Entergy

Entergy Nuclear Northeast
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January 25, 2002

Re: Indian Point Unit No. 2
Docket No. 50-247
NL-02-013

Document Control Desk
U. S. Nuclear Regulatory Commission
Mail Stop O-P1-17
Washington, DC 20555-0001

SUBJECT: Response to Request for Additional Information Regarding Spent Fuel Storage Pit Analysis with Soluble Boron Credit, Indian Point Nuclear Generating Unit No. 2 (TAC No. MB2989)

References:
1. Entergy Nuclear Operations letter (NL01-110) to NRC, "License Amendment Request (LAR 01-010) for Spent Fuel Storage Pit Rack Criticality Analysis with Soluble Boron Credit," dated September 20, 2001
2. NRC letter to Entergy Nuclear Operations, "Request for Additional Information Regarding Spent Fuel Storage Pit Analysis with Soluble Boron Credit, Indian Point Nuclear Generating Unit No. 2 – (TAC No. MB2989)," dated November 30, 2001

By letter dated September 20, 2001 (Ref. 1), Entergy Nuclear Operations, Inc. (ENO) requested changes to the IP2 Technical Specifications (TS) to allow for soluble boron and fuel burnup in the criticality analysis for the spent fuel pit (SFP). The September 20 letter included, as Attachment 3, the Northeast Technology Corporation Report NET-173-01, "Criticality Analysis for Soluble Boron and Burnup Credit in the Con Edison [the former licensee] Indian Point Unit No. 2 Spent Fuel Storage Racks." The U.S. Nuclear Regulatory Commission (NRC) staff reviewed the request and determined additional information was required to complete its review. The NRC staff requested that additional information in its letter of November 30, 2001 (Ref. 2).

Attachment 1 to this letter provides the Entergy Nuclear Operations, Inc. (ENO – the current licensee) response to the NRC's request for additional information.

The assessment submitted in Ref. 1 that concluded that the proposed changes to the TS did not involve a significant hazards consideration is not affected by the additional information submitted herein in support of the application.

A001

This submittal contains a new commitment that is provided in Attachment 2.

Should you or your staff have any questions regarding this submittal, please contact Mr. John F. McCann, Manager, Nuclear Safety and Licensing at (914) 734-5074.

Very truly yours,

Fred Dacimo
Vice President – Operations
Indian Point 2

Attachments

cc: See page 3

cc:

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of ENTERGY NUCLEAR OPERATIONS, INC. Indian Point Nuclear Generating Unit No. 2	)))	Docket No. 50-247

APPLICATION FOR AMENDMENT
TO OPERATING LICENSE

Pursuant to Section 50.90 of the Regulations of the Nuclear Regulatory Commission (NRC), Entergy Nuclear Operations, Inc., as holder of Facility Operating License No. DPR-26, hereby submits additional information to support the application for amendment of the Technical Specifications contained in Appendix A of this license submitted on September 20, 2001.

The specific additional information is set forth in Attachment 1. The assessment submitted on September 20, 2001 demonstrated that the proposed change does not involve a significant hazards consideration as defined in 10CFR50.92(c). That assessment is unchanged by the additional information.

As required by 10CFR50.91(b)(1), a copy of this submittal has been provided to the appropriate New York State official designated to receive such amendments.

BY: [signature]
Fred Dacimo
Vice President – Operations
Indian Point 2

Subscribed and sworn to
before me this 25 day
January, 2002.

[signature] Ersilia A. Amanna (Bonnie)
Notary Public

ERSILIA A. AMANNA
Notary Public, State of New York
No. 01AM6039669
Qualified in Westchester County
Commission Expires March 20, 2002

ATTACHMENT 1 TO NL-02-013

Response to Request for Additional Information Regarding Spent Fuel Pit Criticality Analysis Using Credit for Soluble Boron and Fuel Burnup

ENTERGY NUCLEAR OPERATIONS, INC
INDIAN POINT UNIT NO. 2
DOCKET NO. 50-247

The NRC staff requested additional information that related to the information in NET-173-01. ENO provides the following responses to the questions asked by the NRC staff in their request for additional information (Ref. 2). The responses are presented in the three major categories as the information was requested.

Benchmarking

Question No. 1

Appendix A to NET-173-01 describes the benchmarking of computer codes SCALE-PC and CASMO-4 used for performing criticality and safety analysis sequence. In the computation of the mean bias and its standard deviation (Eqs. 3.1 and 3.2) associated with a SCALE-PC estimate of k_{eff}, provide a discussion of where and how are you taking account for the experimental error associated with each critical assembly measurement of k_{eff}. Also, describe how are you propagating that error into the final estimate of the SFP k_{eff}?

Response to Question No. 1

The individual reactivity effects from experimental uncertainties are given in the International Handbook of Evaluated Criticality Safety Benchmark Experiments and Reference 4 of Appendix A. For the critical experiments modeled in Appendix A, these bounding experimental measurement uncertainties result in increases in the bias uncertainty values ranging from +0.0012 to +0.0031 Δk_{eff} depending on the experiment. The bias uncertainty for the criticality experiments in Appendix A includes these experimental uncertainties. The methodology bias uncertainty is combined in a root-mean-square sense in the calculation of the 95/95 k_{eff}.

It is noted, however, that the uncertainty values reported are bounding, in that they include fuel rod tolerance effects that are assumed to be at the most conservative tolerance limit with respect to positive reactivity effects and are not necessarily representative of the actual experimental configuration. Without an assay of each fuel rod to accurately quantify the deviation from the nominal value (i.e., the as-built fabrication value) a realistic 'best estimate' of the effect of experimental uncertainty (i.e., tolerances) on k_{eff} cannot be exactly determined. The control of manufacturing processes usually precludes all fuel rods being at the upper bound of a manufacturing tolerance. Typically, some rods are in a slightly more reactive configuration, while others are in a less reactive configuration and the two tend to offset one another. As the critical experiments are high fidelity configurations and are modeled accordingly, the actual effect on bias uncertainty due to experimental measurement uncertainty is deemed negligible. Nonetheless, it has been conservatively included in calculating the sub-critical margin.

Question No. 2

In Tables 6-3 and 6-4 what are the reference k_{eff} values that are uncorrected for bias?

Response to Question No. 2

The reference eigenvalues (non-bias corrected) for Table 6-3 are 0.92520 for no soluble boron and 0.87520 with soluble boron. The corresponding values for Table 6-4 are 0.96495 without soluble boron and 0.91495 with soluble boron.

Question No. 3

In both KENO and CASMO, discuss how are you modeling (both geometric representation and compositions) the degraded Boraflex? How do you assure that in the calculation of the same unit cell that the 3-D representation of degraded Boraflex in KENO gives the same neutronic effect as the 2-D representation in CASMO? Are your bias estimates affected by the difference in modeling of the Boraflex?

Response to Question No. 3

Table 4-3 shows that an actual loss (including thinning, gaps, and local dissolution) of, for example, 20.8% ± 2.5% in Region 1, is equivalent in reactivity effect to pure thinning of 44.2%. Thus, in a 2D CASMO model, the pure thinning equivalent is used. In a KENO model, either the 2D equivalent model (e.g., for reference calculations) or the 3D model (e.g., for accident analyses) can be used, since both were shown to be reactivity equivalent.

In both CASMO and KENO, the Boraflex is modeled as pure ^{10}B, with no credit for the other constituents. The critical experiments used for benchmarking contained cases with absorber panels, as well as cases with no absorbers. Since no bias dependence on macroscopic absorber cross section was found, the effect on the bias of modeling geometry variation of the Boraflex panels is bounded.

Question No. 4

In order to meet the 95/95 keff ≤ 0.95 confidence criterion under accident conditions, you are crediting 1495 ppm of boron. In Regulatory Information Summary 2001-12, the NRC identified a concern that the results reported in NUREG/CR-6683 were indicating that reactivity equivalencing in the context of high boron concentrations can lead to non-conservative results. Discuss how you have addressed this concern.

Response to Question No. 4

As noted in Section 5.1, "The reactivity equivalencing bias accounts for potential deficiencies in the methodology of equivalencing the reactivity of depleted fuel to that of a fresh fuel assembly at a lower enrichment. For the analyses performed here, this bias is only applicable in calculations involving misplaced bundles and the interface between regions." For these analyses, bounding estimates of the bias were used to conservatively adjust the results. In all other cases, where equivalencing could become an issue, comparisons were made assuming the presence or absence of dissolved boron (whichever was more conservative), even if one case had boron and the other did not.

The soluble boron requirements for the accident conditions were determined based on the limiting differential boron worth. For each of the fuel rack regions defined in NET 173-01, the differential boron worth was calculated, at various burnups, enrichments and soluble boron concentrations (up to 1500 ppm) with CASMO. This was done to determine the minimum differential boron worth for the pool. This worth takes into account the reduced boron worth due to fission products, the spectral effects of residual Boraflex and increasing soluble boron concentration and rack geometry.

RACKLIFE

Question No. 1

In the first paragraph of Section 4.2, "Background," there are a list of assumptions (provided as bullets) that were relied upon in the RACKLIFE simulations. Explain in more detail the statement in the third bullet; in particular the statement about "placement of '95th percentile' assemblies...". Give a specific example to illustrate the meaning.

Response to Question No. 1

To micromanage the placement of assemblies in the IP2 pool would be a significant administrative burden. Thus, to simulate future refueling operations, 95th-percentile assemblies are used as representatives of all assemblies moved in operations subsequent to the RACKLIFE model used in this analysis. For example, it is projected that in late 2002 the current Cycle 15 core will be fully offloaded. The exact characteristics of the assemblies in that future discharge are unknown, as well as where assemblies will be placed in the Region 1 racks. An analysis of all previous Vantage+ assemblies discharged from IP2 is shown in Table 1-1 (page 5 of 36 of this Attachment). The table shows the 95th percentile highest initial fuel loading, enrichment, and power sharing, and the 95th percentile lowest (5th percentile highest) burnup; these selections increase the spent fuel gamma energy deposition to Boraflex from the mean. Comparing these percentiles with other distribution values shown in

the table illustrates how close to bounding these assemblies are. Even though only the full core of 193 assemblies could be placed into Region 1 after the end of Cycle 15, it is assumed that all 269 cells in Region 1, whether currently available or not, are populated with a 95th-percentile assembly discharged from Cycle 15.

The conservatism is further established with three additional points. First, percentiles within batches were used, instead of population percentiles, to account for the potential correlation of properties within batches. Second, the probability of having two "worst case" assemblies on either side of a panel of Boraflex is small. Having two 95th-percentile assemblies will bound the distribution of potential adjacent assemblies with greater than 95% confidence. Third, a 95th-percentile assembly, as developed here, is very likely bounding on actual assemblies. For example, an assembly with a 95th percentile power sharing will also have a high burnup, not a 5th percentile burnup.

Table 1-1
The 95th Percentile Vantage+ Assembly Discharged to Region 1 for Subsequent Reload

	Initial Fuel Loading [MTU]	Initial Enrichment [w/o U-235]	Burnup [MWD/MTU]	Power Sharing
All Vantage+ Assemblies				
Maximum	0.4246	4.9481	49131.9	1.422
95th percentile	0.4239	4.9455	47714.3	1.385
Average	0.4226	4.5808	31466.3	1.154
5th percentile	0.4213	4.3940	20533.1	0.845
Minimum	0.4209	4.3900	18464.6	0.517
Batch Q, Cycle 13 Discharge (Q-13)				
Maximum	0.4246	4.7980	28790.0	1.342
95th percentile	**0.4240**	4.7960	28260.8	1.317
Average	0.4229	4.4586	25864.5	1.234
5th percentile	0.4219	4.3939	22312.4	1.050
Minimum	0.4214	4.3900	20461.1	1.001
Batch Q, Cycle 14 Discharge (Q-14)				
Maximum	0.4246	4.7984	49131.9	1.111
95th percentile	0.4240	4.7961	48605.4	1.095
Average	0.4229	4.4586	44885.9	0.955
5th percentile	0.4219	4.3938	37060.1	0.640
Minimum	0.4214	4.3901	36480.8	0.517
Batch R, Cycle 14 Discharge (R-14)				
Maximum	0.4236	4.9481	26731.1	1.422
95th percentile	0.4233	**4.9475**	26579.3	**1.413**
Average	0.4221	4.8223	23745.0	1.270
5th percentile	0.4210	4.5993	**19727.9**	1.082
Minimum	0.4209	4.5954	18464.6	1.055
Values used in simulations	**0.4240**	**4.9475**	**19727.9**	**1.413**
From batch	Q-13	R-14	R-14	R-14

Question No. 2

Define the "escape coefficient" and whether the staff's assumption that it means (panel cavity flow)/(bulk pool flow) is correct. Is it an integral parameter valid over the whole pool region; or does each panel have its own escape coefficient?

Response to Question No. 2

Boraflex panels are typically enclosed in stainless steel racks. Sometimes this enclosure takes the form of a picture frame with rack cell walls on either side. Other rack designs have the Boraflex against a rack cell wall and covered by a wrapper plate (also called a cover plate or capture plate) that is bent around the sides and ends of the panel. These designs typically leave some space between the rack structure and the panel. This space, which is filled with spent fuel pool water, is called the panel cavity.

The panel cavities are manufactured such that they communicate with the bulk pool. Water flows into and out of a cavity at a rate called the escape coefficient. The water flowing out of the cavity transports both reactive silica and polymerized silica to the pool water, where it can be measured by pool chemistry. For a given panel and its associated panel cavity, the escape coefficient is the rate of fluid flow from the panel cavity to the bulk pool (and thus the rate of fluid flow from the bulk pool to the panel cavity) in liters/day per volume of fluid in the panel cavity in liters. It is thus a volumetric exchange rate normalized to the volume of the panel cavity. The escape coefficient is determined by iterative adjustment to closely match the reactive silica concentration, as measured by the plant chemistry personnel. This trend may indicate time varying values of the escape coefficient as the panels dissolve and thus, exchange a greater quantity of fluid with the bulk pool volume. Typically, the escape coefficients for various rack designs are consistent and thus, for a two region pool, the storage racks would be characterized by two escape coefficients – one for the flux-trap (Region 1) design and one for the "egg-crate" (Region 2) design.

Question No. 3

What is meant by "a geometric increase in the escape coefficient over time"? Also, provide the mathematical expression. How are the coefficients in the rate expression determined? Does the value of the coefficient vary from panel to panel for a given point in time? Over what range of the dependent variables is the estimate of the expression valid? What is the uncertainty in the coefficient? Does the uncertainty in the coefficient vary with time?

Response to Question No. 3

As a panel of Boraflex dissolves, its associated panel cavity becomes larger. This provides a larger cross sectional area for flow, which reduces the effects of skin friction on the flow. Thus, over time, the flow rate, a component of the escape coefficient, may increase. This increase can be observed as an increased rate of silica buildup in the spent fuel pool over time beyond what would be observed due to increasing absorbed dose alone. Based on the IP2 data it was observed that the escape coefficient increased by a factor of ~1.778 over the course of 961 days. To account for uncertainties, the time scale was reduced to 943 days (~2 years and 7 months). Conservatively modeling the increase as geometric (since the dissolution process is geometric, even though the reduction in skin friction is less than geometric), a future (t_n) escape coefficient (C_{esc}) for the i^{th} panel cavity, $C_{esc,i}(t_n)$, can be calculated from a previous (t_{n-1}) value as follows:

$$C_{esc,i}(t_n) = C_{esc,i}(t_{n-1})\ (1.778)$$

where $t_n = t_{n-1} + 943$

The result calculated at a given time is conservatively applied uniformly to the preceding 943 days. Thus, if a Region 1 cavity had an escape coefficient of 3.20 on 2000-02-21, it would be predicted to be 5.69 from 2000-02-21 to 2002-09-21, and 10.11 from 2002-09-21 to 2005-04-21.

Question No. 4

The second paragraph of Section 4.2 reads "If some of these assumptions prove to be invalid..., it is expected that the RACKLIFE model can be updated to reflect actual operating conditions and will show that the projections remain conservative." Why do you only "expect" that the projections will remain conservative? How do you plan to determine that the value of the escape coefficient is no longer valid? What statistical model do you employ to determine whether the escape coefficient is still valid? What measurements and at what interval contain this information? Are the measurements following the same Boraflex panels as function of time/dose?

Response to Question No. 4

The use of the word "expected" is meant to convey the idea that for all "anticipated and credible" violations of the assumptions, the projections will remain conservative. Consider the following example, albeit unrealistic. Suppose that somehow spent fuel assemblies were discharged from the reactor far in advance of the time mandated by the Plant Technical Specifications. This would violate an assumption in the model, and would likely result in effects (e.g., higher absorbed doses) that could not be mitigated by updating the model to reflect actual operations up to that time.

The validity of the projected escape coefficients in the IP2 spent fuel pool will be verified by tracking the measured spent fuel pool silica levels against those projected by RACKLIFE. If silica trends showed that the conservative levels predicted by RACKLIFE might be exceeded at some future date, then there would be enough lead time to perform a new BADGER test to recalibrate the model. Statistical models would not be necessary for this analysis. Currently, IP2 plant personnel update the silica data in the RACKLIFE model on a one to two month cycle; this is sufficient for trend comparisons with the RACKLIFE predictions.

Further, with respect to measurements, Entergy has adopted a "defense in depth" strategy of Boraflex surveillance at Indian Point 2[1] to assure that the design basis of the fuel storage racks is maintained.

The first level of defense includes the following surveillance activities:

- Surveillance Coupon Program
- Monitoring Pool Reactive Silica Levels
- Tracking Industry Experience with Boraflex
- RACKLIFE Modeling of the pool and racks

As elevated pool silica levels and results from the surveillance coupon program indicated the onset of Boraflex deterioration, the second level of defense, BADGER testing and RACKLIFE modeling, was implemented. The BADGER test results confirmed the RACKLIFE projections and the third level of defense has been implemented. This includes the analysis package described in NET-173-01 with partial credit for Boraflex, depending on the extent of Boraflex deterioration observed. Soluble boron credit and decay of Pu-241 has been assumed in the analysis, which compensates for the loss of neutron absorbers. Future measures to further compensate for Boraflex degradation may be applied. Such measures may include use of neutron absorber inserts and the application of administrative controls.

<u>Question No. 5</u>

What (i.e., "state of the panels") does RACKLIFE project and how is it done? Define the term "state of a panel." Explain and give the unit(s) of the degradation measure(s). Given the state of a particular panel at some time t_1, does RACKLIFE give the state of the same panel at some later time t_2, or does it give the mean state of all the panels with an associated variance?

<u>Response to Question No. 5</u>

The "degradation" of a panel in RACKLIFE is measured as a percent boron carbide loss from the as-built condition (actually, as a "percent remaining"). RACKLIFE allows viewing output on a pool average basis versus time or for individual panels at a specific

[1] See response to NRC Generic Letter 96-04

point in time. The following is an edited excerpt of the introduction to the RACKLIFE theory and numerics report; it summarizes what RACKLIFE does, how it does it, and what a state point is:

> 'RACKLIFE simulates the loss of the criticality controlling neutron absorber boron carbide (B_4C) from Boraflex as the latter dissolves in the spent fuel pool water. The boron carbide itself does not dissolve in water, but the silica matrix that binds it does, particularly after irradiation. Since silica can be measured in the pool water, silica dissolution and transport can be simulated based on the measured data, and from the results the amount of boron carbide loss from each panel can be calculated.
>
> The amount of data that RACKLIFE can generate is potentially enormous. Consider a moderate sized BWR spent fuel pool with 2,500 rack storage cells and 5,000 panels of Boraflex. Simulation data (the state variables of silica, temperature, radiation dose, boron carbide loss, etc.) must be computed for each of these panels at each time step. In addition, the numerical solution of the silica kinetics equations must be executed simultaneously for all of the panels and the pool. Tracking all eleven state variables for just 5,000 panels hourly for a 20 year simulation results in well over 100 billion floating point operations performed on 10 billion state point variables over 175,000 time steps. Thus RACKLIFE has been organized to be selective in its output of all of this data; the output of the state variables at a point in time is called a "state point".
>
> Each Boraflex panel is contained in a water-filled volume referred to as a panel cavity. The Boraflex panel provides a (finite) source of silica which can dissolve into the cavity water. The amount of silica dissolution is a function of the radiation dose that the Boraflex has absorbed, the temperature, the pH, the presence of solubility inhibitors, and the amount of silica already in solution.
>
> The dissolved silica results in some concentration of aqueous reactive silica in the panel cavity. Reactive silica has an equilibrium concentration, above which no further silica will dissolve into the water. As silica concentrations in the water increase, however, reactive silica will form polymerized silica and colloidal particles, without limit, thereby reducing the reactive silica concentration and allowing for more Boraflex dissolution. The sum of reactive and polymerized/colloidal silica is referred to as total silica. Concentrations of reactive silica are relatively easy to measure, while total silica is quite difficult.'

Question No. 6

How are the RACKLIFE projected results translated into the requisite input values for KENO and CASMO calculations for some future time? What is the sensitivity of the RACKLIFE computed state of a Boraflex panel to a change in the escape coefficient?

Response to Question No. 6

Table 4-3 of NET 173-01 shows the equivalent loss of a panel for the rack regions defined. KENO 3-D models of explicit Boraflex panel dissolution (as measured by BADGER) were created to determine the reactivity effect. The reactivity effect of pure thinning was then determined by creating KENO 2-D models, in which panel thinning (thickness reduction) was the sole dissolution mode and iterating to find the equivalent thickness that produced the same reactivity effect. RACKLIFE assumes a uniform boron carbide loss, whereas in reality, dissolution of the polymer matrix may be local or uniform. In this manner, 3-D reactivity effects could be translated into a 2-D model. As stated in Question 3 above, modeling of the geometric increase in escape coefficient was made based on the historical measured silica trend.

The uncertainty in escape coefficient on predicted boron carbide loss can vary based on the specific rack design (in particular the boraflex cavity volume). Typically an uncertainty of +20% in escape coefficient may produce a relative increase of 15-20% in the predicted B_4C loss, that is, if you are originally predicting 5% loss, you would see an additional +0.75-1% loss for a 20% increase in escape coefficient.

Badger Measurements

Question No. 1

On page 4-3, the second paragraph starting with “Models of the panels…” is confusing. Rewrite the material and make the relationships (especially statistical) clear and introduce figures, where necessary.

Response to Question No. 1

To clarify the discussion on Page 4-3 of NET-173-01, Section 2 from NET-170-02 has been reproduced as an aid[2], as one should be familiar with NET-170-02 to understand the methodology employed in taking credit for residual Boraflex. The Appendices referred to on page 4-3, simply illustrate the specific panel dissolution for the panels that characterize each region, similar to Figure 4-1 of NET-173-01.

When the work in NET-170-02 was completed, Region 1 was divided into three zones: Zone 1-1 was bounded by 100 percent Boraflex loss, Zone 1-2 bounded by 27 percent loss and Zone 1-3 bounded by 10 percent loss. In a similar manner, Region 2 was

[2] See Appendix A to this attachment

divided into four zones: Zone 2-1 bounded by 100 percent Boraflex loss, Zone 2-2 bounded by 23 percent loss, Zone 2-3 bounded by 5 percent loss and Zone 2-4, which could be either 100 percent or 23 percent, depending upon how it is utilized. In order to facilitate rack management in the current analysis, zones 2 and 3 in Region 1 were conservatively collapsed into one zone bounded by 50 percent loss. Zones 2, 3 and 4 in Region 2 were conservatively collapsed into one zone bounded by 30 percent loss.

Question No. 2

In Example 1, "Loss Equivalence," on page 4-4, what is meant by "a strong bias towards the 'worst' panels"? The NRC staff believes that the issue is not the worst degraded panel, but rather the panel with the worst degradation rate. Given that you have measurements only at one time point (February 2000), how can you determine a degradation rate and make projections to which an uncertainty can be assigned to eventually compute the 95/95 k_{eff} of the spent fuel pool with degraded Boraflex panels?

Response to Question No. 2

In selecting panels for BADGER testing, RACKLIFE is used to identify those panels, which have sustained the greatest boron carbide loss. The panels, which have sustained the greatest loss, are typically those, which have absorbed a high gamma dose early in their service life. The majority of the panels tested consist of these high B_4C loss panels. Accordingly, the population of panels used for the subsequent criticality analysis is based on these high B_4C loss panels in 2000 and an extremely conservative projection of their condition in 2006.

Based on the projected discharge schedule provided by Entergy, bounding assemblies (shown in the table in response to RACKLIFE Question 1) were selected to represent those being discharged in future cycles. The dissolution modes of Boraflex modeled in RACKLIFE are well known to be primarily dependent on absorbed dose and residence time. The dose to an assembly is primarily dependent on end of cycle power sharing (assembly normalized power). The silica release rate as a function of absorbed dose, pool temperature and pH has been studied extensively via laboratory testing, thus the release rate calculated by RACKLIFE (and consequently, the degradation rate) is well known. Based on the offload schedule provided by Entergy and using conservative (with respect to end-of-cycle relative power) bundles being discharged, the worst panel degradation rates will be accelerated in determining the state of the Boraflex panels in 2006. As a verification of the RACKLIFE predictions, BADGER testing will be performed again in 2003 to confirm that the assumptions used in the current analysis are still valid. This provides sufficient time for any additional mitigation measures to be implemented.

Appendix A

[Section 2 of NET-170-02]

2.1 Region 1 Panels

Based on the IP2 RACKLIFE model, the Region 1 racks in 2006 can be divided into three distinct zones, characterized by their degree of B_4C loss. These zones are illustrated in Figure 2-1.

Zone 1-1. Module A and the north end of Module B.

BADGER testing in 2000 showed that, of the 13 cells tested in this zone, the average B_4C loss was 10.3% and the maximum loss was 17.9%. However, conservative RACKLIFE projections show that by the end of 2006 many of these panels will have completely dissolved. Figure 2-2 shows the distributions of RACKLIFE estimated B_4C loss from all panels in this zone in 2000 and 2006. The projections show significant loss throughout this zone. Each stair step in Figure 2-2 shows the fraction of panels that have sustained the loss covered by the step. For example, the last step to the right in the 2006 projections shows that 14.1% of all panels in the zone have sustained between 95% and 100% loss.

Because of this large loss, there is too much uncertainty in making projections and tallying reactivity credit for the remaining Boraflex. Thus, this zone is characterized as having 100% loss of Boraflex. Note that this is based on a conservative RACKLIFE model; future models that track actual operations in the pool over the coming years may make projections of reactivity credit viable.

Zone 1-2. The south end of Module B.

Figure 2-3 shows the distributions of RACKLIFE estimated B_4C loss from all panels in this zone in 2000 and 2006. In contrast to Figure 2-2, these projections show only moderate loss in this zone, bounded by 27% loss. Thus, predictable amounts of credit for the remaining Boraflex can be quantified in this zone.

Zone 1-3. Module C.

Figure 2-4 shows the distributions of RACKLIFE estimated B_4C loss from all panels in this zone in 2000 and 2006. These projections show that while a few isolated panels are approaching 10% loss, over 80% have sustained only 2% loss or less. Significant credit for Boraflex can be expected for this zone.

The panels measured in early 2000 can be used as a set of representative panels for Zones 1-2 and 1-3 that can conservatively take credit for Boraflex. Table 2-1 shows how the 20 panels measured in the Region 1 racks during the BADGER campaign can

be allocated to the zones in Region 1. The first column of check marks indicates two panels that were measured by BADGER to have gained areal density. This seemingly non-physical result is actually a measure of the uncertainty in the initial areal density of any Boraflex panel. Manufacturing uncertainties in B_4C loading and thickness mean that material certifications are necessary to know precisely the initial areal density of a panel so that changes from that value can be quantified. However, these material certifications were not available so the nominal areal density was assumed. Excluding these apparent gains from being representatives is conservative.

The second column of check marks indicates the "zero-dose" panels tested – panels that have accumulated a negligible amount of dose and hence would not be expected to exhibit significant loss. Excluding these panels from being representatives is conservative.

The third column of check marks in Table 2-1 is for panels that will represent Zone 1-2. The second column of Table 2-2 shows that the BADGER measured losses to these panels do not approach the 27% maximum loss predicted by RACKLIFE for this zone in 2006. Thus the losses to these panels must be projected from a maximum of 17.9% (BADGER measured in 2000) to 27% (RACKLIFE predicted for 2006), an increase of a factor of about 1.5. To account for this, the distribution of losses in these panels was increased by a factor of 1.5 to project the character of these panels to the higher losses. The local distribution values are then conservatively rounded up to the nearest 1/3rd inch gap size and 5% local dissolution loss, as described in Appendix A. The target panel losses for these panels are shown in the last column of Table 2-2. Figure 2-5 compares the loss distributions for the sample and the Zone 1-2 projections.

Figure 2-6 compares the cumulative distributions for the sample panels and the Zone 1-2 projections. Since the sample distribution is below the predicted distribution, the sample is a conservative representation of the Boraflex panels in Zone 1-2. For example, only about 57% of the panels in the sample have sustained less than 25% loss, while over 89% of the actual projected panels are at less than 25% loss. Thus the sample has more panels over 25% loss than the predictions it is meant to represent.

The two panels in the third column of Table 2-1 marked with asterisks, B14N and B14S, were not part of the selection for Zone 1-2 because they were measured as having losses below 10% (with BADGER measurements of 3.9% loss each). However, the distribution of their loss is largely manifested as gaps that exceed predicted gap sizes for these panels. The low loss is likely an offset due to a higher than average initial areal density. For conservatism, these two panels are included in the sample so that their gap and local dissolution distributions are accounted for; however, their areal densities are reduced to match the mean areal density of the remainder of the sample.

The last column of check marks are the panels that, at the time of BADGER testing, exhibited 10% loss or less. The distribution of gaps and local dissolution in these

panels is thus representative of the panels in Zone 1-3, which, as noted above, have sustained less than 10% loss. The actual losses measured by BADGER for these panels are shown in Table 2-2. (The RACKLIFE predictions in 2006 for these specific panels, discussed previously, are also shown.) As noted above, the losses in Zone 1-3 are generally well below 10%. Figure 2-7 compares the distribution of loss for this sample of BADGER measured panels with the RACKLIFE predictions for all panels in Zone 1-3. Figure 2-8 compares the distributions as cumulative distributions. Again, because the sample cumulative distribution is below the projected Zone 1-3 cumulative distribution, the sample is conservative with respect to loss.

The characteristics of each panel in the sample of panels representative of Zone 1-2 are shown in Appendix A. The interpretation of these figures is described there. The characteristics of each panel in the sample of panels representative of Zone 1-3 are shown in Appendix B

2.2 Region 2 Panels

Based on the IP2 RACKLIFE model, the Region 2 racks in 2006 can be divided into four distinct zones, characterized by their degree of B_4C loss. These zones are illustrated in Figure 2-1.

Zone 2-1. Modules D, E1, and the north end of Module E2.

BADGER testing in 2000 showed that, of the 20 cells tested in this zone, the average B_4C loss was 7.4% and the maximum loss was 21.7%. However, conservative RACKLIFE projections show that by the end of 2006 a few of these panels will have completely dissolved. Figure 2-9 shows the distributions of RACKLIFE estimated B_4C loss from all panels in this zone in 2000 and 2006. The projections show significant loss scattered throughout this zone with most panels between 40% and 60% loss but a few reaching 100% loss. As for the figures in Section 2.1, each stair step in Figure 2-9 shows the fraction of panels that have sustained the loss covered by the step. For example, the last step to the right in the 2006 projections shows that 4.1% of all panels in the zone have sustained between 95% and 100% loss.

Because of the large loss to most panels in this zone, there is too much uncertainty in making projections and tallying reactivity credit for the remaining Boraflex. Thus, this zone is characterized as having 100% loss of Boraflex. Note that this is based on a conservative RACKLIFE model; future models that track actual operations in the pool over the coming years may make projections and reactivity credit viable in some parts of this zone.

Zone 2-2. Modules E3, F2, G1, and G2.

Figure 2-10 shows the distributions of RACKLIFE estimated B_4C loss from all panels in this zone in 2000 and 2006. In contrast to Figure 2-9, these

projections show only moderate loss in this zone, bounded by 23% loss. Thus, predictable amounts of credit for the remaining Boraflex can be quantified in this zone.

Zone 2-3. Module H and the south end of Module E2.

Figure 2-11 shows the distributions of RACKLIFE estimated B_4C loss from all panels in this zone in 2000 and 2006. These projections show that all of the panels will have sustained less than 5% loss. Significant credit for Boraflex can be expected for this zone.

Zone 2-4. Module F1.

Figure 2-12 shows that this zone is difficult to characterize. In 2000 the panels in this zone had similar or less loss than the panels in Zone 2-2. However, in the RACKLIFE simulations to 2006 this module was used to store the discharged fuel from cycles having outages after 2000. The effect on this module is significant, especially because of the conservative assumptions that the simulations were based on. The maximum predicted loss in Module F1 is almost 60%, though the majority of the panels are clustered around 46% and 24% loss. The disposition of this module will depend on the results of a criticality safety analysis for the IP2 spent fuel pool. If Zones 2-2 and 2-3 provide sufficient space for the higher reactivity bundles in the IP2 pool, then this module can be classified as part of Zone 2-1, with no credit for the Boraflex. If Boraflex credit is needed in this module, however, then a detailed cell-by-cell analysis might be required. Note that as operations continue at IP2 and the RACKLIFE model is updated, it may be shown that the projections are overly conservative and that this module can be included as part of Zone 2-2.

The panels measured in early 2000 can be used as a set of representative panels for Zones 2-2 and 2-3 that can conservatively take credit for Boraflex. Table 2-3 shows how the 20 panels measured in the Region 2 racks during the BADGER campaign can be allocated to the zones in Region 2. The first column of check marks indicates eight panels that were measured by BADGER to have gained areal density. As for the Region 1 panels, this is a measure of the uncertainty in the initial areal density of any Boraflex panel. Excluding these apparent gains from being representatives is conservative. The second column of check marks indicates the "zero-dose" panels tested – panels that have accumulated a negligible amount of dose and hence would not be expected to exhibit significant loss. Excluding these panels from being representatives is conservative.

The third column of check marks in Table 2-3 is for panels that will represent Zone 2-2. Table 2-4 shows that the BADGER measured losses to these panels do not quite approach the 22.9% maximum loss predicted for this zone in 2006. Thus the losses to these panels must be projected from a maximum of 21.7% (BADGER measured in 2000) to 22.9% (RACKLIFE predicted for 2006), an increase of a factor of about 1.06.

This small increase is within the BADGER uncertainty and is smaller than the resolution with which the panels are characterized in the appendices. Therefore, this increase will be handled as a reduction in the uniform areal density. The target panel losses for these panels are shown in the last column of Table 2-4. Figure 2-13 compares the loss distributions for the sample and the Zone 2-2 projections.

Figure 2-14 compares the cumulative distributions for the sample panels and the Zone 2-2 projections. Since the sample distribution is below the predicted distribution, the sample is a conservative representation of the Boraflex panels in Zone 2-2. For example, only about 86% of the panels in the sample have sustained less than 20% loss, while over 99% of the actual projected panels are at less than 20% loss. Thus the sample has more panels over 20% loss than the predictions it is meant to represent.

The three panels in the fourth column of Table 2-3 marked with asterisks were not part of the selection for Zone 2-2 because they were measured as having gained areal density with respect to the as-manufactured nominal areal density. However, the distribution of their loss is largely manifested as gaps that exceed predicted gap sizes for these panels. The low loss is likely an offset due to a higher than average initial areal density. For conservatism, these panels are included in the sample so that their gap and local dissolution distributions are accounted for; however, their areal densities are conservatively reduced.

The last column of check marks are the panels that, at the time of BADGER testing, exhibited low loss, or had absorbed a low dose. The distribution of gaps and local dissolution in these panels is thus representative of the panels in Zone 2-3, which, as noted above, have sustained less than 5% loss. The actual losses measured by BADGER for Region 2 panels are shown in Table 2-4. (The RACKLIFE predictions in 2006 for these specific panels, discussed previously, are also shown.) Figure 2-15 compares the distribution of loss for this sample of BADGER measured panels with the RACKLIFE predictions for all panels in Zone 2-3. Figure 2-16 compares the distributions as cumulative distributions. Again, because the sample cumulative distribution is below the projected Zone 2-3 cumulative distribution, the sample is conservative with respect to loss.

Table 2-1: Allocation of BADGER-Tested Panels to Region 1 Zones

Panel ID	Above Nominal	Zero Dose	Zone 1-2	Zone 1-3
A14E			√	
A14N			√	
A14S			√	
B14N			*	√
B14S			*	√
B14W			√	
B15S				√
B15W			√	
B17E				√
B17S				√
B17W			√	
D9N			√	
D9S				√
E10N	√			
H21N	√			
J20S				√
J20W				√
J25N		√		
J25S		√		
J26N		√		

Table 2-2: BADGER Measured, RACKLIFE Predicted, and Target Losses for Zone 1-2 for the 20 BADGER-Measured Region 1 Panels

Panel ID	BADGER Measured Loss in 2000	RACKLIFE Predicted Loss in 2006	Target Loss for Zone 1-2
A14E	13.4%	100.0%	20.3%
A14N	14.7%	100.0%	22.2%
A14S	17.6%	100.0%	26.6%
B14N	3.9%	99.9%	
B14S	3.9%	97.6%	
B14W	15.4%	93.7%	23.3%
B15S	2.7%	100.0%	
B15W	17.9%	100.0%	27.0%
B17E	10.0%	60.6%	
B17S	3.6%	63.2%	
B17W	15.8%	60.5%	23.9%
D9N	17.3%	85.4%	26.1%
D9S	9.7%	76.6%	
E10N	-2.3%	82.5%	
H21N	-8.1%	25.0%	
J20S	2.3%	18.2%	
J20W	7.4%	18.9%	
J25N	-13.4%	1.6%	
J25S	-0.3%	1.6%	
J26N	1.5%	1.6%	

Table 2-3: Allocation of BADGER-Tested Panels to Region 2 Zones

Panel ID	Above Nominal	Zero Dose	Zone 2-2	Zone 2-3
CG50N			√	
CH41E	√		*	
CH45N			√	
CH45S			√	
CH45W			√	
CH51N			√	
CH51S			√	
CJ40E	√			*
CJ42E	√		*	
CJ42N			√	
CK41W	√		*	
CL40E	√			*
CL40W			√	
CL42W			√	
CL46E			√	
CL46W			√	
CN40E	√		√	
CN40W	√			*
DP66N		√		√
DP66S	√	√		*

Table 2-4: BADGER Measured, RACKLIFE Predicted, and Target Losses for Zone 2-2 for the 20 BADGER-Measured Region 2 Panels

Panel ID	BADGER Measured Loss in 2000	RACKLIFE Predicted Loss in 2006	Target Loss for Zone 2-2
CG50N	13.5%	13.5%	14.3%
CH41E	-9.2%	18.8%	
CH45N	21.1%	15.8%	22.3%
CH45S	21.7%	16.3%	23.0%
CH45W	10.7%	19.4%	11.3%
CH51N	9.0%	95.4%	9.5%
CH51S	8.4%	99.2%	8.9%
CJ40E	-0.8%	2.8%	
CJ42E	3.3%	30.5%	
CJ42N	9.3%	22.9%	9.8%
CK41W	-1.5%	28.1%	
CL40E	-5.7%	2.9%	
CL40W	11.9%	3.1%	12.6%
CL42W	11.1%	34.5%	11.8%
CL46E	16.4%	69.5%	17.4%
CL46W	16.9%	42.4%	18.0%
CN40E	13.3%	2.3%	14.1%
CN40W	-0.6%	2.9%	
DP66N	6.2%	4.6%	
DP66S	-7.1%	4.5%	

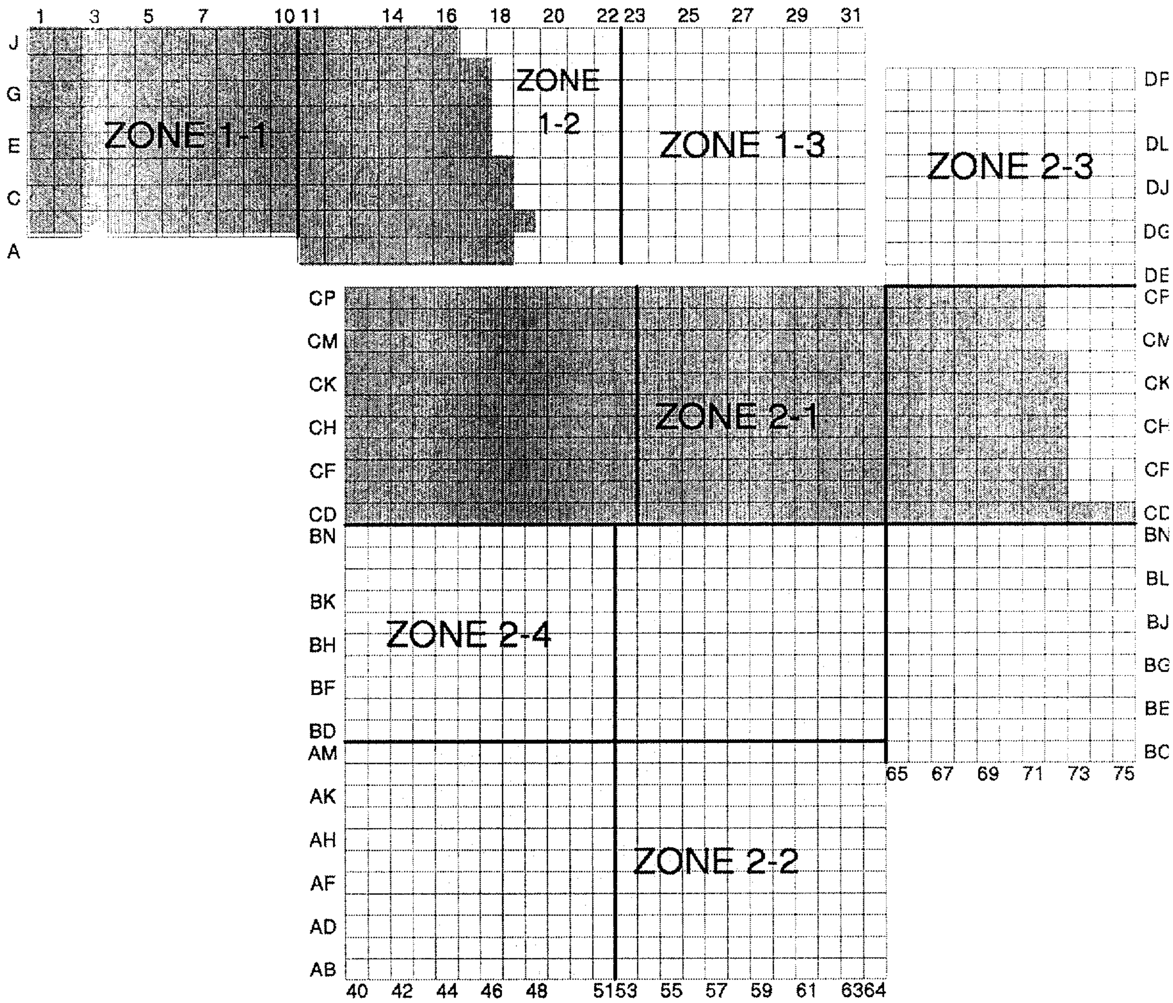

Figure 2-1: Pool Layout of Zones

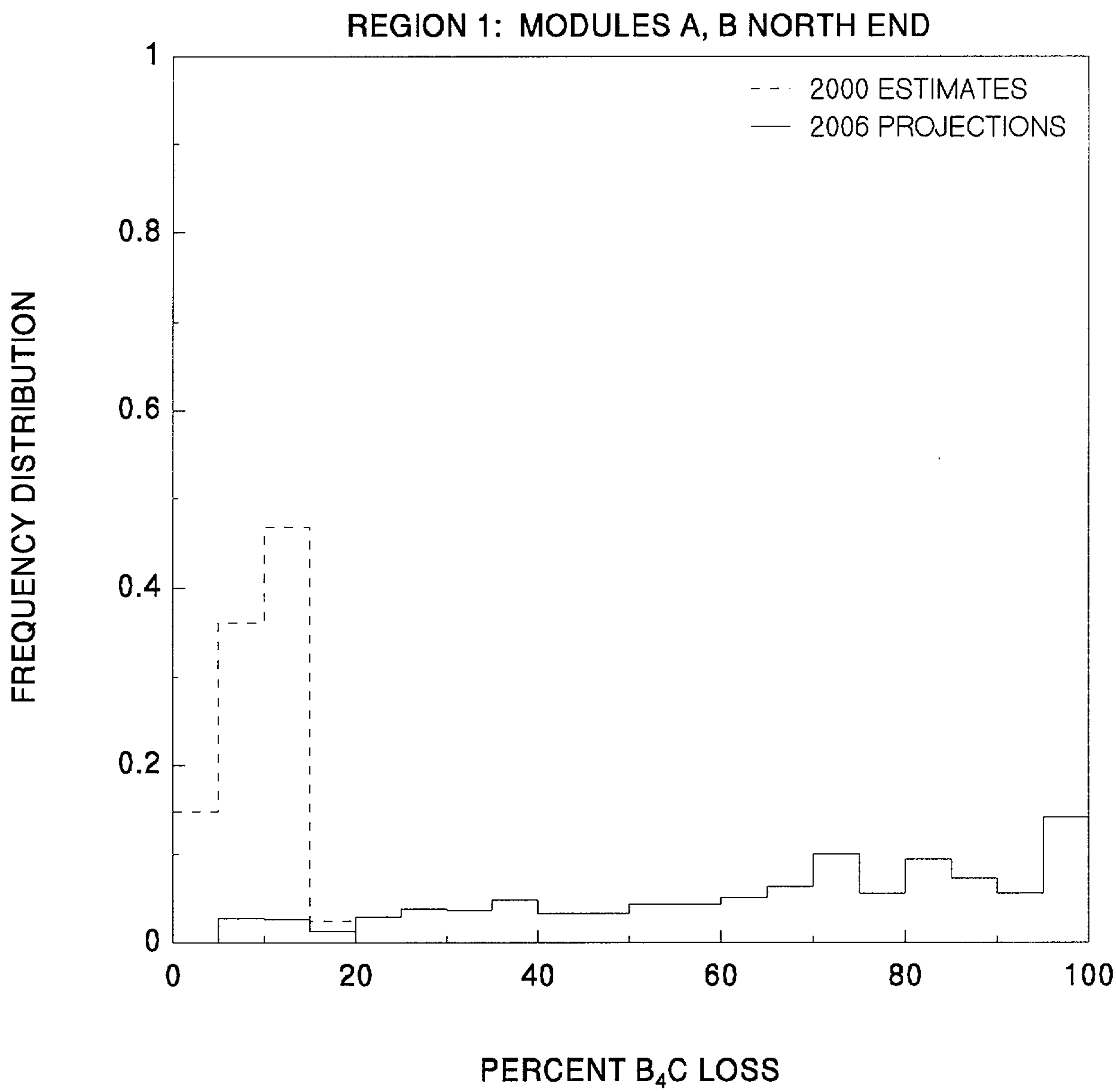

Figure 2-2: Distribution of Panel Loss in Zone 1-1

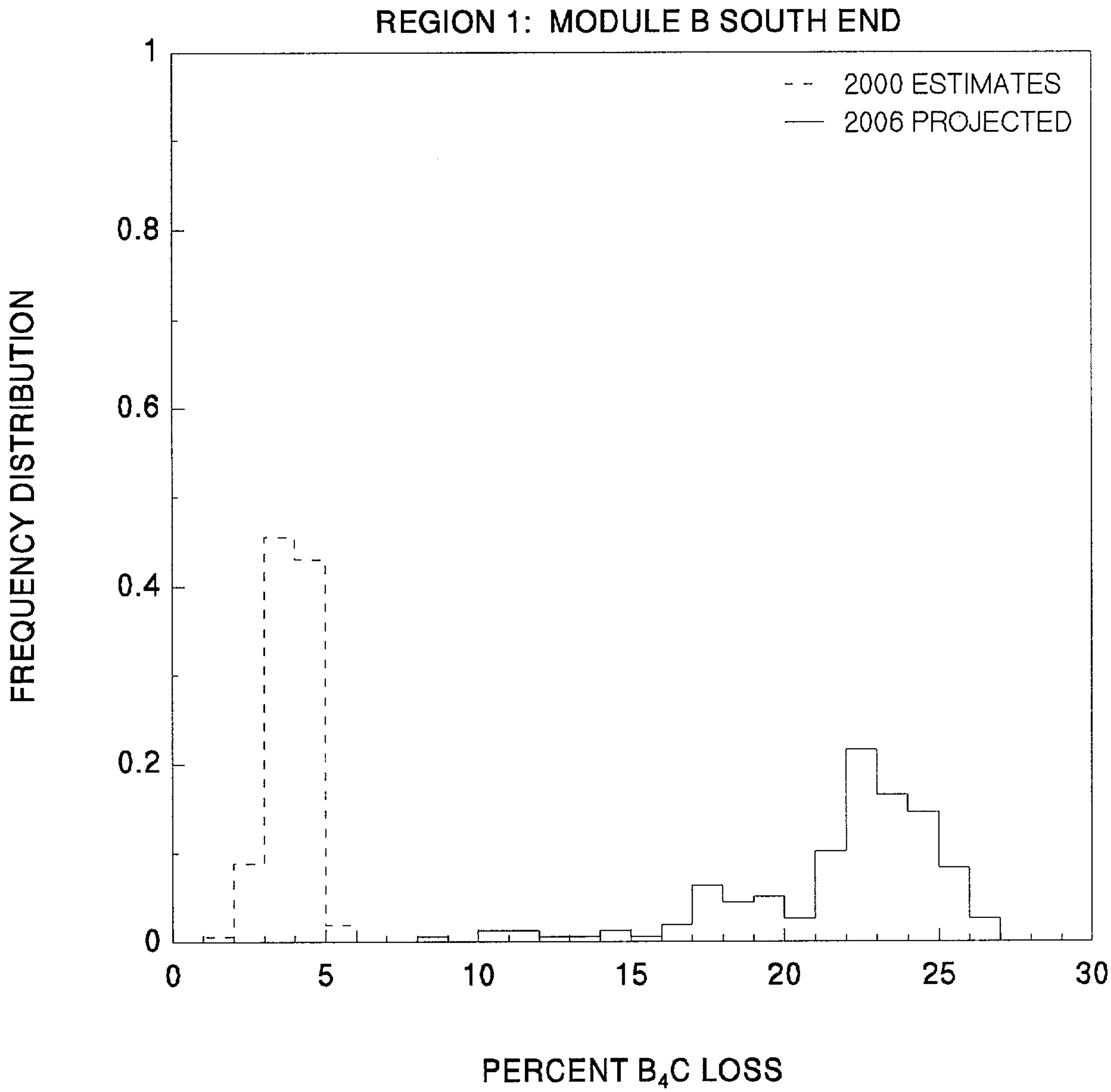

Figure 2-3: Distribution of Panel Loss in Zone 1-2

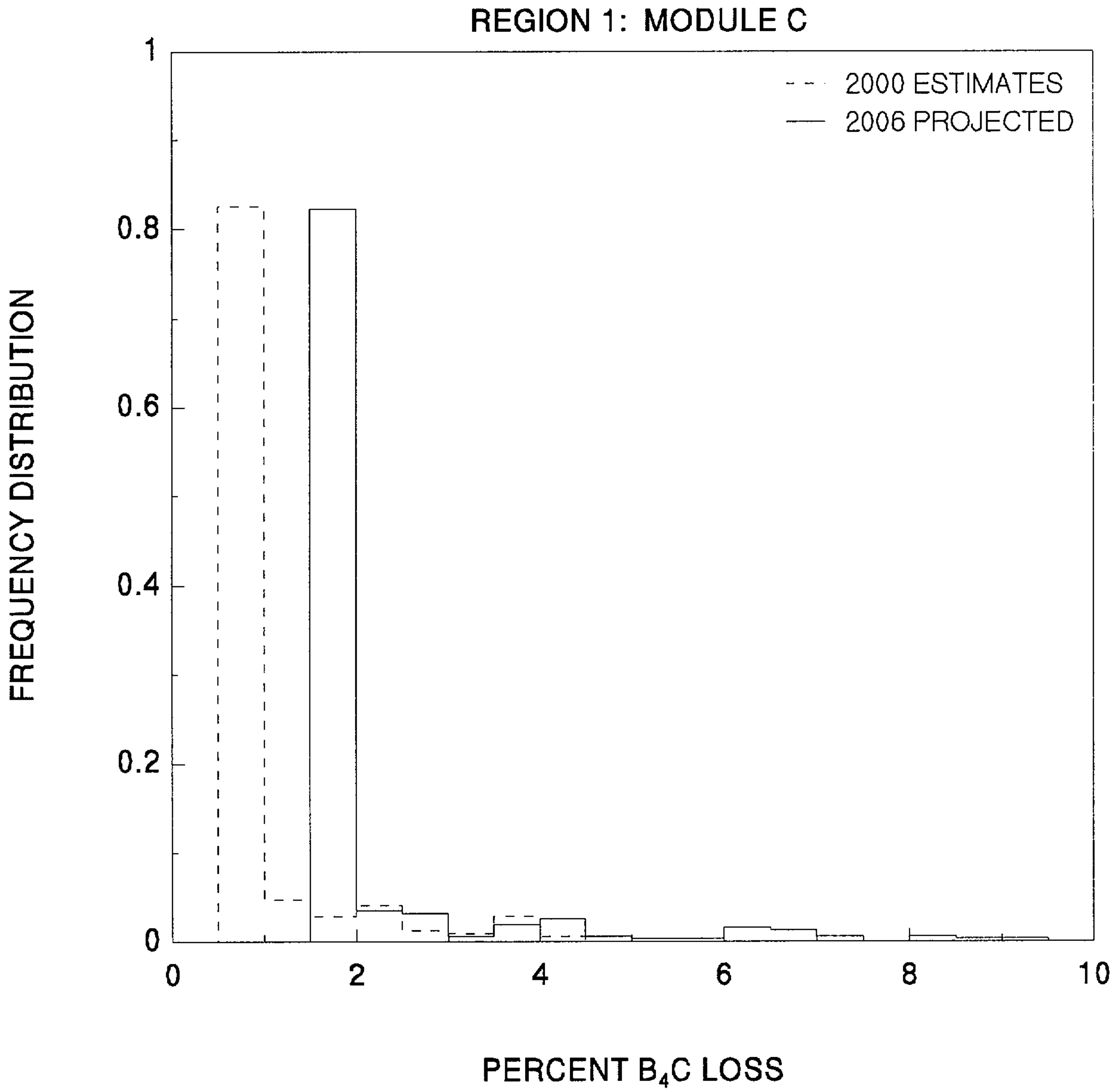

Figure 2-4: Distribution of Panel Loss in Zone 1-3

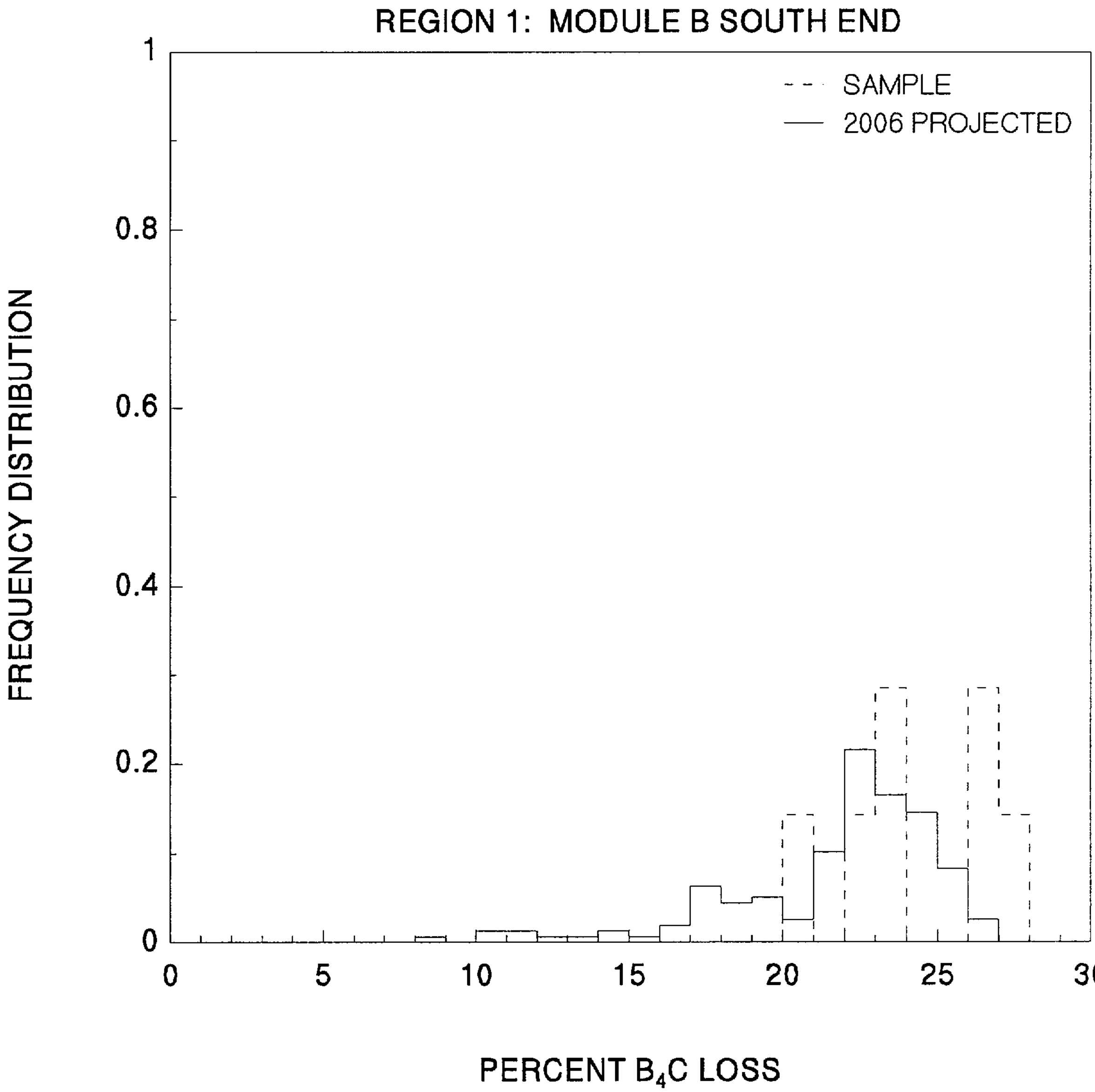

Figure 2-5: Sample and Projected Panel Losses in Zone 1-2

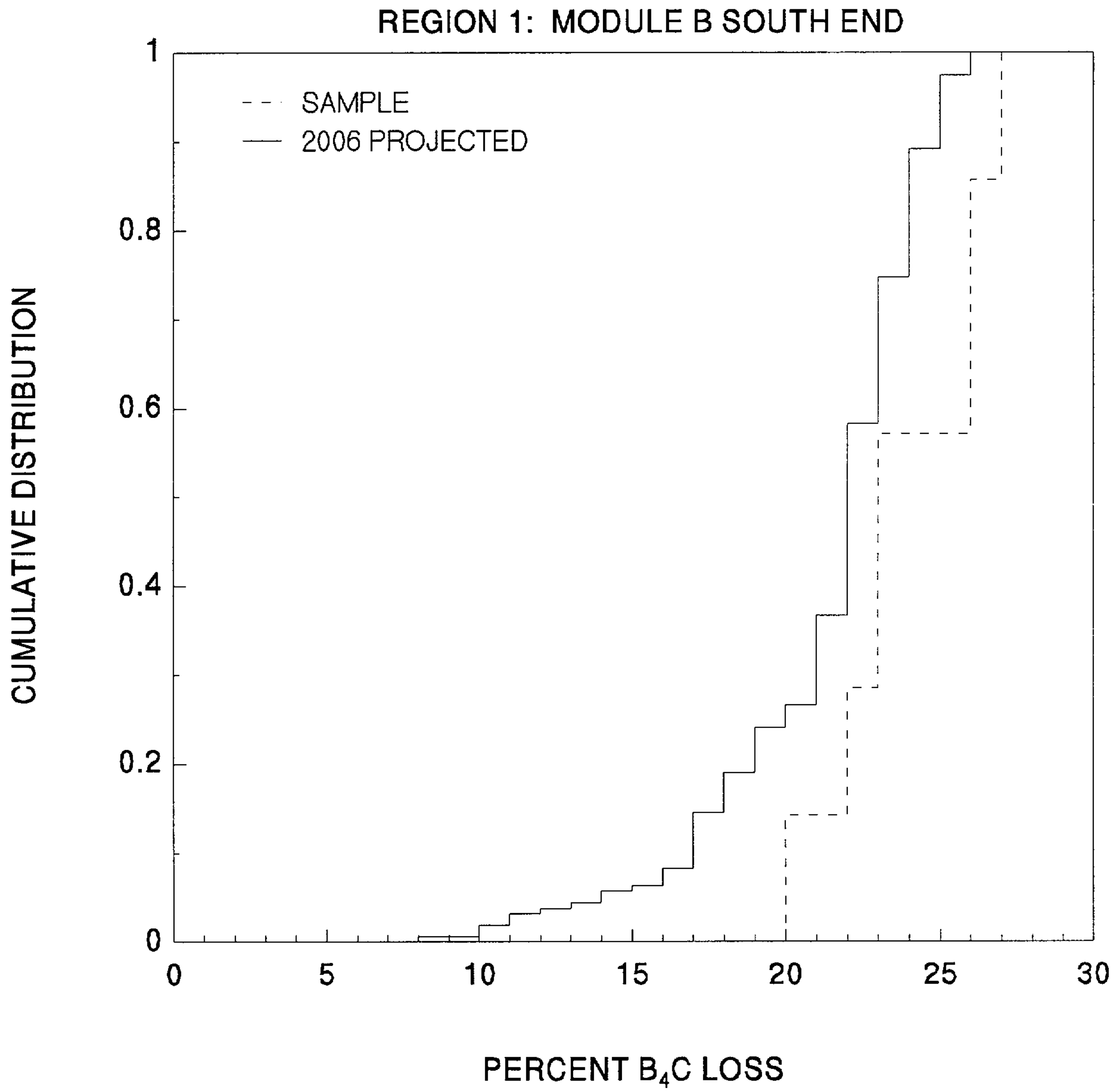

Figure 2-6: Cumulative Distribution of Sample and Projected Panel Losses in Zone 1-2

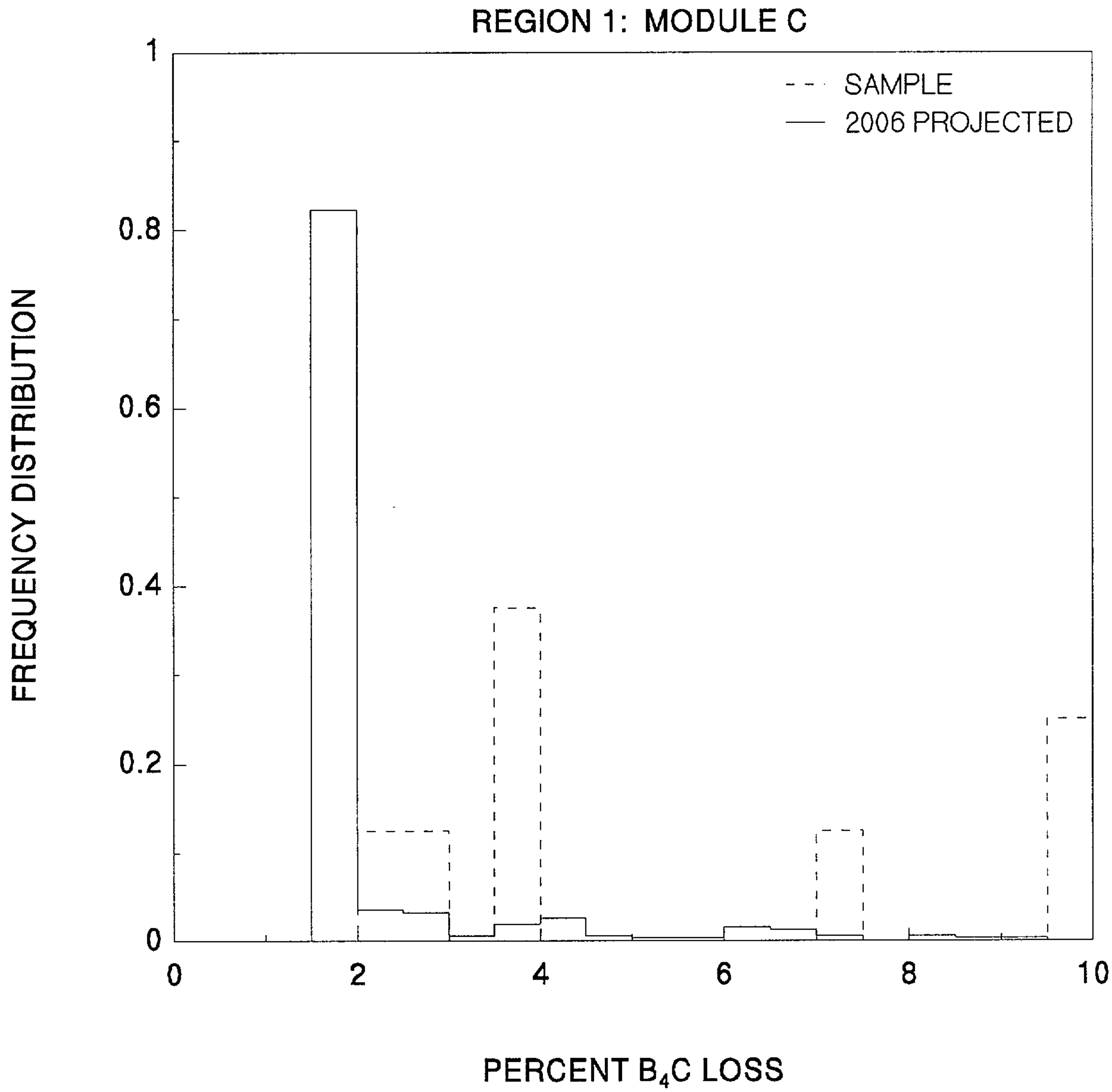

Figure 2-7: Sample and Projected Panel Losses in Zone 1-3

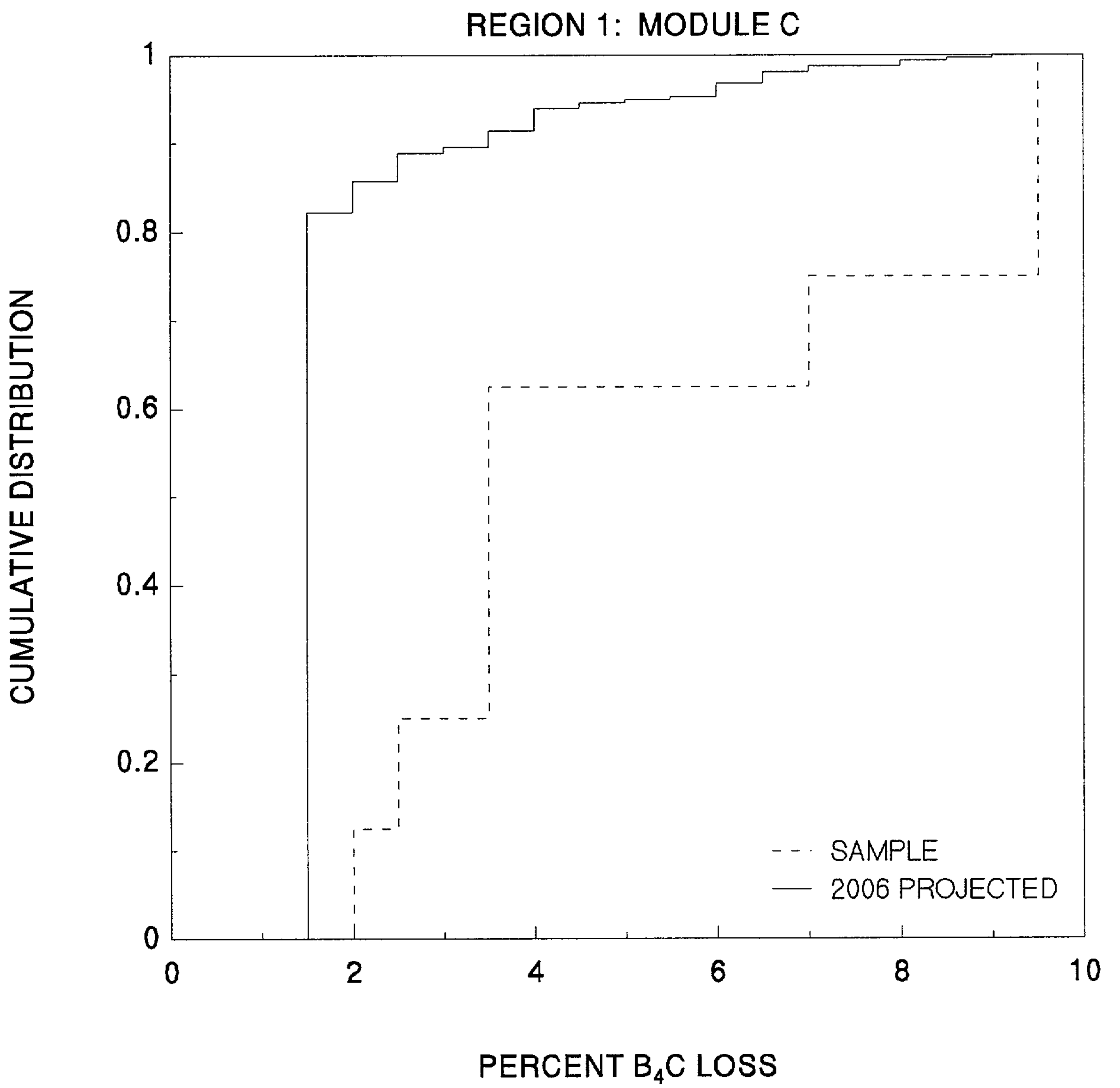

Figure 2-8: Cumulative Distribution of Sample and Projected Panel Losses in Zone 1-3

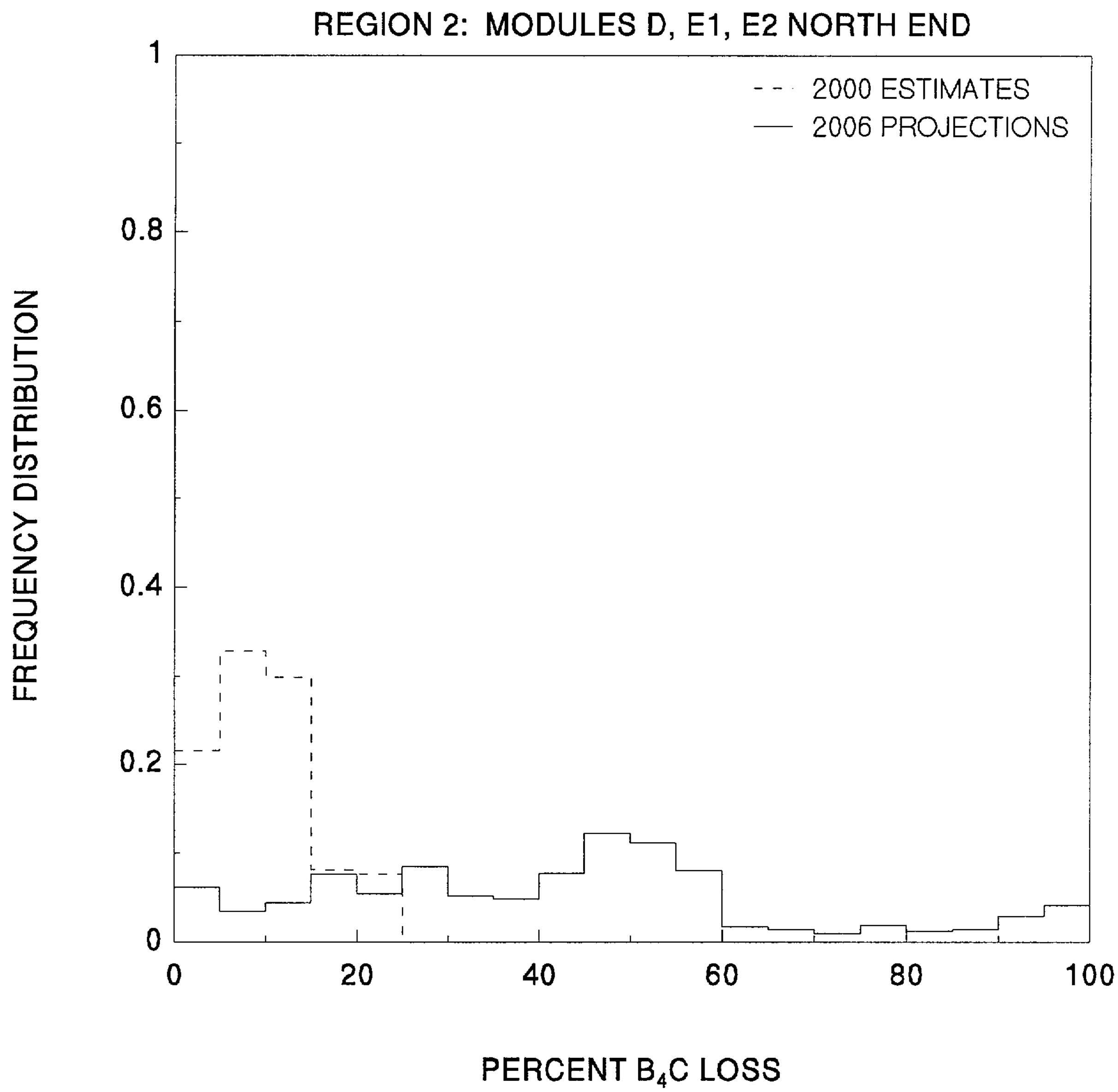

Figure 2-9: Distribution of Panel Loss in Zone 2-1

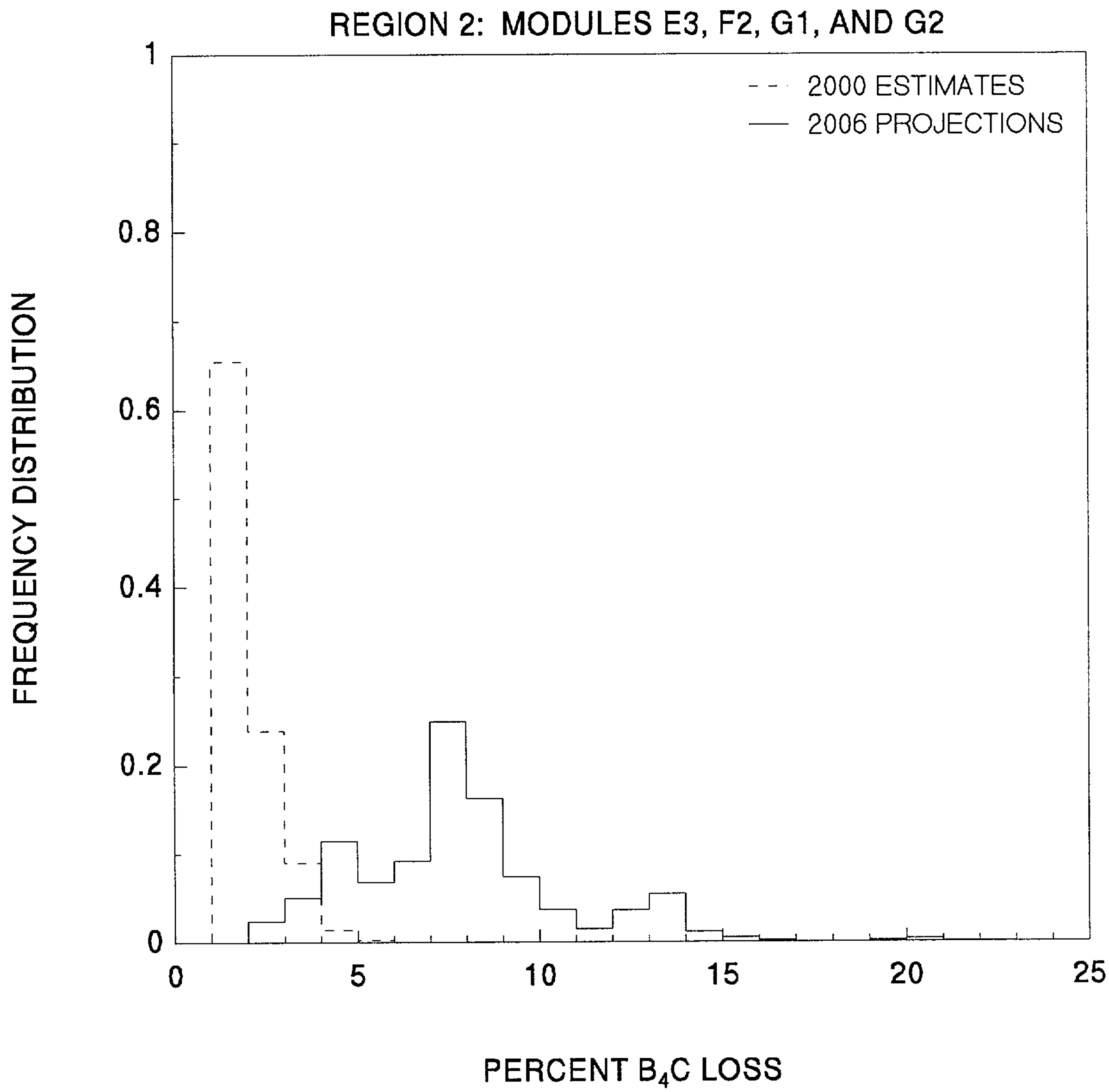

Figure 2-10: Distribution of Panel Loss in Zone 2-2

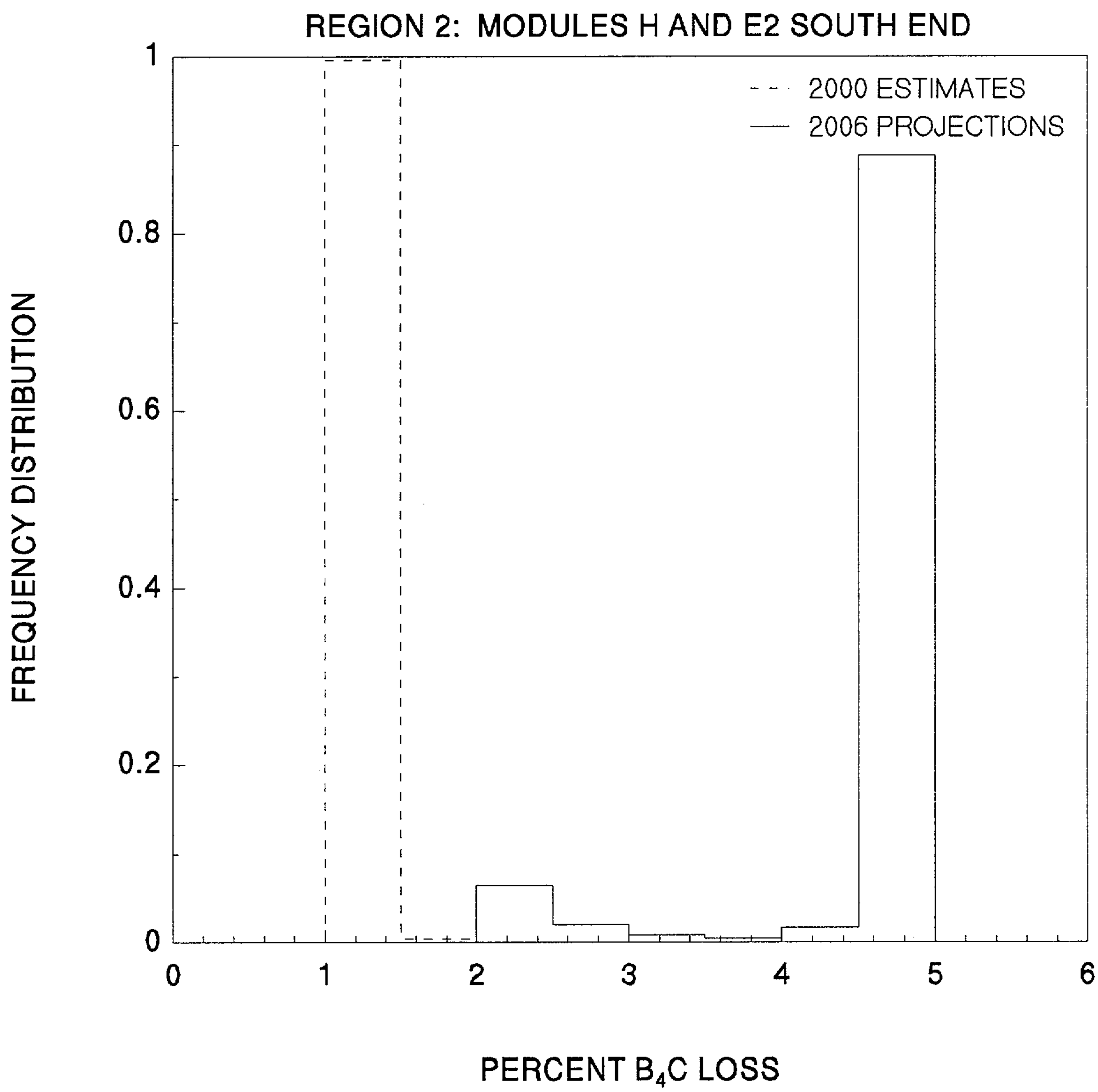

Figure 2-11: Distribution of Panel Loss in Zone 2-3

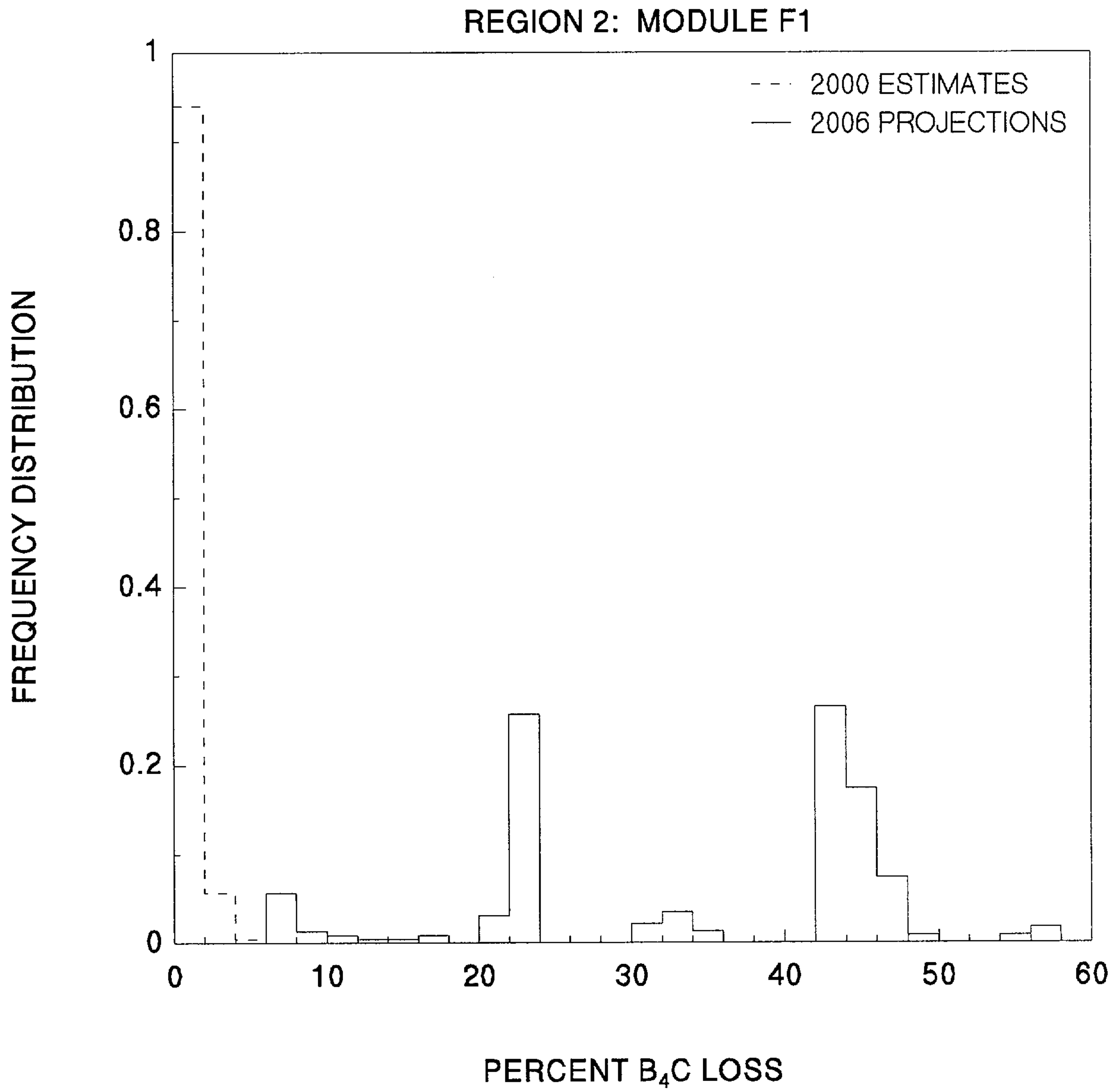

Figure 2-12: Distribution of Panel Loss in Zone 2-4

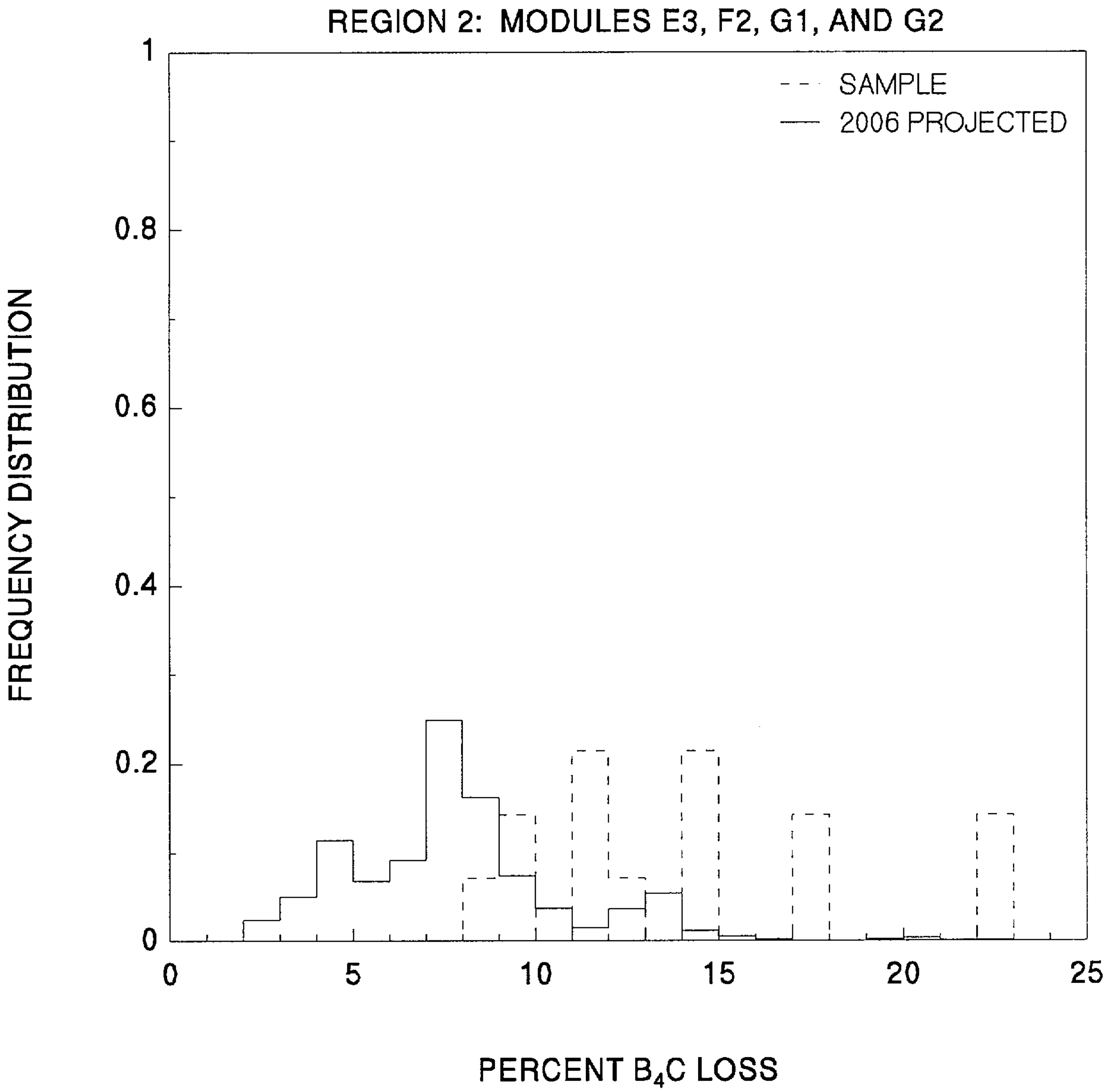

Figure 2-13: Sample and Projected Panel Losses in Zone 2-2

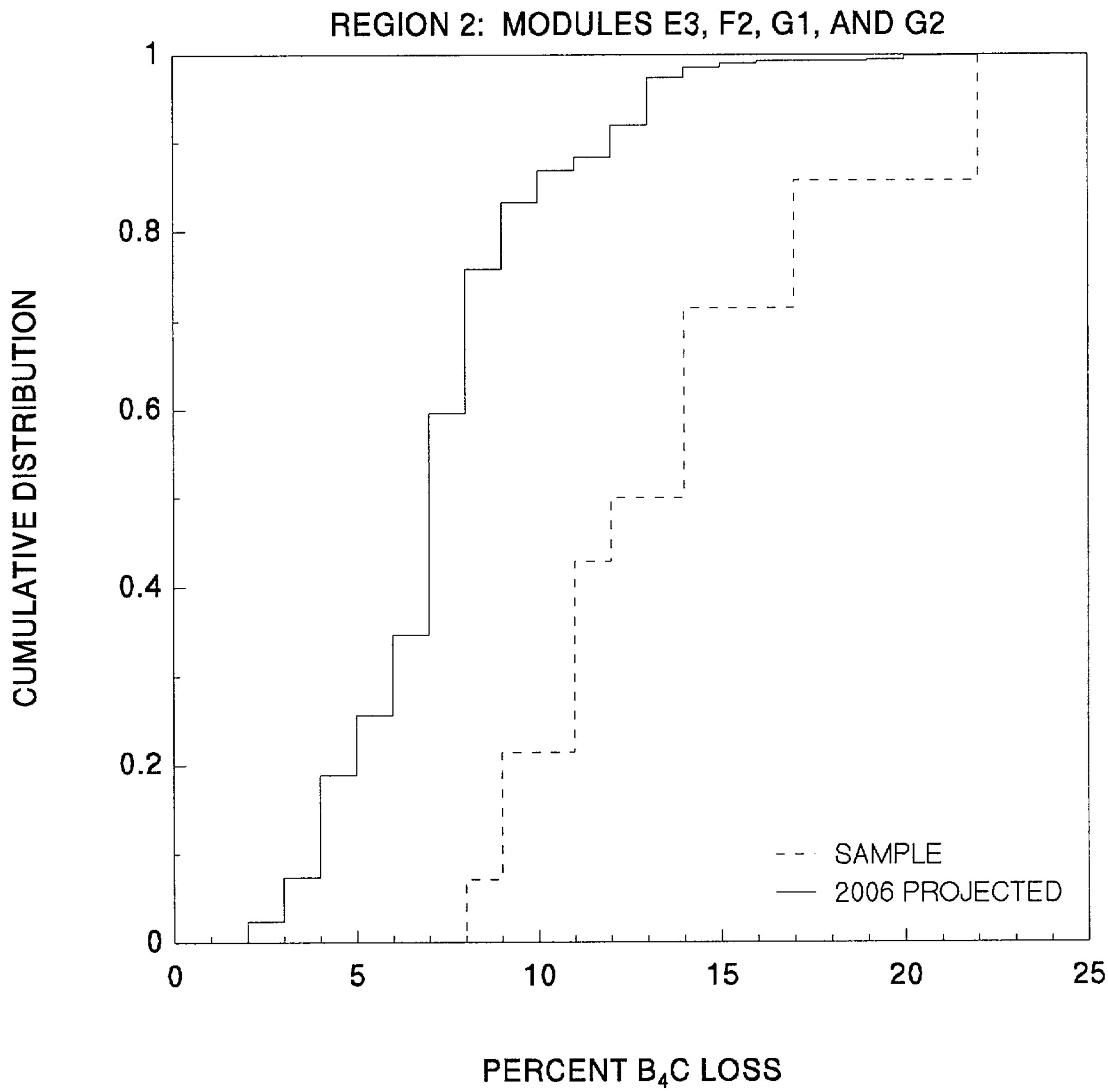

Figure 2-14: Cumulative Distribution of Sample and Projected Panel Losses in Zone 2-2

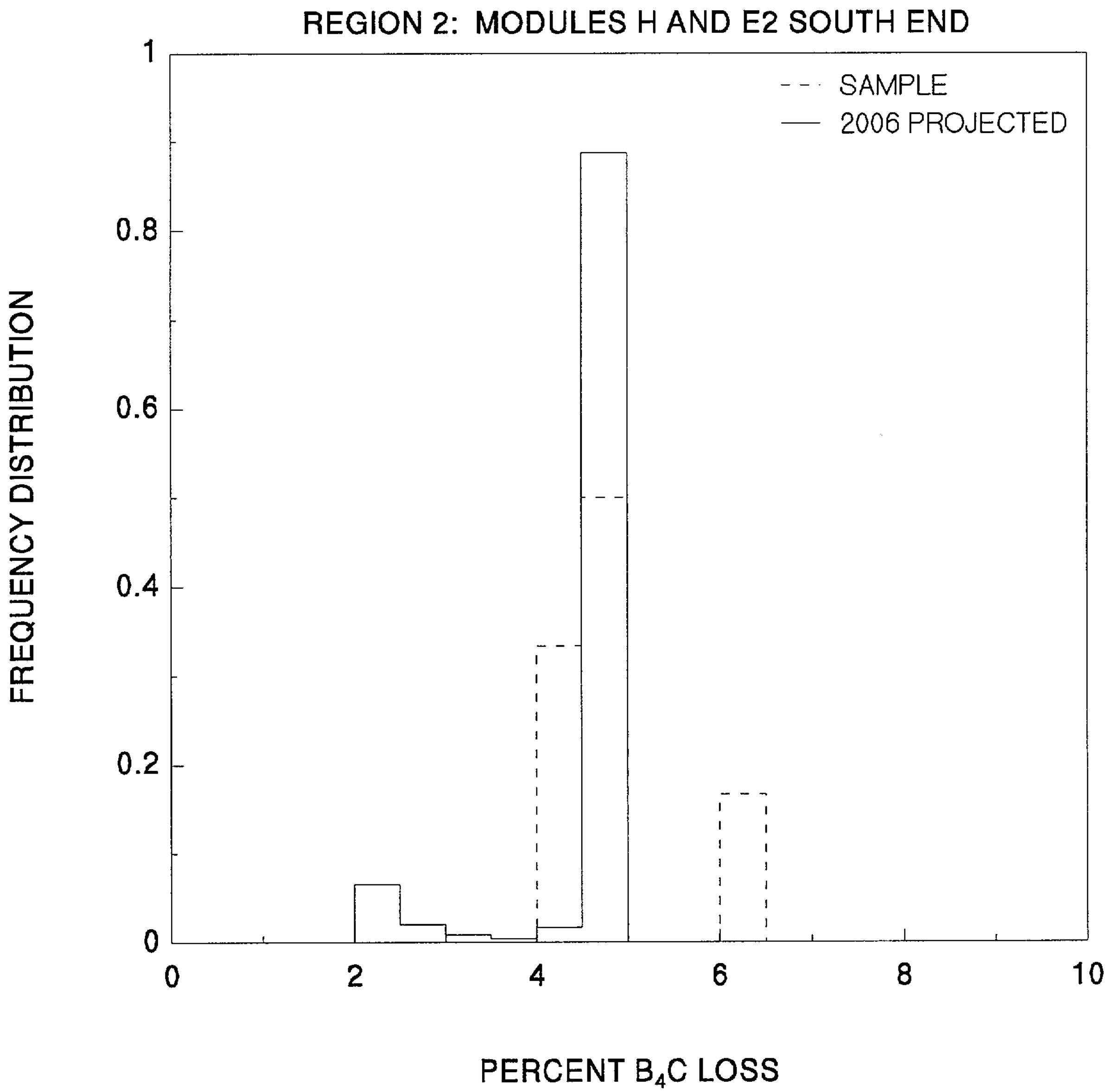

Figure 2-15: Sample and Projected Panel Losses in Zone 2-3

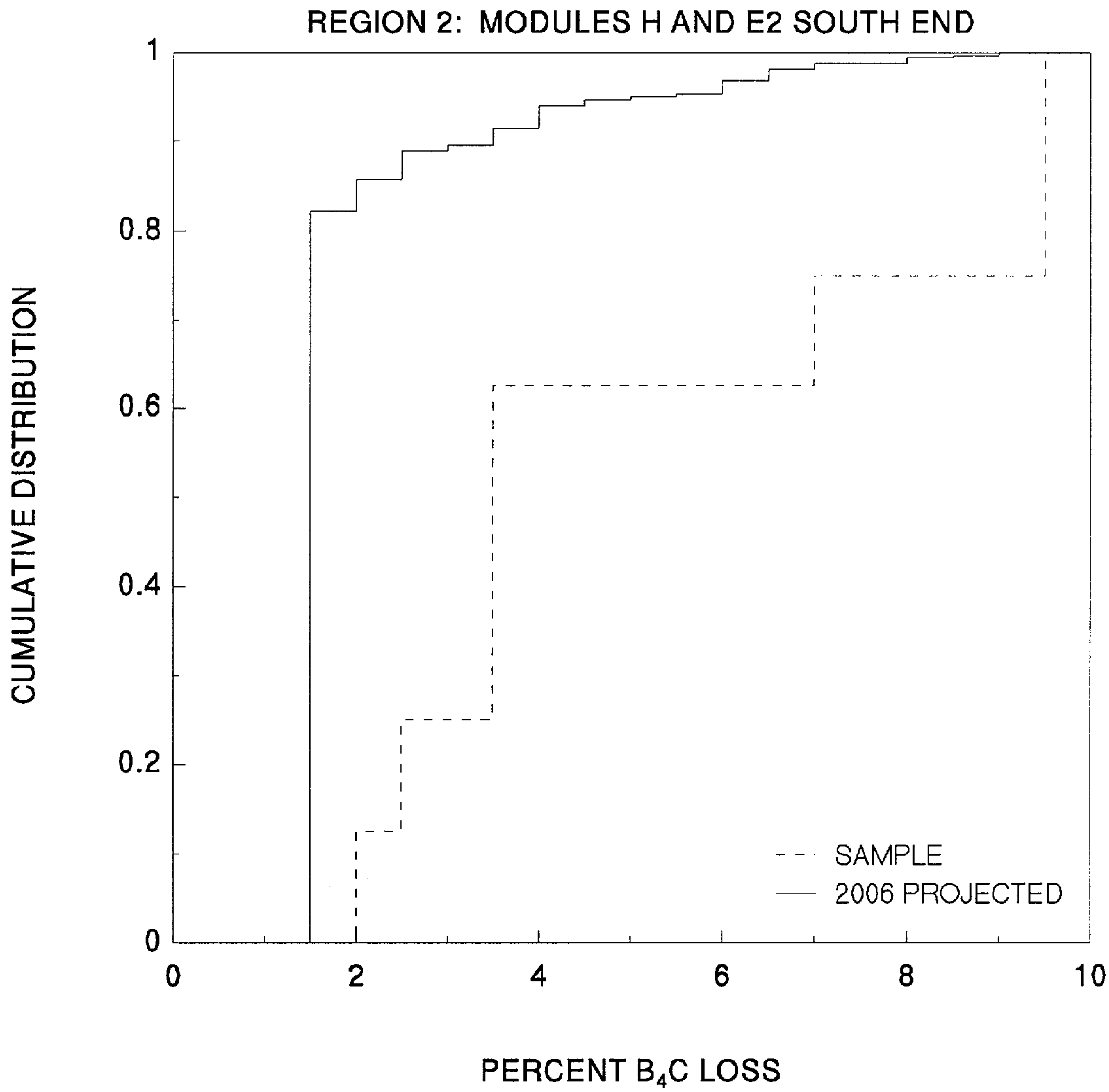

Figure 2-16: Cumulative Distribution of Sample and Projected Panel Losses in Zone 2-3

[End of Section 2]

ATTACHMENT 2 TO NL 02-013

Commitments

ENTERGY NUCLEAR OPERATIONS, INC
INDIAN POINT UNIT NO. 2
DOCKET NO. 50-247

Commitments

No.	Commitment Description	Implementation Schedule
1.	BADGER testing will be performed to confirm that the assumptions used in the current analysis are still valid.	During the year 2003