AECL
TECHNOLOGIES INC.

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U.S. Nuclear Regulatory Commission,
Document Control Desk,
Washington, D.C. 20555

Attention: Mr. William D. Beckner
Program Director, New, Research and Test Reactors Program
Division of Regulatory Improvement Programs
Office of Nuclear Reactor Regulation

References:

1. Letter W.D. Beckner to J. Polcyn, "Pre-Application Safety Assessment Report (PASAR) for the Advanced CANDU Reactor (ACR-700)", October 27, 2004.
2. Letter V.J. Langman to B. Sosa, "Regulatory Treatment of Limited Core Damage Accidents for the ACR-700", May 10, 2004.
3. Letter G. Archinoff to J.E. Dyer, "Submission Date for ACR-700 Design Certification Application to the NRC", January 03, 2005, 108US-ACNU05-0001L.

Re: **The NRC's Pre-Application Safety Assessment Report (PASAR) for the ACR-700**

The staff of AECL Technologies (AECLT) and AECL has carefully reviewed the NRC staff PASAR for the ACR-700 (Reference 1). We appreciate the recognition, in many of the areas that the NRC staff has reviewed, that the ACR-700 contains significant aspects of the CANDU technology which is mature, has an extensive technology base and a successful regulatory history both in Canada and in a number of other countries around the world. We also appreciate the NRC's stated belief that AECL will, "...ultimately be able to satisfactorily address these potential policy, regulatory, and technical issues during the design certification review." It is our intention to do that, and to provide the required information to a sufficient level of detail to obtain Design Certification in a timely manner that supports Dominion Energy's North Anna COL Project.

There were certain issues raised in the PASAR where further discussions appear warranted to ensure the ACR-700 design is not unduly penalized by the application of requirements that are unique to pressure vessel reactors but are not appropriate for the ACR-700, e.g., the ACR-700 is

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a pressure tube reactor, with a separate heavy water moderator, and a simple fuel bundle design due to on-power refuelling. A prime example of this is one aspect of the NRC staff's current position on AECLT's proposed treatment of a class of accidents referred to as Limited Core Damage Accidents (Reference 2). The use of multiple fuel channels instead of a pressure vessel reactor core allows the presence of an additional passive heat sink, the heavy water moderator surrounding the fuel channels, which ensures that a beyond design basis event involving a total loss of emergency core cooling (LOECC), coincident with the worst case large break loss-of-coolant accident (LOCA) in the ACR-700, will not lead to severe core damage in the PWR/BWR sense (i.e., core melt). In the event of such a highly unlikely accident in the ACR-700, the fuel channel geometry would be preserved and the fuel would be contained within the fuel channels. Thus, it is AECLT's position that the frequencies of accidents such as LOCA/LOECC should not be summed with the frequencies of accidents that lead to severe core damage to determine the overall Core Damage Frequency for the ACR-700. Although the probability of an accident such as LOCA/LOECC is very low, in the severe core damage accident range, the consequence is not a core melt. AECLT requests a meeting to discuss the NRC staff's position as outlined in the PASAR and to discuss more fully the regulatory treatment of LCDAs as proposed in Reference 2.

The NRC's acceptance criteria for fuel design is another key issue where current NRC requirements have been developed based on the expected performance of the larger fuel assemblies used in PWRs/BWRs. By comparison the ACR-700 fuel design is quite simple. The features that differ from LWR fuel, such as collapsible clad, have been proven by decades of successful operation of CANDU reactors in Canada and around the world. This experience base, along with the existing extensive database of applicable research reactor tests, will be essential to the NRC staff's understanding and acceptance of the ACR-700 fuel design.

We believe it would be beneficial to NRC staff and to AECLT to have a timely series of technical meetings prior to the submission of our Design Certification application, which will occur by December 15, 2005 (Reference 3). This series of meetings would be of two-fold benefit. First, it would allow AECLT to explain the significant progress made since May 2004 on many of the items raised in the PASAR, and to obtain timely feedback from NRC staff such that there will be a high degree of confidence that we address these items in the Design Certification application such that they will be readily acceptable to the NRC staff. Second, a series of technical meetings would allow AECLT to clarify many of the technical details associated with the various focus topics at a time while NRC's regulatory positions for ACR-700 are still under development. I request your support to ensure that these technical meetings occur in a timely manner.

Finally, our review of the PASAR identified several items for which clarification by NRC staff would be helpful to us. These items are identified in the attachment to this letter, along with suggested clarifications from AECLT staff that could be used by NRC staff in their review of specific topics and in discussions of the PASAR and its impact on the DCD.

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If you have any questions on this letter or the attachment please contact me at (301) 228-6637.

Yours sincerely,

Glenn H. Archinoff
Manager ACR Licensing

/Attachment:
1. Suggested Clarifications for the ACR-700 PASAR

Attachment 1
(Letter G. Archinoff to W. Beckner, "The NRC's Pre-Application Safety Assessment Report (PASAR) for the ACR-700", January 05, 2005)

Suggested Clarifications for the ACR-700 PASAR

The following comments on the PASAR are offered to clarify certain information to NRC staff and to identify topics for which we request further discussions or clarification. The comments are in three parts:

PART A – Requests from AECLT for clarification of statements made in the PASAR
PART B – Clarification provided by AECLT on key issues in the PASAR
PART C – Additional items of clarification provided by AECLT

Please note that the following page references refer to the page numbers in the electronic (pdf) version of the PASAR, as the hardcopy page numbering may be different.

PART A

I. (Page 1-10, Section 1.7.1) The first paragraph of the section includes the statement, "However, the staff will need to generically determine (1) whether, for the purposes of 10 CFR 50.34(a)(3)(i), the ACR-700 is a water-cooled nuclear power plant, similar in design and location to plants for which construction permits have been issued...". It was our observation that the pre-application discussions took place based upon the fact that the ACR-700 is a light water cooled reactor subject to the existing general design criteria (GDC) and Standard Review Plan (SRP), while recognising some of the unique design features of the ACR-700 (pressure tubes) that are not addressed by the GDC and SRP. We request clarification on how the staff intends to perform the certification review. If there are continuing staff reservations on this subject, we request a separate AECLT-NRC discussion.

II. (PASAR page 3-10, Section 3.5.2.1.2) The PASAR states: "The agreement seems to indicate that there is a possibility of cancellation of errors among the three major physical phenomena (up-scattering, reduction in scattering density, and fuel Doppler)." We do not understand the basis for this statement. No support is given nor is a reference provided for this conclusion, and it would be helpful for AECLT to understand the genesis of the statement.

III. (PASAR page 3-42, Section 3.6.1.16) The report states that NRC staff has asked for more information on the subject of the assumption of mixed flow and its adequacy to describe header flows, especially during the reflooding period following a LOCA. We are not aware of such a request, nor could we find reference to this particular subject in the set of

RAIs on the CATHENA code and thermal hydraulics. We request clarification of specifically what information was requested and in what manner.

IV. (PASAR page 4-2, Section 4.3) The PASAR refers to an interoffice working group that is developing a recommendation for probabilistic event selection. We would appreciate receiving any additional information that can be provided on the status of this effort, and would like to discuss it with NRC staff at a meeting to be arranged.

V. (PASAR page 4-3, Section 4.4) The PASAR refers to a PIRT on severe accident analysis. We would appreciate receiving any information on this PIRT that can be provided to us.

VI. (PASAR page 4-4, Section 4.4) The report states: "For source term perspective, the staff believes that it is useful to consider the point of extensive core debris interactions with PTs and calandria tubes as marking the boundary between DBAs and severe accidents." We do not understand the meaning of this statement and request that it be clarified. Our confusion stems from the fact that in an ACR-700, the "core debris" will include material from PTs and calandria tubes, so we do not understand the reference to "core debris interactions with PTs and calandria tubes".

VII. (PASAR page 6-7, Section 6.7) The document refers to 10CFR50.54(x) in the context of staffing requirements. However, 10CFR50.54(x) does not cover staffing requirements. Presumably, the PASAR intended to refer to 10CFR50.54(m). We request clarification.

PART B

A. Coolant void reactivity (CVR)

We offer two clarifications with respect to the discussion of CVR.

First, PASAR page 3-17, Section 3.5.2.1.8, states: "The most commonly accepted voiding pattern implies a progression, which starts as a fully cooled core (no voiding) to one in which every other fuel channel is voided and finally to a fully voided situation. This progression implies that during the voiding scenario, the resulting core configuration has a 'checkerboard' void pattern."

The implication from the description above is that all fuel channels in one core-pass void completely while all of the other fuel channels remain liquid-filled, and then once the first core pass is completely voided, the second core pass starts to void and voids completely. This does not represent the physical situation. While the first pass voids at a much more rapid rate than the second pass for certain large breaks, there is no process by which one pass can be fully voided and the other fully solid, as implied by the statement. The nature of the voiding affects the timing, sign and magnitude of the reactivity transient.

Second, PASAR Section 8.3.2 page 8-11 (and also in Section 8.5) states: "Pursuant to insights emerging from the nuclear analysis PIRT process, the staff completed best-estimate neutronic calculations that predict the CVR to be positive during the initial checkerboard voiding of alternate fuel channels in large-break LOCAs. Such a positive reactivity response would cause reactor power to initially rise during the first few seconds before shutdown rods can be inserted".

It is our understanding that the NRC staff has not performed predictions of CVR during large-break LOCAs. The calculations we have seen and that are reported in the PASAR are static, stylized calculations that do not represent the actual voiding patterns that occur during a LOCA. AECLT has carried out preliminary dynamic calculations which show that initially following the break, the CVR is negative, and then becomes positive. Based on these results, it would be incomplete to observe that the power would "initially rise during the first few seconds". Our simulations indicate that the power would decrease initially and would subsequently start to rise. We have not completed analyses to determine whether shutdown system action would be rapid enough to prevent a power increase for all LOCAs under all conditions.

B. Limited Core Damage Accidents (LCDAs)

(PASAR Page 2-7, Section 2.2) This section includes the following statement: "The proposed ACs for these two DBEs [stagnation feeder break (SFB) and severe channel flow blockage (SCFB)] deviate from the 10 CFR 50.46 requirements which do not allow cladding oxygen embrittlement, fuel cladding, or fuel melting to occur as a result of a LOCA. AECLT will likely have to obtain an exemption from the 10 CFR 50.46 fuel performance ACs for these two DBEs."

Our May 10, 2004 letter discussed the regulatory treatment of limited core damage accidents. As the PASAR acknowledges, LCDAs are unique to the ACR-700:
LCDAs are a group of accidents unique to the ACR design (and CANDU plants, in general) because of their use of multiple, separated fuel channels, surrounded by a cool, low pressure heavy-water moderator contained within a calandria vessel. This design is substantially different from current generation LWRs, in which the fuel is organized into a core that is contained within a reactor vessel.

However, in its interpretation of 10 CFR 50.46, the PASAR does not account for the differences in the design of the ACR-700 and U.S. LWRs. Furthermore, the PASAR does not fully acknowledge or credit the channel design of the ACR-700 with the safety advantages that accrue from a distributed core. In particular, we believe that the criteria in 10 CFR 50.46 were intended to evaluate the effectiveness of emergency core cooling systems (ECCS) in mitigating accidents that affect the reactor core as a whole, and not to accidents involving an individual channel. Therefore, we believe that 10 CFR 50.46 is not applicable to LCDAs.

Moreover, the PASAR is internally inconsistent in its treatment of LCDAs. For example, PASAR Chapters 2, 4, and 10 consider the LCDAs to be design basis accidents (DBAs). In contrast, PASAR Section 9.3.2 considers LCDAs to be severe accidents (i.e., it includes the statement that "...the total CDF of the ACR (i.e., the sum of the LCDF and the SCDF))". As stated in our letter of May 10, 2004, LCDAs are different from both DBAs and severe accidents, and therefore NRC's positions on DBAs and severe accidents are not applicable to LCDAs. Instead, LCDAs represent a new category of accident not previously considered by the NRC. As a result, there is a need to develop a new regulatory position for LCDAs, and our letter of May 10, 2004 outlines the basis for such a new position. To date we have received no feedback from NRC staff on this letter.

Section 3.4 of the PASAR (page 3-3) states: "...the staff understands that for certain potential break sizes to be analyzed for the ACR-700, the results may not fall within the ACs for LOCAs outlined in 10 CFR 50.46. The staff understands that AECLT plans to file an exemption request to this regulation based on the low probability that a break will occur within this size range." Such an exemption had not been a part of AECLT's plans. Instead, the May 10 letter proposed that separate acceptance criteria be established for the LCDAs to reflect the expectations that these events could be shown to have a low frequency of occurrence and that the design would inherently limit the extent of fuel damage that might occur to a small fraction of the core. In terms of the objectives of the 10 CFR 50.46 requirements, it is not appropriate to measure the effectiveness of the ECCS based upon its ability to mitigate the consequences in the affected channel of a stagnation feeder break or a severe channel flow blockage event, since the ECCS for the ACR-700 is not intended to mitigate fuel heatup in the affected fuel channel for such single channel events. Instead, the acceptance criteria in 10 CFR 50.46 should be applied to the ACR-700 to evaluate the effectiveness of the ECCS in mitigating accidents that affect the core as a whole.

In this regard, we believe that the NRC should treat LCDAs similarly to its proposed treatment of fueling events. For example, PASAR Section 7.3.2 (page 7-10) includes the following as part of a discussion of single channel events that could result from fueling operations: "The staff recommends developing acceptance criteria for these potential limited fuel damage events provided that the overall risk is equivalent in terms of frequency times consequences". This same principle should be applied to LCDAs.

C. PRA Guidance

AECLT understands the NRC staff cautions relative to PRA content and quality (Section 9.1.1, page 9-2). We believe it is important to point out that the CANDU generic reference analyses sent to the staff were not intended to be complete scope PRAs and were provided as examples of the methodology implementation. It was never intended that these examples represent a full-scope PRA.

D. DBA Source Term Development

(PASAR Page 2-10, Section 2.5.4) This section includes the following statement: "The DBA source terms proposed by AECLT are major deviations from the 10 CFR 50.34 requirement...Currently operating reactors were licensed (1) using a source term 'hypothesized for purpose of site analysis,' and hence not mechanistic, and (2) assuming 'substantial meltdown of the core'...Since the AECLT approach deviates from the requirements of 10 CFR 50.34, this issue will require Commission consultation."

AECLT has proposed to use a source term developed from a study of the reactor conditions associated with a LOCA plus a loss of emergency core cooling; this represents a beyond design basis accident. Therefore, the source term is based upon a major accident as specified in Section 50.34. Furthermore, this source term does assume release of appreciable quantities of fission products as specified in Section 50.34. Section 50.34 does not require that a meltdown be postulated in all cases, but instead states that such accidents have generally been assumed to involve meltdown. Therefore, the fact that the proposed source term is not based on substantial meltdown of the core is not in contradiction of the requirements of 10 CFR 50.34. Based upon Section 50.34 and upon our discussions with the staff during the pre-application review, we believe that an applicant may postulate, for the purposes of site analysis, other types of major accidents involving a substantial release of fission products. We believe that the source term proposed by AECLT does not constitute a "major deviation" from 10 CFR 50.34.

E. Fuel validation testing

(PASAR Page 10-2, Section 10.3) The PASAR states: "Because of the duration of these irradiations and the subsequent hot-cell PIEs, AECLT will not complete its final validation program in time to support the proposed ACR-700 design certification schedule."

While it is correct that the current schedule for one set of experiments extends beyond the date proposed for design certification, AECLT will demonstrate that the results of these experiments are not essential to the NRC staff decision on design certification. We request that NRC staff allow for the possibility that the material submitted during the design certification schedule will be sufficient for NRC to certify the design.

PART C

1. (PASAR page xii) MFMI stands for "Molten Fuel Moderator Interaction."

2. (PASAR page 2-7, Section 2.2) Third sentence of the paragraph contains a typographical error: "...but it assumes cladding melting and fuel melting in the affected channels is expected could occur." Delete "...is expected..."

3. (PASAR page 2-8, Section 2.3) The first paragraph on page 2-8: "stain" is a typographical error.

4. (PASAR page 3-1, Section 3.1) In the first paragraph, the sentence "Each PT comprises a fuel channel," is not strictly correct. "The assembly of a pressure tube, the two end fittings and associated hardware is termed a fuel channel" would be a more accurate description. In the second paragraph, there is a typographical error ("pattens") in the last line.

5. (PASAR page 3-4, Section 3.5.1) The PASAR states: "The applicant's stated expectation (see ACR-700 Technical Description, Revision 0) is that the CVR will be negative in all operating conditions (i.e., burnup, voiding pattern, and fuel management scheme)." NRC staff analyzed some non-physical situations for core voiding, such as a 1/7th slice of a fuel channel voided. The ACR-700 design analysis does not cover such non-physical situations.

6. (PASAR page 3-17, Section 3.5.2.1.8) The PASAR states: "The most commonly accepted voiding pattern implies a progression, which starts as a fully cooled core (no voiding) to one in which every other fuel channel is voided and finally to a fully voided situation." While it may be a bounding assumption to consider that one half of the fuel channels is fully voided and the other half solid, it is not a physically realistic scenario for a LOCA. The two different core passes will void at different rates, but the extreme situation described cannot happen.

7. (PASAR page 3-24, Section 3.5.3.2) The report states: "To determine the true value of the CVR for a reactor, the bias and uncertainty must be estimated and included. Thus, AECLT commonly uses the following relationship to include these effects (see Beuthe and Hanna, "CATHENA MOD-3.5c/Rev.0 Theoretical Manual," COG-00-008, November 2000)". The reference to the CATHENA manual appears to be an incorrect reference for defining the CVR bias and uncertainty. We suggest the following reference: COG-01-144, "System Validation Manual for WIMS-IST/DRAGON-IST/RFSP-IST Reactor Physics Code Suite."

8. (PASAR page 3-29, Section 3.5.4) The report states that staff requested AECL to provide the latest versions of the intermediate codes T16MAC and PROC16, as well as the latest fuel and core models. We are not aware that these requests had been made formally, but will take the comments in the PASAR as requests for these codes and will provide them on a schedule to be agreed to with NRC staff.

9. (PASAR page 3-54, Section 3.7.3, last paragraph) Pressure tube deformation that would initiate contact with the calandria tube is not expected for DBAs for the ACR-700. This has been AECLT's position throughout the pre-application discussions.

10. (PASAR page 3-57, Section 3.8.1.1 Integral Test Data, paragraph 2 of the subsection) The PASAR states: "The RCS flow in the ACR-700 is in a figure-eight arrangement. Each of two headers feeds 146 channels. The channels form five rows of offtakes from

the header. Each row is 45 degrees apart and contains approximately 30 feeder offtakes." The offtake angles are not at 45 degrees apart, which implies 2 of the rows are at the header centerline (at 90 degree angles from the bottom of the header). In ACR-700 all offtakes are below the header centerline at 36 degrees apart (the highest 2 rows are at 72 degree angles from the bottom of the channel). The NRC staff was advised during a thermal-hydraulics meeting at Stern Labs and Sheridan Park on July 13-14 that all the ACR-700 feeder offtakes are below the header centerline. The actual angles have been further provided in a response to a RAI sent under cover letter dated October 4, 2004. The implication of this difference is important with respect to the steam or water that feeders from each row receive when ECC is injected into the headers (see last paragraph on page 3-58 of the PASAR).

11. (PASAR page 3-59, Section 3.8.1.1, fourth paragraph beginning "In the ACR-700, this functional integration...") This paragraph seems to confuse clad heatup rates with PT heatup rates, in that it compares an experimentally observed clad temperature of 500°C to a temperature of 600°C that could lead to deformation of the channel. A pressure tube temperature of around 600°C could lead to deformation of the pressure tube, but a clad temperature of 600°C would not cause the pressure tube temperature to be so high. The paragraph also implies that a clad heatup rate of 60°C/s can be assumed to continue for some time. Such a rapid heatup rate will occur only until the sheath temperature reaches the temperature of the fuel pellet outer surface, after which the heatup rate will be driven by the decay power and cooling conditions, and will be much less than 60°C/s under decay power conditions.

12. (PASAR pages 4-2 to 4-4, Section 4.4) This sub-section discusses technical issues associated with two main accident sequences. The first is a whole core event that leads to core collapse into the bottom of the calandria. The second is a single-channel event leading to expulsion of hot fuel debris into the moderator and possible Molten Fuel Moderator Interaction. We find it difficult to understand to which sequence the technical issues discussed in this section apply. We would appreciate the opportunity to discuss this at a meeting with NRC staff.

13. (PASAR Section 7.2, System Descriptions) This section contains a mixture of ACR-700, CANDU 6, and Bruce A type reactor descriptions, and reflects generic material provided to NRC staff. As such some of the descriptions do not apply to the ACR-700 design, although the text indicates that the description is specific to ACR-700.

14. (PASAR page 7-8, Section 7.2.3) The PASAR describes how spent fuel is transported in the fueling machine. The process is different for ACR. In actual fact, spent fuel is carried in the fueling machine with the magazine full of water and pressurized to about 450 psi. In the event of a total loss of cooling to the FM, it will take much longer before the fuel is at risk compared to the scenario described in the PASAR.

15. (PASAR page 7-10, Section 7.3.2) The PASAR discusses the probability of on-power fueling-induced LOCA and events involving inadequate heat removal from irradiated fuel in the fueling machine, and gives frequencies for these events. We believe the frequencies are overestimates for events that could lead to fuel failures. We would appreciate an opportunity to discuss this with NRC staff and then provide clarification of the frequencies.

16. (PASAR page 7-10, Section 7.3.2, last paragraph) The PASAR states: "Based on its review of the referenced documents provided by AECLT, the staff identified a potential policy issue associated with the use of Canadian codes and standards for the design of components and structures of the ACR-700 on-power fueling technology as discussed in Section 5.3 of this report." However, Section 5.3 concludes by stating, "The staff has identified no new policy issues in the use of Canadian codes and standards for the ACR-700 design." This is an apparent inconsistency in the document.

17. (PASAR page 9-2, Section 9.1.1) The PASAR states that the staff identified some general weaknesses in the PRA methodology. It should be noted that the document sent to NRC staff for their review was intended as a framework to perform a full scope PSA by documenting the methodology and tools. Only selected pieces of analyses were performed. The full PSA for ACR-700 will address the concerns identified in this section of the PASAR.

18. (PASAR page 9-6, Section 9.4.1) The PASAR states, "The PRA presumes that the refueling machine is always 'on reactor.'" We believe that this statement resulted from a misunderstanding during the February 5-6, 2004 meeting at the NRC offices. At that time, AECLT representatives noted that many of the ACR-700 safety analyses will be performed with the assumption that the refueling machine is "on reactor." However, the PRA will not include the presumption that the refueling machine is always "on reactor." The minimum fueling time is currently estimated at around 4.5 hours per day.

19. (PASAR page 9-10, Section 9.4.1) Near the bottom, this section reads, "Level 2 PRA. The ACR PRA methodology for conducting the Level 1 PRA consists of the following six steps...". The text should actually read "... the Level 2 PRA consists of...".

20. (PASAR page 9-11, item (b)) The CDS2 definition, which deals with limited core damage events, includes the phrase "...pose a containment integrity challenge." AECLT's PSA methodology states that CDS2 includes events that pose a *potential* containment integrity challenge.

21. (PASAR page 10-7, Section 10.4, third paragraph on page) The PASAR states "For the ACR-700 design, the postulated single channel flow blockage event results in significant fuel melt within the affected channel." There may be some molten material within the fuel channel prior to failure of the pressure tube and calandria tube, comprising molten cladding material and a eutectic resulting from the reaction of UO_2/Zr. However, there

will be no fuel melt comprising molten UO_2, as the fuel channel fails prior to the UO_2 melting point being reached.

22. (PASAR page 10-7, Section 10.4, third paragraph on page) The statement in the parentheses of the last sentence in the paragraph, "...(which could be initiated by a simple lapse in foreign material control)..." ignores the provisions in the ACR-700 design, including measurement of channel pressure drop after refueling and strainers during commissioning to prevent and mitigate a flow blockage as well as the low likelihood of an obstruction being just the right size to cause blockage. AECLT does not believe that a "simple" lapse could lead to severe flow blockage, and we suggest the parenthetical expression be removed.

23. (PASAR page 10-7, Section 10.4, fifth paragraph beginning "The CHF corresponds...") "Allowing degraded clad-to-coolant heat transfer (e.g., DNB) or channel voiding during normal operation or AOOs is a significant departure from current design criteria." AECLT agrees that this would be a significant departure from current design criteria, but such criteria are not proposed for the ACR. Degraded heat transfer leading to dryout is not permitted for AOOs.