From: "Gucwa, Len" <LGUCW90@entergy.com>
To: "Rick Ennis" <RXE@nrc.gov>
Date: 8/2/05 2:28AM
Subject: BVY 05-072 Attach. 3,4,5,7,8

<<BVY 05-072 Attachment 3 R4.doc>> <<BVY 05-072 Attachment 4 R4.doc>> <<BVY 05-072 Attachment 5 R1.doc>> <<BVY 05-072 Attachment 7 R3.doc>> <<BVY 05-072 Attachment 8 R2.doc>>

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Subject: BVY 05-072 Attach. 3,4,5,7,8
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From: "Gucwa, Len" <LGUCW90@entergy.com>

Created By: LGUCW90@entergy.com

Recipients
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Files	**Size**	**Date & Time**
MESSAGE	249	08/02/05 02:26AM
TEXT.htm	2206	
BVY 05-072 Attachment 3 R4.doc		53760
BVY 05-072 Attachment 4 R4.doc		63488
BVY 05-072 Attachment 5 R1.doc		633344
BVY 05-072 Attachment 7 R3.doc		84480
BVY 05-072 Attachment 8 R2.doc		103424
Mime.822	1290185	

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Expiration Date:	None
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Attachment 3

Vermont Yankee Nuclear Power Station

Proposed Technical Specification Change No. 263 – Supplement No. 30

Extended Power Uprate

Response to Request for Additional Information

Overview of Steam Dryer Issues

Total number of pages in Attachment 3 (excluding this cover sheet) is 4.

Overview of Steam Dryer Issues

By letter dated July 27, 2005 and meetings on May 9, 2005 and June 15-16, 2005, the NRC provided additional questions with respect to the VYNPS steam dryer analysis provided by Entergy in submittals dated March 31, 2005, April 5, 2005 and June 2, 2005. The purpose of this discussion is to provide an overview of Entergy's understanding of the fundamental issues to be addressed, the approach to address and the results. The major issues that have been raised by the staff relative to the VYNPS dryer analysis can be summarized as follows:

- Uncertainties that could exist in the Acoustic Circuit Analysis (ACA)
- Benchmarking and uncertainty of the computational fluid dynamics (CFD) model
- Development/evaluation of the 120% VYNPS load definition
- Adequacy of the GE scale model test (SMT) benchmark of the ACA
- Applicability of knowledge gained from QC2 instrumented dryer tests to VYNPS assumptions, methods and conclusions

The major issues above are the distillation of 129 individual questions. The purpose of this discussion is to provide an overview of Entergy's strategy in addressing the issues to assist the reviewers in understanding the context of the responses to the individual questions.

There is no change to the fundamental approach Entergy has taken, which consists of developing an analytical model that can convert empirical main steam system strain gage and pressure measurements to loads on the steam dryer. These dryer loads will then be compared to specific acceptance criteria in the power ascension dryer monitoring program. An essential concept in this approach to providing reasonable assurance that steam dryer integrity will be maintained at EPU is the fact that there is significant margin between the dryer loads at 100% CLTP and the structural fatigue limits. Based on the absence of any significant detectable main steam system acoustic excitation at 100% CLTP and industry experience to date, VYNPS dryer loads at EPU conditions are still expected to provide significant margin to the structural fatigue limits. The Entergy power ascension dryer monitoring program contains acceptance criteria which will be used to verify that structural limits are not challenged during power ascension. By taking this approach, Entergy relies on detecting, and appropriately responding to, any unexpected phenomena that might occur during power ascension. This can be accomplished with reasonable certainty, rather than attempting to create a bounding 120% VYNPS EPU load prediction.

In response to the NRC questions, Entergy has updated the VYNPS steam dryer structural integrity analysis to incorporate the following:

1.) To address the issue of uncertainties that could exist in the ACA, Entergy calculated these uncertainties for both the methodology and the measurement techniques and applied them to the analysis to determine the overall impact on the steam dryer load definition. A significant amount of evaluation has been performed to more precisely determine the ACA model uncertainty. This information is described below and will be presented in response to the applicable RAI's. Three of the four elements of this uncertainty have been quantified and completed including methodology, strain gage, and venturi uncertainty and the remaining element, instrument location uncertainty, is in final review. The four uncertainty contributors will be combined to quantify a conservative total analysis uncertainty. It is expected that this will be submitted, along with all of the RAIs applicable to ACA model uncertainty, for staff review by

8/4/05. Entergy anticipates the staff's review of the bases for the model uncertainty determination during the audit scheduled for 8/22/05.

2.) To address the issue of benchmarking and uncertainty of the computational fluid dynamics model, Entergy has provided benchmark references and performed sensitivity analyses for mesh size and turbulence intensity in order to quantify the CFD load uncertainty.

3.) To address the issue of development/evaluation of the 120% VYNPS load definition, Entergy developed 120% CFD transient loads and evaluated the impact of these loads on the structural analysis. Entergy also evaluated the characteristics of the ACA signatures based on VYNPS operating data from 80% to 100% CLTP and other industry experience.

4.) To address the issue of adequacy of the GE scale model test (SMT) benchmark of the ACA, Entergy performed additional benchmark data assessment including review of the model setup and operation and the impact of phasing sensitivity. All of the elements of this effort, with the exception of the phasing sensitivity evaluation that is in final verification, are complete. It is expected that this will be submitted, along with all of the RAIs applicable to SMT benchmark, for staff review by 8/4/05. Entergy anticipates the staff's review of the bases for the SMT benchmark evaluation during the audit scheduled for 8/22/05.

5.) To address the issue of applicability of knowledge gained from QC2 instrumented dryer tests to VYNPS assumptions, methods and conclusions, Entergy reviewed the QC2 reports for any findings or conclusions that could adversely impact assumptions, methods, or techniques used in the VYNPS analysis. This review has verified that the approach implemented by Entergy for VYNPS remains valid, is reinforced by the QC2 790MWe benchmark data, and the uncertainties applied to the VYNPS analysis contain sufficient conservatism. It is expected that results will be submitted, along with all of the RAIs applicable to the quantification of the impacts of the QC2 test experience on the VYNPS dryer evaluation, for staff review by 8/4/05. Entergy anticipates the staff's review of the bases for the QC2 impact assessment during the audit scheduled for 8/22/05.

<u>Acoustic Circuit Analysis Uncertainty</u>

The uncertainty associated with the ACA is a combination of measurement uncertainty and methodology uncertainty. Entergy evaluated the measurement uncertainty of the ACA by calculating the error associated with strain gage and pressure sensor measurement methods. The methodology uncertainty was assessed empirically by comparing predicted results against measured loads in two benchmark tests (SMT and QC2 full scale). Additionally, the frequency response uncertainties observed in the benchmark tests were converted to load uncertainties and included in the methodology uncertainty. The impact of uncertainty associated with the instrument location relative to the dryer on the analysis was also evaluated.

<u>CFD Model Benchmarking and Uncertainty</u>

The Fluent CFD methodology has been benchmarked against measured data and determined to provide an accurate representation of the modeled system. Included with the justification are several papers that describe benchmarking of the methodology.

To assess the uncertainty associated with CFD loads, a sensitivity analysis of the model mesh size and inlet turbulence parameters was conducted. Results demonstrate that the model is relatively insensitive to further refinements of mesh size in the steam dome. The Large Eddy Simulation (LES)-appropriate fine mesh in the plenum region is sufficient to accurately compute the hydrodynamic forces acting on the dryer. The CFD model was also determined to be insensitive to large variations in inlet turbulence.

Development/Evaluation of 120% VYNPS Dryer Load Definition

The VY steam dryer loads are generated from two fluid models. An acoustic circuit model (ACA) developed by Continuum Dynamics Inc. was used to convert empirical data at between 80% and 100% CLTP to loads on the dryer face. This methodology will be used to measure acoustic loads above 100% CLTP. Because the ACA model may not completely account for low frequency hydrodynamic loads associated with vortex shedding, a computational fluids dynamics model (CFD) was developed by Fluent Inc. to evaluate these loads. Stresses from both models are combined in the VYNPS dryer structural analysis. The ACA loads are based on empirical measurements. The ACA methodology that converts these measurements to dryer loads was benchmarked to demonstrate the ability of the model to predict loads on the dryer not only at 100% CLTP, but at increasing steam velocities as power is increased. The Entergy approach recognizes that the ability to project acoustic loads at higher power levels could be challenged by the excitation of acoustic resonances that occur as flow changes. This is why the fundamental approach does not rely on a predicted load curve above 100% CLTP. The performance criteria that Entergy has developed are based on reducing the code allowable stress for the component by the dryer load that is based on the CFD analysis, then determining what additional load is available for acoustic loading and establishing acceptance criteria that ensure acoustic loads are within the available margin. Entergy has evaluated CFD loads for both 100% CLTP and 120% EPU conditions and the maximum CFD loads are applied to dryer components.

Although the Entergy approach does not rely on a prediction of acoustic loads at EPU conditions, it should be noted that a reasonable extrapolation of ACA load data calculated between 80% and 100% CLTP predicts that there would continue to be a wide margin between dryer loads and structural limits at 120% EPU conditions. The absence of any significant detectable main steam system acoustic excitation at 100% CLTP and industry experience to date also support this expectation.

Scale Model Benchmark of the ACA

Since the Entergy approach relies heavily on the ability of the ACA methodology to accurately convert empirical data collected from the Main Steam system to acoustic pressure loads on the face of the dryer, the principle objective in the SMT benchmark test was to demonstrate not only the ability of the ACA to model the transmission of anticipated main steam system signals, but also to demonstrate the ability of the model to detect new acoustic sources at EPU flows that are different from those detected at 100% CLTP or those observed at Quad Cities (QC). To accomplish the goal of demonstrating the ability to detect new acoustic sources, the Entergy benchmark program used broadband signals as inputs to excite a wide spectrum of acoustic frequencies, not just discrete frequencies that might be expected based on Quad Cities data. Additionally, a wide range of test conditions such as multiple flow rates (including a zero flow case) and two diverse broadband sound sources were used. Multiple runs were performed to verify repeatability of test data at each test condition. Finally, microphones were calibrated before, and calibration checked, after testing to ensure reliability of the data.

Many of the RAIs focus on the impact of differences between the configuration of the SMT facility and VYNPS plant-specific characteristics. Because the purpose of the benchmark test was not to predict actual VYNPS loads, these minor differences in configuration are less important to establishing the validity of the ACA than they might be in an effort to predict actual dryer loads. The most important requirement of the scale model is that it accurately represents the actual acoustic features at VYNPS.

Applicability of QC2 Instrumented Dryer Tests/Benchmark to VYNPS

The QC2 benchmark of the ACA performed at 790MWe used the same version of the ACA model used in the SMT benchmark and for VYNPS (e.g. damping, acoustic speed, reflective boundary assumptions). Results are similar to SMT benchmark which is generally conservative.

The QC2 results at 790MWe, along with the SMT benchmark results, were used to develop the ACA load uncertainty applied to the VYNPS dryer load definition.

Conclusions

The CDI acoustic circuit analysis methodology used for the VYNPS dryer load definition is appropriate and reasonably accurate. The ACA methodology was benchmarked against the GE SMT and the Quad Cities 2 instrumented dryer. The QC2 benchmark at OLTP involved steam flow velocities similar to those for VYNPS at EPU power levels. The QC2 benchmark provides evidence that further supports Entergy's application of the ACA methodology for VYNPS' load definition. A review of the QC2 results supports use of the ACA loads combined with the CFD loads for the VYNPS loads and application of appropriate uncertainties is appropriate.

Entergy is confident that the FIV load definition and uncertainty values provide conservative loads and adequate margin to the acceptance limit curves. With the use of these curves, Entergy can ensure dryer structural integrity is maintained through the power ascension to EPU conditions and continued operation at full EPU power levels. This will be accomplished through careful monitoring of main steam system fluctuating pressures during controlled power ascension, and assessment against acceptance curves.

Attachment 4

Vermont Yankee Nuclear Power Station

Proposed Technical Specification Change No. 263 – Supplement No. 30

Extended Power Uprate

Response to Request for Additional Information

Electrical and Instrumentation and Controls Branch RAIs

Total number of pages in Attachment 4 (excluding this cover sheet) is 6.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION REGARDING APPLICATION FOR EXTENDED POWER UPRATE LICENSE AMENDMENT VERMONT YANKEE NUCLEAR POWER STATION

PREFACE

This attachment provides responses to the NRC Electrical and Instrumentation and Controls Branch's (EEIB) individual requests for additional information (RAIs) in NRC's letter dated July 27, 2005.[1] Upon receipt of the RAI, discussions were held with the NRC staff to further clarify the RAI. In certain instances the intent of certain individual RAIs may have been modified based on clarifications reached during these discussions. The information provided herein is consistent with those clarifications.

The individual RAIs are re-stated as provided in NRC's letter of July 27, 2005.

Electrical and Instrumentation and Controls Branch (EEIB)
Electrical Engineering Section (EEIB-A)

RAI EEIB-A-1

The licensee's submittal dated March 24, 2005 (Supplement No. 25), provided revised station blackout (SBO) analyses for VYNPS in response to a finding documented in the NRC's inspection report dated December 2, 2004. The finding relates to the requirements in Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.63, "Loss of all alternating current power." Specifically, 10 CFR 50.63(c)(2) requires, among other things, that the time required for startup and alignment of the alternate alternating current (AC) power source and required shutdown equipment be demonstrated by test. The licensee has not indicated in their submittal that they are planning to do any kind of integrated test, with all parties involved, to show they can meet the 2-hour basis for starting and aligning the alternate AC power source (i.e., the Vernon Hydroelectric Station (Vernon Station)), should it have to be re-started during a regional blackout. The staff considers such a test to be critical to showing that appropriate procedures and protocols are in place to coordinate between the multiple entities that would be involved. Provide a discussion on how the licensee intends to meet the 10 CFR 50.63(c)(2) test requirements.

Response to RAI EEIB-A-1

Entergy's letter of March 24, 2005,[2] described the regular, periodic testing currently conducted to demonstrate the ability of the alternate AC (AAC) source to power required electrical loads under a postulated station blackout event. The testing consists of two components:

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[1] U.S. Nuclear Regulatory Commission (Richard B. Ennis) letter to Entergy Nuclear Operations, Inc. (Michael Kansler), "Request for Additional Information – Extended Power Uprate, Vermont Yankee Nuclear Power Station (TAC No. MC0761)," July 27, 2005

[2] Entergy letter to U.S. Nuclear Regulatory Commission, "Vermont Yankee Nuclear Power Station, Technical Specification Proposed Change No. 263 – Supplement No. 25, Extended Power Uprate – Station Blackout and Appendix R Analyses," BVY 05-030, March 24, 2005

- Actual black start of the AAC source by TransCanada in accordance with ISO New England operating procedure OP-11, "Black Start Capability Testing Requirements." This testing is conducted and documented annually.

- Surveillance testing of the Vernon Tie in accordance with Entergy VYNPS procedure OP-4142, "Vernon Tie and Delayed Access Power Source Backfeed Surveillance." Performance of this test demonstrates actual ability to power required SBO loads. This testing is conducted and documented during each refueling outage.

These tests perform all actions required to restart the Vernon Hydroelectric Station (VHS) and, upon delivery of power to the Vernon Tie, the reenergization of a VYNPS 4KV bus. The only step not performed is the opening and closing of certain breakers in the interfacing switchyard as this would cause an unnecessary blackout to the general public. These breaker manipulations are performed in a continuously manned regional operations center and controlled by system procedures. Completion of these external activities will take less than five minutes of the two hour coping duration and are considered simplistic actions not requiring periodic validation.

Entergy recently held discussions with TransCanada, the owner/operator of the VHS, and the regional grid control center regarding procedural requirements and communication protocols for a postulated SBO event. These communications have resulted in system restoration procedure improvements and have served to promote a better understanding of the expectations relative to Entergy's reliance on the VHS during a SBO.

Entergy has established administrative controls to assure performance of a once per operating cycle tabletop review of the procedures that complete the actions to repower a VYNPS 4KV bus from the VHS. Pursuant to discussions with co-host REMVEC, a system-wide annual tabletop review will take place in October 2005. During this meeting Entergy will lead a tabletop review of all actions required to support the restoration of 4KV AC to VYNPS. This review will discuss the interfaces with the operator of VHS and the regional grid operator to verify that roles and responsibilities and timelines are understood and that there have been no changes that would impact the assumption in the VYNPS SBO coping strategy. Entergy will also provide the participants with additional insights regarding offsite power issues for nuclear power stations including plant response to and consequences of a SBO.

RAI EEIB-A-2

Since the operators of the Vernon Station are not Entergy personnel or Entergy contractors or vendors, and the station is not manned 24 hours per day, 7 days per week, the NRC staff requires additional information to have reasonable assurance that the operators will respond to the station as required and perform their duties in a reliable manner as needed to provide the alternate AC power source to VYNPS. Please address the following issues:

a) Are specific operators designated "on-call" to respond to the Vernon Station, as needed, during periods when the station is unmanned?

b) Are the operators subject to any fitness-for-duty requirements?

c) Are the operators, responsible for responding to the station when it is unmanned, required to remain within a certain distance from the Vernon Station?

d) The licensee's submittal states that since the Vernon Station is designated a "black start" facility under arrangements with the regional grid operator, this designation requires that the facility be capable of being black-started within 90 minutes after the operator is notified. From the onset of a regional grid collapse, during a period for which the Vernon Station is unmanned, discuss all assumptions regarding the time required for the operator to reach the station (e.g., adverse weather conditions, distance traveled), and the time required for the operator to perform the necessary actions to black start the station.

Response to RAI EEIB-A-2

Entergy has discussed these questions with TransCanada, the owner/operator of the Vernon Hydroelectric Station (VHS). In support of its commitment with ISO-NE to provide black start capability, TransCanada currently has four personnel that work out of the VHS during the normal day shift and report to that location. These personnel may be used to support activities at the other TransCanada units. These workers are trained to return the unit to service and make it available to be connected to the system. They have an on-call supervisor assigned who covers the Vernon, Bellows Falls and Wilder hydroelectric facilities and carries a pager. For off hour events, TransCanada's control station, which is continuously manned and located in Wilder VT, would contact the on-call supervisor who would call in the necessary support personnel to restart the VHS. Any alarm indication that the VHS has tripped off line is treated as a critical alarm and would prompt the call-in immediately upon receiving the alarm. Based on their experience, which includes off hours events in which the VHS needed to be re-started, TransCanada indicated that they had restarted the unit within the required ISO-NE response timeframe. They also indicated that they had not experienced situations where personnel were unavailable to support restart of the unit.

TransCanada indicated that they did have company policies that include a fitness-for-duty program. Although random drug testing is not performed on all personnel, supervisory observations that identified a potential for alcohol or drug abuse would lead to drug testing. It is TransCanada's expectation that the on-duty supervisor be fit to perform this duty when on-call.

A key assumption in the coping evaluation time line is that the personnel in the Wilder control station would be aware of a regional black-out almost immediately. During off hours, which maximizes response time, the control center would contact the on-call supervisor who would contact and dispatch personnel to restart the VHS. Given current agreements, testing practices and past experience, the timeline assumes that this will be completed within 90 minutes.

For a regional blackout, ISO-NE would direct the system restoration and order the transmission owner to close the switchyard breakers supplying VYNPS. These breakers can be operated remotely by the transmission owner. VYNPS' operators would then close the breakers supplying power to our emergency bus. The VYNPS breakers are operated from the VYNPS main control room, and these actions can occur very quickly. The coping study uses a two hours duration which bounds the actions discussed above.

To account for additional unforeseen circumstances (e.g., adverse weather beyond assumed travel time) the coping study is done with conservative inputs that provide additional margin. For example, should the SBO event occur during a winter snow storm that could delay VHS startup, the conservatisms in heat sink temperature (which assumes peak summer allowable temperature) would allow for additional coping time.

Entergy believes that use of a two hour coping time together with conservatisms inherent in the coping analysis, in addition to conservatively estimated response times, provides reasonable assurance that the VHS will be available to support mitigation of a SBO event.

RAI EEIB-A-3

Provide a discussion on the agreements between Entergy and other entities to bring the Vernon Station online from black-start conditions in order to provide electric power to VYNPS during an SBO event (i.e., whether there are formal written agreements supported by written procedures). If there are no formal written agreements, discuss why there is reasonable assurance that the alternate AC power source will be available, as needed, consistent with the time frames assumed in the revised VYNPS SBO analyses.

Response to RAI EEIB-A-3

Vermont Yankee has an Alternative AC Source Agreement dated July 31, 2002, with Green Mountain Power (GMP), which is the retail electricity provider in the area, to make available at the point of interconnection between the Vernon switchyard and the Vernon Tie up to 3 MW of energy from the Vernon Station during an emergency affecting Vermont Yankee. This agreement requires GMP to take all reasonable steps to keep the Vernon Tie energized at all times. GMP has in turn entered into an agreement, dated as of July 31, 2002, with USGenNE (the operator of the Vernon Station at the time) and now assigned to supply this power to Vermont Yankee in an emergency, and a Service Agreement for Network Integration Transmission Service Between New England Power Company and Green Mountain Power Corporation, effective July 31, 2002, which commits New England Power (the owner of the transmission facilities at the Vernon Station) to keep the Vernon Tie energized during normal utility operations and to make reasonable efforts to keep the line energized during emergency situations, subject to ISO, NEPOOL and REMVEC requirements. TransCanada has affirmed that they are committed under tariff to provide black start capability of the VHS to ISO-NE.

Both the NEPOOL and REMVEC procedures state that "the most critical power requirement after a blackout is the assurance of reliable shutdowns of nuclear generators, and that expeditious restoration of alternative off-site power sources to nuclear units is imperative to promote the continued reliability of shutdown operations." NEPOOL Operating Procedure No. 6, System Restoration, App. A (System Restoration Guidelines); REMVEC II Operating Procedure No. 6, System Restoration, App, B (Guidelines and Philosophies).]

As a backup to local indication available to grid operators of a regional blackout, VYNPS procedure OT 3122 "Loss of Normal Power" Appendix A "Station Blackout Procedure" directs operators to immediately contact the regional grid control center to initiate a blackstart of the VHS if the Vernon Tie is unavailable due to a regional grid blackout. The regional grid control center actions are directed by Operating Procedure OP-6 "System Restoration." This directs certain hydro station operators (including the VHS) to initiate blackstart procedures, and upon notification that the units are started, provide instructions to align power to VYNPS and to communicate when these actions are complete to the VYNPS control room. The owner of the VHS has a procedure for the actual blackstart.

RAI EEIB-A-4

With respect to the battery capacity requirements during an SBO event, verify that sufficient DC power is available, under worst case conditions during the two hour coping period, to close the 4160 volt breakers associated with the alternate AC power source.

Response to RAI EEIB-A-4

A review of the worst case scenario has been performed by adding the 6 amp load of the Vernon Tie breaker closing for a full minute, for conservatism, to the end of the 2 hour duty cycle. The run was compared to calculation VYC-2154, Rev. 0, MCC 4 and shows no change to the required battery capacity. This additional load also has no effect on end voltage.

RAI EEIB-A-5

Provide a discussion regarding the changes required to plant procedures for SBO coping (e.g., which procedures will be changed and brief discussion of the changes to be made). Also, address when the operator training on the revised procedures is expected to be completed.

Response to RAI EEIB-A-5

Procedure changes for SBO coping include the following:

- Operating Procedure OP 2124, " Residual Heat Removal System" has been "revised for training" to include direction on how and when to place the second RHRSW pump per RHR heat exchanger in service when placing the torus cooling mode of RHR in service.

- Operational Transient procedure OT 3122, "Loss of Normal Power" has been revised to direct operators to immediately contact the regional grid control center to initiate a blackstart of the VHS if the Vernon Tie is unavailable due to a regional grid blackout. In addition, the procedure has been "revised for training" to commence a cooldown within one hour of the SBO event, and when power is restored, to place two RHRSW pumps in service per OP 2124 (see above). Also, a note was added about exceeding the drywell air temperature of 280°F for a short period of time without exceeding the 280°F drywell shell temperature.

Training on the changes to OP 2124 and OT 3122 is currently underway. Once the training cycle is complete (scheduled for September 1, 2005), the procedures will be revised and issued for use.

Various operating, surveillance and administrative procedures will be revised to incorporate a higher condensate storage tank inventory limit as either a precaution or an administrative limit by October 15, 2005.

Attachment 5

Vermont Yankee Nuclear Power Station

Proposed Technical Specification Change No. 263 – Supplement No. 30

Extended Power Uprate

Response to Request for Additional Information

Mechanical and Civil Engineering Branch

Total number of pages in Attachment 5 (excluding this coversheet) is 28.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
REGARDING APPLICATION FOR EXTENDED POWER UPRATE LICENSE AMENDMENT
VERMONT YANKEE NUCLEAR POWER STATION

PREFACE

This attachment provides responses to the NRC to Mechanical and Civil Engineering Branch's (EMEB) individual requests for additional information (RAIs) in NRC's letter dated July 27, 2005.[1] Upon receipt of the RAI, discussions were held with the NRC staff to further clarify the RAI. In certain instances the intent of certain individual RAIs may have been modified based on clarifications reached during these discussions. The information provided herein is consistent with those clarifications.

The individual RAIs are re-stated as provided in NRC's letter of July 27, 2005.

Mechanical and Civil Engineering Branch (EMEB)
Component Integrity and Testing Section (EMEB-A)
Civil and engineering Mechanics Section (EMEB-B)

RAI EMEB-B-41

On Page 22 of Attachment 6 to Supplement 26, GE discusses the modified steam dryer analysis results. The acoustic and CFD pressure loadings were calculated up to 100% of the current licensed thermal power (CLTP) level. For the square type dryer similar to the ones at VYNPS and Quad Cities, no significant cracking was identified during operation at 100% OLTP. However, this type of steam dryer failed when Quad Cities Units 1 and 2 operated at EPU conditions. Analysis up to 100% CLTP does not demonstrate dryer integrity at EPU conditions. Provide the evaluation of VYNPS modified steam dryer for EPU conditions.

Response to EMEB-B-41

Entergy's modified steam dryer analysis relies on measured main steam system data for input to the acoustic circuit analysis in order to generate dryer loads. The CLTP dryer stresses calculated based on those loads, incorporating uncertainty, show substantial margin to the ASME fatigue limit. In addition, the CFD analysis performed assuming 120% EPU steam flow conditions does not show a significant increase in hydrodynamic loads. Entergy agrees that analysis up to 100% CLTP does not conclusively demonstrate dryer integrity at EPU conditions. The square type dryer installed at VYNPS is similar not only to Quad Cities, but to other BWR's. One such BWR that has been operating at EPU conditions since 1998 recently conducted a comprehensive dryer inspection that found no indications of significant cracking. Although no significant cracking was identified at Quad Cities or VYNPS during operation at 100% OLTP, VYNPS is the only square hood plant to perform a comprehensive internal and external inspection for indications prior to operation at EPU conditions. Additionally, Quad Cities

[1] U.S. Nuclear Regulatory Commission (Richard B. Ennis) letter to Entergy Nuclear Operations, Inc. (Michael Kansler), "Request for Additional Information – Extended Power Uprate, Vermont Yankee Nuclear Power Station (TAC No. MC0761)," July 27, 2005

instrumented dryer and main steam system measurements show evidence of acoustic source excitation at 100% OLTP, whereas VYNPS main steam measurements do not. Industry evidence suggests that the increased steam flow rate associated with EPU does not create new acoustic phenomena, rather it exacerbates phenomena that existed at OLTP. Based on the absence of any significant acoustic excitation at 100% CLTP and industry experience to date, VYNPS dryer loads at EPU are still expected to provide wide margin to the structural fatigue limits.

Entergy plans to collect data during the controlled and methodical power ascension for use in evaluating EPU dryer loads with respect to defined performance criteria and to verify that structural limits are not challenged during power ascension. The performance criteria that Entergy has developed are based on reducing the code allowable stress for the component by the dryer load that is based on the CFD analysis, then determining what additional load is available for acoustic loading and establishing acceptance criteria that ensure acoustic loads are within the available margin. Entergy has evaluated CFD loads for both 100% CLTP and 120% EPU conditions and the maximum CFD loads are applied to dryer components. By taking this approach, Entergy relies on detecting, and appropriately responding to, any unexpected phenomena that might occur during power ascension. This can be accomplished with reasonable certainty, rather than attempting to create a bounding 120% VYNPS EPU load prediction.

RAI EMEB-B-49

On Page 29 of Attachment 7 to Supplement 26, CDI compares the calculated steam dryer loads for Quad Cities Unit 2 and VYNPS. CDI states that the added energy content present in Quad Cities Unit 2 is the result of distinct deterministic mechanisms that exist at the feed flow rates at which Quad Cities Unit 2 operates, and that these mechanisms are not excited at the much lower feed flow rates at which VYNPS operates. Discuss the basis for the assumption that the higher steam flow rates to be achieved during EPU operation at VYNPS, combined with the plant-specific steam system configuration, will not result in the excitation of distinct deterministic mechanisms similar to Quad Cities Unit 2.

Response to EMEB-B-49

There is no explicit or implicit assumption made in the discussion cited by this RAI regarding excitation of deterministic mechanism at VYNPS as a result of EPU operation. The comparison of VYNPS acoustic circuit analysis loads with Dresden and Quad Cities in Attachment 7 to Supplement 26 is based on use of measured main steam system data for input. Figure 15 of Attachment 7 provides a peak load comparison between VYNPS and QC2 at OLTP. The comparison discussion asserts that the QC2 peak loads are a result of deterministic mechanisms that are excited at the unit's OLTP feed flow rates. Rated feed flow of QC2 at OLTP is 50% greater than VYNPS. This difference in rated feed flow is cited as the justification for why no such sources are detected at VYNPS OLTP operating conditions.

As stated in response to RAI EMEB-B-41, Entergy agrees that analysis up to 100% CLTP does not conclusively demonstrate dryer integrity at EPU conditions. Entergy will collect data during power ascension for use in evaluating EPU dryer loads to verify that structural limits are not challenged during power ascension. By taking this approach, Entergy relies on detecting, and appropriately responding to, any unexpected phenomena that might occur during power ascension.

The discussion cited in this RAI reflects that QC2 has deterministic excitation mechanisms at OLTP. Quad Cities instrumented dryer and main steam system measurements confirm acoustic source excitation at 100% OLTP. Based on the absence of any significant acoustic excitation at 100% CLTP, VYNPS dryer loads at EPU are still expected to provide wide margin to the structural fatigue limits.

RAI EMEB-B-73

With regard to Section 3.1.2 of Attachment 6 to Supplement No. 26, the vortex shedding pressure loading was input into ANSYS from a Fluent LES compressible flow simulation of the dryer at 100% of CLTP conditions. Entergy should provide documentation that benchmarks and validates the CFD code's ability to predict vortex shedding in the complex flows of the dryer.

Response to EMEB-B-73

Exhibits EMEB-B-73-1 through 3, provided in Attachment 11, are papers that benchmark the CFD codes prediction capability through the comparison of LES simulation results measured data.

EMEB-B-120

With regard to Attachment 1 (Fluent Final Report TM-675, "CFD Modeling of the Vermont Yankee Steam Dryer Phase - II) to Supplement 29, please provide a more detailed discussion of the lessons-learned during the Phase I analysis of the steam dryer along with more information on how these lessons-learned were addressed by the Phase II analysis.

Response to EMEB-B-120

The Phase I analyses consisted of an incompressible URANS simulation on the full upper vessel geometry and an incompressible LES simulation on a clipped geometry. Comparisons of these two results yielded an improved understanding of the flow field and flow structures within the dryer. Low frequency shifts in the flow field were noted as a result of the steam jet interaction occurring at the inlet to the dome. The lesson learned was not to neglect the interaction between the dome and the plenum. Strong vortices were observed near the steam line inlets as the steam turned into the steam lines. These vortices were noted to rapidly make small shifts in position with time, thereby causing large pressure gradient fluctuations on the opposing vertical faceplate. Large pressure gradients within the vortices were considered unrealistic and assumed to be caused by flow incompressibility. The resulting lesson learned was to avoid modeling the fluid (steam) as incompressible. Variations in mass flow at the outlets indicated potential steam line flow interaction. High frequency features were difficult to characterize with the limited data collected for this phase. The resulting lesson learned was to collect sufficient data in order to characterize high frequency features.

Lessons learned from the Phase I analysis that were addressed in the Phase II analyses included: coupled plenum-dome flow domain to account for transients in dome, flow compressibility, extension of outlet steam lines to common outlet plenum. Surface pressure (difference) data was collected for all dryer walls.

RAI EMEB-B-121

On page 1 of Attachment 1 to Supplement 29, the Fluent report states that the model geometry was modified to raise the overall accuracy of the Phase I model. What specific measure or basis is used to support the improvements in accuracy?

Response to EMEB-B-121

Accuracy improvements were expected because some assumptions from the Phase I model were removed and the geometry was better presented in Phase II.

Assumptions in Phase I that were removed:

- Flow is incompressible. This assumption has an affect on the pressure gradient across the vortices in front of the nozzles. Using a compressible gas would allow the fluid to compress and expand and thus to absorb a portion of centrifugal force in a strong vortex in a density change.

- Interaction between dome and plenum is negligible. A decoupled plenum simulation with a stagnant boundary condition does not reflect the dynamic interaction between the flow in the dome and the plenum.

Better represented geometric components:

- Inclusion of dams
- Curvature at steam line nozzle
- Extended pipe network
- 2" gap around steam dryer

The modifications made in Phase II have led to some changes of the simulation results that represent the problem better than in Phase I. Those modifications and the resulting improvements included:

- pressure difference across the vortex in front of steam lines is lower because of compressibility effects;
- large scale, low frequency oscillations in the dome are observed and feed into the plenum at the face plates;
- curved steam line nozzles allow flow to enter pipes more smoothly;
- some flow in the 2" gap has been observed; and
- some flow rate oscillations in steam lines were observed.

EMEB-B-122

On page 1 of Attachment 1 to Supplement 29, the Fluent report states that the model geometry was modified to raise the overall accuracy of the Phase I model. Are there any further refinements of the geometric details that could be made? Please discuss any remaining geometric simplifications that are present in the model and the basis for assuming these simplifications do not impact the predictions.

Response to EMEB-B-122

The following simplifications were made:

1. Material thickness was neglected. The thickness of the gussets and other interior walls is small compared to the size of the dryer. By neglecting the thickness the flow area has increased by a small amount. Neglecting the wall thickness is common practice in CFD simulations when the thickness is small compared to the size of the flow path.

2. Hooks and bolts were neglected. Small features such as hooks and bolts create some local disturbances but have very little impact on the main flow pattern. These features can be neglected if they are small compared to flow path.

3. Dryer vane geometry was not included. Instead a porous media model was used to represent the pressure loss in the vane bank. The dryer vane banks are located relatively far from the face plate. The influence of the vane banks on the face plate loading was deemed to be small because of its distance to face plate. The question of the influence of the porous media and the dryer vane bank on the hydrodynamic loads at the face plate is discussed in RAI EMEB-141.

4. Steam line simplifications:

    - The steam lines were shortened downstream of the strain gauges, any turns were neglected.

    - The valve assembly was simplified.

    - Details in the steam lines such as branch lines, dead ends, and contractions were neglected.

The main purpose of including the steam lines was to obtain pressure data at the location of the strain gauges and to couple the steam lines to enable communication between the steam lines. It was assumed that the details of the flow in the steam lines do not impact the face plate loading because the steam line flow is downstream of the face plate. Turbulent disturbances cannot be convected upstream except through pressure waves and acoustic modes. However, capturing acoustic modes was not the focus of the analysis.

EMEB-B-123

On page 1 of Attachment 1 to Supplement 29, the Fluent report states that "the Phase I study showed that an LES model could be successfully applied to the dryer model." Please define the success criteria used to support this conclusion.

Response to EMEB-B-123

The LES model was applied successfully in the sense that the simulation was completed within a practical time frame. The time and length scales are such that the volume around the area of interest could be resolved with an appropriate mesh while being able to obtain a solution for one scenario within one or two months. Furthermore, the simulation provided some qualitative insight into the flow pattern in the steam dryer.

EMEB-B-124

On page 1 of Attachment 1 to Supplement 29, the Fluent report states that improvements were made to the physical models. Assuming that certain assumptions are made in a typical CFD simulation, please discuss the remaining major assumptions and limitations of the physical models used in relationship to the flow physics and conditions expected in this specific problem. Please describe how computational limitations affected your modeling approach.

Response to EMEB-B-124

Remaining assumptions of the physical model include:

- Steam represented as an ideal gas
- Liquid fraction can be neglected
- Rigid walls (as opposed to elastic walls), no two-way fluid-structure-interaction

Viscous heating was neglected in the simulation because the amount of energy dissipated compared to the thermal energy in the fluid is relatively small. Viscous heating is considered for applications with very high shear rates, such as torque converters and other rotating machinery, which is not the case in this simulation. Pressure work and turbulent kinetic energy were not included in the energy equation because the pressure variations and the turbulent kinetic energy were assumed to be small compared to the thermal energy in the fluid based on general experience.

Thermal boundaries were treated as adiabatic.

The pressure variations in the domain are small. Therefore, the ideal gas law should be sufficient to describe the density sufficiently in the vicinity of the operating pressure. The molecular weight was adjusted to match the real gas density of steam at the operating point.

The liquid fraction was small after the flow went through the dryer vane bank and therefore was neglected.

The CFD analysis did not consider any effect of the structural deformations on the flow. Potentially, there could be some fluid structure interaction. The structure can transmit some of the energy absorbed from the fluid back to the fluid.

Computational limitations primarily affected the model mesh size, time step, and extent of the geometry.

EMEB-B-125

On page 2 of Attachment 1 to Supplement 29, the Fluent report states that a "highly refined mesh, consistent with LES requirements" was used in a specific domain. Discuss the specific rationale used to determine the mesh size in the LES-appropriate mesh region and provide the specific computations used in this determination. Where appropriate, compare mesh sizes to relevant length scales, such as the Taylor or Komolgorov micro-scales or the boundary layer thickness (wall y+). Discuss the size of the mesh in the rest of the model regions (noted to be too large for ideal LES simulations) in terms of relative size of the mesh compared to an ideal LES mesh to give an idea of the relative coarseness of this mesh.

Response to EMEB-B-125

The mesh used in the LES section of the Phase II model was taken from the Phase I LES study. Results from the Phase I URANS calculation were used to define mesh requirements for the Phase I LES model. Meshing guidelines for LES calculations require that computational cells be sized such that they are larger than the Taylor length scale and smaller than the integral length scale. The Taylor length can be estimated as $(10\nu k/\varepsilon)^{1/2}$ and the integral length scale can be estimated as $C_\mu k^{3/2}/\varepsilon$. Based on the estimated k and ε fields from the URANS calculation, typical values in the plenum for Taylor and integral length scales are 0.03 inches and 1.5 inches, respectively. Typical cell size used in the plenum for the LES section of the model was 0.65 inches. Only one plenum was modeled with this cell size, which was sufficiently representative for the dryer region of greatest interest. In the opposite plenum, the cell size was approximately 1.5 inches. The cell size in the dome ranged from the approximately 1.5 inches to 6 inches. These cell sizes are appropriate for these regions of the model for the purpose of capturing the large scale unsteadiness and flow pattern in the dome.

EMEB-B-126

On page 3 of Attachment 1 to Supplement 29, the Fluent report discusses a comparison of LES and unsteady Reynolds-Averaged Navier-Stokes (URANS) in an attempt to demonstrate that the LES model would not produce significantly different results from the URANS model. On page 12, it is noted that Figures 8 through 15 show that the LES model sufficiently represents the URANS solution. In light of the complex jet interactions in the upper dome of the reactor, explain the basis for using the URANS solution as a reference point given the lack of specific validations for this complex flow pattern. In addition, discuss the sufficiency argument for the LES to URANS comparison in the context of Figures 14 and 15 which show a significant variation in velocity magnitude as well as the spatial variation in the velocity.

<u>Response to EMEB-B-126</u>

Phase II model was seen as an improvement over Phase I. The URANS model showed some unsteady behavior that was important to capture in Phase II.

The acceptance criteria for using the LES approach included:

- Mean flow contours are similar.
- LES model is less diffusive than URANS and therefore shows more pronounced gradients and higher peaks.
- LES model does not show any results that are apparently unphysical.

Some variations between the LES model and the URANS approach were expected. The URANS solution is sufficient for use as a reference point because it was the best available description of the flow features in the dome at the time of the comparison.

The LES model showed similar unsteady behavior in the dome based on visual inspection of velocity magnitude animations.

The LES to URANS comparison is sufficient based on the similarity in flow features. Flow features that are similar in both the URANs and LES cases can be found in Figures 8 through 15.

Pressure contours in Figure 10 and Figure 11 are similar. The difference between minimum and maximum pressure is similar.

Figure 12 and Figure 13: High pressure spot in same location. There is a layer of low pressure on the surface of the dryer. It is more pronounced in the LES results.

Figure 14 and Figure 15: There are differences in peak velocities, however, the spatial distribution of the flow is quite similar. Flow features that can be found in both URANS and LES include:

- streak of high velocity in 1 o'clock position along dome,
- horizontal streak of high velocity at about 1/4 height of the dome (from outermost dryer jet),
- streak of high velocity pointing in 11 o'clock direction.

The LES results show an additional feature on the right hand side above the horizontal streak of high velocity.

<u>EMEB-B-127</u>

On page 5 of Attachment 1 to Supplement 29, the hybrid mesh is described and it is noted that the flow domain is coupled by resolving the entire domain for the LES simulation. Conceptually, discuss the significance of the coarse mesh on this "boundary condition" at the edge of the LES appropriate mesh region. Given the strong dependence of LES solutions on the applied boundary conditions, discuss the potential for sensitivity of the results to variations in the coarse mesh size.

Response to EMEB-B-127

The influence of boundary conditions on the result in the flow domain depends in general on the forces that act upon the flow in the domain. If the forces in the domain are very strong then the boundary conditions are less important. If the forces are weak then the boundary conditions have a big impact on the flow field. For example, in a pipe flow the inlet boundary condition will prolong for a long distance. If the distance is long enough a fully developed pipe flow evolves. If there is a turn in the pipe then the flow is likely to separate on the inner wall. The flow profile downstream of the turn is more influenced by the turn than by the inlet profile.

For the sensitivity of the solution on the 'boundary condition' at the edge of the LES appropriate mesh regions, two aspects can be considered: first, the distribution of flow entering the LES region, second the content of turbulent kinetic energy in the flow.

Figure EMEB-B-127-1 shows the velocity distribution on a plane located a small distance in front of the face plate. Velocity magnitude contours from a steady state RANS simulation and time averaged velocity magnitude contours from the LES simulation (100 % load) are shown. From these figures it can be seen that the LES case represents the flow distribution well compared to the RANS study. The spatial distribution and the velocity magnitudes are in good agreement including the flow distribution in the dome. From this perspective, the boundary conditions used in the LES model are sufficient.

Potentially, there could be an influence of the solution in the LES region on the 'flow condition' in the area where the mesh transitions from the coarse mesh to the fine mesh. Vortices that are generated upstream could be convected downstream and could influence the solution in the LES region. If the dome region had been adequately resolved, more turbulence would be generated in the dome and carried over to the face plate.

The distribution of turbulent kinetic energy on the mesh transition face is shown in Figure EMEB-B-127-2 for both the LES and steady state RANS cases. The mesh employed in the steady-state RANS case is adequate to resolve local turbulent kinetic energy (TKE) production in the dome. The steady state RANS simulation shows the distribution of TKE on this face. In both cases, the TKE carried over from the dome to the face plate is smaller than the TKE generated at the face plate. The peak TKE levels are higher in the LES simulation.

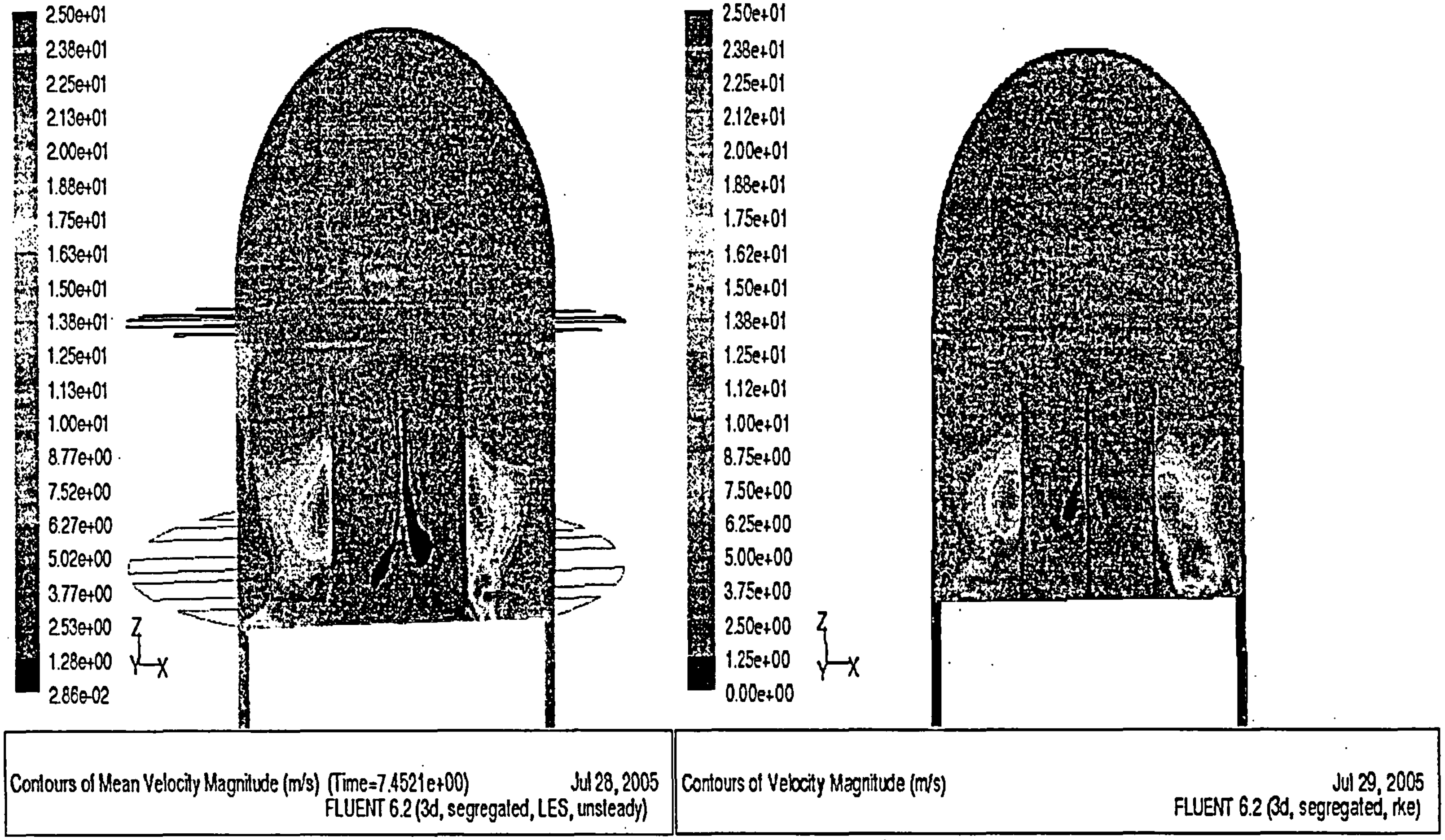

Figure EMEB-B-127-1: Velocity Magnitude Contours from RANS (left) and LES (right)

Potentially, there could be an influence of the solution in the LES region on the 'flow condition' in the area where the mesh transitions from the coarse mesh to the fine mesh. Vortices that are generated upstream could be convected downstream and could influence the solution in the LES region. If the dome region had been adequately resolved, more turbulence would be generated in the dome and carried over to the face plate.

The distribution of turbulent kinetic energy on the mesh transition face is shown in Figure EMEB-B-127-2 for both the LES and steady state RANS cases. The mesh employed in the steady-state RANS case is adequate to resolve local turbulent kinetic energy (TKE) production in the dome. The steady state RANS simulation shows the distribution of TKE on this face. In both cases, the TKE carried over from the dome to the face plate is smaller than the TKE generated at the face plate. The peak TKE levels are higher in the LES simulation.

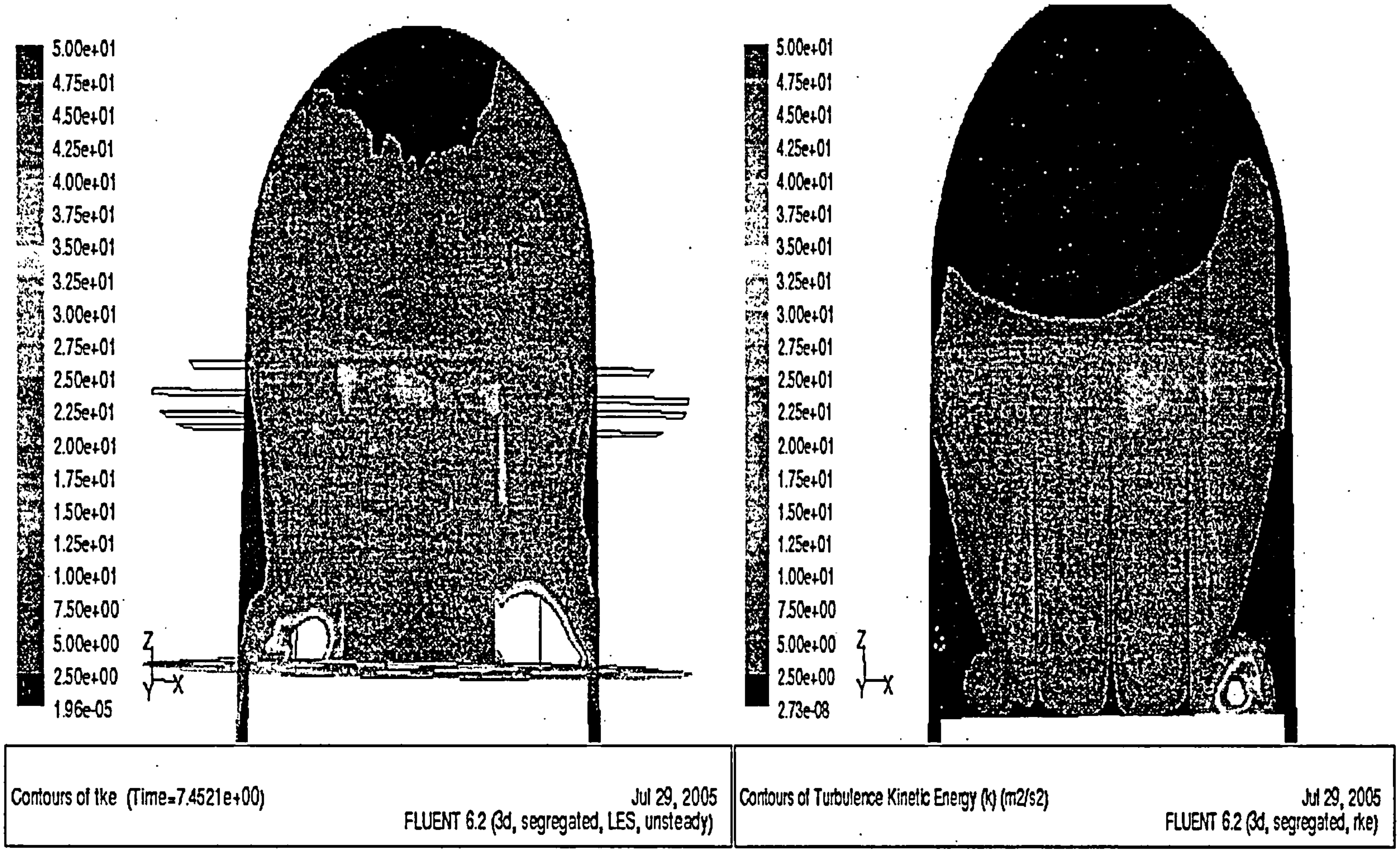

Figure EMEB-B-127-2: Steam Dome and Dryer Face Turbulent Kinetic Energy Contours from RANS (left) and LES (right)

EMEB-B-128

On page 5 of Attachment 1 to Supplement 29, the hybrid mesh is described and it is noted that the flow domain is coupled by resolving the entire domain for the LES simulation. Discuss the spatial and temporal filtering that could be expected to occur as the result of excess diffusion in the coarse tetrahedral region in the upper dome. What is the potential impact of not having resolved potentially higher frequency spatial and temporal variations on the conceptual "input boundary" to the LES appropriate mesh region? Could the lack of higher frequency information in the final results be partially attributed to a lack of resolution of these frequencies in large portions of the domain?

Response to EMEB-B-128

The effect of the coarse mesh in the dome is a reduced ability of the simulation to resolve local turbulence (in the dome) with high frequency information. At a mean flow velocity of about 10 m/s and a mesh size of about 6" or 0.15 m (as can be found in the dome) the maximum frequency based on the Nyquist criterium is: mean flow velocity/ (4* mesh size) = 10/(4*.15)=16.6. The Nyquist criterium requires a minimum resolution of a sinusoidal signal with 4 points. With the assumption that a disturbance is convected with the mean flow velocity the above relationship can be found. Therefore, the high frequency portion of the spectrum is underresolved in the dome.

Figure EMEB-B-128-1 shows the comparison of the LES results and the steady state RANS. The LES and RANS simulation generate about the same level of turbulence in the dome.

The time averaged velocity magnitudes from a steady state RANS and the LES simulation in the dome are shown in Figure EMEB-B-128-2. The LES results represent the mean flow patter well compared to the RANS solution in terms of spatial distribution and peak velocities. The coarse mesh also leads to excess numerical diffusion which causes the jets to diffuse more quickly.

The flow velocities in the plenum are larger than in the dome. The lengths scales are smaller. Therefore, significant contributions at higher frequencies are more likely to be generated in the plenum than in the dome. Figure EMEB-B-128-3 shows the PSD of 62.2 Hz at the face plate. The signal this PSD is based on includes pressure fluctuations from acoustic and hydrodynamic sources. The hydrodynamic sources are represented by the local peaks.

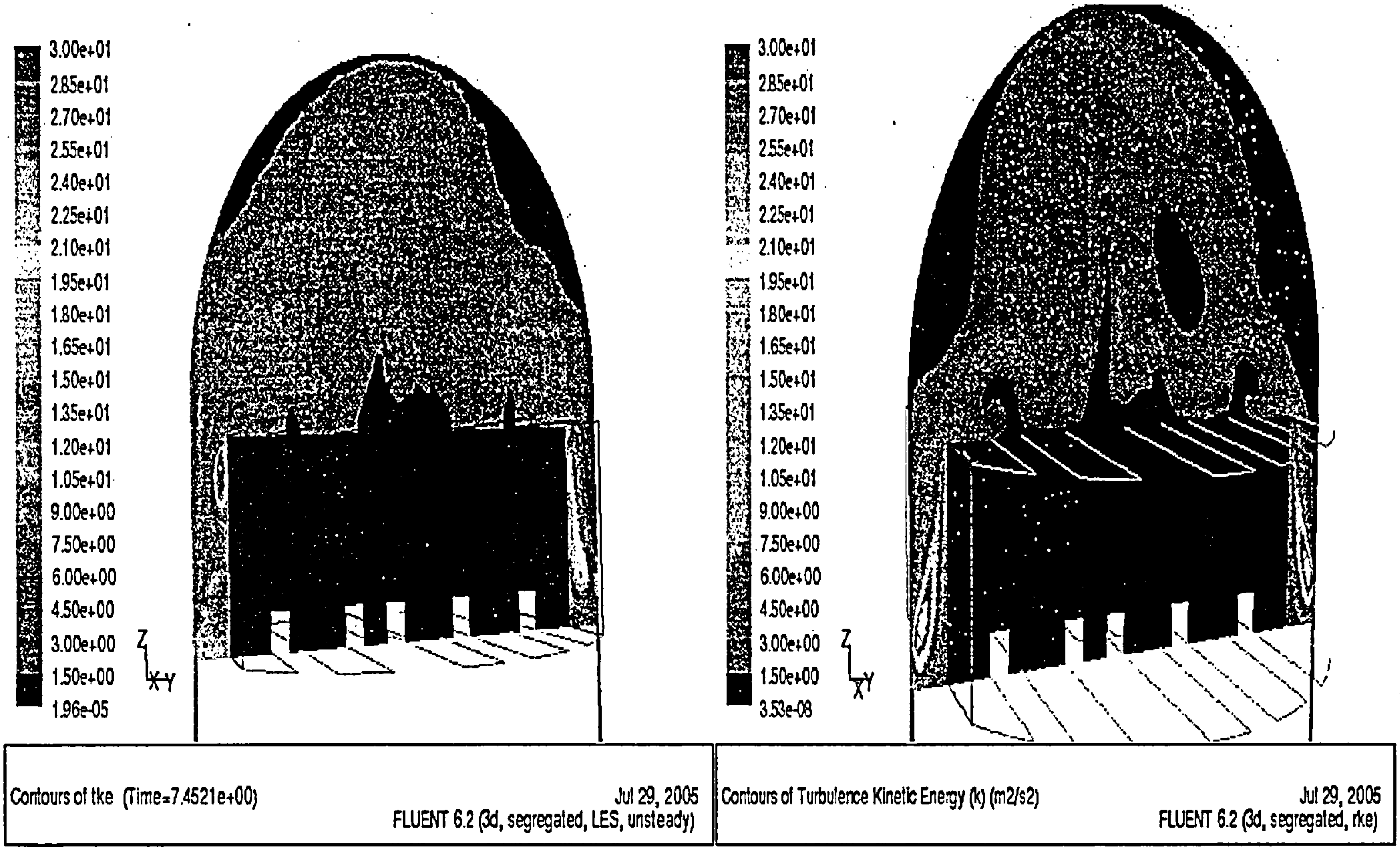

Figure EMEB-B-128-1: Steam Dome Turbulent Kinetic Energy Contours from RANS (left) and LES (right)

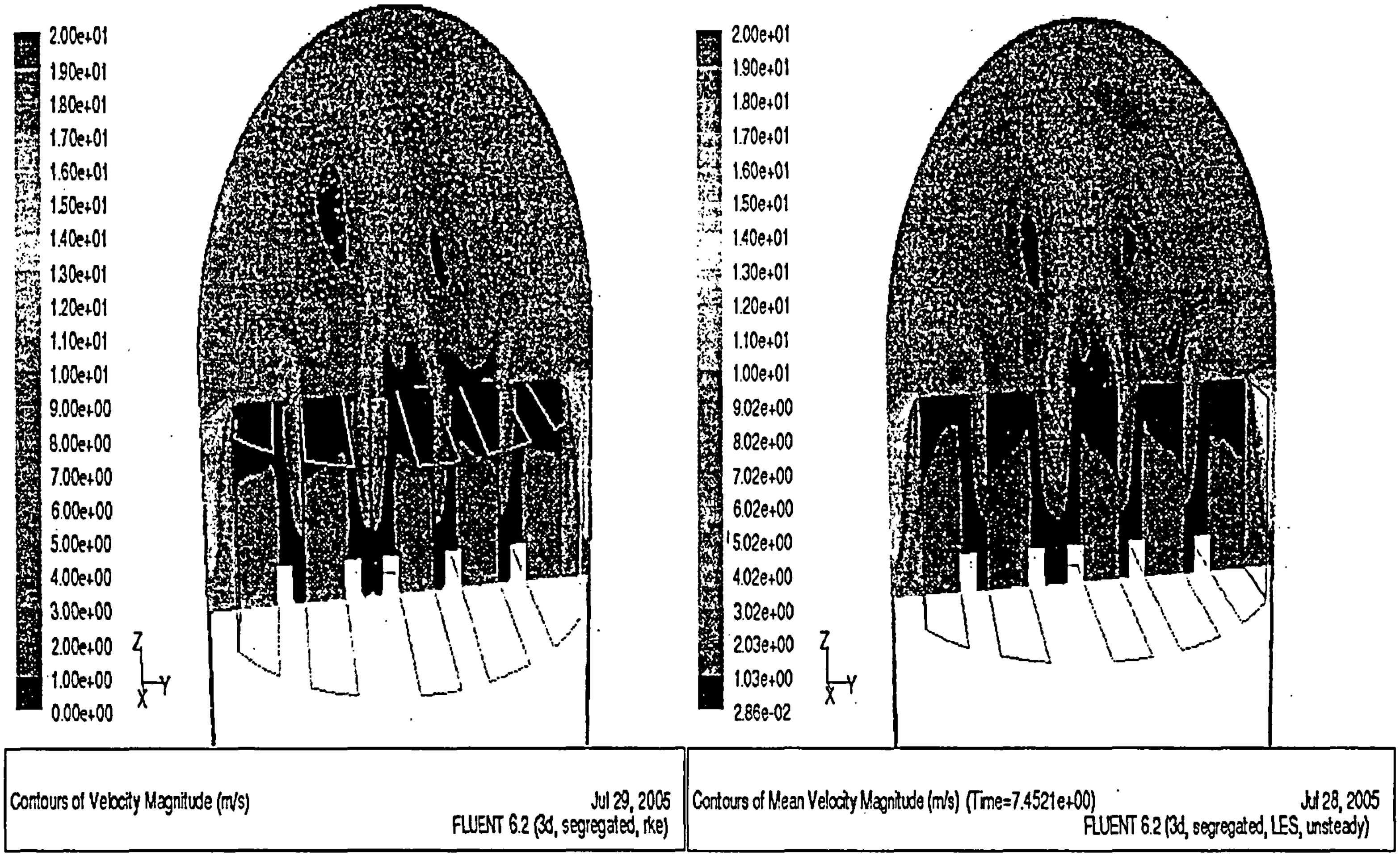

Figure EMEB-B-128-2: Velocity Magnitude Contours from RANS (left) and LES (right)

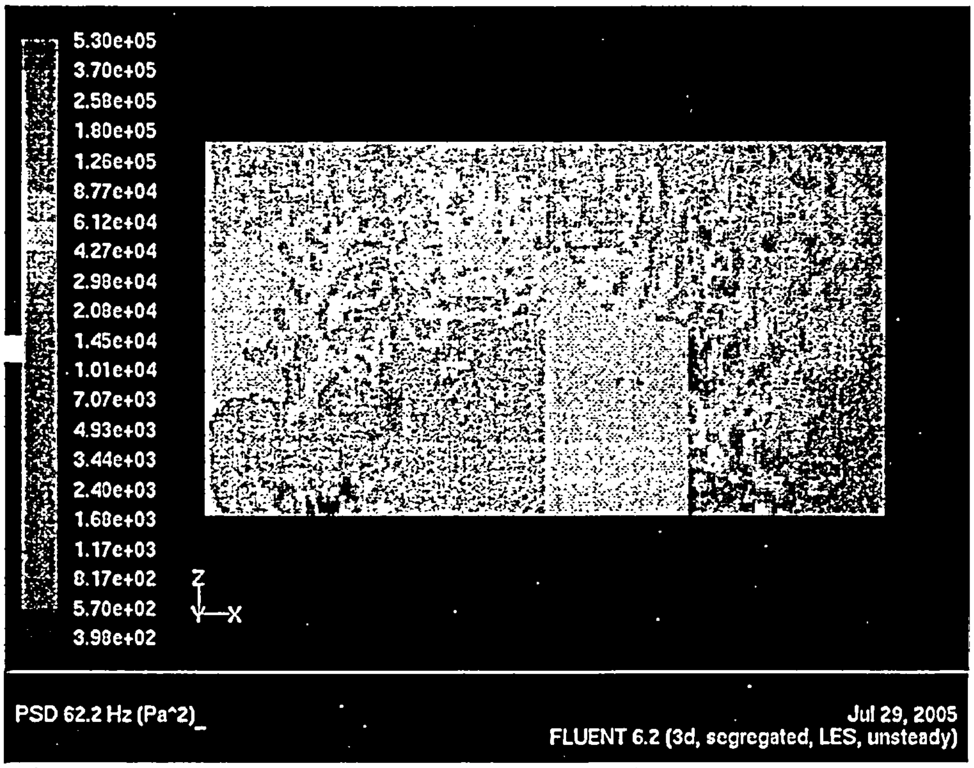

Figure EMEB-B-128-3: PSD of 62.2 Hz at the Dryer Face Plate

EMEB-B-129

On page 5 of Attachment 1 to Supplement 29, it is stated that "the success of obtaining an LES solution on the hybrid mesh hinged on the capacity for the LES model to sufficiently resolve the flow field on the coarse mesh." The concept was tested by comparing the LES and URANS solutions. How can one determine that the LES model sufficiently resolves the flow on the coarse mesh without comparison to data? Is comparing a specific turbulence model to another turbulence model considered to be a validation?

Response to EMEB-B-129

Relevant engineering data required of the simulation is based on the resolution of <~70 Hz signals. The LES model simulation is therefore required to be able to resolve the flow characteristics in this frequency range. A sufficiently fine mesh and time step size is required for this resolution. The model was set up to meet and exceed this resolution requirement in the regions where the turbulence production was considered to be significant, i.e., in the plenum region.

In the dome, a coarser mesh was used. The comparison study, as well as a follow-on steady-state RANS study, showed that the LES model on the coarser mesh in the dome region was able to resolve the mean flow features and low frequency oscillations. The steady-state RANS study verifies this quantitatively as discussed in responses to RAI 127 and 128.

In the absence of experimental data, a comparison of results with that of a second or third turbulence model along with mesh refinement studies is an appropriate validation. The LES model is the most universal turbulence model available and applicable to most flow regimes. Therefore, comparing results obtained from different turbulence models can support the validation of results.

EMEB-B-130

On page 9 of Attachment 1 to Supplement 29, it is noted that a central differencing scheme is used. What is the order of accuracy for the solution and what impact does the boundary treatments have on this accuracy? Does the accuracy at the boundaries impact the overall solution accuracy? Were higher order schemes attempted? What is the expected sensitivity of the solutions to the central differencing scheme and the wall treatment accuracy?

Response to EMEB-B-130

Second-order upwind schemes have been widely used for RANS computations. Numerical diffusion introduced by upwind schemes is accepted in RANS simulations because the eddy viscosity is orders of magnitude larger than the molecular viscosity. In LES simulation the subgrid scale viscosity is much smaller than the eddy viscosity in a RANS simulation. The numerical diffusion can therefore overwhelm the physical diffusion when upwind schemes are used. To improve the accuracy of LES solutions, Fluent has developed the bounded central differencing scheme that is less diffusive and dissipative than upwind schemes. The central differencing scheme is the recommended scheme for LES problems.

Sensitivity to wall treatment has been discussed in response to RAI 133.

References to differencing schemes can be found in:

Kim, S.E., Mohan, L.S.: "Prediction of Unsteady Loading on a Circular Cylinder in High Reynolds Number Flows Using Large Eddy Simulation", 24th International Conference on Offshore Mechanics and Arctic Engineering, Greece, 2005

Kim, S.E.: "Large Eddy Simulation Using Unstructured Mesh and Dynamic Subgrid-Scale Turbulence Models", AIAA Paper 2004-2458

EMEB-B-131

On page 9 of Attachment 1 to Supplement 29, it is noted that a dynamic Smagorinsky-Lilly model for subgrid scale stresses is used. What is the expected sensitivity of the solutions to variations in the subgrid scale stress model?

Response to EMEB-B-131

Upon review of this RAI modeling question, it was discovered that the dynamic Smagorinsky model was not enabled during the simulation as was reported in Attachment 1 to Supplement 29. Regardless, the question of sensitivity is addressed in response to this RAI.

The subgrid scale stresses are determined, in part, by the Smagorinsky constant, Cs. The default constant is set to 0.1. The dynamic Smagorinsky model allows for a variation in this constant based on local scales and can vary from 0 to 0.23. If the constant is larger, the subgrid scale stresses are larger.

On coarse meshes, the computed subgrid scale stresses are likely to be of the same order or smaller than numerically derived stresses (numerical diffusion) and hence the sensitivity to the subgrid scale model is small.

On adequately resolved meshes, the subgrid scale stress term becomes important. For free shear flows, as is found in the VYNPS steam dryer simulation, the Smagorinsky constant is generally found to be at the higher end of the spectrum (0.2). Since a lower value was actually used (0.1), the local stresses were computed to be lower, and the result would likely be a conservative over-estimation of local pressure forces.

EMEB-B-132

On page 9 of Attachment 1 to Supplement 29, it is noted that the turbulence level of the boundary condition is not important because the flow will develop as it traverses through the dryer. Please comment on the accuracy in the turbulence level as it reaches the LES appropriate mesh. Does the turbulence develop appropriately in the porous models within the dryer? Does the turbulence develop appropriately in the relatively coarse tetrahedral mesh in the upper dome? Are any sensitivities completed to justify the statement that the turbulence level at the inlet "does not have any impact" on the flow in the dryer?

Response to EMEB-B-132

A steady-state RANS simulation was performed to assess the sensitivity of the resolution of the flow field to turbulence inlet boundary conditions. In one case, a low level of turbulence was applied (1% intensity with a viscosity ratio of 2). In a second case, a high level of turbulence was imposed (50% intensity with a viscosity ratio of 20000). Distributions of turbulent kinetic energy (TKE) from these two cases can be seen in the figures below. Figure EMEB-B-132-1 compares the TKE near the inlets. The left figure clearly shows a much higher input of turbulent energy. The overall impact of the change in the dome can be seen in Figure EMEB-B-132-2 where it can be seen that the distribution of turbulent kinetic energy within the dome is comparable between the high and low inlet turbulence cases.

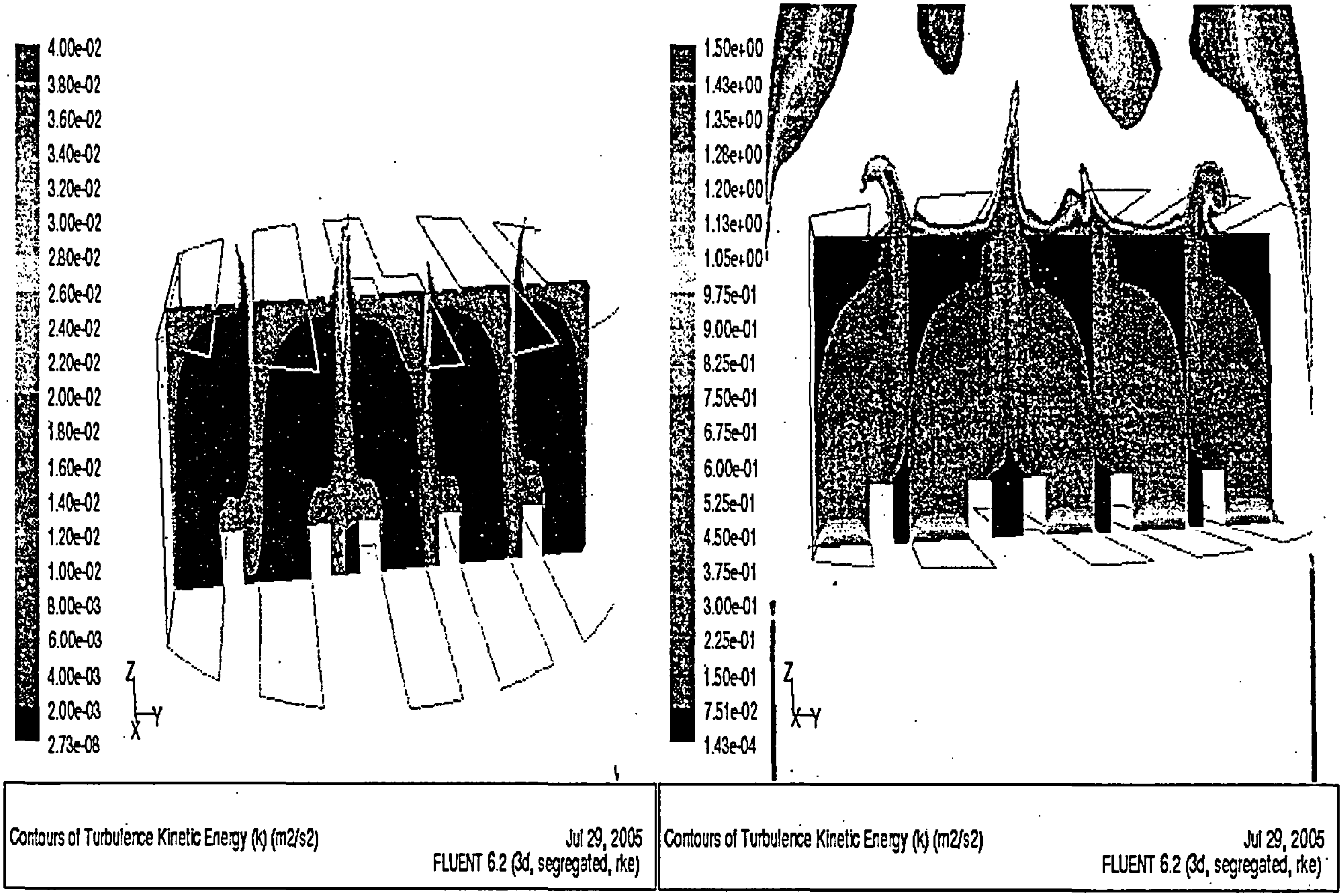

Figure EMEB-B-132-1: TKE for 50% and 1% Assumed Dryer Inlet Turbulence Intensity

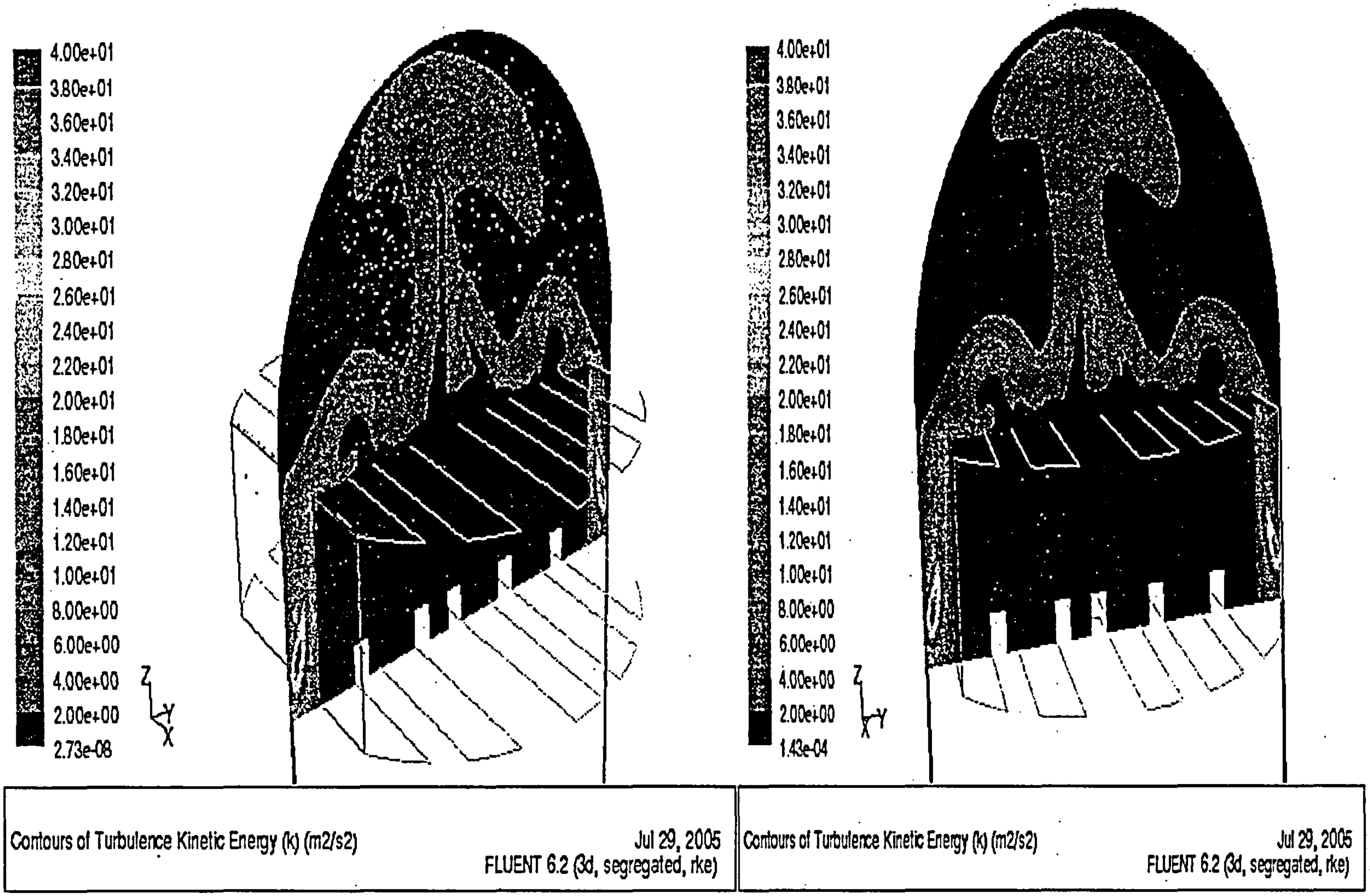

Figure EMEB-B-132-2: Resulting Dome TKE for 50% and 1% Inlet

EMEB-B-133

On page 10 of Attachment 1 to Supplement 29, it is noted that y+ values are in the range of 3,000 to 15,000. What are "best practice" values for y+ in an LES simulation? Assuming the y+ values used are larger than "best practice" guidelines would require, discuss the potential impact of the wall treatment (wall boundary condition) on LES predictions.

Response to EMEB-B-133

In general, best practice y+ values for LES simulations should be on the order of 1. However, these constraints can be relaxed for conditions when wall-bounded effects are unimportant. For the present study, free shear flows dominate the region: e.g., free jets, vortical structures impinging on the vertical faceplates and turning into the steam lines.

Boundary layers are important to resolve in external aerodynamic application such as the fuselage of an aircraft, or in flows that are dominated by friction near a wall, such as pipe flow. In case of the VYNPS steam dryer simulation, the large eddies are dictated by the arrangement of the geometry and the flow distribution. These eddies are much larger than the thickness of the boundary layer. The size of eddies generated in the boundary layer are expected to be at the same order of magnitude as the boundary layer thickness and associated time scales are proportionally smaller.

EMEB-B-134

On page 10 of Attachment 1 to Supplement 29, the time step size is listed. Please provide further details on the determination of the time step size for this type of LES analysis.

Response to EMEB-B-134

The time step size was selected to resolve the hydrodynamic effects of the smallest, resolved eddies. It was not the objective of this simulation to model the acoustic effects. An appropriate time scale can be estimated from local velocity and length scales with an assumed Courant number ($U\Delta t/\Delta x$) of 1. By imposing the Courant number constraint, disturbances traveling at a velocity U can be resolved a distance Δx away in a time span of Δt. Local mean velocities within the plenum did not exceed 40 m/sec. With a cell size of ~0.65 in (0.016m), the corresponding Δt is ~0.0004 seconds.

EMEB-B-135

On page 11 of Attachment 1 to Supplement 29, the determination of pressure differences is discussed. Are pressure fluctuations expected on the back side of the plate? Would this model determine pressure fluctuations in this region given the location of the inflow boundary condition and the non-prototypical influence of the porous media regions? What impact might these assumptions have on the reported pressure fluctuations?

Response to EMEB-B-135

As a mass flow inlet boundary condition type was used, pressure fluctuations could arise at the inlet to enforce the constant mass flow rate condition. These fluctuations were not expected to be significant, but were nevertheless accounted for in the calculation for pressure differences. The presence of the porous media would tend to isolate any disturbances in pressure within the regions separated by the media. Turbulence generation is expected to be low upstream of the dryer vanes because of the low flow velocity in this region. Neither location of the inflow boundary condition nor porous media assumptions have significant impact on pressure fluctuations.

EMEB-B-136

Given the complex nature of the jets and interactions highlighted in Figure 32 of Attachment 1 to Supplement 29, discuss the impact of the coarse tetrahedral mesh on these flows and its potential subsequent impact on the "boundary" to the LES appropriate mesh region.

Response to EMEB-B-136

See the response to RAI 127.

EMEB-B-137

On page 17 in the first paragraph of Attachment 1 to Supplement 29, it is implied that improvements to accuracy are obtained locally in the specific region that is resolved using the LES appropriate mesh. The basic question is whether or not additional fluctuations would be present if the entire domain were modeled with an LES appropriate mesh. Please summarize the basis for assuming that the prediction in a local region is accurate when the predictions in the surrounding regions can be assumed not to be accurate. This discussion should consider the importance of boundary conditions in LES predictions.

Response to EMEB-B-137

The basis for using a coarse mesh in the dome was the assumption that the bulk of the production of the turbulence occurs in the plenum. Figure EMEB-B-137-1 shows the turbulent production distribution in a steady state RANS simulation. The highest production of turbulence occurs in the plenum..

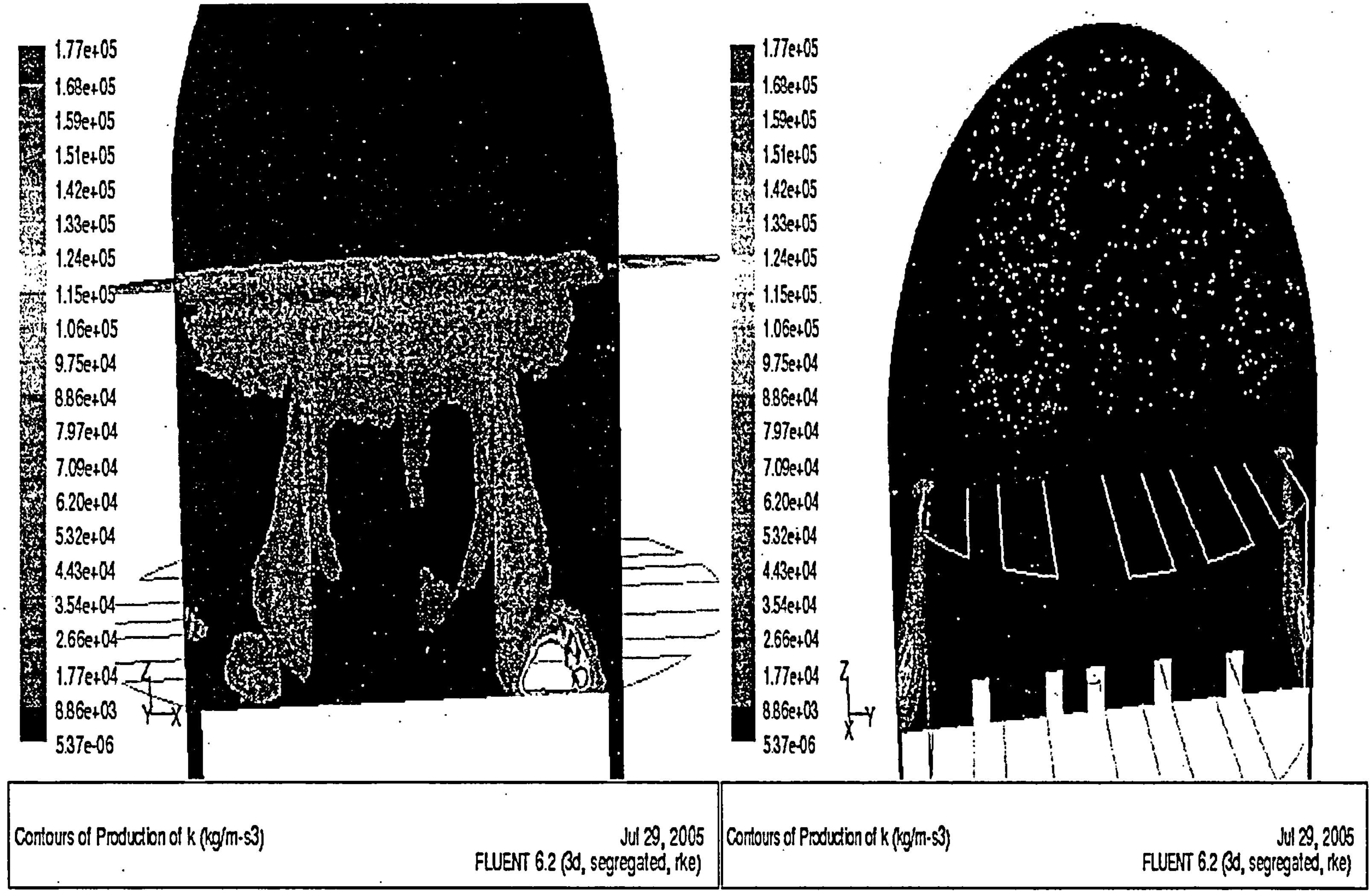

Figure EMEB-B-137-1: RANS Turbulent Production Distribution

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<u>EMEB-B-138</u>

With regard to the work described in Attachment 1 to Supplement 29, discuss in general the applicability of a single CFD prediction (no sensitivity studies for key assumptions or parameters) in a flow domain where no data are used for validation or benchmarking.

<u>Response to EMEB-B-138</u>

Generally, CFD is applied as a complementary tool to other analytical techniques, including experimentation. CFD is useful in extracting absolutes (validation quality) and for sensitivity studies. Ideally, results from a model are validated with specified experimental data before perturbations to the model are studied. In the absence of experimental data, sensitivities to modeling parameters are warranted. Given the immense CPU requirements associated with LES modeling, such sensitivity studies can become impractical. Under these conditions, the modeler must rely on using sound engineering judgments and best practices to achieve a solution developed from the governing equations of motion. Supported by complementary studies, single CFD predictions can still be considered a useful tool. Sensitivity studies were performed to investigate the impacts of varying mesh size and inlet turbulence intensity. These studies were performed using a steady state RANS version of the VYNPS steam dryer CFD model. Results of these sensitivity studies are contained in responses to RAI's 127, 132, 136 and 140. Benchmarking of Fluent LES methodology against experimental data is described in three papers enclosed as Exhibits EMEB-B-73-1 through 3.

<u>EMEB-B-140</u>

On page 9 of Attachment 1 to Supplement 29, a uniform inlet turbulence intensity of 2% is specified. The inlet dissipation rate (which along with turbulence intensity defines characteristic flow length scales) is not specified. Entergy is requested to discuss the sensitivity of the simulated steam dryer loading to the inlet turbulence intensity and dissipation rate.

<u>Response to EMEB-B-140</u>

The LES model was set-up such that it used a constant mass flow rate at the inlet. The mass flow inlet boundary condition does not allow specifying any perturbations of the inlet velocity. Velocity variations could have occurred because of pressure and density fluctuations. An inlet dissipation rate does not apply to the LES model.

The response to RAI 132 highlights the lack of sensitivity to inlet turbulent boundary conditions for this particular case using a RANS model.

<u>EMEB-B-141</u>

On page 9 of Attachment 1 to Supplement 29, a porous media is described which simulates the head loss across the dryer. Entergy is requested to describe the effects of the porous media model on the turbulence intensity and characteristic length scales of the jet flow emanating from the top of the dryer. Also, the sensitivity of the simulated steam dryer loading to the porous media should be provided.

Response to EMEB-B-141

The porous media model does not have any direct influence on the turbulence intensity and length scales. Through the pressure loss term in the momentum equations the porous media models the flow resistance of the dryer vane bank. The flow distribution adjusts accordingly. Turbulence is generated only from stream line curvature and shear in the flow.

The loss coefficient in flow direction is derived from known pressure drops.

EMEB-B-142

The PSDs averaged over the dryer face plate are compared for 100% of CLTP and 120% of CLTP conditions (or EPU conditions) in Figures 45 and 46 of Attachment 1 to Supplement 29. The comparison shows significant increases in loading at EPU condition at frequencies of about 32, 45, and 62 Hz. The amplifications strengthen near the MSL inlets. Entergy indicated on page 48 that low-frequency increases are due to hydrodynamic effects, and high-frequency increases are due to acoustic effects. Entergy also indicated that the time step size used in the compressible LES solutions is too large to resolve acoustic effects accurately. Entergy is requested to explain whether the peaks at 32, 45, and 62 Hz are due to acoustic amplification, and if so, explain how the time step size affects the amplitudes of the peaks. The evaluation should be based on an assessment of significant acoustic modes of the MSLs and dome contributing to pressure fluctuations on the steam dryer.

Response to EMEB-B-142

In order to verify the acoustic nature of frequencies larger than 30 Hz a Fast Fourier Transform (FFT) was performed on time series of pressures at the dryer surface, including the top, the face plate and the skirt. The FFT generates coefficients of cosine and sine functions for each frequency under consideration. The signal at each frequency is represented as a_n*cos(wt)+b_n*sin(wt). Figures EMEB-B-142-1, EMEB-B-142-2 and EMEB-B-142-3 show the a_n –coefficients for 32Hz, 45.5 Hz and 62.2 Hz, respectively. The data is taken from the 120% load case.

The contours plots indicate that the dome and the gap around the skirt interact to form acoustic modes. The 32Hz mode oscillates in vertical direction. The 45.5 Hz and 62.2Hz modes oscillate from one plenum to the opposite plenum. There could also be a component in circumferential direction in the gap around the dryer. The face plates are impacted by these acoustic modes as can be seen from the contour plots.

Accurate predictions of the propagation of pressure waves can be obtained if the time step is chosen such the Courant number based on the speed of sound is close to unity. The time step chosen was based on the fluid flow velocity rather than the speed of sound and is about 10 times larger than required for tracking sound waves. With a large time step pressure waves are propagating at the speed of sound. However, a sharp pressure front could be diffused and attenuated with distance from its origin. The large time step relative to acoustic phenomena could have a damping effect on any acoustic signal.

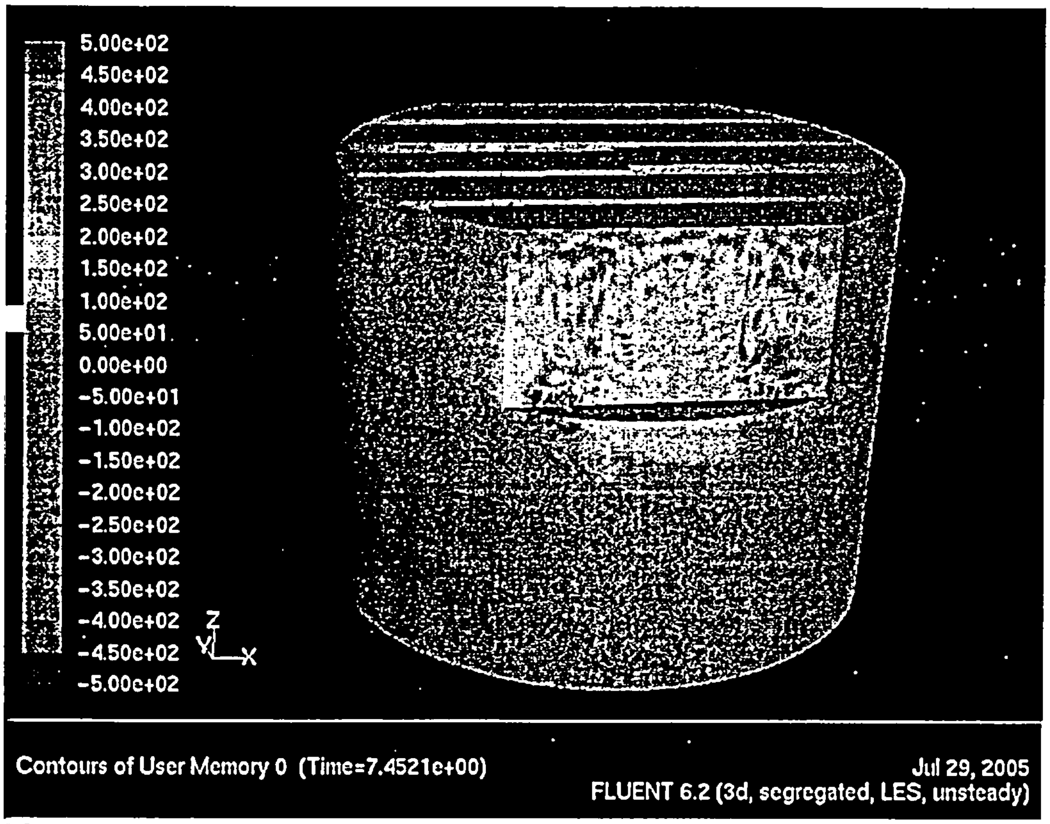

Figure EMEB-B-142-1: a_n coefficient for 32Hz

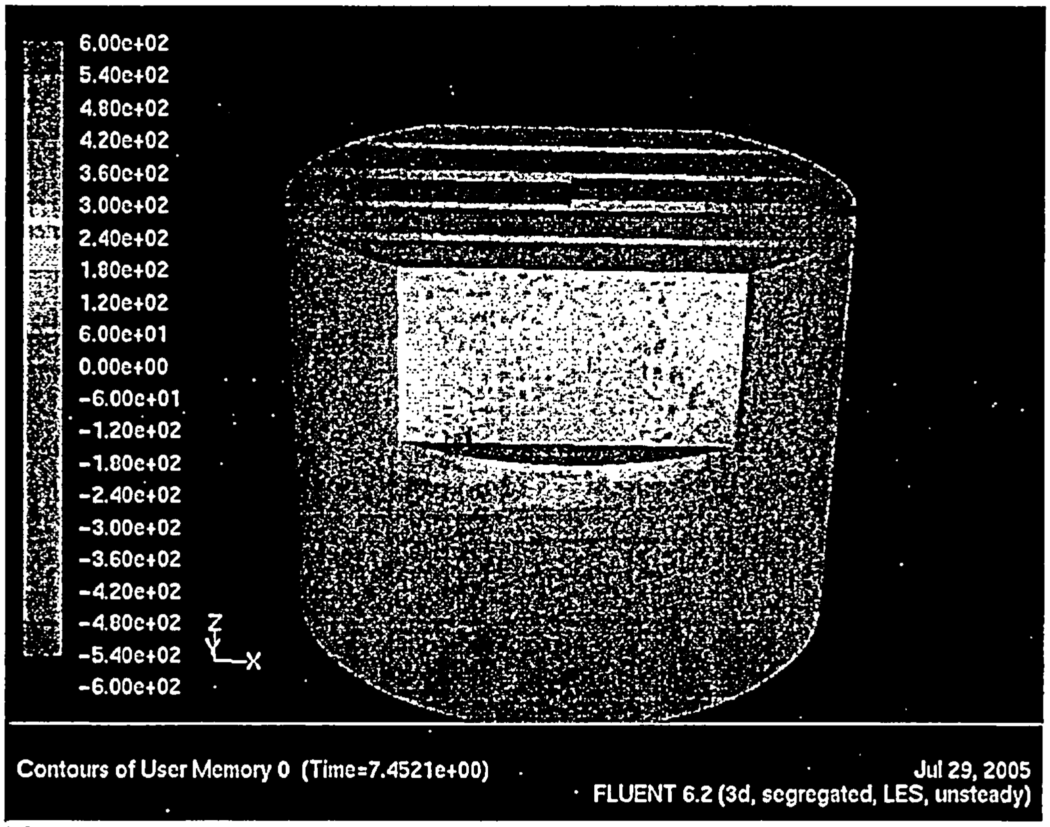

Figure EMEB-B-142-2: a_n coefficient for 45.5Hz

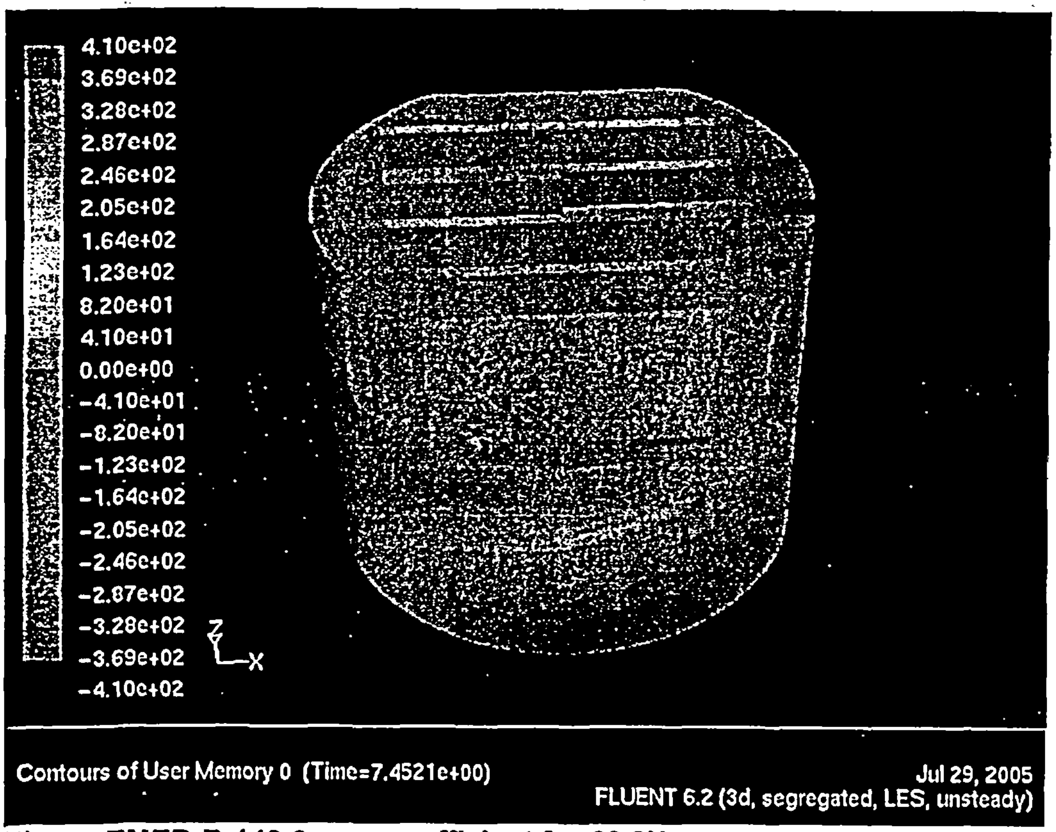

Figure EMEB-B-142-3: a_n coefficient for 62.2Hz

Attachment 7

Vermont Yankee Nuclear Power Station

Proposed Technical Specification Change No. 263 – Supplement No. 30

Extended Power Uprate

Response to Request for Additional Information

Probabilistic Safety Assessment Branch

Total number of pages in Attachment 7 (excluding this cover sheet) is 5.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION REGARDING APPLICATION FOR EXTENDED POWER UPRATE LICENSE AMENDMENT VERMONT YANKEE NUCLEAR POWER STATION

PREFACE

This attachment provides responses to the NRC Probabilistic Safety Assessment Branch's (SPSB) individual requests for additional information (RAIs) in NRC's letter dated July 27, 2005.[1] Upon receipt of the RAI, discussions were held with the NRC staff to further clarify the RAI. In certain instances the intent of certain individual RAIs may have been modified based on clarifications reached during these discussions. The information provided herein is consistent with those clarifications.

The individual RAIs are re-stated as provided in NRC's letter of July 27, 2005.

Probabilistic Safety Assessment Branch (SPSB)
Containment and Accident Dose Assessment Section (SPSB-C)

RAI SPSB-C-47

The response to RAI SPSB-C-41 is not clear as to why required NPSH values, based on lower pre-EPU suppression pool temperatures, satisfy pump requirements at the higher EPU suppression pool temperatures. Does the increased suppression pool temperature affect the magnitude of the required NPSH or the time period at a given required NPSH, or both?

Response to RAI SPSB-C-47

The pump NPSH requirements are based on the lower pre-EPU suppression pool temperatures only to the extent that the pump vendor used the minimum available NPSH based on those temperatures and no overpressure credit as their starting point in evaluating the core spray and residual heat removal pumps capability. Attachment 5 of calculation VYC-0808[2], the vendor's summary report, recommended time-dependent minimum NPSH requirements which bounded the minimum available NPSH values. These requirements are not dependent on any particular scenario or suppression pool temperature. Therefore, neither the magnitude nor the time period at a particular NPSH is affected.

The minimum NPSH requirements continue to be met at the higher pool temperatures associated with EPU conditions by crediting containment overpressure. Therefore, the license amendment requested credit for containment overpressure for DBA-LOCA and ATWS events.

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[1] U.S. Nuclear Regulatory Commission (Richard B. Ennis) letter to Entergy Nuclear Operations, Inc. (Michael Kansler), "Request for Additional Information – Extended Power Uprate, Vermont Yankee Nuclear Power Station (TAC No. MC0761)," July 27, 2005

[2] Calculation VYC-0808, Rev. 8 was provided to the NRC in VYNPS Proposed Change No. 263, Supplement No. 18, BVY 04-106, October 5, 2004

RAI SPSB-C-48

In response to RAI SPSB-C-39, Entergy stated that the emergency operating procedure NPSH curves are independent of specific event scenarios. However, credit was taken for the minimum available NPSH curves. Aren't these curves event-specific to the large break loss-of-coolant accident (LBLOCA) at pre-EPU conditions? Why is this acceptable?

Response to RAI SPSB-C-48

The emergency operating procedure (EOP) NPSH curves are based on the minimum required NPSH from Attachment 5 of calculation VYC-0808. The minimum required NPSH is a characteristic of the pump in question and is not dependent on any particular event. As noted above in the response to RAI SPSB-C-47, the required NPSH values are only based on the lower pre-EPU suppression pool temperatures in the sense that the pump vendor used the available NPSH at those lower temperatures as the starting point in evaluating the core spray and residual heat removal pumps' capability to function under those conditions.

For any specific event, operators refer to the core spray and residual heat removal NPSH curves included in the EOPs to confirm operation within NPSH limits. The EOP curves allow the operators to account for flow, pool temperatures, and containment overpressure.

RAI SPSB-C-49

Supplement 25, dated March 24, 2005, states that credit for containment accident pressure is no longer required in determining adequate available NPSH for the residual heat removal and core spray pumps for the postulated Appendix R fire and the SBO scenario. Was it necessary to take credit for the minimum available NPSH curves in reaching this conclusion?

Response to RAI SPSB-C-49

Yes. The NPSH curves used in the evaluations for the postulated Appendix R fire and the SBO scenario are based on the minimum required NPSH from Attachment 5 of calculation VYC-0808. These are the same curves used to evaluate NPSH margin for current licensed thermal power operating conditions.

RAI SPSB-C-50

Provide a comparison of the emergency core cooling system (ECCS) pump flow rates for the 10 CFR 50.46 LBLOCA analysis with the ECCS flow rates used for the short-term and long-term NPSH analyses.

Response to RAI SPSB-C-50

For conservatism, minimum flows are assumed for the 10 CFR 50.46 analysis and maximum flows are assumed for short-term and long-term NPSH analysis. The 10 CFR 50.46 values (as presented below in Tables SPSB-C-50-1, SPSB-C-50-2, and SPSB-C-50-3) are defined as a function of the differential pressure between the reactor vessel and containment.

Table SPSB-C-50-1

One RHR Pump injecting into one recirculation loop (LPCI mode) 10 CFR 50.46 Analysis	
Pressure Difference (psid)	Pump Flow (gpm)
260	0
20	6,300
0	6,550

RHR pump NPSH evaluations for a single pump, reqardless of mode (LPCI, containment spray, torus cooling) assume a maximum flow rate of 7,400 gpm constant.

Table SPSB-C-50-2

Two RHR Pumps injecting into one recirculation loop (LPCI mode) 10 CFR 50.46 Analysis	
Pressure Difference (psid)	Pump Flow (gpm)
260	0
20	11,251
0	11,765

RHR pump NPSH evaluations for two pumps injecting into one recirculation loop assume a maximum flow rate of 14,200 gpm constant.

Table SPSB-C-50-3

One CS Pump injecting into the reactor vessel 10 CFR 50.46 Analysis	
Pressure Difference (psid)	Pump Flow (gpm)
260	0
20	2,800
0	4,000

CS pump NPSH evaluations assume 4,600 gpm constant for short-term (i.e. first ten minutes of the DBA-LOCA event) and 3,500 gpm constant for long-term (beyond the first ten minutes of the

DBA-LOCA event, the pump is assumed to be throttled).

RAI SPSB-C-51

Describe how instrument uncertainty is taken into account, either in the EPU containment analyses (both peak pressure and minimum pressure for NPSH), surveillance procedures, or in some other way.

Response to RAI SPSB-C-51

Instrument uncertainty is factored into the input parameters in certain key areas. See Table SPSB-C-51-1 below. The input parameters defining initial conditions are based on design basis or technical specification limits.

Table SPSB-C-51-1

Parameter	Input Value	Instrument Uncertainty
Initial Reactor Power	1950 MWt	A 2% uncertainty is assumed. This accommodates all the instrument uncertainties that provide input to the plant heat balance calculations, which are used to monitor compliance with the licensed operating power.
Initial suppression pool temperature	90°F	This is the Technical Specification maximum. The required condition is less than 87.3°F to accommodate worst case instrument uncertainty.
Initial suppression pool volume	68,000 cu ft	This is the Technical Specification minimum. The required condition is greater than 68,255 cu ft to accommodate instrument uncertainty.

Instrument uncertainty is also applied to the RHR and core spray flow rates assumed in the NPSH analysis. Surveillance procedures assure the pumps meet their Technical Specification requirements. The acceptance criteria in the procedures accommodate instrument uncertainties. The instrument uncertainties are applied to assure the pumps meet minimum head and flow requirements. Since NPSH margins are minimum when the pump flow rates are maximized, the NPSH analysis is based on assuming the instrument uncertainties are applied in the opposite direction.

RAI SPSB-C-52

The effects of a loss-of-ventilation on a SBO event are discussed in Supplement No. 25, Attachment 2, Section 2.3. Please provide the references listed in that section for NRC staff review (i.e., References 3, 6, 7, 12, 13, and 16).

Response to RAI SPSB-C-52

Those sections of the requested calculations that deal with the loss of ventilation are provided in Attachment 11 as Exhibits SPSB-C-52-1 through SPSB-C-52-6. The information provided in the Exhibits is summarized in Table SPSB-C-52-1 below.

Table SPSB-C-52-1

Exhibit No. SPSB-C-52-	Reference No.	Discussion
1	3	VYC-0886, Rev. 2, Calculation Change Notice (CCN) Number 4, is provided. CCN 4 specifically addresses the impact of power uprate on VYC-0886, Rev. 2. The relevant information is on pages 5 and 6 of Attachment A.
2	6	VYC-1347, Rev. 0, calculates the heat-up in the main steam tunnel upon loss of ventilation for two scenarios (1) main steam and feedwater isolated and (2) main steam and feedwater not isolated. Scenario (1) applies to SBO. This is called Case MST1 in the calculation, and the results are discussed in Section 2.2.1 on pages 20 and 21. The results show that the HPCI and RCIC isolation setpoints would not be exceeded until approximately 18 hours after the loss of ventilation.
3	7	VYC-1502, Rev. 0, calculates the heat-up in the control room due to loss of ventilation for an Appendix R event. The heat loads for the Appendix R event bound those for the SBO event.
4	12	VYC-2405, Rev. 0, calculates the drywell heat-up for the SBO event and was done specifically for power uprate operating conditions and a 2 hour coping time.
5	13	VYC-2279, Rev. 0, evaluated the effect of power uprate on ambient space temperature during normal operation. Only those portions that deal with the steam tunnel are provided. The calculation shows that ambient steam tunnel temperatures during normal operation will increase by less than 1 degree F due to power uprate.
6	16	Only those parts of Operating Procedure OP-2192, Rev. 31, "Heating, Ventilating, and Air Conditioning System," related to the loss of control room ventilation are included.

Attachment 8

Vermont Yankee Nuclear Power Station

Proposed Technical Specification Change No. 263 – Supplement No. 30

Extended Power Uprate

Response to Request for Additional Information

Plant Systems Branch

Total number of pages in Attachment 8 (excluding this cover sheet) is 12.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION
REGARDING APPLICATION FOR EXTENDED POWER UPRATE LICENSE AMENDMENT
VERMONT YANKEE NUCLEAR POWER STATION

PREFACE

This attachment provides responses to the NRC Plant Systems Branch's (SPLB) individual requests for additional information (RAIs) in NRC's letter dated July 27, 2005.[1] Upon receipt of the RAI, discussions were held with the NRC staff to further clarify the RAI. In certain instances the intent of certain individual RAIs may have been modified based on clarifications reached during these discussions. The information provided herein is consistent with those clarifications.

The individual RAIs are re-stated as provided in NRC's letter of July 27, 2005.

Plant Systems Branch (SPLB)
Balance of Plant Section (SPLB-A)

RAI SPLB-A-25

Section 6.3.1 of Attachment 6 of the application dated September 10, 2003, indicates that in the unlikely event of a complete loss of spent fuel pool (SFP) cooling capability, the SFP will reach the boiling temperature in six hours. This conclusion does not appear to be consistent with the information that is provided for the alternate cooling system (ACS) in Updated Final Safety Analysis Report (UFSAR) Section 10.8 which indicates that upon a loss of all SFP cooling, boiling will occur in two-to-three days. Please explain this apparent inconsistency.

Response to RAI SPLB-A-25

The apparent inconsistency is due to two different scenarios—one assumes a batch off-load, the other a full core off-load.

Section 10.8.4 of the current UFSAR indicates that upon a loss of all SFP cooling, boiling will occur in two-to-three days. Section 10.8.4 also indicates that this time is based on a fuel pool heat load of 7.8×10^6 BTU/hr. This heat load is based on a batch off-load.

The six hour time to boil value for extended power uprate (EPU) is based on a full core off-load. Following extended power uprate, the time to boil value for a batch off load is approximately two days.

[1] U.S. Nuclear Regulatory Commission (Richard B. Ennis) letter to Entergy Nuclear Operations, Inc. (Michael Kansler), "Request for Additional Information – Extended Power Uprate, Vermont Yankee Nuclear Power Station (TAC No. MC0761)," July 27, 2005

RAI SPLB-A-26

UFSAR Section 10.8 indicates that the deep basin has a water capacity of 1.48 million gallons and that a water inventory of 1.45 million gallons is sufficient to assure seven days worth of ACS cooling capability. Please explain in detail how this conclusion was reached for post-EPU operation, quantifying all water additions and losses that are assumed to occur over this seven-day period along with how these values were determined, and how much inventory is required at the end of seven days to satisfy pump net positive suction head (NPSH) requirements.

Response to RAI SPLB-A-26

Water losses are due to evaporation, drift and external factors (e.g., pipe drainage during ACS setup, silt buildup and collapse of non-seismic portions of cooling structure). No makeup to the cooling tower is assumed for the entire duration of the ACS event. For ACS mode design basis heat loads and meteorological conditions, total seven day losses due to evaporation and drift were calculated to be 1,040,000 gallons and 29,000 gallons, respectively. Total losses due to external factors were calculated to be 266,800 gallons. The cooling tower has a minimum capacity of 1,451,700 gallons. Therefore, remaining inventory at the end of seven days of ACS operation is 116,000 gallons, equating to an inventory margin of 8%.

To maintain positive margin on NPSH over the entire seven day ACS event, two of the four RHRSW pumps are removed from service after 48 hours. The resultant reduction in suction header friction losses compensates to some degree for the reduction in suction static head caused by evaporative losses. At the end of four pump operation at 48 hours, minimum basin level is calculated to be 10 ft. above the first stage impeller of the RHRSW pumps. For the maximum pump flowrate at this point (approximately 2,105 gpm), required NPSH is 19.4 ft., and available NPSH is calculated to be 26.1 ft., yielding a margin of 6.7 ft., or 34%. At the end of seven days of ACS operation with only two pumps in operation, minimum basin level is calculated to be 4.2 ft. above the first stage impeller of the RHRSW pumps. For the maximum pump flowrate at this point (approximately 2,144 gpm), required NPSH is 19.9 ft. and available NPSH is calculated to be 29.9 ft., providing a margin of 10 ft., or 50%.

RAI SPLB-A-27

The response to RAI SPLB-A-17 in Supplement No. 28 indicates that there is sufficient margin between the minimum transient reactor feedwater pump (RFP) suction pressure and the current RFP suction pressure trip setpoint to ensure RFP operation during normal operation and the loss of one condensate pump transient. This does not appear to be consistent with the information provided in the RAI response that indicates that the condensate pumps only have a 7% flow margin to pump runout conditions, which would suggest that two condensate pumps operating are not sufficient to ensure RFP operation following the loss of one condensate pump. Please explain the basis for concluding that continued RFP operation is assured following the loss of one condensate pump.

Response to RAI SPLB-A-27

For clarification, the response to RAI SPLB-A-17 in Supplement No. 28 relates to the impact on current equipment and system margins due to EPU implementation.

The 7% condensate pump flow (CP) margin discussion applies to normal EPU operation with all three CPs operating. The 7% flow margin is determined by comparing total condensate system flow during normal EPU conditions and the maximum possible condensate system flow demand assuming minimum total condensate and feedwater system resistance. That is, at EPU, the CPs will be required to produce 7% more flow to sustain the maximum possible system flow. This is well within the capabilities of the CPs since the runout flow for the CPs is 7,450 gpm whereas the maximum required system runout flow per CP is 5,781 gpm.

The RFP suction pressure trip setpoint discussion relates to the basis for selection of the RFP suction pressure trip setpoint. This setpoint is based on assuring that, for normal and off-normal operation (including the trip of one condensate pump), sufficient pressure exists at the suction of the RFPs to provide more NPSH available than NPSH required by the pump to avoid potentially harmful pump suction cavitation.

The response to RAI SPLB-A-17 in Supplement No. 28 also described an automatic runback of the recirculation pumps that will be implemented for EPU. This feature is designed to ensure that upon a trip of a condensate pump or a feedwater pump, a recirculation pump runback will occur to quickly reduce reactor power and steam flow to values that allow the remaining operating pumps to support continued plant operation.

The loss of an operating CP at EPU conditions results in:

1. Reduced feedwater flow, which affects reactor water level. That is, with two operating CPs, following a loss of one of the three CPs, the condensate and feedwater system is incapable of supplying feedwater flow rates necessary for full power operation--even if the demineralizers are at the cleanest condition and the feedwater regulating valves are 100% open.

   Upon a loss of a CP, to maintain full power, each remaining CP would have to provide about 8,100 gpm. However, given the system hydraulic characteristics with the feedwater regulating valves 100% open, the maximum flow possible per CP is calculated to be 7,537 gpm following a loss of a CP. Thus, it is not possible to maintain full power following a loss of a CP.

   As indicated above, the reactor recirculation (RR) system runback feature is intended to quickly reduce reactor power and steam flow to values that allow the remaining operating pumps to support continued plant operation at a reduced power level.

2. The calculated RFP suction pressure following the trip of one CP at EPU is approximately 124 psig. This suction pressure is the minimum pressure predicted prior to the RR runback assuming the feedwater regulating valves are full open and maximum DP across the condensate demineralizers. The RFP low suction pressure trip setpoint is currently set to 98 psig, to avoid a RFP suction pressure trip following a CP trip. This setpoint will be retained for EPU conditions.

3. The remaining two operating CPs will continue to maintain sufficient NPSHA for the RFPs at the maximum resulting individual CP flow of 7,537 gpm. This maximum flow of 7,537 gpm would be available prior to the runback, assuming the feedwater regulating valves are full open and minimum DP across the condensate demineralizers.

   The resulting individual CP flow of 7,537 gpm is 87 gpm or approximately 1% more than the published characteristic curve maximum flow of 7,450 gpm (i.e., 7,537 – 7,450 = 87 gpm). Since the increased flowrate is practically insignificant, reasonable estimates of CP capabilities, TDH and NPSHR, can be obtained by extrapolating the pump characteristic curve to the slightly higher flowrate. From this extrapolation, it is estimated that at the resulting flow rate of 7,537 gpm, the CP NPSHA is about 10 feet above the estimated pump NPSHR indicating that more than sufficient NPSHA exists to prevent CP cavitation.

   Since the remaining two CPs continue to operate with more than sufficient NPSHA, the lowest calculated RFP suction pressure will be approximately 124 psig or well above the RFP suction trip setpoint of 98 psig.

RAI SPLB-A-28

EPU operation will result in a substantial reduction in the available condensate and feedwater system operating margin and plant modifications must now be credited for preventing challenges to reactor safety systems that would otherwise occur upon the loss of a RFP or a condensate pump. Because the plant response to loss of RFP and condensate pump events following EPU implementation is substantially different from the response at the current licensed power level, and the expected EPU response has not been confirmed by previous full power tests or plant transients, the NRC staff requires that the power ascension test program include sufficient testing at the 100% EPU power level to confirm that the plant will respond as expected following a) the loss of a RFP, and b) the loss of a condensate pump. Please provide a complete description of the full-power testing that will be completed in this regard for the staff's review and approval, and propose a license condition that will assure that the proposed testing will be completed as described and that the results are fully satisfactory as a prerequisite for continued operation at the EPU power level.

Response to RAI SPLB-A-28

This response is supported by the information previously provide in response to RAI SPLB-A-17, page 9 of 23, and RAI-SPLB-A-18, page 12 of 23, as Attachment 1 to Entergy letter BVY-05-046, dated April 22, 2005.

A modification to the condensate and feedwater system was installed at VYNPS to add a reactor recirculation (RR) pump runback as a trip avoidance feature to reduce the potential for a reactor low water level scram on the loss of either a feedwater or condensate pump at EPU conditions. Although not required to achieve full EPU operation, Entergy determined it is prudent to avoid this potential plant transient/trip in the very unlikely event that a condensate pump (CP) or reactor feedwater pump (RFP) trips at EPU operating conditions. A dynamic analysis of a single feedwater pump trip at EPU conditions indicates that an automatic reactor recirculation runback can reduce core flow and thermal power to within the capability of the running feedwater pumps and avoid a reduction in reactor water level to the scram setpoint.

VYNPS has been analyzed to respond to a reactor trip on low reactor water level at EPU conditions and maintains adequate margin to safety for this event. The RR pump runback feature is not a safety function because the reactor is designed to scram if operating limits are exceeded; it is rather an operational reliability issue because it is preferred that the loss of a condensate or feedwater pump not result in a scram.

The runback logic is enabled when reactor power exceeds the capability of two feedwater pumps, as measured by total steam flow (approximately 112% of CLTP). A runback is initiated when fewer than three feedwater pumps and three condensate pumps are running and total feedwater flow exceeds the capacity of two feedwater pumps. The automatic runback will rapidly reduce core flow to approximately 60% of rated EPU core flow.

A transient analysis performed by GE in support of VYNPS using an NRC approved code (ODYN) shows that even in a degraded condition:

> *"The results of the single feedwater pump trip evaluations show that even the cases with a very degraded response and 1-element feedwater control show the acceptability of the reactor recirculation run back. Reactor water level remains above the low reactor water scram setpoint and below the high reactor water level trip setpoint (Level 8) for all conditions."*

Thorough logic testing was performed as part of the modification, including using breaker trips to initiate the runback circuitry and monitoring RR pump controls. Based on the analysis of the plant response to the pump trip and the offline testing performed during post-modification testing, it has been determined that no functional test is warranted.

The EPU configuration differs from the current configuration which uses two RFPs with one RFP available as a standby pump. During steady state EPU operation, the three RFPs will operate at lower pump capacity (5,831 gpm) with less stress on pumps and motors than two RFPs operating at CLTP (6,965 gpm). This reduction in individual RFP flow increases the available margin from normal operating flows to runout for the individual pump. Each CP will be required to provide the increased flow associated with EPU operation with the same number of pumps (i.e., three) currently being used. The CP flow margin between the EPU conditions and the runout with three RFPs and three CPs will be approximately 7% greater than the required EPU flow. Industry criteria typically recommend a 5% margin. As such, the available margin exceeds that typically required by industry.

The operation of the feedwater and condensate systems in terms of required response to initiating events does not fundamentally change at EPU. At CLTP the trip of a CP requires operator action to reduce RR flow/power level to a point supported by the remaining pumps. When one RFP is out of service operations must also reduce flow/power rapidly to avoid the low level trip. In fact, without the modification the likelihood today is that the trip of a RFP without a standby pump in autostart will likely result in a reactor trip. The RFPs and CPs at VYNPS have a long history of reliable operation. No pump trips at power have occurred in at least the last ten years of power operation.

Based on discussions with others in the nuclear industry, no other uprated BWR needed to perform an integrated test to confirm the RR runback performed as designed. Additionally, for BWRs that installed the runback feature as part of original plant design, only one BWR plant could be identified as having performed the test.

This modification was installed for both operational support and economic reasons. The economic reasons include keeping the plant on line and minimize operator response to a transient involving the loss of a single RFP or CP at EPU conditions. The operational support reasons are to avoid an unnecessary low level scram during EPU conditions due to a loss of a RFP or CP at EPU conditions.

NRC's Standard Review Plan (SRP) 14.2.1, Section III.B.1 states: "The reviewer should assess if the licensee adequately identified functions important to safety that are affected by EPU-related modifications, setpoint adjustments, and changes in plant operating parameters. In particular, the licensee should have considered the **safety impact** (emphasis added) of first-of-a-kind plant modifications, the introduction of new system dependencies or interactions, and changes in system response to initiating events. The review scope can be limited to those **functions important to safety** (emphasis added) associated with the anticipated operational occurrences described in Attachment 2 to this SRP, "Transient Testing Applicable to Extended Power Uprates." To assist in this review, Attachment 2 also includes typical transient testing acceptance criteria and functions important to safety associated with these anticipated events."

The RR runback based on a RFP or CP trip or low feedwater pump suction pressure does not meet any of the criteria per Attachment 2, "Transient Testing Applicable to Extended Power Uprates." However, additional insight is gained by review of the exception criteria provided in SRP 14.2.1 Section III.C.

Addressing SRP Section III.C:

a. Previous operating experience:

   Entergy is unaware of any VYNPS or industry EPU operating experience that supports performance of this test. The operational history of VYNPS and the very limited industry experience with RFP and CP trips at power supports that there is little benefit in injecting this transient.

b. Introduction of new thermal hydraulic phenomena or identified system interactions:

   There are no new thermal hydraulic phenomena (reducing RR flow based on a pump trip is not a new thermal hydraulic phenomena) or system interactions that may be introduced as a result of the RR runback. Feedwater flow changes due to plant events (e.g., pump trip, valve malfunction) result in pre-analyzed transients (low water level reactor trip, high level turbine trip).

c. Facility conformance to limitations associated with analytical analysis methods:

The ODYN analysis cannot provide 100% confidence that a scram is avoided. It is dependent on the actual runback rate and various systems' performance at the time of the postulated event. There may be certain operating conditions where the plant is more vulnerable to scram. The real margin to a scram will depend on the actual instrument setting and whatever instrument drift upwards may occur. This is acceptable as the impacted systems are not safety related and uncertainty in the analysis would not alter potential outcomes (no outcome different than analyzed events).

d. Plant staff familiarization with facility operation and trial use of operation and emergency operating procedures:

Plant operators have been trained on both the automatic plant response and any required operator actions in response to these events. This includes simulator exercises that include these events. No different types of operator actions are required.

e. Margin reduction in safety analysis results for anticipated operational occurrences:

There is no reduction in margin to safety in either installation of the modification performed or the lack of an online integrated test. The modification was installed to minimize operational transients and avoid a plant trip in response to the pump trip. Failure of the modification to initiate the runback, failure in the execution of the runback, or a plant response to the runback different than that modeled in the analysis will lead to a reactor low level trip or a high level turbine trip (analyzed events that have been experienced at VYNPS and elsewhere).

f. Guidance contained in vendor technical reports:

No guidance is contained in vendor technical reports related to performing integrated tests related to the RR runback.

g. Risk implications:

VYNPS is not proposing a risk informed basis for not performing certain transient tests.

Conclusion

Entergy has instituted all of the necessary modifications and required post-modification testing at VYNPS to provide reasonable assurance that the feedwater and condensate system will remain highly reliable, and in the event of a pump trip, no new challenge to safety occurs. Therefore, Entergy believes that there is no need for a license condition, and no need to perform an integrated plant test to trip both a CP and separately a RFP at full EPU conditions to demonstrate the ability of the RR runback and feedwater low suction pressure modification to function as designed.

RAI SPLB-A-29

The licensee's response to RAI SPLB-A-20(a) in Supplement No. 28, is incomplete in that only the balance-of-plant (BOP) startup transient response criteria for the main steam isolation valve closure and generator load rejection transients were addressed. In accordance with the review criteria provided in NRC Review Standard RS-001 and draft Standard Review Plan (SRP) Section 14.2.1, the staff's request applies to the BOP transient response for all of the startup tests that are potentially impacted by the proposed EPU. Please provide the additional information that is needed in this regard.

Response to RAI SPLB-A-29

For all startup tests that are potentially impacted by the proposed EPU, GE Document No 22A2217, Revision 1, Vermont Yankee Startup Test Specification, dated January 5, 1973 was reviewed to determine if any of the original VYNPS balance of plant (BOP) startup testing transient response criteria are affected. The criteria section of this document specifies Level 1 and Level 2 criteria which are defined as follows:

Level 1:

These values of process variables assigned in the design of the plant and equipment are included in this category. If a Level 1 criterion is not satisfied, the plant will be placed in a hold condition which is satisfactory, until a resolution is made. Tests compatible with the hold condition may be continued. Following resolution, applicable tests must be repeated to verify that the requirements of the Level 1 criterion are satisfied.

Level 2:

The limits considered in this category are associated with expectations in regard to the performance of the system. If a Level 2 criterion is not satisfied, operating and testing plans would not necessarily be altered. Investigations of the measurements and of the analytical techniques used for the predictions would be started.

Table SPLB-A-29-1 below lists the startup tests that are potentially impacted by the proposed EPU, and the Level 1 and Level 2 Acceptance Criteria per GE Document No 22A2217, Revision 1, Vermont Yankee Startup Test Specification, dated January 5, 1973.

Conclusion:

After reviewing the list below, for all of the startup tests that are potentially impacted by the proposed EPU, none of the original VYNPS balance of plant (BOP) startup testing transient response criteria are affected.

Table SPLB-A-29-1

Test #	Description	BOP Transient Response Acceptance Criteria Evaluation
1	Chemical and Radiochemical	Level 1: o Water quality must be known and must conform to water quality and fuel warranty specifications. o The activity of gaseous and liquid effluents must be know and must conform to license limitations. o Chemical factor defined in the Technical Specifications must be maintained within limits specified. Level 2: o None
2	Radiation Measurements	Level 1: o The radiation doses of plant origin and occupancy times shall be controlled consistent with the guidelines of the standards for protection against radiation 10CFR20. Level 2: o None

10	IRM Performance	Level 1: o None Level 2: o The IRM channels will be calibrated to read equal to or grater than the actual percent of reactor rated thermal power, and will overlap the SRM and APRM reading.
12	APRM Calibration	Level 1: o The APRM channels must be calibrated to read equal to or greater than the actual core thermal power. Level 2: o None
19	Core Performance	Level 1: o Reactor power, maximum fuel surface heat flux, and minimum critical heat flux ratio (MCHFR) must satisfy the following limits: o Maximum fuel rod surface heat flux shall not exceed 134 W/cm^2 (425,500 BTU/hr-ft^2). o Minimum CHF ratio shall not be less than 1.9 when evaluated at the operating power level. The basis for evaluation of MCHFR shall be "Design Basis for Critical Heat Flux Condition in BWRs" APED-5286, Sept. 1966. o Normal reactor power shall be limited to 1593 MWt for the steady state conditions. Level 2: o None

22	Pressure Regulator	Level 1: o The decay ratio must be less than 1.0 for each process variable that exhibits oscillatory response to pressure regulator changes. Level 2: o The decay ratio is expected to be less than or equal to 0.25 for each process variable that exhibits oscillator response to pressure regulator changes when the plant is operating above the lower limit setting of the Master Flow Controller. o During the simulated failure of the operating pressure regulator, the backup pressure regulator shall control the transient such that the reactor does not scram.
23	Feedwater Control System Testing	Level 1: o The decay ratio must be less than 1.0 for each process variable that exhibits oscillatory response to feedwater system changes. Level 2: o The decay ratio is expected to be less than or equal to 0.25 for each process variable that exhibits oscillator response to feedwater system changes when the plant is operating above the lower limit setting of the Master Flow Controller.

24	Turbine Valve Surveillance	Level 1: o The decay ratio must be less than 1.0 for each process variable that exhibits oscillatory response to bypass valve changes. Level 2: o The decay ratio is expected to be less than or equal to 0.25 for each process variable that exhibits oscillator response to bypass valve changes when the plant is operating above the lower limit setting of the Master Flow Controller. This transient is not expected to cause a scram.
25	Main Steam Isolation Valves	Level 1: o MSIV stroke time will be between 3 and 5 seconds. Reactor pressure shall be maintained below 1230 psig, the setpoint of the first safety valve, during the MSIV closure event. Level 2: o The maximum reactor pressure should be 35 psi below the first safety valve setpoint. This is a margin of safety for safety valve weeping.
100	Main Steam and Feedwater Piping Vibration	Not part of the original Startup Test Specification