Fuel Channel Life Management 10 - 62444

Partial Release Business Case Summary N - BCS - 31100 - 10001 – R000

1/ RECOMMENDATION:

We recommend a Partial Release of $12.3 Million OM&A for the Fuel Channel Life Management Project. A request for the remainder of the project cost (estimated at $12.7M) will be submitted in August 2010 when more certainty of the full scope and cost of the total project will be developed. This project is jointly funded between OPG and Bruce Power.

Fuel channel pressure tubes in most OPG CANDU units are beginning to approach their nominal operating life of 210k Equivalent Full Power Hours (EFPH). Accordingly, the prospect of multi-unit stations requiring refurbishment within a few years of each other is a growing concern because that would lead to competition for scarce re-tubing resources to support concurrent refurbishment operations. As a result, OPG is considering alternatives to achieve greater value from operating units and provide greater planning flexibility.

Moreover, due to the various degradation mechanisms related to fuel channels, the exact criteria for end-of-life or when fitness-for-service limits will be reached are not well defined. The methodologies, models and their bases currently used to demonstrate fuel channel fitness-for-service may not be adequate for late life assessments. In addition, there is an insufficient amount of inspection data and test results from ex-service pressure tube material on which to base projections. For these reasons, OPG fuel channel experts currently do not have a high level of confidence that the Darlington units can exceed 187k EFPH.

At this time, fuel channel R&D to support fitness-for-service is conducted through COG work packages which address the needs of all COG partners. However, if the pace of these COG activities is not accelerated and tailored to satisfy the specific objectives of OPG, the possible refurbishment start date of Darlington may need to be advanced to 2014 from the current planning scenario start date of 2016. As it takes more than 5 years to plan such a major undertaking, adequate lead time for a possible start date of 2014 would already be an issue.

The objective of this project is to have high confidence that Darlington can operate to 210k EFPH or beyond and that Pickering B can operate to 240k EFPH or beyond. This partial release will allow the critical path/long lead items to be initiated with the appropriate contractors to provide the results by 2012 which will subsequently support development of technical basis documents for continued fitness-for-service.

This project will accelerate some work being conducted through the CANDU Owners Group (COG) Research & Development (R&D) program as well as resolve issues which are outside of the general COG scope. The activities which will be initiated with this Partial Release includes the following key elements (to the end of 2010):

1. The first 1-1.5 years of a four year COG Joint Project with AECL and Bruce Power (BP) to conduct burst tests on ex-service pressure tubes to determine their fracture toughness at end-of-life (EOL) conditions;
2. Additional fracture toughness tests to support EOL limits
3. Defining annulus spacer surveillance requirements for subsequent testing/examination activities when pressure tubes and spacers are removed;
4. The first 1-1.5 years of 2 and 3 year experimental programs on pressure tube crack initiation to improve the basis for modifying the fitness-for-service methodologies and demonstrate increased margin to crack initiation.

$M (incl contingency)	Type	LTD 2008	2009	2010	2011	2012	2013	Later	Total
Currently Released	None								-
Requested Now	Partial		2,533	9,728					12,261
Future Funding Req'd	Full				7,741	4,010	908		12,659
Total Project Costs		-	2,533	9,728	7,741	4,010	908	-	24,920
Non Project Costs									-
Grand Total		-	2,533	9,728	7,741	4,010	908	-	24,920
Investment Type: Value Enhancing		Class: OM&A		NPV: 2,198		IRR: N/A		Discounted Payback: N/A	

Submitted By:

for W. Robbins
Chief Nuclear Officer

Date: 27 July 09

Finance Approval:

D. Hanbidge
SVP & Chief Financial Officer

Date:

Line Approval (Per OAR Element 1.2 Project not in Budget)

T. Mitchell
President & Chief Executive Officer

10 Aug 2009
Date

2/ BACKGROUND & ISSUES

Although the life limiting pressure tube degradation mechanisms vary slightly between stations (See Project Charter), this can change over time and the degradation mechanisms listed below have an impact on pressure tubes at both Pickering B and Darlington.

This type of R&D work is typically eligible for Scientific R&D tax credit, and one will be pursued to reduce the overall cost to OPG.

Deuterium ingress and its impact on material properties

During hot operation, fuel channel pressure tubes react with the heavy water coolant and, as a consequence of this, the concentration of hydrogen (deuterium and protium quoted in terms of the equivalent hydrogen concentration, H_{eq}) increases over time. As well, in the pressure tube/end fitting rolled joint region, there is an additional galvanic corrosion component which makes the process in this region much more rapid. Since pressure tube material has a limited solubility of hydrogen which increases with increasing temperature, the brittle hydride phase is present during unit heat-up and cool-down transients - which makes fuel channel pressure tubes susceptible to an active cracking mechanism, delayed hydride cracking (DHC). As well, it is unknown whether the H_{eq} anticipated to be found later in fuel channel life will have an adverse impact on the mechanical properties of pressure tubes.

Due to the limited fracture toughness data available for high H_{eq} conditions, CSA N285.8 limits the allowable H_{eq} in the main body of a pressure tube (BOT) and in the tensile portion of the rolled joint (RJ) region to 70 ppm at the inlet and 100 ppm at the outlet. These values are therefore referred to as "End-of-Life" (EOL) limits. Although these are currently hard limits, operation below this value (but above the solubility limit) cannot be supported with the available data.

As a result, OPG fuel channel experts have only medium confidence (up to 70%) that the pressure tubes in Darlington will achieve its nominal operating life of 210k EFPH. This is due to a lack of scrape data from the Darlington Units to support model predictions, the fact that Darlington Unit 3 scrape samples in 2002 exhibited some very high uptake trends that exceeded the upper bound of the CANDU 6 model, and that Darlington pressure tubes have some of the highest initial impurity hydrogen ($H_{initial}$) values in any CANDU units. Other contributing factors include a scarcity of rolled joint H_{eq} data and the lack of a predictive rolled joint model. If the currently defined EOL limits are reached in Darlington earlier than 210k EFPH, then it may be necessary to advance the refurbishment schedule from the current plan of 2016 to as early as 2014. As it takes more than 5 years to organize for such a major undertaking, adequate lead time to start in 2014 is already an issue (as illustrated in Attachment D). In addition, there is a significant loss in economic value if the Darlington units need to be refurbished earlier. Aside from issues concerning reaching this limit, it should be recognized that there little high hydrogen material property data from ex-service pressure tubes. Hence, there is insufficient data to provide the needed technical basis supporting operation of pressure tubes with H_{eq} above the solubility limit and beyond.

Until recently, Pickering B was not expected to exceed the EOL limits during the pressure tube nominal operating life of 210k EFPH. This expectation was related to the lower operating temperatures in Pickering B. However, the hydrogen and deuterium profiles through the inlet and outlet rolled joint regions of surveillance tube P6 M14 have challenged this belief (report issued December 2008). It appears that P6 M14 has much higher deuterium uptake in the compressive regions of the pressure tube and the H_{eq} exceeds the solubility limit at both inlet and outlet rolled joint burnish marks.

Although the fuel channel work conducted under COG is considerable, if it continues at its current pace, it will not address the following concerns in time for OPG to make confident predictions of fuel channel pressure tube life in order to optimally plan potential refurbishment activities:

a) Pressure tube material property changes with high H_{eq};
b) Kinetics of deuterium ingress (increasing H_{eq}) in the rolled joint region - to project future values and predict when EOL values will be reached; and
c) The appropriateness of the current limits

If it is demonstrated that there remains an adequate margin on material properties with high H_{eq}, changing the limits may be justified, thereby increasing confidence that Darlington can operate to 210k EFPH or beyond and that Pickering B can operate to 240k EFPH or beyond.

Crack Initiation

Extensive flaw populations in Pickering B were generated in pressure tubes, largely during commissioning due to

construction debris entrained in the Primary Heat Transport System (PHTS). Flaws that fail to satisfy the acceptance criteria provided in CSA N285.4-05 must be evaluated for acceptability and the condition must be dispositioned with the regulator. CSA N285.8-05 provides the recognized and accepted means of assessing flaws. One requirement is to demonstrate that crack initiation will not occur from DHC, fatigue and hydrided region overload. Pickering B currently has a number of flaws where crack initiation is predicted. This has resulted in the imposition of thermal cycle limits on operation and a requirement for re-inspection to assure that there has been no crack propagation. Although crack initiation has never been observed, these flaws continue to be monitored with a decreasing number of available cycles due to increasing deuterium concentration in the pressure tubes. Procedures currently used to assess flaws carry a significant degree of conservatism which is becoming increasingly limiting.

Test programs are underway to address the excessive conservatism involving the use of more realistic flaw geometries, H_{eq} and sample conditioning. Initial results have shown much greater resistance to crack initiation in pressure tubes using these conditions. However, it is proceeding at a pace that will not produce the desired results by 2012 as required by OPG to better plan possible refurbishment activities.

A recent attempt to modify the evaluation procedure for fatigue crack initiation was not accepted by the CNSC because there was insufficient data to support the proposed changes. Following this, an 'interim approach' was adopted with a commitment to produce more data in the next few years to support the original request. This would include testing pressure tube material in air and reactor water (to capture any environmental effects).

Additional testing to support changes to all crack initiation mechanism evaluation procedures would increase the operating window (especially for Pickering B) by showing that pressure tubes currently in service have a higher resistance to crack initiation than they are currently given credit for in assessments.

Probabilistic Core Assessments and Leak-Before-Break

CSA N285.8-05 requires that probabilistic core assessments be conducted to demonstrate that the probability of pressure tube rupture remains acceptably low, and that leak-before-break capability remains.

In addition to evaluating detected flaws found during inspections, the condition and acceptability of the pressure tubes in the reactor core as a whole must be evaluated using a Probabilistic Core Assessment (PCA). Among other input information, data from crack initiation experiments and the subsequent evaluation methodologies in the PCAs which impact on the probability of pressure tube rupture are to be evaluated against an acceptance criterion. The current state-of-the-art understanding of crack initiation is not captured in the current PCA code and, for this reason, the results are considered to be conservative. As well, the tool is not qualified to the industry standard of CSA N286.7. This exposes OPG to some regulatory risk.

Leak-before-break refers to the scenario where a through-wall crack in a pressure tube results in a leak into the Annulus Gas System which is detected and subsequent operator actions are taken to place the reactor in the cold and depressurized state prior to reaching the extent of crack propagation when pressure tube would catastrophically fail. Assurance of this capability is becoming increasingly difficult as the pressure tube properties degrade with time, and a change in methodology and/or input parameters can have a significant impact on the eroding margin between what is done at the stations and what needs to be done to demonstrate compliance.

Spacer Integrity and PT/CT Contact

Annulus spacers perform the critical function of maintaining a gap between the pressure tube and calandria tube – to assure that contact between these components cannot occur. This contact led to the catastrophic failure of channel G16 of Pickering Unit 2 in 1983. As such, spacer integrity must be demonstrated over the full operating life of the reactor.

The spacers used in Darlington are a tight-fitting design made from Inconel X-750 design which is meant to remain in its as-left position for the duration of the operating life. Recent OPEX from the recent removal of the pressure tube and spacers from channel O18 in Darlington Unit 2 has indicated that the structural integrity of this spacer design may not be sufficient to achieve the current nominal operating life of 210k EFPH. This is because the removed spacers arrived at AECL-CRL (Chalk River Laboratories) in several pieces and testing indicated that some material properties had degraded. Although the flasking and transportation to AECL-CRL may have led to the ultimate failure of these spacers, their degraded properties are due to operation. It is unknown at this time whether the degradation in properties of spacers in service at Darlington has saturated or if degradation will continue. This issue is one that could result in premature shutdown of Darlington units, since failure of a spacer leading to pressure tube-calandria tube (PT-CT) contact in the outlet region of almost any pressure tube in Darlington would result in hydride blister formation and subsequent pressure tube rupture.

Although the material properties of the loose-fitting Zr-Nb-Cu spacers in Pickering B are considered to be adequate for a 240k EFPH pressure tube life, the root cause investigation of the failed calandria tube in Pickering Unit 7 channel A13 revealed significant spacer wear as well as wear on the adjacent pressure tube and calandria tube surfaces. This calls into question whether the spacers in Pickering B are capable of maintaining a PT-CT gap during a 240k EFPH pressure tube. The root cause investigation team has produced an interim report, but the current funding source will not support additional activities to determine the root cause of spacer wear, the extent/severity of spacer is in OPG reactors, or the impact of worn spacers on PT-CT contact predictions.

In addition, there is currently no program to periodically assess spacer integrity as they can only be examined when a fuel channel pressure tube is replaced. Moreover, they aren't part of the normal surveillance activities associated with fuel channel replacement. Therefore, a spacer program is needed to assure structural integrity over the full unit operating life. Elements of this program include: a comprehensive literature survey to determine the credible degradation mechanisms and subsequent assessment methods/procedure and acceptance criteria for the results.

3/ ALTERNATIVES AND ECONOMIC ANALYSIS

$ Millions EFPH 000's	Timing	Base Case			Recommendation		
		DNGS	PNGSB	Total	DNGS	PNGSB	Total
		187K EFPH	210K EFPH		210K EFPH	240 EFPH	
Revenue	2009 to EOL	120,551	6,513	127,064	131,831	12,198	144,029
OM&A Operations	2009 to EOL	(54,964)	(4,341)	(59,305)	(59,321)	(7,672)	(66,993)
OM&A Project	2009 to EOL	0	0	0	(12)	(12)	(25)
Refurb (Capital)	2009 to EOL	(5,827)	0	(5,827)	(6,051)	0	(6,051)
Present Value (PV)	2009 to EOL	9,053	1,261	10,314	10,321	2,191	12,512
Net Present Value (NPV)		**N/A**	**N/A**	**N/A**	**1,268**	**930**	**2,198**

Base Case: Not Recommended - Continue with current COG R&D program to support Fuel Channel FFS (Do nothing)

At the pace with which fuel channel R&D is proceeding under COG, the results of testing and associated analyses will be not be completed in time to demonstrate high confidence (>70%) in fitness-for-service beyond 187k EFPH for Darlington and beyond 210k EFPH for Pickering B. This could result in Darlington units reaching their end-of-life as early as 187k EFPH with the possible refurbishment advanced from 2016 to 2014 - at substantial cost. For Pickering B, support for the technical basis for operation of fuel channel components to 240k EFPH will likely not have the required confidence by 2012 if the work is not accelerated.

Alt. 1: Recommended - Follow proposed plan to acquire appropriate information for 2012 (Do this)

Completing the proposed experimental and analysis work within the required timeframe in conjunction with executing LCM planned inspections and maintenance will demonstrate whether there is high confidence (>70%) that Darlington units can operate to 201k EFPH or beyond and Pickering B can operate to 240k EFPH or beyond – allowing possible refurbishment activities to be planned effectively at Darlington. The operation of Pickering B to 240k EFPH would realize greater economic value from these units.

Alt. 2: Not Recommended - Delay proposed work by one year

If the proposed work is delayed by one year, the required results to support high confidence nominal EOL predictions will not be realized until 2013. This is one year later than the target date and only one year before possible Darlington refurbishments would have to begin if operation beyond 187k EFPH cannot be supported with high confidence (>70%), leaving no adequate lead time to plan the refurbishment.

Note: Regulatory conditions require that at least some of this work is funded and initiated in the short term (i.e. fatigue crack initiation experiments).

Alt. 3: Not Recommended - Conduct some of the work proposed (Do less)

This alternative is a 20% cost reduction in scope over the recommended Alternative 1 where the work with the least impact on satisfying the project objective was removed from the scope. It is anticipated that the impact of reducing the scope would result in a reduction to the confidence to below 70% in EOL predictions required to support operation of Darlington to 210k EFPH and Pickering B to 240k EFPH.

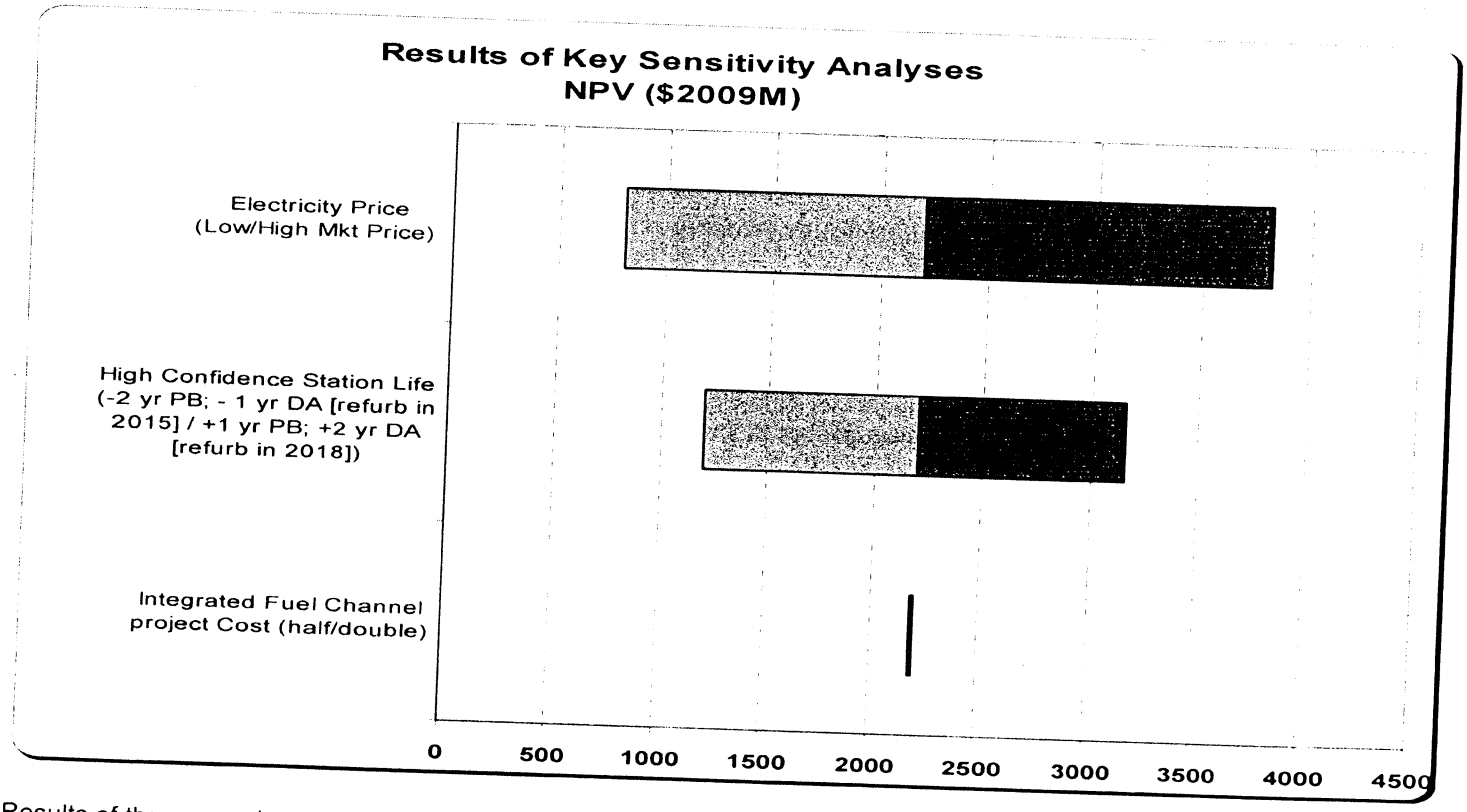
This alternative is not recommended based on supporting high confidence (>70%) projections of operating Darlington units to 210k EFPH or beyond (from 187k EFPH) and Pickering B units to 240k EFPH or beyond (from 210k EFPH), the calculated value of this work exceeds the estimated cost and any reductions to the scope could impose an unacceptably large risk on the project and impede achievement of objectives.

Alt 4: Not Recommended - Request regulatory relief on life limiting issues

In the area of fuel channel fitness-for-service, several submissions to revise the fitness-for-service methodologies (or inputs to these methodologies) have not been completely accepted by the regulator and 'interim approaches' have been utilized which include commitments to conduct additional work to justify the original submissions. By requesting relief in areas where commitments have been given (including some cases with formal plans) to justify previous submissions, the regulator may lose confidence in OPG since the regulator may already consider the 'interim approaches' to be a form of relief. Moreover, technical experts in the industry share most of the concerns of the regulator, and it would be prudent to get the appropriate answers rather than requesting relief.

Alt. 5: Not Recommended - Accelerate program further to get answers in 2011 (Do more)

Although having answers sooner (i.e. 2011) would be very beneficial, it is unlikely that additional funds would make this possible. The current limitation in this work is resources – specifically technical experts, technicians and facilities. Even if the funding could be made available immediately, facilities similar to those at AECL-CRL, capable of conducting work on pressure tubes, cannot be built in the time required.



Results of the economic assessment were tested for sensitivity to key inputs such as (i) assumed electricity price, (ii) length of additonal station life achieved, and (iii) integrated fuel channel project costs, and indicate the following:
(i) The value is extremely sensitive to the assumed electricity price. In a high price regime, the value would be $3.8 B and in a low price regime, the value would be $800 M. A low price regime would result from low electricity demand and low gas prices, such as during a prolonged economic slowdown or high conservation.
(ii) The value is sensitive to the station life that can be achieved with high confidence. If Pickering B units achieve only 225k EFPH and Darlington units achieve only 200k EFPH with Darlington refurbishment starting in 2015, then the value would be $1.2 B. If the Pickering B units achieve 248k EFPH and the Darlington units achieve 225k EFPH with Darlington refurbishment starting in 2018, then the value would be $3.1 B.
(iii) The value is insensitive to project costs even if they are doubled.

4/ THE PROPOSAL

This Partial Release is to start critical path/long lead time work required to increase confidence that Darlington units will operate to 210k EFPH or beyond and that Pickering B units will operate to 240k EFPH or beyond. It is intended that this program will provide the results by 2012 thereby allowing development of the appropriate bases to support fitness-for-service. The partial release will fund the project work to be conducted until the end of 2010.

The scope of work for the complete project includes activities to address:

1. Deuterium ingress and its impact on material properties
2. Crack initiation
3. Leak Before Break and Core Assessments
4. Spacer Integrity and PT/CT contact

Tasks under each category are designed to create a more comprehensive, overall understanding of fuel channel degradation and fitness-for-service limits. This work will support regulatory submissions to modify fitness-for-service methodologies, acceptance criteria, etc. related to fuel channels. This would essentially shift the fitness-for-service limits and (ideally) support the operation of Pickering B units to 240k EFPH or beyond and the operation of Darlington to 210k EFPH or beyond.

The following work includes the total current project work scope to be conducted over the next 3 years as a joint project between OPG and Bruce Power with cost sharing at a ratio of 5.5:3.5 (OPG:BP).

Deuterium Ingress and its Impact on Material Properties

A method will be developed to add hydrogen/deuterium to ex-service pressure tube material in a manner which does not affect the irradiation damage*. After this technique is qualified, tests to determine the fracture toughness at proposed end-of-life conditions will be conducted as proposed in the COG Joint Project 4299. Since it is anticipated that the engineering/qualification of a new method/technique will require approximately one year of effort and to mitigate the risk of a new technique not being capable of achieving the desired results, a parallel task involving the current technique will be pursued with a plan for its implementation as a non-ideal solution. Other, supplementary fracture toughness tests on both ex-service and un-irradiated pressure tube material will be conducted to support the development of fracture toughness curves at end-of-life H_{eq} levels.

Other activities to support deuterium ingress projections will be conducted including: developing detailed requirements for rolled joint H_{eq} model to ensure that the modification of current code addresses concerns over the lack of predictability; updating the body-of-tube deuterium ingress model to improve the accuracy of long term predictions; and using existing and new data/models to calculate the time reach end-of-life H_{eq} values for all units.

* *This work currently carries the greatest degree of uncertainty/risk because the vendor(s) have not stated conclusively whether or not they can conduct some of the proposed work in their hot cells. Because of this, a parallel path of doing the engineering and initial qualification in other hot cell facility will be followed.*

Spacer Integrity and PT/CT contact

To address concerns over tight-fitting (Darlington) spacer integrity, the major scope of work includes: determination of the mechanism of degradation of I-X750 spacer material, development of a comprehensive program of condition monitoring including evaluation methods and acceptance criteria for examination of ex-service spacers and pursuing the implementation of PT-CT gap measurements to assure spacer integrity and capability to maintain an appropriate gap. As well, an experimental program to irradiate I-X750 may be warranted to determine the rate of degradation in early life for extrapolation and projection to late life operation.

To address the concerns over loose-fitting (Pickering B) spacer wear, the major scope of work includes: completing the root cause investigation for P7 A13, determination of the impact of spacer wear on PT-CT predictions, and examination of other available ex-service spacers to determine the possible extent of spacer wear in OPG reactors.

Crack initiation

Tests using more realistic sample geometries and conditioning cycles will be conducted to quantify increased crack initiation resistance. This will allow flaws in Pickering to pass fitness-for-service evaluations in the future as well as support Probabilistic Core Assessments.

The work includes: quantifying the positive benefit of reduced pressure shut down on crack initiation, increasing the variability

and H_{eq} validity range on the non-ratcheting factor, determining the effect of having surface flaws and angled flaws versus full-length/axial flaws. Preliminary assessments of this type of work has indicated that pressure tubes are more resistant to crack initiation than current methodologies credit and, with the data to be acquired from these tests, the technical basis to modify fitness-for-service methodologies can be made.

Fatigue crack initiation experiments will be conducted in air on both ex-service material and un-irradiated material, as well as in a reactor water environment on un-irradiated material to support regulatory commitments to use the current 'interim approach' and make subsequent changes to the evaluation procedures. This will enable Pickering B to pass flaw evaluations and remove cycle limitations imposed by fatigue crack initiation.

Probabilistic Core Assessments and Leak-Before-Break

The Probabilistic Core Assessment tool will be updated to reflect the current understanding of fuel channel degradation, as determined by other parts of this project, to offer a more realistic assessment of reactor core integrity. In addition, the tool will be qualified to the requirements of CSA N286.7 as an Industry Standard Tool (IST).

A new approach to the leak-before-break methodology will be explored which follows what is done in US plants to move away from the overly conservative treatment currently used. This will enable increased margin to be demonstrated in assessments. This increased margin will allow further material degradation and equipment availability issues to be accommodated more easily.

The project work will also include ensuring that condition monitoring prescribed in the OPG Fuel Channel Aging and Life Cycle Management Strategy and Plan is executed. The resultant data is essential to determine when fitness-for-service limits will be reached. In addition, it is essential that experimental results be analyzed and technical basis documents developed to support improved methodologies meeting technical and regulatory requirements.

5/ QUALITATIVE FACTORS

This work is intended to be part of an industry-wide initiative to gain greater certainty on the fitness-for-service limits for fuel channels. If this is executed as a COG Joint Project, it gives Bruce Power important information concerning the timing of possible OPG refurbishment activities. This will help the industry to optimize refurbishment plans, and may reduce the strain on resources to conduct refurbishment of many units in parallel.

Even if it is determined that the current base case is accurate, and refurbishment activities must be brought forward in time from 2016 to 2014, this will be much more advantageous than unplanned shutdown of the units.

This work is part of a comprehensive Fuel Channel Life Management Plan which has been developed to drive to higher levels of confidence in longer pressure tube lives for the OPG nuclear units. Achieving higher levels of confidence has many benefits which are not easy to quantify including providing enhanced flexibility to OPG to:

(i) Manage the lead time constraints, and other preparatory issues (e.g. resource constraints, long lead time material, project mobilization) associated with the Pickering B refurbishment, should it proceed;
(ii) Manage the overall refurbishment schedule for the nuclear units, particularly the uncertainty around the refurbishment schedule for the Darlington units given current uncertainties in unit end-of-life dates, should it proceed;
(iii) Manage the uncertainties created by any potential delays to new nuclear in-service dates; and
(iv) Manage the potential significant capital and resource requirements and financial sustainability of OPG associated with multiple simultaneous refurbishments and new build nuclear campaigns;
(v) Manage regulatory risks associated with fitness-for-service limits.

6/ RISKS (see Attachment D for details)

Low = 1 to 3 | Medium = 4 to 9 | High = 10 to 25

Probability \ Impact	1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Risk Description	Mitigating Activities	Before Mitigation: Probability x Impact									After Mitigation: Probability x Impact								
		Finance	Schedule	Quality	Corporate Reputation	Regulatory	Health & Safety	Environment	Nuclear Safety	Risk Rating (1 to 25)	Finance	Schedule	Quality	Corporate Reputation	Regulatory	Health & Safety	Environment	Nuclear Safety	Risk Rating (1 to 25)
Resources unavailable to do the work in the required timeframe	Get estimates and resource commitments from vendors before full release. Close collaboration with the COG fuel channel work program to ensure optimum utilization of existing resources. Pursue alternate facility for engineering work associated with new hydrogen addition technique. Spread work over multiple facilities with ability to scale up work at alternate facility.		12							**12**		8							**8**
Results indicate degraded properties which impact on continued operations (including other stations)	Pre-establish performance criteria and evaluate impact Monitor results progressively with hold points to ensure that expected performance attained and potential impact. Establish more comprehensive fitness-for-service assessments	10			10	10				**10**	4			4	4				**4**
Funding not available in time to complete work	Establish schedule based on release of funds and accelerate work if necessary and possible		15							**15**		8							**8**
Other EOL work not funded - negating large benefit of this work	Hold challenge meeting with OPG and industry partners to minimize probability of unfunded work.		10							**10**		5							**5**
Regulator disallows use of the results in determination of end-of-life limits.	Obtain buy-in from regulator on project plan and approach to be undertaken				6	12				**12**				2	3				**3**

BUSINESS CASE SUMMARY

Low = 1 to 3	Medium = 4 to 9	High = 10 to 25

Probability \ Impact	1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Risk Description	Mitigating Activities	Before Mitigation: Probability x Impact									After Mitigation: Probability x Impact								
		Finance	Schedule	Quality	Corporate Reputation	Regulatory	Health & Safety	Environment	Nuclear Safety	Risk Rating (1 to 25)	Finance	Schedule	Quality	Corporate Reputation	Regulatory	Health & Safety	Environment	Nuclear Safety	Risk Rating (1 to 25)
	Keep the regulator informed of results as project progresses.																		
Unable to hydride material to appropriate levels with new technique	Parallel work to use current technique to get necessary data		8							8		4							8
FC LCM planned work not completed during outages to obtain necessary data	Ensure stations are aware of the impact of not conducting inspection work in LCM				12	12				12				4	4				4
Results from inspections show increased D-uptake rate in RJ	Use this work as basis, if possible, for increasing EOL limits	10				8				10	6				4				6
Vendor resists using new hydriding technique in hot cells	Pursue alternate facility for engineering work associated with new hydriding technique		9							9		4							4
Irradiated spacer properties indicate that properties are continuing to degrade	More comprehensive assessments will be conducted to demonstrate fitness-for-service	9					12			12	6				6				6
Unanticipated event causes hot cell unavailability	Allow enough lead time in work to absorb some delay		8							8		4							4
Bruce Power and/or Atomic Energy of Canada chooses not to co-fund this work in subsequent years	Contingency added in out years to accommodate any reductions in funding by other participants Additional OPG funding may be necessary to complete defined scope	8				8				8	4				4				4

7/ POST IMPLEMENTATION REVIEW PLAN

Type of PIR:	Targeted Final AFS Date:	Targeted PIR Approval Date:	PIR Responsibility (Sponsor Title)
Simplified	Dec 2013	Jun 2014	VP, Science and Technology Development Division

	Measurable Parameter	Current Baseline	Targeted Result	How will it be measured?	Who will measure it? (person / group)
1.	Results received from experiments and analyses	2016 assuming COG funding remains at current level, and appropriate task funded.	August 2012	Date final results are received to support next parameter	Manager, MCED
2.	Submission of technical basis to modify FFS to regulator	2016 based on appropriate results (see Item 1)	December 2012	Date of submission of documents to the regulator	Project Sponsor
3.	High confidence EOL predictions for Pickering B Fuel Channels	210K EFPH	240K EFPH	Fuel Channel experts concur with high confidence	Manager, MCED
4.	High confidence EOL predictions for Darlington Fuel Channels	187K EFPH	210K EFPH	Fuel Channel experts concur with high confidence	Manager, MCED

Appendix "A" Glossary (acronyms, codes, technical terms)

EOL – End-of-life – Based on design life of 210k EFPH
H_{eq} – equivalent hydrogen concentration if all deuterium [D] were replaced with protium [H] (H_{eq} = [H] + [D]/2)
D-ingress – with hot operation, deuterium enters pressure tube material
Hydriding – the process of adding hydrogen (deuterium or protium) to pressure tube material to simulate later life conditions
RJ – rolled joint between the pressure tube and end fitting
PT – Pressure tube
CT – Calandria tube
PHTS – Primary Heat Transport System
COG – CANDU Owners Group
PCA – Probabilistic Core Assessment, used to evaluate degradation of all fuel channels based on established methodologies and inspection results
CNSC – Canadian Nuclear Safety Commission, Canadian regulator under the Nuclear Safety and Control Act
AECL – Atomic Energy of Canada Limited
AECL–CRL – Chalk River Laboratories of AECL where ex-service fuel channel examination and testing is typically conducted

Appendix "B" Project Funding History

$ 000's		All Existing and Planned Releases (incl contingency) Cumulative Values									
Release Type	Month	Year	2009	2010	2011	2012	2013	2014	2015	Later	Total
Partial	Jun	2009	2,533	9,728							12,261
Full	Aug	2010			7,741	4,009	908				12,658
											0
											0
											0
											0

Comments:

Appendix "C" Financial Model – Assumptions

Financial Assumptions:

Discount Rate	7%	Cost Escalation (yr)	2%	SR & D Opportunity	See Comments
Progress Payments	N/A	Foreign Currency	???	Retainer Fee	???
Income Tax Rate		PST	???	Interest Rate (Capital)	???
Depreciation Rate (Capital)	N/A	Leasing	???	Indexed Priced Contract	???

Comments:
SR&D opportunity to be explored. It is likely that at least some of this work would qualify.

Project Cost Estimate:

Design Complete	N/A	Quality of Estimate	Budget + 30% to - 15%	3rd Party Estimate	N/A
Reviewed by Sponsor	Yes	OPEX used	N/A	Lessons Learned	none available
Similar Projects	Yes	Budgetary Quote(s)	No	First Unit Actual Used	Not unitized
Cost Sharing	TBD	Contracts in place	Some in place	Competitive Bid	None requested
Fixed Price Contract		Fee for Service	N/A	Firm Vendor Proposal	No

Comments:
Partner through COG and the CANDU industry will be sought to reduce costs to OPG.

Rationale for Cost Classification:

N/A

Generation Plan Assumptions:

Station	Unit	EOL		MW	Capacity	Planned Outages for Project Work (eg P1071)						
Pickering A	1	N/A	N/A		N/A							
	4	N/A	N/A									
Pickering B	5	N/A	N/A	N/A	N/A							
	6	N/A	N/A									
	7	N/A	N/A									
	8	N/A	N/A									
Darlington	1	Jun	2018	935	88%							
	2	Sep	2016									
	3	Mar	2020									
	4	Dec	2021									

Comments:
N/A

ONTARIO POWER GENERATION

OPG Confidential	Page: 16 of 18
BUSINESS CASE SUMMARY	

Fuel Channel Life Management 10 - 62444

Partial Release Business Case Summary N - BCS - 31100 - 10001 – R000

Attachment "A"

Project Cost Summary

	$000's OM&A	LTD 2009	2010	2011	2012	2013	2014	2015	Later	Total
Scores Basis	Project Mgmnt & Support	302	416	416	416	208				1,758
	Engineering	300	[redacted]							
	Procurement									-
	Construction									-
	Other									-
	Project R&D	1,866	[redacted]							
	Issue Management System	65								65
										-
										-
	Interest (Capital Project Only)									-
	Project Costs	**2,533**	[redacted]							
	General Contingency	-	[redacted]							
	Specific Contingency									
	Project Costs	**2,533**	**9,728**	**7,741**	**4,010**	**908**	-	-	-	24,920
Cash	Adjust to Cash Basis + / -									
	Project Costs	**2,533**	**9,728**	**7,741**	**4,010**	**908**	-	-	-	24,920

Funding	Currently Released									-
	This Release	2,533	9,728							12,261
	Future Release			7,741	4,010	908			-	12,659
	Project Funding	**2,533**	**9,728**	**7,741**	**4,010**	**908**	-	-	-	24,920

Note: Scores Basis = Cash Basis = Funding Basis (Timing differences only)

Budget	**Variance to Business Plan**	**2,533**	**7,553**	**6,336**	**3,351**	**783**	-	-	-	20,556

Other	Removal Costs included above									-
	Inventory to be written off									-
	Spare Parts in Inventory									-

The estimated variance(s) to the **2009-2013 Business Plan** will be addressed through the portfolio management process. A PCRAF **will be approved by Oct 2009.**

Reviewed By: June 11/09

Norman Webb
Project Manager
Date:

Approved By: 2009-06-17

Don Wilson
Strat IV Manager
Date:

Attachment "B"

Milestones and In Service Declarations

Key Milestones

Completion Date			Description
Day	Mth	Yr	
31	May	2009	List of prioritized work with cost and schedule estimates developed
30	June	2009	BCS approval from AISC
31	Aug	2009	Funding secured for Long Lead items from Partial Release
31	Aug	2009	Issue RFP/RFQs for long lead work identified in plan
15	Sep	2009	Kick-off Meeting
30	Oct	2009	PEP issued for use
30	Jun	2010	BCS finalized with more accurate scope and cost estimates
31	Aug	2010	Approval of funding for project (BCS approved)
31	Aug	2010	Issue RFP/RFQs for balance of work identified in plan
31	Aug	2012	Results obtained from analysis and experiments
31	Dec	2012	Regulatory acceptance of the fitness-for-service basis for continued operation

A Project Execution Plan (PEP) **will be approved by Oct 2009**

In Service Declarations: (Capital Only)

Month	Year	Description	$ 000's	%

Attachment "C"

Risk Probabilities Chart

Likelihood	Improbable	Unlikely	Possible	Likely	Probable
Probability	<= 1 in 1000	About 1 in 100	About 1 in 10	About 1 in 5	>= 3 in 4
Rank	1	2	3	4	5

Risk Impact Chart

Impact Rating	Financial	Project Schedule (12 months)	Quality	Corporate Reputation	Regulatory / Legal	Health & Safety	Environment	Nuclear Safety
5	>80% of Total Project $	> 90 day delay	Significant, unacceptable non-conformance requiring extensive rework	National and international adverse coverage or impacts	Non-compliance with potential for significant implications for personnel, potentially large damages or Criminal Charges **OR** Potential loss of operating licenses	Potential for fatality(s)	Spill or release causing immediate and extended impact with off-site impacts, e.g.: Clean-up costs > $15M Cat. A spill (>55 pts)	Loss or serious degradation of a safety system
4	30% - 80% of Total Project $	30 - 90 day delay	Unacceptable non-conformance requiring some rework, but not major	Long-term local or national impact	Legislative non-compliance with potential for fines, charges, and damages **OR** Major degradation of reputation with regulatory bodies	Potential for life-threatening critical injury or permanent total disability, including occupational disease	Exceedances resulting in charges or Director's Order Cat. A spill (45 - 55 pts) Public complaints with OPG implications Explosion and/or major fire	Reduced effectiveness of a safety system
3	15% - 30% of Total Project $	10 - 30 day delay	Non-conformance bordering design tolerances, potential to require rework	Major local impact or minor national impact. Minor local damage	Systematic non-compliance with potential for fines OR Potential to cause strained relationship with regulator, increased surveillance and/or regulations	Potential for less serious critical injuries (e.g. fractures), permanent partial disabilities and temporary total disabilities of a significant nature	Cat. B spills Emission in exceedance of regulatory or legal limits Field orders or AMP's Public complaints with OPG implications Danger to health, life, or property	Reduced effectiveness of redundant safety system components
2	5% - 15% of Total Project $	3 - 10 day delay	Acceptable non-conformance, within design tolerances, no rework required	Complaints from local officials / politicians	Systematic non-compliance with impacts to project schedule OR Possibility of regulatory / legal implications	Potential for less serious temporary disabilities and injuries requiring off-site medical attention other than first-aid. Complete recovery by worker.	Cat. C spills - reportable Administrative infractions Public Complaints with plant level implications	Impact on a safety support or safety related system
1	<5% of Total Project $	< 3 day delay	Minimal impact on quality Routine non-conformance, can be easily dispositioned	Complaints from local public	Isolated non-compliance OR Routine approval / notification	No medical attention beyond first aid, no impairment to worker or complete recovery of worker.	Administrative, non-reportable events Cat. C spills non-reportable and spills resulting from Acts of God	