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Computing Channel RTD Systematic Errors Using Small Reactor Derates

V. Costiuc[*], *J. Handbury*[**], *T. Whynot*[***]

[*] *Senior Technical Specialist, Atlantic Nuclear Services Ltd., 500 Beaverbrook Court, P.O.Box 1268, Stn.A, Fredericton, N.B., E3B 5C8*

[**] *Senior Project Specialist, Atlantic Nuclear Services Ltd., 500 Beaverbrook Court, P.O.Box 1268, Stn.A, Fredericton, N.B., E3B 5C8*

[***] *Senior Technical Specialist, Reactor Physics Group, Point Lepreau Generating Station, N.B. Power, P.O. Box 10, Lepreau, N.B., E0G 2H0*

1.0 Introduction

To accurately measure CANDU channel flows using heat balance, it is important to determine the systematic errors (bias) in the 380 outlet feeder resistance thermal devices (RTDs). This is done by measuring the difference between the RTD reading and local saturation temperature when the channel coolant is boiling. Currently to assess whether a channel is boiling, the response of the RTD to a reactor run-up is analyzed, and thus biases can only be computed about once per year.

An alternative method[1.0], has been developed to determine which channels are boiling by measuring the response of all outlet feeder RTDs to a small reactor derate (1-3%), e.g. using the plant operational fuel derates. RTDs with small responses (below a pre-established criterion) are deemed to be in boiling and therefore RTD biases can now be updated on a regular basis. *DERATE* program has been coded in FORTRAN[2.0] to automatically compute biases.

2.0 Description of DERATE method

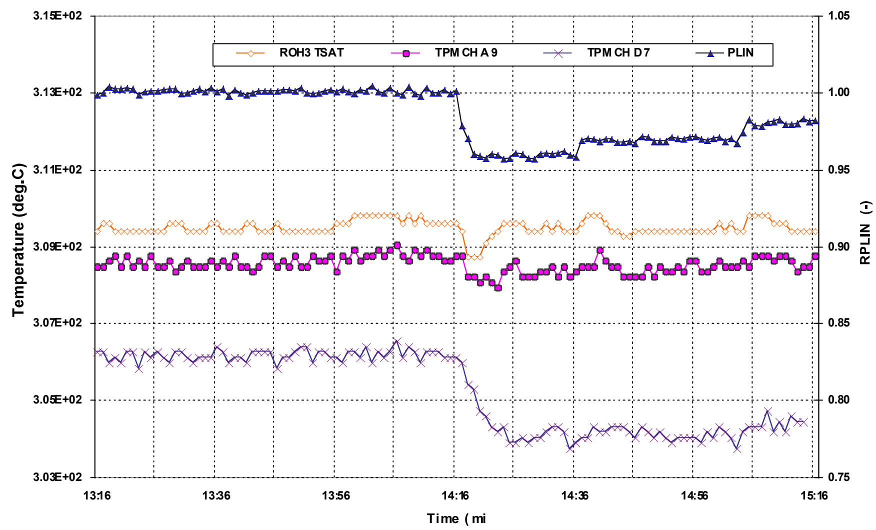
2.1 Assess which channels are boiling

Channels that remain saturated during the power derate have no outlet temperature response channel to decreasing power (outlet quality however is reduced). Figure 1 below shows the responses of channels A09 and D07 to a derate. A09 has no response to the derate thus is deemed to be boiling. Channel D07 outlet temperature decreases with power, which indicates it is not boiling. The following formula adequately flags those boiling channels:

$$(T_{RTD} - T_{SAT})^{FP} - (T_{RTD} - T_{SAT})^{DP} < B(^oC) \qquad \textbf{(1)}$$

where: T_{RTD}^{FP} - RTD reading at pre-derate power
T_{RTD}^{DP} - RTD reading during derate
T_{SAT}^{FP} – header saturation temperature at pre-derate pressure
T_{SAT}^{DP} – header saturation temperature at pressure during derate

Figure 1. Power Derateand Temperature Response From 07 Jan 1996



The B criterion is computed by assessing the total number of boiling channels for varying B values as shown in Figure 2. It has been shown that the optimum B occurs at the initial plateau point or when:

$$\frac{\Delta N}{\Delta B} \cong 0 \quad (2)$$

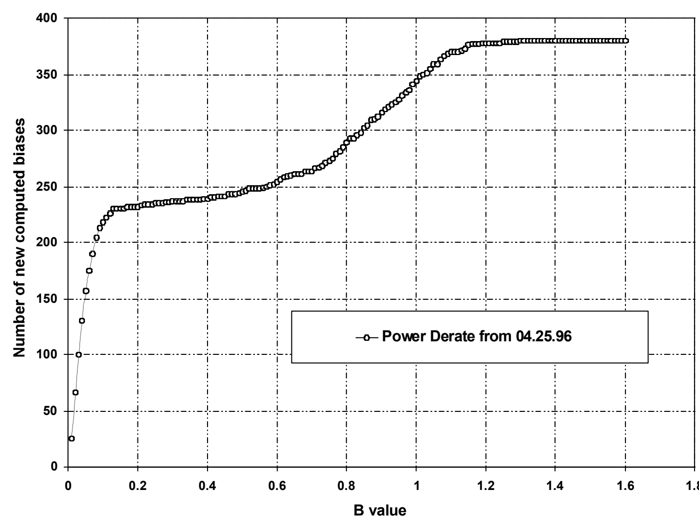


Figure 2.Number of new computed biases vs. "B" value
Power Derate from April 25, '96

Equation **(1)** includes a correction for varying saturation temperature at the RTD location since Reactor Outlet Header Pressure (PROH) can vary significantly during the derate. Figure 3 shows the PROH trend at a fuelling derate on 25 Nov. 1996 which indicates that PROH fluctuates during power changes. The *DERATE* code user should select a data collection period when PROH is stable.

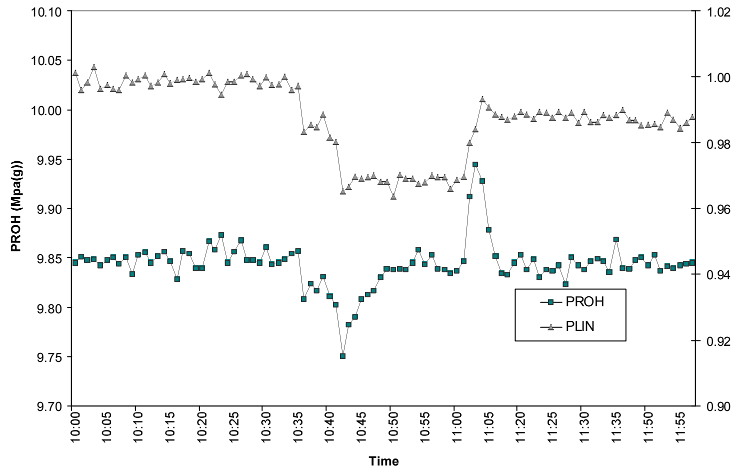


Figure 3. **Example of Power Derate From 96/11/25**

2.2 Computing Full Power Biases for boiling channels

The following formula is used to compute full power RTD biases(T^{FP}_{BIAS}):

$$T^{FP}_{BIAS} = T^{FP}_{SAT} - T^{FP}_{RTD} \quad \textbf{(3)}$$

T_{SAT}^{FP} is the local saturation temperature at the RTD location including the feeder pressure drop. The *convention* adopted at PLGS is that RTDs with negative biases read too high.

2.3 Computing Intermediate Power Biases

Since the RTD bias is usually used at reactor powers other than full power (i.e. flow verification at 77 % FP), it is required to determine RTD biases at intermediate reactor powers. This is done by linearly interpolating the RTD biases at Zero Power Hot (ZPH) and Full Power (FP). The ZPH biases are easily computed by comparing the RTD readings with the accurate Reactor Inlet Header Temperatures (TRIH), with small corrections for decay fuel power and T_{RIH} biases[3.0]. Below is the resulting formula used for computing intermediate RTD biases *(T^{INT}_{BIAS})*[4.0]:

$$T^{INT}_{BIAS} = \alpha + \beta * T^{INT}_{RTD} \quad \textbf{(4)}$$

where: α, β are the extrapolation constants and
T_{RTD}^{INT} is the measured RTD reading at the intermediate power.

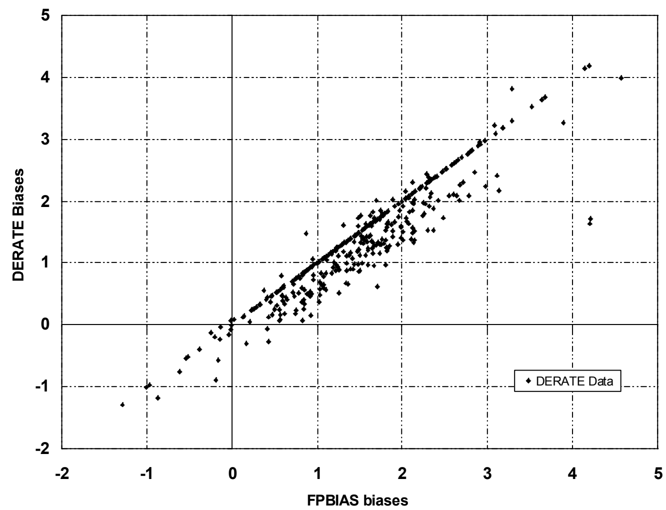
Equation **(4)** has been improved over an earlier formula, which computed intermediate biases as function of bulk reactor power. Equation **(4)** accounts for individual channel power variations.

3.0 Validation of Results

3.1 DERATE vs. FPBIAS Biases

Figure 4 shows an X- Y comparison for RTD biases computed using *DERATE* versus those from a reactor run-up (using *FPBIAS* code). The results compare favorable for most channels with a standard deviation of ±0.32°C. Some channels have large RTD differences and it has been shown that the *FPBIAS* computed bias is in error. This is due to the invalid flagging of non-boiling channels, which experienced local flux transients during the run-up (i.e. channels near Liquid Zone Controllers [LZC]).

Figure 4. Full Power Biases
Data from April 25,'96
(230 new computed biases for B = 0.15 deg.C)
(feeder pressure drop corrections applied)



A similar comparison has been done for intermediate power (77.0%)[5.0] as shown in the Figure 5. Again, the two methods compare favourably.

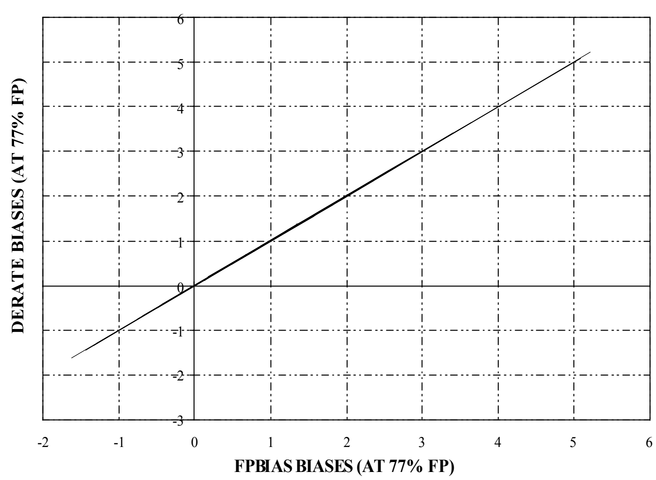


Figure 5. DEC'95 BIAS COMPARISON AT 77% FP
DERATE VS. FPBIAS Results

3.2 Bias variation for different derates

Figure 6 shows the X – Y comparison of *DERATE* computed RTD biases for different derates on the same day[6.0]. The results show good consistency with a standard deviation of their differences of ±0.016°C.

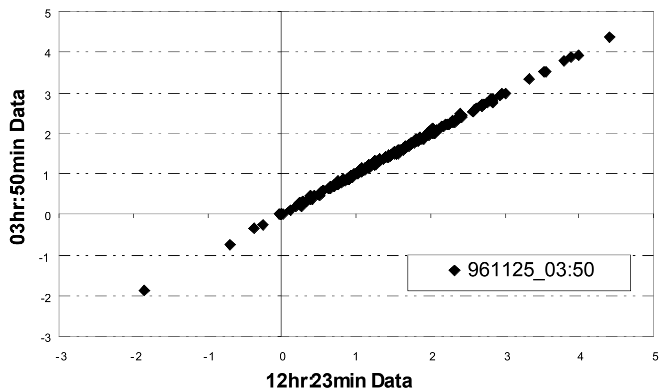


Figure 6. DERATE Code Results
96/11/25 (03h:50min) vs. 96/11/25 (10h:23
(206 compared values, average difference: 0.011d

4.0 Conclusions

The *DERATE* program provides a promising method for computing RTD biases which can be computed during normal operation. The algorithm is applicable only to small derates (2-3%). The accuracy of the method becomes adequate with an appropriate boiling criterion (B value). A conservative value of this criterion minimises the erroneous flagging of boiling channels. The temperature dependent Equation **(4)** eliminates the error in RTD biases due to channel burn-up or fuelling. Further verifications of the method are planned i.e. vs. NUCIRC code results and historical databases[7.0].

5.0 References

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3.0 *J. Handbury, PLGS Physics Internal Report, Analysis of TRIH Biases, PIR-97-008, Revision 0, April 24, 1997*

4.0 *J. Handbury, Verification of* $T_{BIAS} = \alpha + \beta * T_{RTD}$ *Relationship, Memo to E. Young, T.Whynot, Aug.26, 1998*

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