PREDICTION OF THE TIME-TO-NIP-UP FOR THE POINT LEPREAU FUEL CHANNELS

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ABSTRACT

Following the 1999 fuel channel inspection, concerns arose about the possibility of spacer nip-up in Point Lepreau Generating Station (PLGS). Nip-up is an off-design condition in which the spacer is forced into full circumferential contact with the inside of the Calandria Tube (CT) by Pressure Tube (PT) diametral expansion. Nip-up is not a structural integrity issue but needs to be assessed as it will stress the CT beyond the values in the CT stress analysis. Nip-up can become a maintenance issue since it will impair SLAR late in the life of the fuel channels. To deal with potential nip-up, NB Power Nuclear chose to demonstrate that it would not occur prior to refurbishment at185 kEFPH.

To evaluate the potential for nip-up prior to 185 kEFPH, NB Power Nuclear undertook an updated analysis of the onset time for spacer nip-up in PLGS, which featured the following modelling innovations:

1. PT diametral expansion was predicted with an multivariable regression model,
2. The local deformation of the CT cross-section at the spacer due to spacer load was predicted accounting for CT elastic and creep deformations,
3. As-installed CT and PT dimensions were used to calculate the initial clearance of the spacer inside the CT.

This paper presents a summary of the updated nip-up analysis which concluded that nip-up would not occur by 185 kEFPH in PLGS. On the basis of this analysis, no further work related to nip-up was undertaken by NB Power Nuclear.

1.0 Introduction

In the design basis for the CANDU fuel channel, it was assumed that the CT inner diameter would always be larger than the outer diameter of the spacer coil so that spacer loading would be limited to a line load over an arc at the bottom of the CT.

Following the 1999 fuel channel Inspection, a concern arose about the possibility of nip-up in PLGS, prior to refurbishment at 185 kEFPH. To deal with this concern, NB Power Nuclear chose to demonstrate that nip-up would not occur prior to 185 kEFPH. To evaluate the potential for nip-up prior to 185 kEFPH, NB Power Nuclear undertook, in 2007, an updated analysis of the onset time for spacer nip-up in PLGS, which featured the following modelling innovations:

1. A multivariable regression model for PT diametral expansion, based on in-service gauging measurements, was used to predict PT diametral expansion

2. Local elastic and creep deformation of the CT cross-section due to spacer load was predicted,
3. As-installed CT and PT dimensions were used to calculate the initial clearance of the spacer inside the CT.

This paper presents a summary of the updated nip-up analysis that was performed for PLGS, reported in Reference [1].

2.0 Background

The main concern with nip-up is that a significant change in spacer loading will occur at the onset of nip-up. After nip-up, PT diametral expansion would induce circumferential stresses in the CT that are not included in the CT stress analysis.

Table 1 presents the design basis dimensions for the PLGS PT, spacer, and the CT that are relevant to spacer nip-up.

Table 1 – CT, PT, and Spacer Design Basis Dimensions

CT Minimum ID (in)	PT ID (in)	PT Wall (in)	Spacer Coil OD (in)	Nominal Spacer ID (in)
5.077	$4.070^{+0.028}$	$0.165^{+0.019}$	$0.019^{+0.006}$	4.247

ID and OD denote inner and outer diameter, respectively.

For this assessment, spacer clearance is defined as the diametral clearance between the vertical outer diameter of the spacer coil and the vertical inner diameter of the CT. PT deformation denotes PT diametral expansion and wall thinning. CT deformation denotes expansion of the CT ID at spacer locations due to elastic deflection and creep.

Past analyses have considered only PT diametral expansion in assessing spacer nip-up. However, PT wall thinning and localised CT elastic and creep deformation tend to delay spacer nip-up and were accounted for in this assessment.

Three main components of CT localised deformation were considered in this assessment:

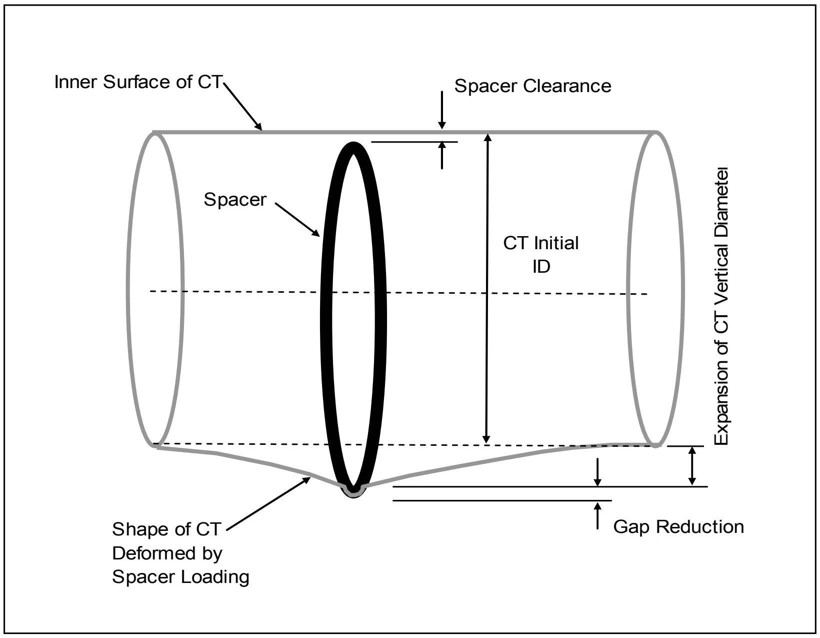
1. Gap reduction creep deformation at the bottom of the CT, as defined in the documentation for CDEPTH 8.2 and 9.0.
2. Expansion of the CT vertical diameter due to creep under spacer loading
3. Elastic expansion of the CT vertical diameter under spacer loading

Figure 1 illustrates the components of localised CT creep deformation at the spacer location: gap reduction and expansion of the CT vertical diameter. For clarity, the PT is not shown in Figure 1. It can be seen in the figure that both gap reduction and the expansion of the CT vertical diameter will increase the spacer clearance, in opposition to PT diametral expansion.

For this assessment the acceptance criterion for the onset of nip-up is 185 kEFPH or greater. Therefore, no explicit margins on the time-to-nip-up are being applied, noting that PLGS actually shut down for retube slightly before 185 kEFPH.

For this assessment it was necessary to minimise the number of spacers analysed for nip-up. This was accomplished through the identification of critical spacer in each of the fuel channels assessed for nip-up, defined as the spacer with the highest rate of diametral expansion in the fuel channel, and the first to reach nip-up.

Figure 1 – Illustration of CT Local Deformation at a Spacer Due to Spacer Loading



3.0 Analytical Procedures

The nip-up assessment consisted of predicting the spacer clearance for the critical spacer in each channel at 185 kEFPH, which involved the following procedures:

1. Determining the axial locations of the critical spacers
2. Predicting PT deformation at the critical spacer locations
3. Predicting the local gap reduction at the critical spacer locations
4. Predicting the elastic expansion of the vertical diameter of the CT at the critical spacer locations
5. Predicting the expansion of the vertical diameter of the CT at the critical spacer locations due to creep
6. Predicting the spacer-to-CT clearance at 185 kEFPH for the critical spacers using both PT and CT deformations

In Step 6 it was assumed that the spacer coil would remain circular under load.

Calculations of spacer clearances at 185 kEFPH included the effects of CT deformation and the use of as-installed CT and PT dimensions, as specified in Section 8.0.

3.1 Identification of Critical Spacers

The first step in the analysis was the identification of the critical spacers for the channels to be analysed for nip-up. As indicated in Figure 2, PT diametral expansion is correlated to fuel channel power, such that only the high power channels need to be assessed. A channel power of 5200 W_{th} was used as the criterion to select the channels to be assessed. .

By definition, the PT diametral expansion rate at the critical spacer in a fuel channel exceeds those at the other spacers. Figure 3 presents the distribution for the axial location of maximum diametral expansion for the gauged PTs in PLGS. The channel with peak diametral expansion at the mid-bundle 7 location is a low power channel in which nip-up is not a concern.

Figure 2 – Plot of Measured Maximum PT Diametral Expansion Versus FC Design Thermal Power

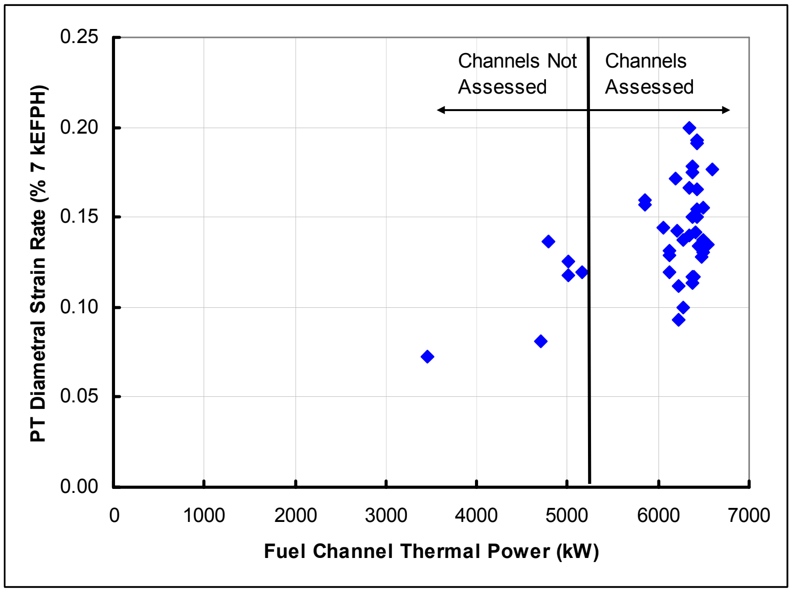
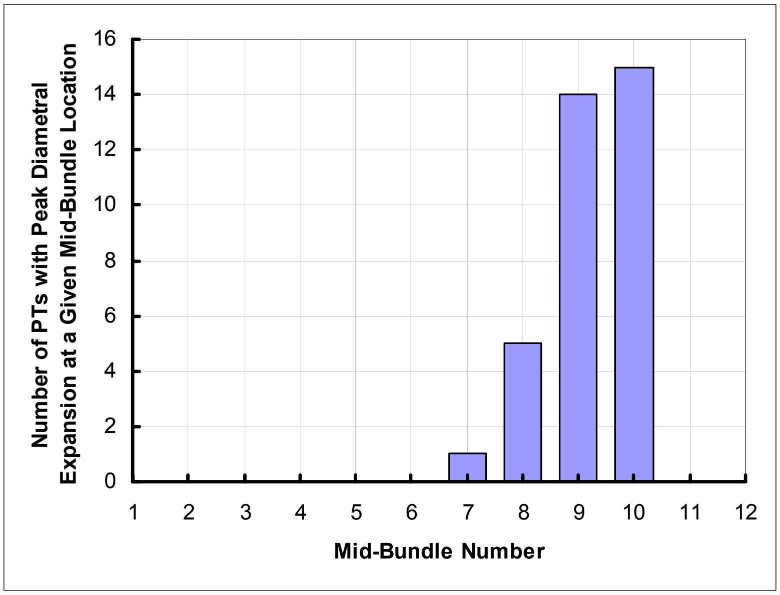


Figure 3 – Histogram for the Mid-Bundle Location With the Highest PT Diametral Expansion



The following procedure, suggested by Figure 3, was employed in order to identify potential critical spacers in each of the channels to be assessed:

1. Current as-left spacer positions from the East Calandria Tube Sheet were converted to positions relative to the mid-planes of fuel bundles 8, 9, and 10
2. Spacers closest to the mid-planes of bundles 8, 9, and 10 were found
3. For the case in which all spacers were upstream of the mid-bundle location Spacer 4 was identified as the critical spacer
4. For the case in which spacers straddled the mid-bundle location a test was carried out to identify the critical spacer or potential critical spacers
5. PT diametral expansion was calculated at potential critical spacers to identify critical spacers

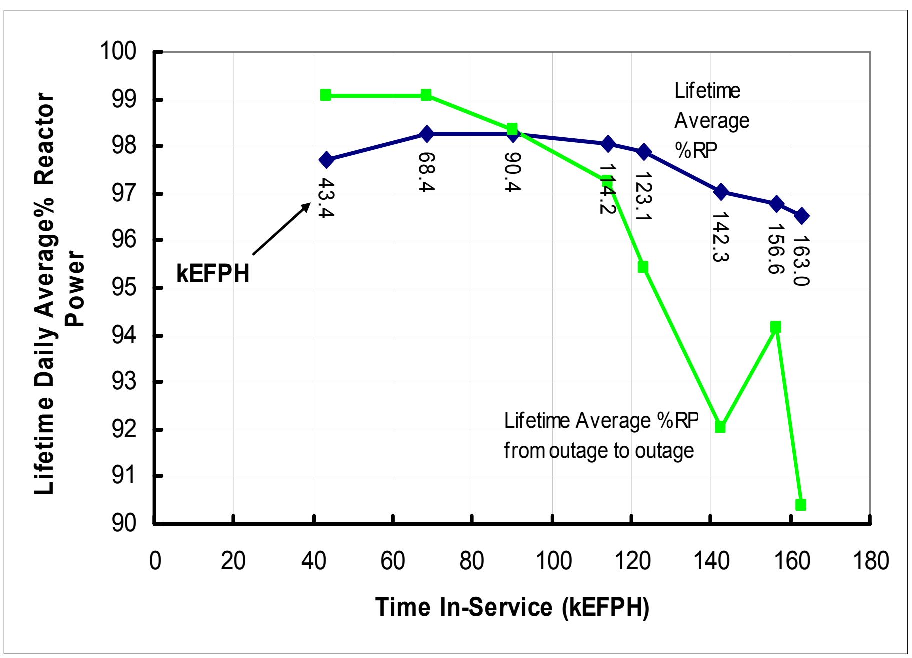
3.2 Generation of PT Lifetime-Averaged Fast Neutron Flux and Temperature Values at Critical Spacer Locations

The standard PT fast neutron flux profiles for PLGS were compiled in 1994. The profiles represent lifetime-averaged flux values in 1993 at the twelve mid-bundle locations, corresponding to operation of the reactor at 98.275% Reactor Power (RP).

As a result of power derating, the lifetime-averaged power rating for PLGS declined with time in-service, as illustrated in Figure 4. For this assessment, the use of the 1993 lifetime-averaged flux values was considered to be unnecessarily conservative.

Therefore, to incorporate the effect of power derating on PT flux and PT expansion, lifetime-averaged PT fast neutron flux profiles were generated for operation of the reactor at 96.467% RP, which represents the lifetime-averaged % RP for PLGS as of August 2005.

Figure 4 – Lifetime Averaged Reactor Power Computed at EFPH Values for the Various Inspections of PLGS



For the channels requiring PT diametral expansion predictions, PT lifetime averaged fast neutron flux values at the critical spacers were determined by interpolation in the PT fast neutron flux profiles.

To account for reduced average temperatures, PT lifetime average temperature profiles from Reference [2] were used in this assessment.

3.3 PT Diametral Expansion

For fuel channels with PT gauging measurements, the rate of diametral expansion for each individual PT at a given spacer location was determined from its average initial ID and the measured diametral expansion at the spacer location.

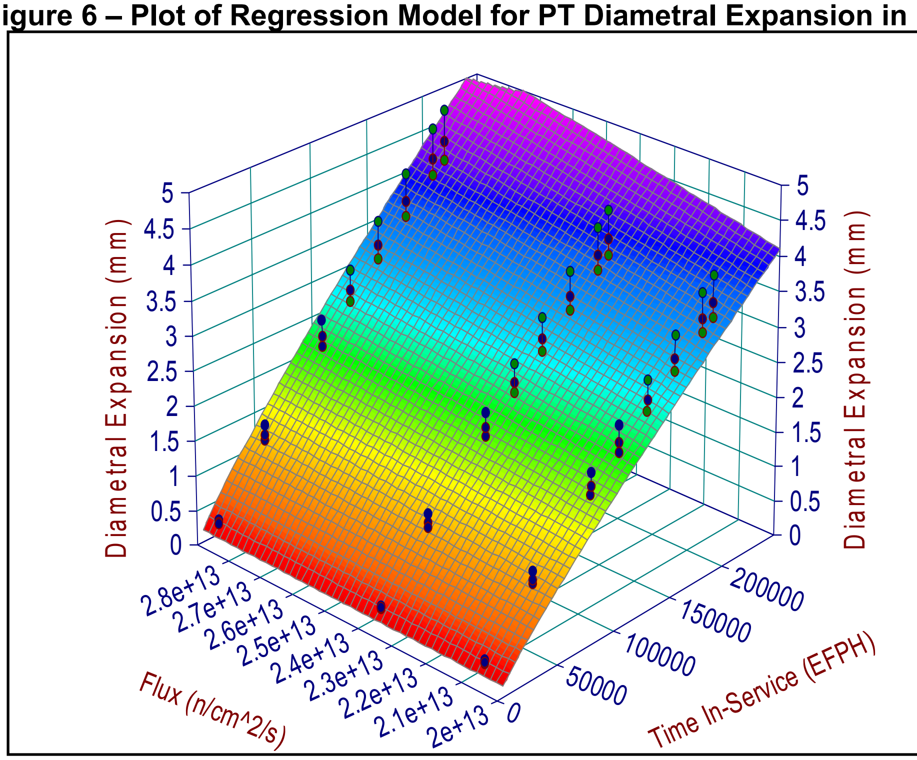
For the channels with no PT gauging measurements, PT diametral expansion at the spacer locations at 185 kEFPH was predicted using the multivariable regression model of Reference [3]:

$$\ln(\Delta ID) = -11.7091 + 0.877754 \ln(t) + 0.537954 \ln(\Phi_{av}) + 0.349468 \ln(P) + 0.656089 (-Q/T_{av}) \quad 1$$

where ΔID is the expected PT diametral expansion in mm, t is the time in-service in kEFPH, Φ_{av} is the PT lifetime averaged fast neutron flux in n/cm^2/s, P is the FC power in W_{th}, and T_{av} is the PT lifetime averaged temperature in K.

The general form of the regression model for PT diametral expansion is depicted in Figure 6.

Figure 6 – Plot of Regression Model for PT Diametral Expansion in PLGS



Note that the data points above the surface are at different temperatures. The variation in diametral expansion with channel power is less pronounced than that with the other variables and is not depicted in the figure.

Equation 1 provides the mean value of ln (ΔID) for a given combination of input variables and does not account for variability from the mean of individual measurements.

Therefore, for the prediction of PT diametral expansion for PTs that have not been inspected, the possible variance in PT diametral expansion about the mean value was accounted for through the use of an Upper Prediction Limit (UPL) on the regression model of Equation 1. Because of the large number of spacer locations to be analysed, it was decided that a 99% confidence level should be employed.

In the diametral expansion analysis, the 99% UPL of PT diametral expansion at the critical spacer locations was calculated using the forecast option in the multivariable regression analysis module of STATGRAPHICS 5.1, also used to derive Equation 1.

An approximate 99% UPL was derived and was used to confirm the 99% UPL values from STATGRAPHICS 5.1.

3.4 PT Wall Thinning

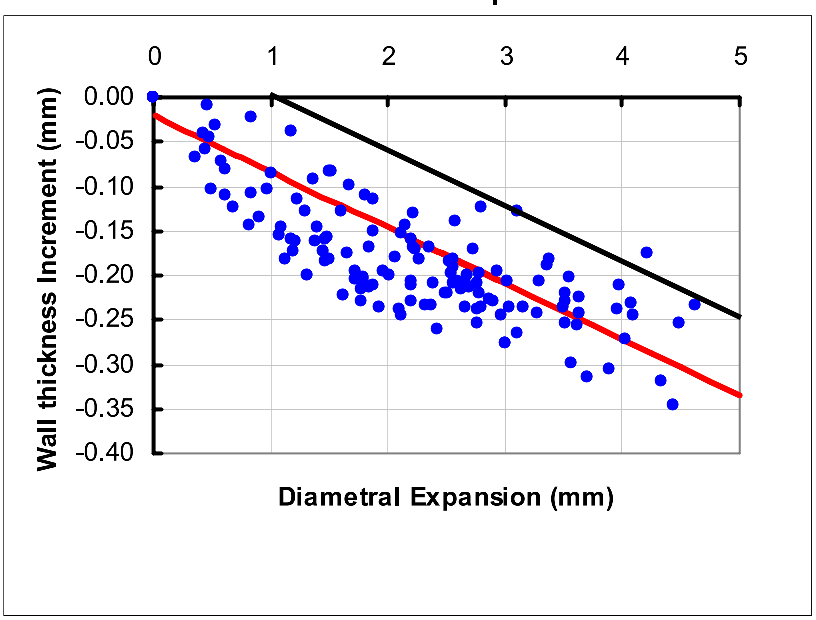
A correlation [4] of PT wall thinning to PT diametral expansion is depicted in Figure 7. The lower line in Figure 7 represents the linear regression model for the wall thinning versus diametral expansion data. The upper line in the figure was used to generate wall thickness values from diametral expansion values at 185 kEFPH for this assessment and is given by:

$$\Delta w = 0.0625 - 0.0625\, \Delta ID \qquad 2$$

where Δw and ΔID are change in PT wall thickness and inner diameter.

It should be noted that for conservatism, the ΔID values used in Equation 2 were mean values for diametral expansion rather than the 99% UPL values for diametral expansion.

Figure 7 – PT Wall Thinning versus PT Diametral Expansion As Measured in the 2004 Inspection of PLGS



3.5 Prediction of Local CT Gap Reduction Deformation

Equation 3, from Reference [5] was used to calculate the local CT gap reduction deformation for each critical spacer location at 185 kEFPH.

$$\Delta r = \Delta\Phi \ SCC_2(C_1 + C_2\, t)(SCC_3\, F)^{(C_3 + C_4 t)} \qquad 3$$

where Δr is the gap reduction
- ΔΦ is the change in fluence over the given period
- SCC_2 is a scale factor for gap reduction
- C_1 is a constant
- C_2 is a constant
- SCC_3 is a scale factor
- t is the duration of the time interval over which the gap reduction occurs
- F is the spacer load
- C_3 is a constant
- C_4 is a constant

Values for constants are provided in Reference [5].

The gap reduction deformation, as indicated previously, represents the local increase in the radius of the CT at the spacer location at the bottom of the CT due to creep over a given time interval with a given spacer loading. Therefore, Δr contributes directly to the in-service expansion of vertical diameter of the CT at the spacer location.

3.6 Prediction of the Expansion of the CT Vertical Diameter under Spacer Loading

As stated, spacer loading results in an expansion of the CT vertical diameter due to CT elastic and creep deformation. Sections 3.6.1 and 3.6.2 outline the methods used to predict the elastic and creep-induced deformations of the CT, respectively

3.6.1 Prediction of the Elastic Expansion of the CT Vertical Diameter under Spacer Loading

The finite element code, ANSYS 9.0, was used to compute the elastic deformation of the CT under spacer loading. Section 3.6.6.1 describes the spacer loading that was applied to the CT model in ANSYS 9.0.

3.6.1.1 Definition of Spacer-CT Contact Surface and Loading

As a result of the load exerted by the PT on the spacer after restart of the reactor following spacer repositioning, the CT would bear a surface contact stress over a narrow arc of a circle at the bottom of the CT, which defines the initial contact surface.

The following defines the contact force distribution, U(θ) that was used in this assessment:

$$U(\theta) = 2/\pi\ \frac{F_s}{r}\cos\ \theta \qquad 4$$

Where F_s is the load applied by the PT to the spacer, r is the CT inner radius, and θ is the angle, relative to the vertical direction:

For the finite element analysis, Equation 4 was used to calculate the distributed loading to be applied at nodal locations corresponding to the contact points of the spacer with the CT.

3.6.2 Prediction of the In-Service Expansion of the CT Vertical Diameter under Spacer Loading due to Creep

The local expansion of the CT vertical diameter at spacer locations due to creep under spacer loading was estimated using CRNL 4001, as follows. Average hoop stress in the CT versus spacer load was obtained from the ANSYS 9.0 elastic analyses. The correlation of average hoop stress to spacer load was used to determine the average hoop stress on each critical spacer. The average hoop stresses at the critical spacer locations were used in CRNL 4001 to calculate the initial and final circumferential creep strain rates of the CT at the critical spacer locations.

The diametral strain and expansion of the CT at the critical spacer location at 185 kEFPH were estimated assuming a constant circumferential creep strain rate to 185 kEFPH that is the average of the initial and final creep strain rates.

4.0 Inputs into the Analysis of Time-to-Nip-Up for PLGS

4.1 EFPH Value at Shut Down for Fuel Channel Replacement

Based on refurbishment documentation, it is assumed that PLGS will be shut down for fuel channel replacement at 185 kEFPH. Therefore, spacer clearance or interference values were predicted for 185 kEFPH.

PLGS Fuel Channel Dimensions

The following are the initial fuel channel design basis dimensions that were used for calculating spacer clearance values in this assessment:

PT maximum allowable as-installed outer diameter:
4.457 inches (Drawing 31110-5-1-DD-D Rev 2)

Maximum allowable spacer coil outer diameter:
Per drawing 31160-2-1-DD-D Rev 1: = 4.247 + (0.190+.006) X 2
= 4.639 inches

Minimum allowable CT inner diameter:
Per Drawing 31231-2-1-DD-E: 5.077 inches

It should be noted that these represent the most conservative dimensions possible for the fuel channel components for the analysis of nip-up.

4.3 Current Spacer Locations for PLGS

For this assessment, it was assumed that spacer locations have not changed from the most recent as-left positions recorded during SLAR. The most recent as-left spacer

positions for PLGS relative to the East CTS were provided to CPUS Limited by NB Power Nuclear in References [6] and [7].
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4.4 As-Left Spacer Loads for PLGS

CDEPTH 9.0 As-Left spacer loads from the most recent SLAR operation in each fuel channel were obtained by combining the data of References [6] and [7]. For this assessment, As-Left spacer loads were obtained directly, except for two groups of channels: (1) L08, M07, and J18, and (2) K06, K16, M13, N19, and S11.

Zero As-Left spacer loads on return to power following SLAR were predicted for the critical spacers of L08, M07, and J18. To calculate CT deformation for these channels, it was necessary to obtain spacer load history predictions, provided by AECL [8].

Critical spacers in the second group of channels were left within 300 mm of an adjacent spacer, so that As-Left loads could reduce with time and couldn't be used to predict CT deformation. CT deformations at the critical spacer locations in these channels were predicted using appropriate values from the spacer loading history plots [8].

4.5 PT Gauging Data for PLGS

For this assessment, 2004 PT gauging results were used to produce empirically-based predictions of CT-spacer clearances for the following fuel channels: F06, F08, G12, J13, N06, O11, P03, Q07, Q08, U11, and U15. The PT gauging data prior to the 2004 inspection were excluded from this assessment since they would overestimate the rates of diametral expansion that occur later in the life of the reactor.

Table 3 presents a summary of the PT gauging data from the 2004 inspection [9].

Table 3 – Summary of Measured PT Dimensions at Critical Spacer Locations from the 2004 Inspection of the PLGS Fuel Channels

FC	Critical Spacer Location[1] (mm)	ID_0 (mm)	ID (mm)	w_o (mm)	w (mm)
F06	5012	103.588	107.177	4.389	4.151
F08	3739	103.740	105.290	4.334	4.127
H08	3388	103.540	106.452	4.423	4.201
J13	3744	103.654	107.173	4.369	4.125
N06	7340	103.607	107.705	4.393	4.166
O11	7233	103.722	107.974	4.398	4.064
P03	3776	103.829	106.587	4.336	4.121
Q07	7170	103.583	108.262	4.389	4.204
Q08	3826	103.709	106.669	4.362	4.157
R13	3666	103.592	107.607	4.380	4.153
U11	6656	103.751	106.414	4.339	4.136
U15	5862	103.634	105.556	4.354	4.140

Note 1 – the spacer location reference point for each FC is the end fitting E-face.
ID_0 is the estimated PT initial inner diameter at the critical spacer location
ID is the measured PT inner diameter at the critical spacer location
w_o is the estimated PT initial wall thickness at the critical spacer location
w is the measured PT wall thickness at the critical spacer location

4.6 As-Installed CT Dimensions for PLGS

Installation records for specific CTs in PLGS were obtained from NB Power Nuclear and were used to generate estimated actual values for the minimum as-installed inner diameters of the CTs. A summary of the estimated as-installed CT inner diameters is presented in Figure 8 for comparison with the design basis minimum CT inner diameter.

4.7 As-Installed PT Dimensions for PLGS

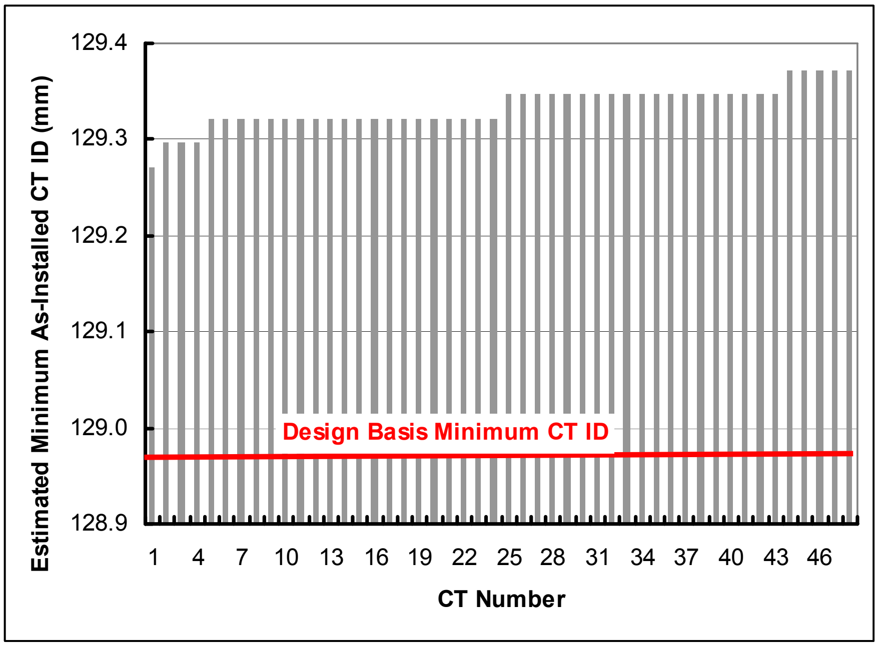
The upper bound (mean plus two standard deviations) ID of the inspected PLGS PTs was found to be 103.817 mm. For the PTs that were gauged in the 2004 inspection, the upper bound initial wall thickness was determined to be 4.430 mm. Based on these dimensions, the estimated upper bound on the PT OD for PLGS is 112.677 mm.

5.0 Ancillary Analytical Results

5.1 Critical Spacer Locations

The distribution of axial position for the critical spacers in the 252 high power channels that were assessed, relative to the inlet end of the fuel string, is presented in Figure 9. The majority of critical spacers are 4000 to 5000 mm from the inlet end of the fuel string.

Figure 8 – Estimated As-Installed Minimum IDs for Selected CTs



5.2 PT Diametral Expansion

The distribution of predicted PT diametral expansion at 185 kEFPH, for the critical spacers in the 252 high power channels that were assessed, is presented in Figure 10. In the figure, the channels are ordered by row and column so that the variation in diametral expansion along each row is evident.

Figure 9- Plot of the Axial Position of the Critical Spacers in the PLGS Fuel Channels Assessed for Nip-Up

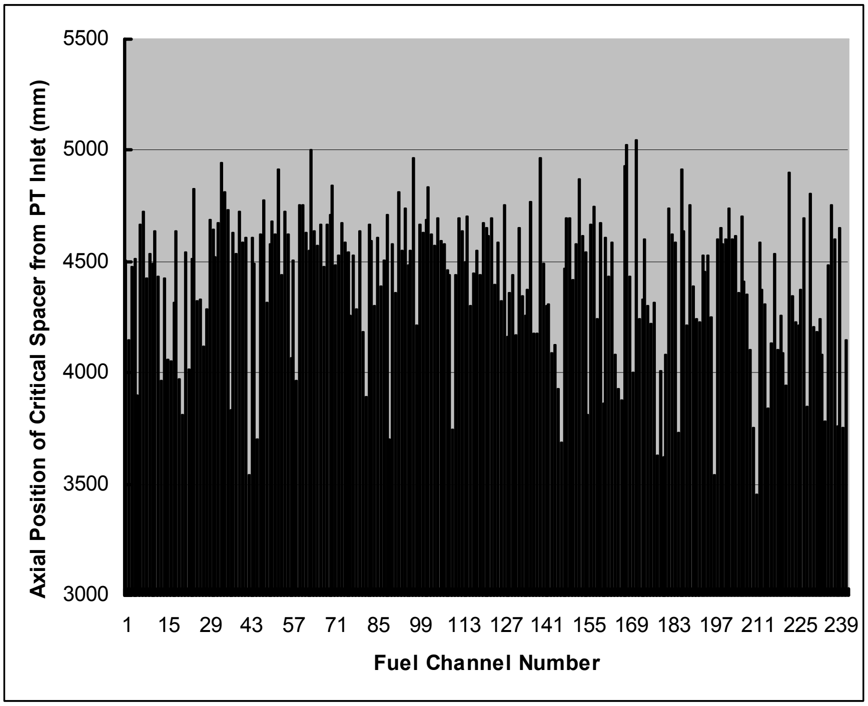
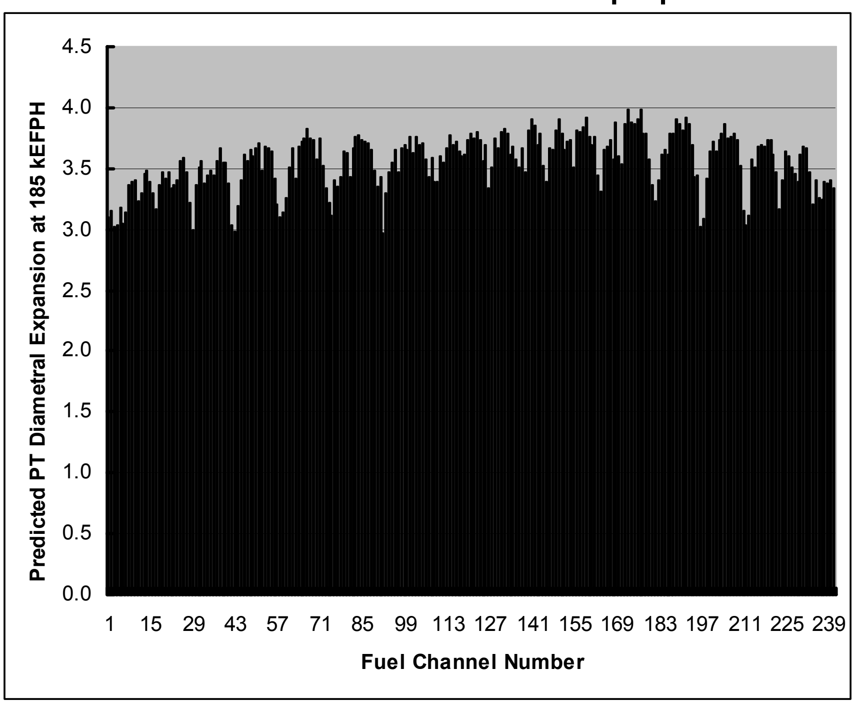


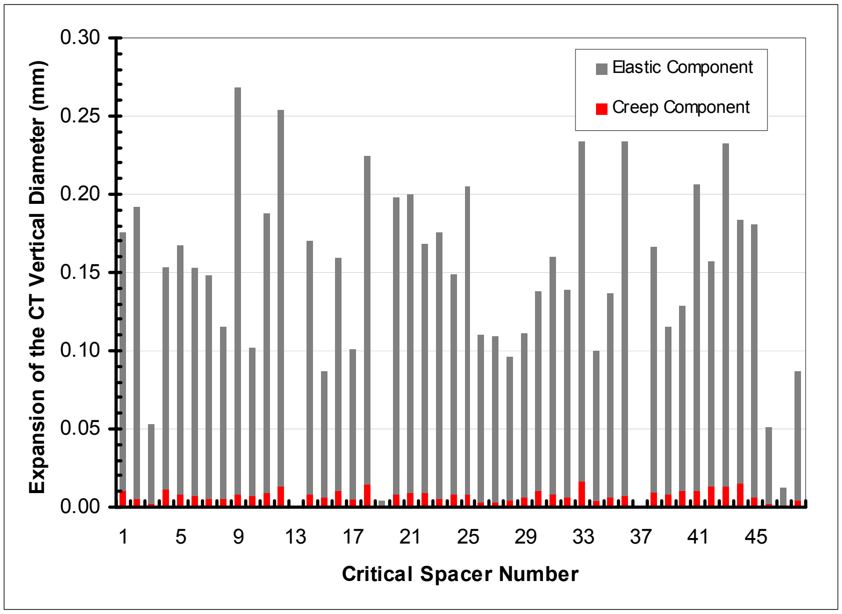
Figure 10 – Predicted PT Diametral Expansion at the Critical Spacers in the PLGS Fuel Channels Assessed for Nip-Up



5.3 Expansion of the CT Vertical Diameter

Expansion of the CT vertical diameter at critical spacer locations, due to elastic and creep deformations was predicted for 48 selected fuel channels (Sections 6.3 and 6.4). Figure 11 presents the expansion of the CT vertical diameter at the critical spacers, including elastic and creep deformation. The predicted creep deformation is a very small fraction of the elastic deformation.

Figure 11 – Predicted Expansion of the CT Vertical Diameter in Selected PLGS Fuel Channels



6.0 Main Analytical Results - Calculation of Spacer Clearances at 185 kEFPH

The approach used in the sequential spacer clearance calculations is presented in Table 4, which gives the modelling assumptions in each step of the analysis.

Table 4 – Description of Sequential Spacer Clearance Calculations

Analysis Case	Features Modelled	PT Dimensions	CT Dimensions
1	PT Deformation[1] Alone	Design Basis	Design Basis
2	PT Deformation and Gap Reduction	Design Basis	Design Basis
3	PT Deformation, Gap Reduction, and CT Diametral Expansion[2]	Design Basis	Design Basis
4	PT Deformation, Gap Reduction, and CT Diametral Expansion[2]	Design Basis	As-Installed
5	PT Deformation, Gap Reduction, and CT Diametral Expansion[2]	As-Installed	As-Installed

Note 1 – PT diametral expansion and wall thinning
2 – CT diametral expansion due to elastic and creep deformations

6.1 Spacer Interferences with PT Deformation Alone

In this analysis only PT deformation was considered; CT inner diameter was assumed to remain constant with time. Out of 252 channels analysed, it was predicted that 156 would reach nip-up by 185 kEFPH. The results of the analysis are presented in Figure 12, which gives spacer interference values for the 156 channels predicted to reach nip-up by 185 kEFPH. Spacer interferences were the greatest for channels in rows M, N, and O, with the greatest predicted diametral expansions, as expected.

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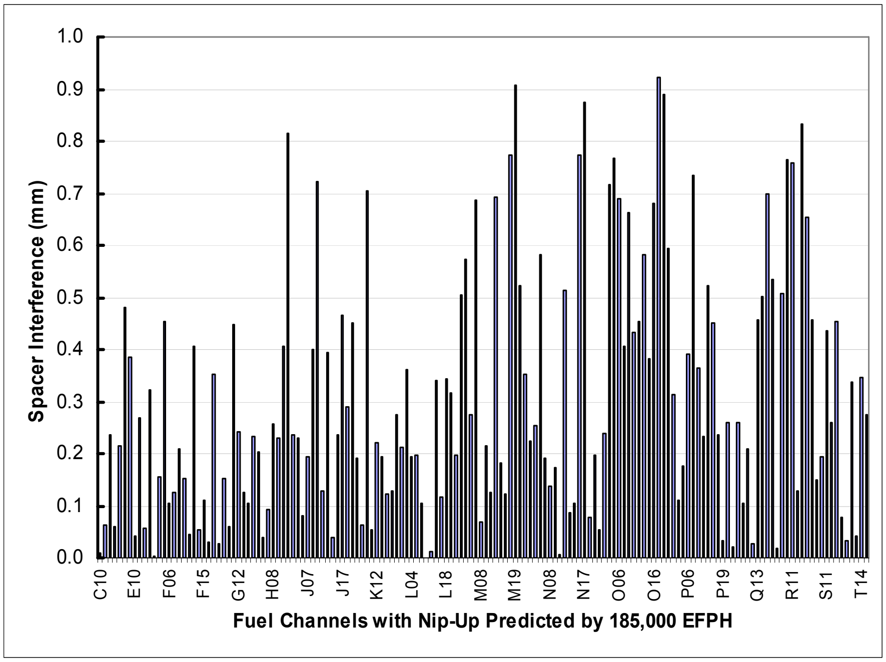
Figure 12– Distribution of Calculated Spacer Interference Values for the 156 Critical Spacers Predicted to be at Nip-Up by 185 kEFPH



6.2 Spacer Interferences with PT Deformation and Gap Reduction

A reanalysis of the 156 channels with nip-up predicted in Figure 12 was conducted to include gap reduction. The bar graph of Figure 13 is a summary of the results. With gap reduction included in the analysis, the number of channels with nip-up was reduced from 156 to 79 and the maximum interference was reduced from 0.92 mm to 0.78 mm

6.3 Spacer Interferences with PT Deformation, Gap Reduction, and CT Diametral Expansion

A reanalysis of the 79 channels with nip-up predicted in Figure 13 was conducted to include CT vertical inner diameter expansion. The bar graph of Figure 14 is a summary of the results. With gap reduction included, the number of channels with nip-up was reduced from 79 to 48 and the maximum interference was reduced from 0.78 to 0.62 mm.

6.4 Spacer Interferences with PT Deformation, Gap Reduction, CT Diametral Expansion, and CT As-Installed Dimensions

The analysis summarised in Figure 14 was repeated using as-installed CT dimensions, outlined in Section 4.6, for the 48 channels with nip-up in Figure 14, the results for which are given in Figure 15. The eleven channels plotted in Figure 15 are channels with nip-up predicted by 185 kEFPH using as-installed CT dimensions.

Figure 13 – Distribution of Calculated Spacer Interference Values for the 79 Critical Spacers Predicted to be at Nip-Up by 185 kEFPH

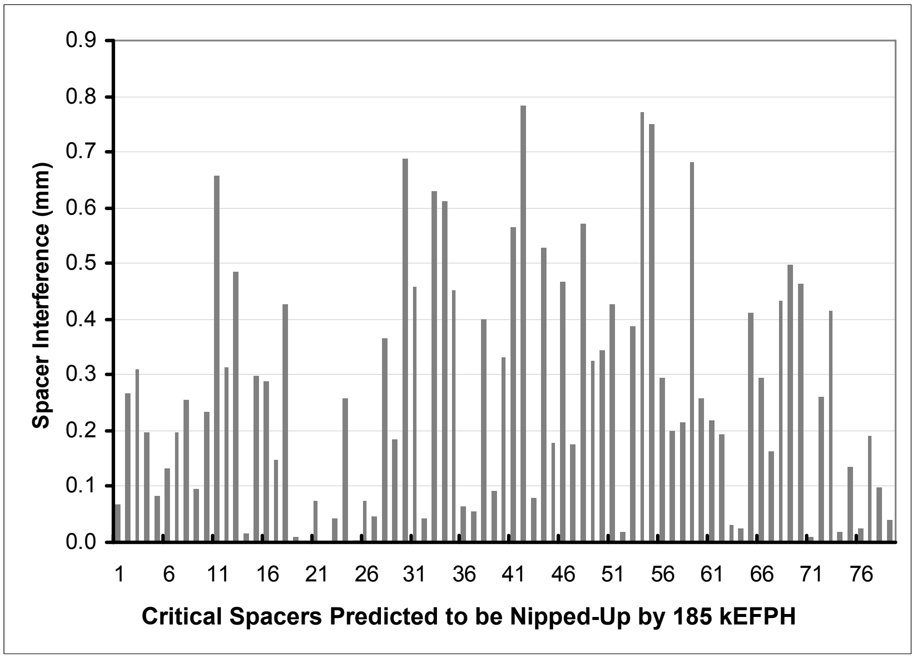
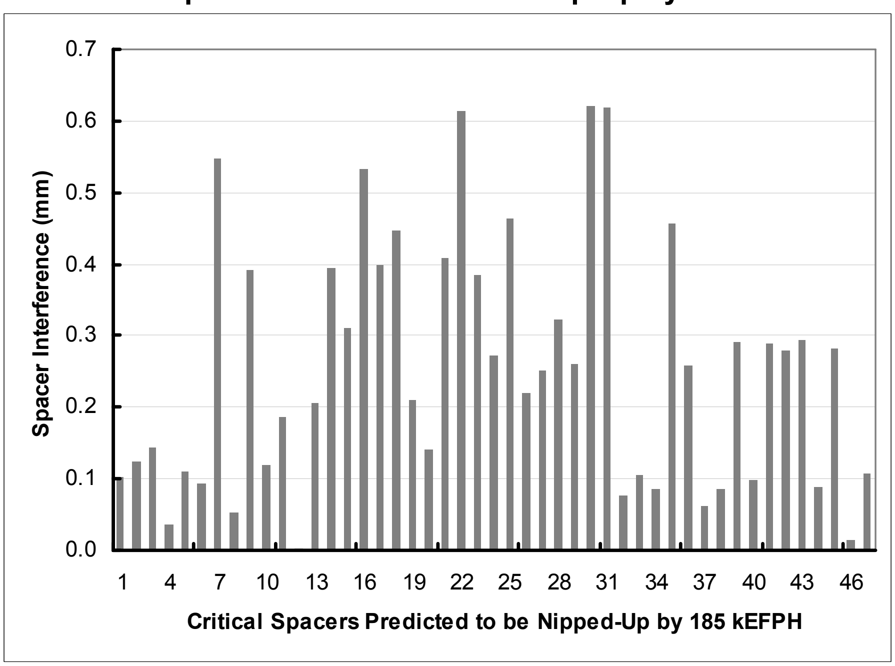


Figure 14 – Distribution of Calculated Spacer Interference Values for the 48 Critical Spacers Predicted to be at Nip-Up by 185 kEFPH



Spacer Clearances with PT Deformation, Gap Reduction, CT Diametral Expansion, CT As-Installed Dimensions, and PT As-Installed Dimensions

The analysis of Figure 15 was repeated using an estimated upper bound value for the PT initial OD, from Section 4.7. The results of the analysis, presented in Figure 16, show that nip-up was alleviated through the use of as-installed PT OD values in each of the channels assessed. Finally, with the use of as-installed PT dimensions, all of the PLGS channels assessed were predicted to be free of nip-up at 185 kEFPH.

Figure 15 – Distribution of Calculated Spacer Interference Values for the Critical Spacers Predicted to be at Nip-Up by 185 kEFPH Using As-Installed CT Dimensions

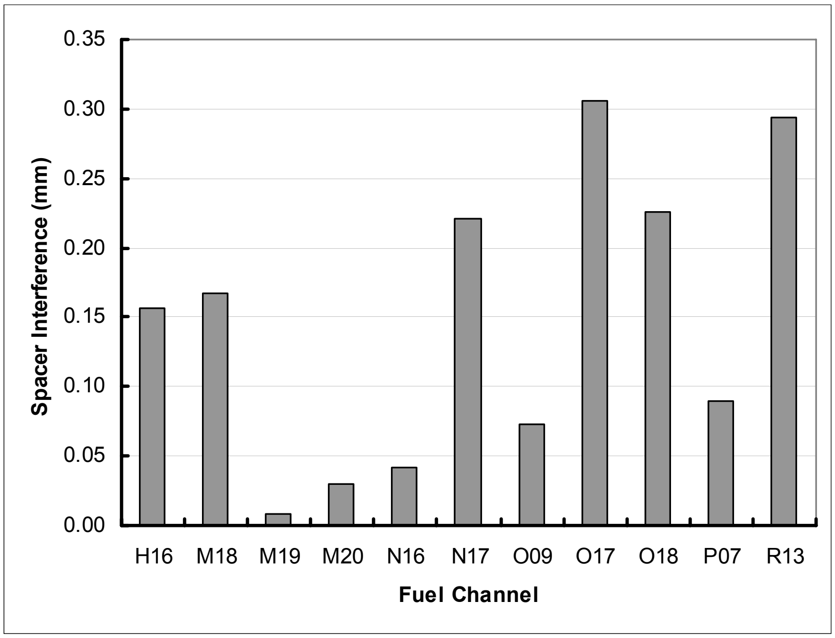
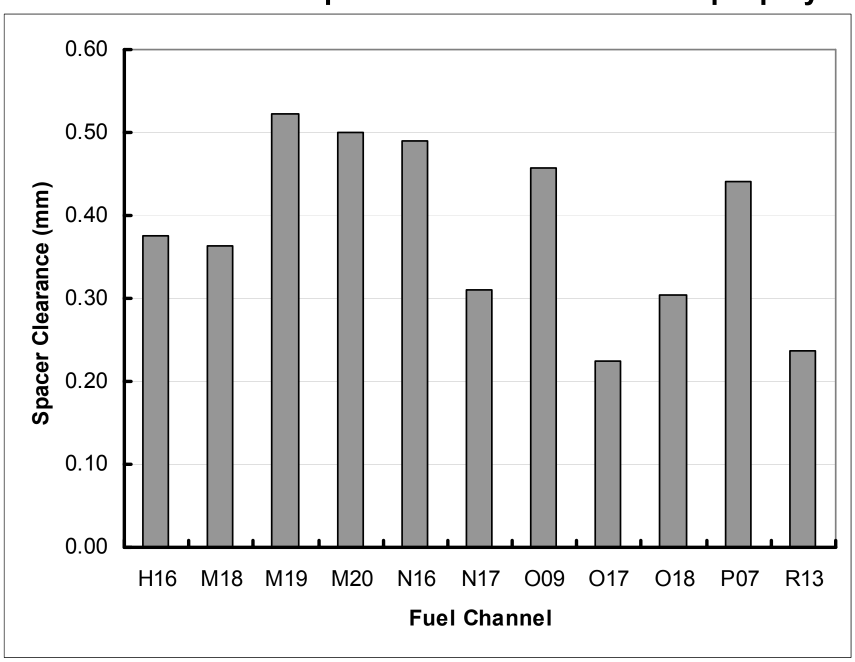


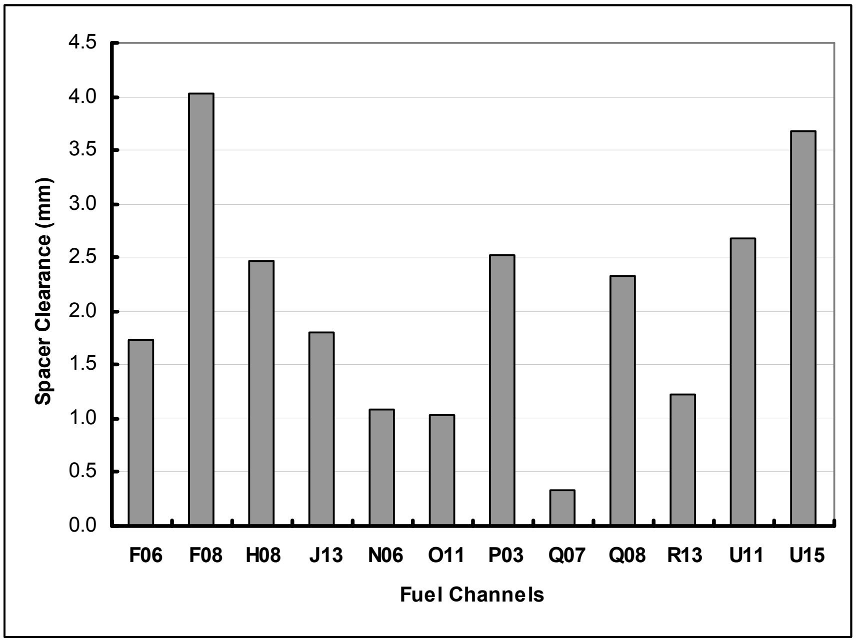
Figure 16 – Distribution of Calculated Spacer Clearance Values Using As-Installed PT Dimensions for the Critical Spacers Predicted to be at Nip-Up by 185 kEFPH



7.0 Spacer Clearance Predictions Based on Recent PT Inspection Results

Figure 17 presents a summary of the calculations of spacer clearance at 185 kEFPH that were performed using inspection results for the 12 channels inspected in 2004.

Figure 17 – Predicted Spacer Clearances at 185 kEFPH Based On Results from the PLGS 2004 Fuel Channel Inspection



It is predicted that none of the channels would reach nip-up by 185 kEFPH. In this assessment, no credit was taken for CT deformation and design basis dimensions were used for the CT and PT, which contributes significant conservatism to the spacer clearance predictions in Figure 17.

8.0 Discussion of Results

The prediction that nip-up could not occur by 185 kEFPH in PLGS is supported by the spacer clearances that were predicted in Figure 17 using PT inspection results, noting that there is significant conservatism in the empirically-based predictions of Figure 17.

In the calculation of the expansion of the CT vertical diameter due to creep under spacer loading, it was noted that CRNL 4001 does not predict significant diametral expansion of the CT. There are preliminary indications that a few mm of CT diametral expansion has occurred at spacer locations in the PLGS CTs and in Gentilly-2.

If the CT deformations in PLGS and Gentilly-2 are verified, a few mm of additional clearance can be added to the predicted interference/clearance values presented in this paper. In this case, the actual margins against nip-up for PLGS would be larger than predicted. This positive outcome for the PLGS fuel channels would be applicable to other CANDU reactors.

9.0 Conclusions

1. Based on the spacer clearance calculations presented, spacer nip-up could not have occurred in the PLGS fuel channels by 185 kEFPH.

2. CT deformation plays a significant role in preventing nip-up of the spacers in PLGS.

3. It is expected that nip-up will not be a fuel channel maintenance issue for the other CANDU 6 reactors besides PLGS.

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11.0 Acknowledgments

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