtotal	**481**	**11,733**	**10,170**						**22,384**	**95**
Contingency			1,145						1,145	5
Total	**481**	**11,733**	**11,315**						**23,529**	**100**

Notes			
Project Start Date	AUG-2015	**Total Definition cost** (excludes unspent contingency for Nuclear)	$1,400 k
Target In-Service (or AFS) Date	SEP-2018	**Contingency included in this BCS** (Nuclear only)	$1,145 k
Target Completion Date	DEC-2018	**Total contingency released plus contingency in this BCS** (Nuclear only)	$4,363 k
Escalation Rate	n/a	**Total released plus this BCS without contingency** (Nuclear only)	$22,384 k
Interest Rate	4.9%	**Total released plus this BCS with contingency** (Nuclear only)	$23,529 k
Removal Costs	$1,000 k	**Estimate at Completion** (includes only spent contingency for Nuclear)	$22,384 k

Prepared by:		Approved by:	
FEB 06, 2018		06 FEB 2018	
Rahul Arora MTL - MMOD Modification Team Leader	Date	Bruce Ottenbrite Senior Technical Advisor - MMOD Project Manager	Date

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Appendix B: Comparison of Total Project Estimates and Project Variance Analysis

Comparison of Total Project Estimates

Phase	Release	Approval Date	Total Project Estimate in k$ (by year including contingency)						Future	Total Project Estimate
			2015	2016	2017	2018	2019	2020		
Definition & Execution	Superseding (from OM&A Project # 82939)	May 2016		1,580	9,717	8,092				19,389
Execution	Partial	Sept 2016		688	10,200	8,501				19,389
Execution	Full	Jan 2018		481	11,733	11,315				23,529

Project Variance Analysis

k$	LTD	Total Project		Variance	Comments
		Last BCS	This BCS		
OPG Project Management		249	190	-59	Reflects current requirements
OPG Engineering (including Design)		587	107	-480	Reflects current requirements
OPG Procured Materials		5,800	6,115	315	Additional material was required by the design change
OPG Other		360	1,812	1,452	Increased oversight by Field Engineering (FE) & Contract Management Office(CMO) required for the inspection of New HX equipment at vendor site and during field installation of new HX equipment
Design Contract(s)					
Construction Contract(s)		6,754	13,319	6,565	After Unit 1 installation OPEX, which reflects change in design for installation of the track system, the discovery issues and schedule delay due to field and unit conditions (such as human performance error, unit hydrazine leak and other station safety concerns)
EPC Contract(s)		-			
Consultants		-			
Other Contracts/Costs		400	0	-400	Included in the construction contract.
Interest		850	841	-9	
Subtotal		**15,000**	**22,384**	**7,384**	
Contingency		4,389	1,145	-3244	Total contingency included in the Partial Execution release BCS of $3,218k was drawn down in 2017.
Total		**19,389**	**23,529**	**4,140**	