U.S. Department of Energy
P.O. Box 450, MSIN H6-60
Richland, Washington, 99352

MAY 2 9 2012

12-WTP-0191

The Honorable Peter S. Winokur
Chairman
Defense Nuclear Facilities Safety Board
625 Indiana Avenue, NW, Suite 700
Washington. DC 20004-2901

Dear Mr. Chairman:

TRANSMITTAL OF DEFENSE NUCLEAR FACILITIES SAFETY BOARD (DNFSB) RECOMMENDATION 2010-2 IMPLEMENTATION PLAN (IP) DELIVERABLE 5.3.3.5

This letter provides you the deliverable responsive to Commitment 5.3.3.5 of the U.S. Department of Energy plan to address Waste Treatment and Immobilization Plant (DOE-WTP) Vessels Mixing Issues; IP for DNFSB 2010-2.

The attachments provide the comment resolution form and summary document for the National Energy Technology Laboratory (NETL) review of the Bechtel National, Inc.'s *Experimental Data Gap Analysis for CFD Verification & Validation* (Commitment 5.3.3.4). The NETL also provided to DOE-WTP a document, *Recommendations for CFD V&V and Test Plan*, to illustrate their issues and recommendations. Open comments and recommendations that impact testing will be resolved prior to the start of NQA-1 testing for Computational Fluid Dynamics (CFD) Verification and Validation (V&V) and the evaluation of whether additional Large Scale Integrated Testing data sets are needed to complete CFD V&V (Commitment 5.3.3.6).

If you have any questions, please contact me at (509) 376-8830, or your staff may contact Ben Harp, WTP Start-up and Commissioning Integration Manager at (509) 376-1462.

Sincerely,

Scott L. Samuelson, Manager
Office of River Protection

WTP:RB

Attachment

cc w/attachment: See page 2

cc w/attachment:
D. M. Busche, BNI
W. W. Gay, BNI
F. M. Russo, BNI
R. G. Skwarek, BNI
C. G. Spencer, BNI
D. McDonald, Ecology
D. G. Huizenga, EM-1
M. B. Moury, EM-1
T. P Mustin, EM-1
K. G. Picha, EM-1
C. S. Trummell, EM-1
A. C. Williams, EM-2.1
M. N. Campagnone, HS-1.1
R. H. Lagdon, Jr., US
M. R. Johnson, WRPS
S. A. Saunders, WRPS
M. G. Thien, WRPS
BNI Correspondence
WRPS Correspondence

ATTACHMENT 1
to
12-WTP-0191

TRANSMITTAL OF DEFENSE NUCLEAR FACILITIES SAFETY BOARD (DNFSB) RECOMMENDATION 2010-2 IMPLEMENTATION PLAN (IP) DELIVERABLE 5.3.3.5

Summary Document for the NETL Review of the Experimental Data Gap Analysis for CFD V&V

(Total Number of Pages including coversheet: 3)

Summary Document for the NETL Review of the Experimental Data Gap Analysis

for CFD V&V

This document serves as a summary of the NETL team's review of the *Experimental Data Gap Analysis for CFD V&V* contained in document *24590-WTP-RPT-ENG-11-152, Rev 1*. Details of the review of this document and explicit comments and questions from NETL related to this document are contained in the NETL Comment Resolution Form for the Gap Analysis. This document contains 4 different areas of concentration:

1. General overview
2. Discussion on dimensional and dimensionless parameters
3. Recommendation to help fill data gaps
4. Technical justification for the recommendation

The NETL team feels that BNI's gap analysis has not adequately captured sufficient details to justify the use of proposed leading order dimensionless parameters to define and/or fill experimental data gaps. The NETL team has reservations about the lack of verification data in the gap analysis that would allow the leading order dimensionless groups chosen by BNI to sufficiently scale across different length and time scales and operating conditions which would allow extrapolating these leading order dimensionless parameters to actual full-scale WTP vessels. The NETL team has concerns that the proposed 8' tank experiments do not adequately capture all the relevant physics of a full-scale WTP vessel. Because of these issues discussed above, the NETL team feels that there are significant risks in the use of the data gaps defined in the BNI gap analysis report to allow sufficient V&V of BNI's CFD FLUENT model for assessing full-scale WPT vessel performance. There is insufficient data and gaps in the proposed experiments using the 8' tank and in general there is a lack of a systematic approach in assessment of model errors and uncertainty at different length scales to extrapolate BNI's CFD FLUENT model to full-scale WTP vessels. That is, using the proposed BNI experimental plan to V&V the CFD FLUENT model is not sufficient to guarantee with confidence that this V&V'ed model can be extrapolated to full-scale WTP vessels because the physics captured in the 8' tank experiments used in this process might not be the same as the physics of a full-scale WTP vessel and hence any uncertainties quantified at the 8' scale cannot be extrapolated to full-scale with confidence.

Based on the concerns above and the gaps in the BNI gap analysis that still exist, the NETL team has submitted for consideration by WTP a document titled "*Recommendation for Experimental Test Matrix*" recommending additional tests to be conducted. These tests when completed should provide additional information for verification that the selected leading order dimensionless parameters can be scaled. The additional data generated from these tests would provide support in the ability of these parameters to scale to full-scale WTP vessel conditions and provide data which could be used to both V&V the BNI Fluent model and conduct the confirmation calculations. The recommendations by NETL include the use of three different size vessels the existing/planned 4' vessel and 8' vessel, and a new 14' vessel identified by BNI and WTP which could be used to fill data gaps. Justification for conducting the experimental test matrix recommended by NETL is because the tests will provide three critical functions:

1. A consistent set of data over wider test vessel scales and parametric range which can be used to demonstrate that the current leading order dimensionless parameters do scale and support to allow extrapolating this information to full-scale WTP vessels. However, in the event these tests show that current parameters do not scale then that would prove that these parameters do not adequately capture the required physics and raise concern about missing leading order dimensionless parameters that have not been identified.
2. By performing the recommended experimental test matrix, it will provide BNI an opportunity to V&V the CFD FLUENT model at the 4' scale rather than using data from various sources which might not be consistent. Once the model is V&V'ed at the 4' scale, the larger 8' and 14' experiments can be used to conduct confirmation calculations with the model. It is noted that currently there are no plans by BNI to validate their confirmation calculation plan.
3. The data collected on three different scales under a set of consistent conditions will allow BNI to exercise both the transient 3D multiphase Eulerian-Eulerian model and the Integrated Pump-Down model in parallel. In addition, the data sets should be used to identify if there exist significant change in relevant physics associated with pulse jet mixing among different scales. The finding can be further used to justify the capability of CFD model in capturing all physics correctly and the feasibility of applying it to full scale.

By performing all the CFD calculations at the three different scales defined in the experimental test matrix recommended by NETL using the same mesh size will allow BNI to evaluate the effect of coarsening the mesh on the predictions. This is a critical issue since BNI is not planning on keeping the mesh size constant throughout the CFD model as they apply the model to full-scale WTP vessels. In summary, the NETL team recommends WTP to implement additional testing into their experimental test program to provide data to support the V&V of BNI's CFD FLUENT model. The details of the additional testing are outlined in the document *Recommendation for Experimental Test Matrix* provided to WTP. For several reasons the NETL team finds the current experimental test plan and also BNI's current approach inadequate: it is not able to support the choice of leading order dimensionless parameters; it is not able to provide evidence that these parameters hold across larger length scales; it is not able to provide sufficient data to satisfactorily V&V the BNI FLUENT model; it is not able to demonstrate confidence in the integrated pump-down model; and it is not able to provide evidence to support extrapolation of the leading order parameters and models to full-scale WTP vessels.

ATTACHMENT 2
to
12-WTP-0191

TRANSMITTAL OF DEFENSE NUCLEAR FACILITIES SAFETY BOARD (DNFSB) RECOMMENDATION 2010-2 IMPLEMENTATION PLAN (IP) DELIVERABLE 5.3.3.5

NETL Recommendations for CFD V&V and Test Plan

(Total Number of Pages including coversheet: 3)

NETL Recommendations for CFD V&V and Test Plan

According to the current plan, V&V of the FLUENT CFD model will be done at 8ft scale and the uncertainty calculated at this scale will be used at the plant scale level. In the original V&V plan, BNI had proposed a multivariate approach to propagate uncertainty from 8ft to plant scale. However, according to the information provided to NETL review team, the multivariate technique will not be used anymore. NETL recommends a validation of the current confirmation calculation plan. Since the current V&V plan is for the 8ft vessel, validating confirmation calculation at the mid plant scale of 14ft may not be viable. Therefore, in order to validate BNI's confirmation calculation plan, NETL recommends additional V&V of the FLUENT model for the 4ft vessel. NETL recommends that 4ft vessel should be used to perform NQA-1 compliant experiments. The test matrix for the experiments is also recommended at the end of this report by NETL. The V&V'ed FLUENT model for the 4ft vessel should then be applied for confirmation calculations of the 8ft vessel. Since BNI plans to perform very detailed experiments for the 8ft vessel, the confirmation calculations based on 4ft vessel V&V'ed FLUENT model will quantify the accuracy/robustness of the current confirmation calculation plan. During this exercise, it is recommended that FLUENT model for the 8ft vessel is exercised in manner identical to that planned for plant scale simulations during confirmation calculations.

During their visit to NETL, BNI staff had presented an Integrated Pump Down (IPD) model which will be used in conjunction with FLUENT CFD model to predict solids accumulation in heel. Since the CFD simulations of draw down are computationally intractable due to large wall times, its coupling with the IPD model was shown to significantly reduce the computational time. The error associated with the IPD model was quantified based on the IPD model's ability to recover an analytically known draw down curve. However, this does not constitute a proper validation of the IPD model which will be used to predict a very critical validation variable. In order to quantify the modeling errors, the coupled CFD-IPD model prediction should be compared against a 3-D fully transient CFD model prediction and available experimental data. The CFD model should ideally be simulated for multiple draw-down cycles in order to assess the error accumulation in CFD-IPD model. Since the CFD model will be computationally very expensive, it is recommended that this validation exercise be performed for 4ft vessel. For the 8ft and 14ft vessels it is recommended that the coupled CFD-IPD be compared against the available experimental data for confirmation calculation. Comparing the CFD model prediction against the coupled CFD-IPD model and experimental data will quantify the model errors which should be incorporated into the overall (CFD and CFD-IPD) model error used in the confirmation calculations.

Recommendations for experimental test plan

During the review of BNI's V&V plan and experimental test gap documents, NETL review team had asked for empirical evidence that the dimensionless group identified by BNI is sufficient to describe the PJM vessels. As an example of an effort that can probe the sufficiency of dimensionless group, NETL had asked WTP to conduct further experiments on the existing 4ft diameter vessel and a new 14' vessel for varying dimensionless parameters identified in the experimental test gap document (such as, particle Reynolds number and jet Reynolds number). The validation variable ZOI measured from experiments will be a function of dimensionless numbers. It was noted that if the dimensionless group is indeed sufficient, then this dependence of validation variables on dimensionless group will collapse on top of each other for different sized vessels and different PJM nozzle diameters and operating conditions. This exercise will support the arguments made in experimental test gap document with respect to filling the data gap. For the above stated reasons and also to validate BNI's current confirmation calculation plan, NETL recommends that a 4ft vessel should be used to perform detailed NQAI compliant experiments. The detailed experiments performed on 4ft, 8ft, and 14ft vessels should be used to demonstrate collapse of ZOI curves. The various test conditions are described below

a) Single PJM
b) Four PJM's
c) Six PJM's
d) Repeat (a-c) with a minimum of two different diameter nozzles.
e) Repeat (a-d) for vessels during pump-down to study the effect of liquid height on ZOI. (Low, Med, Full)
f) Repeat (a-e) for vessels having 3 different solids loadings (2wt%, 5wt%, 10wt%) while maintaining the characteristic particle size distribution.
g) Repeat configurations (a-f) above for the 4 ft diameter vessel.
h) Repeat configurations (a-f) above for 8 ft diameter vessel. Perform confirmation calculations based on V&V'ed CFD model at the 4ft scale.
i) Repeat configurations (a-f) for the new 14 ft diameter vessel to perform confirmation calculations, especially for the more challenging mixing conditions encountered in the WTP vessels. Use V&V'ed CFD models at both 4ft and 8ft scales.
j) In all the CFD simulations the mesh size must be maintained constant as the calculations are taken to larger scales (i.e., 8ft and 14ft tanks).

These tests should be accompanied with measurements of the validation variables (such as ZOI, suction line concentration, etc.) that are currently under the scope of CFD and these values should be used when necessary in the FLUENT IPD model as input. Since the scope of NETL's team is limited to review of CFD V&V plan for PJM equipped vessels, this report does not make any recommendation on the test simulant properties or the vessel geometry.

ATTACHMENT 3
to
12-WTP-0191

TRANSMITTAL OF DEFENSE NUCLEAR FACILITIES SAFETY BOARD (DNFSB) RECOMMENDATION 2010-2 IMPLEMENTATION PLAN (IP) DELIVERABLE 5.3.3.5

Comment Resolution Form
Experimental Data Gap Analysis for CFD V&V

(Total Number of Pages including coversheet: 36)

COMMENT RESOLUTION FORM

Return to: Ricky Bang	Comments Due:		
Document Title: Experimental Data Gap Analysis for CFD V&V	Document No. 24590-WTP-RPT-ENG-11-152	Revision:	Date:

Reviewer: NETL — Date: 2/8/12	Response by: — Date:	Comments Resolved: — Date:

Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
1	1.2.2	It is stated here that "the primary mechanisms observed depend on the local flow conditions." It is assumed here that the CFD calculations will accurately model all the fluid dynamic features of the large scale flow and that the fluid dynamic features of the small scales are independent of these. This situation usually only occurs when there is a very large separation in the length and time scales. Such a situation would be a free jet in an infinite atmosphere, or a boundary layer on an aircraft wing. This is not the case inside these mixing vessels. The multitudes of length and time scales that are concurrently operating in a mixing vessel are not separated by orders of magnitude and they are thus coupled. Changes in one scale will mean that all the other scales will also change, and these changes are not captured by the simple turbulence models which calculate the production and the dissipation of turbulent kinetic energy using a local gradient hypothesis. It is a cornerstone of turbulence theory that the dissipation rate in the small scales can be estimated by calculating the dissipation rate from the large scales. The assumption of scale independence certainly reduces the scope of the problem, but this assumption should be experimentally verified before it is used in the design of vessels that handle nuclear material. Can BNI provide evidence data that supports this assumption?	M		Yes - for the mixing variable most strongly affected by turbulence at the vessel bottom - solids mobilization zone of influence (ZOI) - WTP will show comparison to relevant physical testing in a 12x12 foot flume with 2 full scale PJMs, a 8 foot diameter vessel with single full scale PJM, a 8 foot diameter vessel with half- scale PJMs arranged in two different prototypical PJM arrays, and a 4 foot vessel with PJM arrays. The tests will have been conducted using a wide range of PJM jet velocities, fluid viscosities, and solid loadings.	Response is not satisfactory.
2	1.3	Cloud height has been mentioned as a surrogate variable at several places in this and other WTP documents. A discussion on cloud height measurement similar to other validation variables should be included here.	M		Agreed - will ensure that adequate discussion on cloud height is included.	NETL is satisfied with the response but will need the revised documentation.

COMMENT RESOLUTION FORM

Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
3	1.3.1	*Table 1-1*: lists the functional mixing requirements that must be met by these systems. These mixing requirements are basically the system outputs, or the figures of merit that the system must achieve in order to function properly. The main concern here is that these requirements are stated in a very qualitative way and are not stated in a quantitative or mathematical way. If these mixing requirements are to be assessed using CFD and/or experimentally then they should be given in terms of numbers or mathematical statements which can be directly calculated from the CFD results and from measured data. Then a proper assessment can be made as to whether or not the mixing requirements have been achieved	M		Agreed - this information can be included.	INCONSISTENT TO V&V RESPONSE and response below (4)
4	1.3.1	State the mixing requirements in concrete mathematical terms so that metrics produced by the calculation results may be directly compared to metrics that are extrapolated from experimentally measured quantities. This renders the mixing requirements to be validation variables	M		The mixing requirements are provided by WTP Engineering and are stated as such. Thus they should not be modified.	Agreed

Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
5	1.3.2.1	Is there a precedence (in-house or published literature) where velocity data was used as surrogate to heat transfer predictions? Why not just include the heat transfer calculation in the CFD model only? It is not clear how the velocity data at one point in time can be used to conclude transient heat transfer process. What is the dominant mode of heat transfer in these vessels? If free convection is significant, then it is imperative to account for it in the carrier-phase momentum equation itself (by allowing carrier-phase density to vary naturally)	M		N/A - CFD is no longer going to be used to confirm cool-to-transfer performance for the PJM Vessels.	Agreed
6	1.3.2.1	If ΔT is on the same order as one cycle then the average velocity that is calculated will not be representative of the unsteady velocity that the CFD calculates or unsteady velocity observed in the experiment. What does this average velocity actually mean?	M		Same response as for comment 5.	Agreed
7	1.3.2.1	Only a steady-state value is being used. This implies that the correlations being used require this information only. If the heat transfer is transient, this may not be adequate. There is no discussion of the heat transfer correlations or the heat transfer hardware, so no evaluation can be made of this point. The assertion is made that … "Direct heat transfer calculations from CFD are not necessary to generate accurate solutions for this validation variable." This implies that the heat transfer and temperature changes do not affect the flow in the mixing tank, i.e., one-way coupling. <u>However, there is no evidence presented to justify this assumption and BNI is requested to provide enough evidence that justifies this assumption.</u>	M		Same response as comment 5.	Agreed

COMMENT RESOLUTION FORM

Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
8	1.3.2.2	It is not clear how this inlet is modeled. Please provide full details on how the boundary condition to the suction outlet is defined	M		This detailed explanation will be provided in the CFD V&V Plan Rev. 1 (SWLCD Volume 4)	NETL will need this document
9	1.3.2.3	The discussion in this section is not very relevant as the method to compute time to mix or degree of mixing has been modified and is based on measurement of electrical conductivity of anion concentration (*Draft FLUENT V&V Simulant Development Requirements and Initial Simulant Approach*). Please make the documents consistent so that the reviewers can comment on the latest plan.	M		Agreed - will make the documents consistent.	NETL will need this document
10	1.3.2.3	If the time for fluid density to reach the average of initial and final density is very long, is there a surrogate for this validation variable? Will the suction line be in operation during the sampling as it might affect the measurement?	M		There is not a surrogate variable. No the suction line is not in operation during the blending operation.	NETL will need additional details on this validation variable
11	1.3.2.3	Density measurements are to be "taken at several different locations inside a vessel," however the choice of locations is not given; mixing could be quite different in different parts of the apparatus. How are you going to account for this. Is the location and details of this provided in the test plan document?	M		Yes - the details are provided in the CFD V&V Test Plan document.	There is insufficient details on the exact location of these measurements

Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
12	1.3.2.3	This VV is complicated by the fact that the actual WTP application is the introduction of the denser liquid at the top, however, the experiments where based on situation where a "where a positively buoyant fluid is introduced from above." (However, this is achieved by introducing a saline solution into water … how is this negatively buoyant?) Thus, the validation is based on the comparison of isothermal mixing of an inert constituent. In the actual case, the caustic mixture would react, generating heat, which would affect the density. Heat transfer and mixing would become coupled. However, this is not accounted for in either the test experiments or the validation simulations being considered. How is this going to be account for?	M		It (heat transfer) is not accounted for and the operation is considered as isothermal since the amount of heat generated or lost in the physical operation in the actual vessel is negligible for Newtonian vessels.	The question is not about a physical process, such as heat transfer, but rather it is about heat generated by chemical reactions during the mixing process. If this is negligible then the matter is resolved.

Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
13	1.3.2.3	The precise definition of these validation variables (VV) is a time … "the time it takes the fluid density … to reach a density equal to the average of the initial and final (completely mixed) densities." Presumably, the final density is a calculated quantity, based on the total amounts of each liquid, so that neither the simulations nor experiments need to be run to complete mixing in order for this VV to be well defined. It seems inconsistent that the VV is based on 50% mixing while the mixing requirement is 80% mixing. Please provide justification for this or is this covered by the use electrical conductivity experiments?	M	Granted, the comment is confusing since it mixes several ideas. The first question concerns how the half-time of mixing is to be calculated. Will the calculation be run to a final density or will the final density be calculated from the properties of the components being mixed? If the components are not 'perfect' liquids (using a physical chemistry term) then there would be a change in density while mixing, i.e., the densities would not be additive. This would complicate the calculation of the final density. Please provide details about how the final density will be determined. A second concern is that it seems inconsistent to use a 50% mixing value in the VV process when the requirement is an 80% mixing value.	**Please clarify the question.**	See the comment under the column "M" comment justification
14	1.3.2.3	There is a concept of an ideal vs. non-ideal solution which seems to be relevant in this discussion. It is not clear if this is considered or if it should be. For example, is the density of the completely mixed solution the average by volume of the two mixed liquids?	M		Yes	Ideal or non-ideal? BNI's response is not clear with respect to gas-law.

COMMENT RESOLUTION FORM

Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
15	1.3.2.4	When single or multiple PJM's are used the definition of ZOI should be quantitatively defined to include % area cleared. How will experimental data be compared to calculations in geometrically complex situations? The ZOI is defined but it is not clear how this definition relates to a figure of merit for bottom clearing. How will this be compared to experimental data?	M		The measurement of ZOI has been done successfully in several experiments with prototypical PJM arrays and will be done in a similar fashion in the 8 foot testing and compared to equivalent measurement in the CFD models.	Agreed, however, NETL has not reviewed any such document.
16	1.3.2.4	This discussion is quite complicated. It is not clear that all possible scenarios for jet interaction are enumerated, e.g., the effect of the wall could dominate before ZOIs merge. However, the guiding thought should be to compare similar experimental and numerical quantities. This report states that the … "solids volume fraction should provide an unambiguous indicator of the ZOI boundary in CFD." Unfortunately, realizing that the solids volume fraction is a numerically resolved field, this is not true … for the reasons stated in the report. The value of the solids volume fraction used to define the edge of the ZOI must be specified and should correspond to what the experiment "sees." Moreover, this will be quite sensitive to the spatial resolution of the mesh … and the order of the numerical scheme; 2nd order will be necessary.	M		Agreed- 2nd order solution will be used, and the V&V test cases will demonstrate grid insensitivity (this is a requirement per ASME V&V 20).	Agreed, however, NETL has not reviewed any such document.

COMMENT RESOLUTION FORM

Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
17	1.3.2.4	One of the issues in the documents related to BNI's use of CFD and V&V for the Hanford waste is the assumption that the 8 ft diameter cold flow experiments being proposed to fill in data gaps is representative of the larger full-scale system. It is commonly accepted that small-scale hydrodynamics are not necessarily the same as large-scale hydrodynamics and all solid particles do not scale the same. In the proposed 8 ft tank experiments the depth of the bed is relatively shallow compared to most of the WTP vessels with PJM's. Major hydrodynamic features such as ZOI, accumulation at the heal, upwashing of the solids along the wall of the tank, and general bubbling behavior and mixing in the lower region of the tank could all be influences by the depth of the bed. Furthermore, hydrodynamic features present in the WTP vessels with PJM's may be missing in the 8 ft. tank experiments. For example, certain circulation patterns or gas-liquid channeling induced by the deep beds and larger differential pressure drop across the bed in the WTP vessels could have significant effect on major hydrodynamic features. These non-homogeneities present in deep beds are less likely to occur in a shallow bed and could have impact on ZOI's and hydrodynamic data generated in the 8 ft tank. To avoid or minimize the concerns above the data gap should include test plans for different bed heights to demonstrate and understand how bed heights influence ZOI, upwashing and other major hydrodynamic features.	M		Agreed. The current RTD for the V&V Test Plan specifies that testing in the 8 foot vessel for both single PJM and 4 PJM array will be conducted at 10% and 2% weight solids loadings which produce different bed depths.	The water level should be varied while maintaining the same total amount of solids to demonstrate its effect on PJM performance. This is not in RTD. Varying solids loading does not have the same effect as varying bed height as the former approach will change physical regime of the application while the later approach (varying bed height) will not do so.

Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
18	1.3.2.5	There is an inconsistency in this definition. The concentration by constituent is introduced, C_s. This is a concentration. The initial concentration is measure at the beginning of the pump-down, $(C_s)_{initial}$. However, after pump-down, "the total mass of each particular constituent, $(C_s)_{Final}$, is measured " … this is not a concentration but a mass. Thus, it is *not* possible to compare this number with $(C_s)_{initial}$. However, if the total volume of the heel is known, then a final mass can be converted to a final concentration to allow comparison. If this is, in fact, the meaning of $(C_s)_{Final}$, a final concentration by constituent, then the two numbers can be compared. However, there is no reason that "$(C_s)_{Final} \leq (C_s)_{initial}$"; this is what is to be established. The concern is that some constituent might concentrate in the heel, so that, for some constituent, $(C_s)_{Final} > (C_s)_{initial}$.	M	The document says that "the total **mass** of each particular constituent, $(C_s)_{Final}$, is measured " Although labeled by a *C*, $(C_s)_{Final}$ is a mass. Thus, a "concentration" ,$(C_s)_{initial}$, will be compared to a "mass." This is not possible since they have different units … apples and oranges. Either change the document to read "the **concentration** of each particular constituent, $(C_s)_{Final}$, is measured" or explain how $(C_s)_{initial}$ and $(C_s)_{Final}$ will be converted to a common unit so that they can be compared. This is one concern. A more fundamental concern is the assertion in the document that $(C_s)_{Final} \leq (C_s)_{initial}$. There is no *a priori* reason that this inequality should be satisfied. In fact, this is what is to be determined. If this condition is satisfied then it is predicted that there will be no buildup; if this is not satisfied for any component, then there is a problem.	**Please clarify the question and then the document will incorporate the requested clarification.**	See the comment under the column "M" Comment Justification
19	1.3.2.5	Another concern is that the constituents are not identified. It is important to identify what constituents are of concern. This requires more extensive discussion.	M		Agreed - more extensive discussion will be provided.	NETL will need this documentation

COMMENT RESOLUTION FORM

Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
20	1.3.4	Since the current V&V plan will not cover vessels with non-Newtonian fluid, should UFP-VSL-00002A/B (non-Newtonian vessel according to Page 10) be removed from Table 1-3?	M		Yes	Agreed
21	2.1	*Page 15, last paragraph*: Although I agree with the statement in general, its generalization to multiphase flows is not proven. In other words, there has never been a good scaling study demonstrated in multiphase flows that shows kinematic self similarity. Neither has no study been able to identify a unique group of non-dimensional numbers that can be used to scale up or scale down a multiphase flow application without loss of physical phenomena. It will be a worthwhile exercise if BNI can demonstrate successful scaling with a group of non-dimensional numbers for a multiphase flow application. <u>It is recommended that BNI clearly shows that the dimensionless group chosen by it is sufficient to describe the problem.</u> One recommendation is to calculation ZOI for 4ft and 8ft vessels for varying particle Reynolds and jet Reynolds numbers. Other dimensionless variable can also be varied in the study. If the current dimensionless variables are sufficient, then the ZOI profiles obtained in 4ft and 8ft vessels should collapse on top of each other. The failure of ZOI profiles to collapse will point to the deficiency of current dimensionless variables to describe the problem, and, by extension, the design of test matrix in the experimental data gap analysis is also questionable.	M		ZOI's for both 4 foot and 8 foot diameter vessel tests will be obtained from previous and planned tests with similar PJM arrays and velocities, and will be compared.	See document provided to WTP on Recommendations for Experimental Test Matrix. The experiments listed in this document are strongly recommended.

COMMENT RESOLUTION FORM

Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
22	2.1	*Page 17*: Table 2-2. Please double check the range of total solids loading. Is the upper limit of solids loading 20% or 15.2%? In addition, the detailed list of particles per vessel cannot be found in Table 6-48. It seems that the reference should be Table 6-47	M		The upper limit for the planned testing is 10% solids loading and is documented in the current V&V Test Specification.	NETL will need the final version of this document

COMMENT RESOLUTION FORM

Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
23	Section 3	It is not clear in this description of test vessels what the actual testing conditions were for each of the various configurations or how the experimental configurations compared to the actual designs, or how the tests were conducted. There are no initial conditions or transient conditions shown for the various test configurations and there are also no measured results shown where we can compare CFD calculations to these experiments. This is a significant gap in experimental data. The exact configuration for each test vessel should be shown as well as a matrix of where the initial and loading conditions are areas well as the experimental results which may then be directly compared to calculations. Because this is not done it cannot say how well the test vessels performed in mixing. A dimensional analysis like the one described below can alleviate the above concerns. -Initiate a well designed experimental program where the key independent parameters are changed and measure the results. Compare these to calculations having the exact same boundary and operational conditions. If possible I would like to do this. (JVO) -For the first trial of this a suggested list of these is given in the following equation for the average jet velocity: The independent parameters are dive time, gravity, fluid viscosity, fluid density, resting fluid height in the vessel, average solids density, resting height of solids in vessel, pressure difference at end of suction phase, pressure difference during pulse phase, velocity at start of drive, velocity at end of drive, vessel hydraulic diameter, diameter of the PJM tube, diameter of the PJM nozzle exit plane, distance of the PJM nozzle exit plane	M		**Please clarify the question/comment.**	See document provided to WTP on Recommendations for Experimental Test Matrix. The experiments listed in this document are strongly recommended.

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Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
24	3.1	Please correct the number of total available tests for the fluid velocity data set.	M		N/A - these tests are no longer being used.	Agreed
25	3.2.1	Page 25: There are 38 test sets identified for a single configuration, 20 with fluid only and 18 with solids. Of the 18 sets with solids, 9 contain 5 wt% of 10 μm particles and 9 contain 20 wt% of 35 μm. Thus the statement … "particle diameter ($10 \le dp \le 35$), and particle loading ($5 \le Wt\%p \le 20$)" … is somewhat misleading as this 2-D parameter space was not sampled in any meaningful way; there is data for only two points in this space: dp =10 with Wt%p = 5 and dp =35 with Wt%p = 20. No information on particle density (not given) is stated other than it is too low. Only one value of the supernate density was used. There is no information on a system with a particle size/density distribution. Please provide details to address the above concerns.	M		Some of the requested information is not available and thus cannot be provided.	It is not clear how this concern could not be clear. It is about ineffective approach to filling the data gap which should not require any data. Need details for the experiments on size and wt% choices
26	3.2.3	It is stated that "time-to-mix (as defined in the report) varies from 15 minutes to greater than 94 minutes." Is this value based on 50% or 80% mixing, or some other criteria?	M		Per WTP-RPT-077, the time to mix is when the particles are either suspended in solution or the mixture is completely homogenized. This was evaluated by monitoring the density measurements at three positions as a function of time	NETL needs more clarification. Not sure why particles are mentioned in the response since the referenced experiments did not include any particles

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Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
27	3.3.3	With respect to this VV, the statement is "For this variable, the test vessel misses the cross sectional area comparison (Vessel section to total PJM section, low ... *by a factor of 10*), the nozzle offset ratio (low ... *by < a factor of 2*), and the PJM velocity (low ... *by < a factor of 3*)." However, according to Table 3-4, the PJM nozzle diameter (the governing variable according to the text) of the test (2 in.) is smaller than that of the WTP vessel (4.3 in.) by a factor of ~2. There appears to be an inconsistency between the statements in the text and what is in the table. Please clarify this.	M		We do not see the description of low "by a factor of" in the section referenced. **Please clarify**.	The information in italics was added by NETL to be more specific since the comments included by the authors are a little misleading. For example, the first instance uses the adjective "low" to describe a section ratio that is off *by a factor of 10*. This seems disingenuous.
28	3.3.3	The comments … "simulant and particle definitions do not span … and are low compared to the WTP vessels in most instances."… doesn't seem to make sense. The tests were only with water and a saline solution. No particles were considered. Can BNI clarify if particles were indeed present in these tests? If the particles were not present, then make the text in the document consistent as well.	M		The phrasing in this instance is poor. No particles were present, only the sodium thiosulfate.	Based on this response can BNI address row 26 (see comment given)

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Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
29	3.3.3	The last entry in Table 3-5 on page 37 for particle density … "1307" … seems to be a typo as there were no particles present in the test. Notice that the presence of particles can change the supernate viscosity by a factor of 30 (0.0001 to 0.03 kg/ms) and its density significantly (998 to 1374 kg/m^3).	I		This is mislabeled. The value shown is the given density of the 50% solution, not of a particle.	Agreed
30	3.3.4	The situation with respect to this VV seems quite favorable. The diameter ratio between WTP vessels and test vessels is ~ 5:1 (564 <> 138 in.), which is the suggested safety limit. However, there seems to be no recognition of the effect of polydispersity. The repeated pulsed could, in fact, be a concentration mechanism for dense particles of a specific size, as in the formation of placer deposits (Komar, Paul D.,and Martin C. Miller, "The threshold of sediment movement under oscillatory water waves," *J.Sedimentary Petrology*, 43, 1101-1110, 1973.). Also, see Todeschini, S., C. Ciaponi and S. Papiri, "Laboratory Experiments and numerical modeling of the scouring effect of flushing waves on sediment beds," *Engineering Applications in Computational Fluid Mechanics*, 4, 365-373, 2010. This paper describes a coupling between the flow and the deposit. This could be compared to that used by Bechtel. Can BNI review these papers and comment	M		BNI will review these papers and comment.	NETL will need BNI's response

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Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
31	3.3.5	The discussion in this section is quite vague … "A single test (MCE Pump-down) is used for this variable, compared with a total of *17 vessel sets (see Tab*le 1-3). The design parameters show some overlap for most conditions, with the PJM nozzle velocity displaying the least. The supernate and particle parameters show consistent overlap *for all variables." A review of Tables 3-4&5 gives more i*nformation. The vessel diameter scale between WTP vessels and the test vessels was >10 (564 <> 43.3 in.). The nozzle diameter (the important parameter) was very different (4.3 <> 0.7 in.) The supernate viscosity of the test was somewhat lower than is expected in the WTP vessels (0.03 <> 0.008 kg/(m·s)).	M		**Please clarify the question.**	Again, as with Item 27, the quoted text seems to be misleading compared to the more specific information in the tables.
32	4.1.2.1	Nearly all the vessels in Table 1.3 require this as a validation variable. There is a lot that hinges on the success 8ft vessel and subsequent suction line measurements. It is hard to fathom how the 8ft vessel can close all gaps in short time when there were so many past experimental studies performed at several places but none of them could provide this very crucial data. Can BNI summarize the data that will be generated in the 8 ft experiments.	M		Yes - this information is provided in the current RTD and Test Specification.	The response is not satisfactory.
33	4.2.1	*"By the end of batch, much of the rapidly settling solids have been removed from the vessel"*: Is this confirmed by the experimental observation? If not, will the 8 ft experiments address this?	M		Yes and Yes.	Agreed

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Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
34	4.2.1	*Page 44, Bullet 4*: I do not completely agree with this reasoning. Do you mean that since all solids are easily suspended due to high fluid viscosity, so one can assume single phase flow? What about solids loading? One can assume single phase flow only if the solids loading is very low. If all the solids in the system are readily suspended then that does not imply that the solids will not affect the carrier phase. The carrier phase governing equations will still be augmented by the interphase exchange terms and will not reduce to single phase CFD. It will still be a multiphase flow problem. High fluid phase viscosity implies lower particle Stokes number (see the comment below) due to which particles follow the fluid streamlines more closely than in lower viscosity fluid.	M		Please clarify the question. Note that the planned 8 foot vessel tests will use a simulant that includes 6 particle classes ranging from very large to extremely small and thus the stated concern should be evidenced by these tests.	Agreed, as long as the same mixture composition is used for all experiments recommended in the experimental test matrix document that NETL provided to WTP

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Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
35	4.2.1	*This is a general critique of the document*: a very useful number to decide if solids will be readily suspended or go on their and cluster in the high-strain regions of the carrier flow is particle Stokes number which is defined as the ratio of the particle response time to fluid response time. A low Stokes number will imply that particles will follow the carrier fluid and a high Stokes number implies very inertial particles that do not follow the fluid streamlines. In this documentation, somehow for low Stokes number particles (generally small sized particles), it is always concluded that the problem will reduce to single phase CFD which is mature and, hence, the resulting data gap is not a serious one. Please note that low Stokes number particles with high loading need the same amount of respect in terms of multiphase flow modeling as high Stokes number particles. Additionally, low Stokes number particle in the current application turn out to very small sized particles as well. These very small particles can be embedded and/or trapped within larger particles and result in cohesive agglomerates. There is enough evidence in the multiphase flow literature that cohesive agglomerates cannot be successfully simulated with the current closures. There have been some ad-hoc extension to drag closures but they are ad-hoc at best and tailored to very unique applications. So even though the smallest size particles may have a very low loading, it will be worthwhile to perform experiments with full particle size distribution typical to WTP PJM vessels.	I		This is good feedback. Our strategy is to test with a simulant that has multiple particle classes that span the range of WTP waste including large and very small particles. The results of the testing for accumulation, solids mobilization, and suction line concentration will be compared to the CFD predictions of those tests. If the agreement is good then we can say that CFD is simulation the effects referred to in the comment reasonably well. If the agreement is not good then we will need to possibly investigate this issue further.	Agreed, as long as the same mixture composition is used for all experiments recommended in the experimental test matrix document that NETL provided to WTP

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Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
36	4.2.1	*Page 44, bullet 6*: This point is very confusing and does not really bring out the entire picture. Looking at Table 6-47 (Page B-2), for HLP-VSL-00022 and UFP-VSL-00001 A/B (heat transfer vessels), it is clear that the characteristic density of 2900 kg/m^3 spans the entire particle diameter range from 11 to 700 micro meter but only small sized particles are covered by the test vessels. Now the small sized particles are readily suspended, and based on the same argument made over and over in this section, this will reduce to single phase CFD and by consistent reasoning this should be easily simulated since single phase CFD is a mature technology. Again, this is confusing as the high density *and* small sized particles can be considered as single phase CFD only because of low loading and not due to being readily suspended alone.	M		Agreed – that is why the conclusions of the Data Gap analysis were that a gap exists in relevant data. The intent of the 8 foot vessel testing is to collect data for the representative range of WTP waste particle classes which include small particles at very high density and large particles at 2900 density.	Agreed, as long as the same mixture composition is used for all experiments recommended in the experimental test matrix document that NETL provided to WTP
37	4.2.1	In the V&V document (24590-WTP-PL-ENG-11-002, Rev. B), it is mentioned on page 13 under thermal management vessel that momentum interchange coefficients are set to zero in the CFD model. Is this applicable to these vessels?	M		CFD is no longer planned to be used for Thermal Management anlaysis.	Agreed

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Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
38	4.2.1	Velocity measurements should be taken and compared with calculations in as many places as is possible. This becomes a very difficult for multiphase flows and probably intractable in regions of the flow field where the solids flow is dense. There are experimental techniques that could be applied here but these have not been used and would require considerable effort in order to be used. Can BNI explain if and how velocity measurements will be reliably taken in the regions of high particles loading.	M		Yes – this explanation is provided in detail in the current CFD V&V Test Plan, including discussion of the instrumentation, data collection strategy, and probe locations.	NETL will need this document
39	4.2.1	The rates of change of the free surface height should be measured and calculated during a normal PJM cycle for vessels that have no solids loading and also vessels that are loaded. This will give a very good indication of how the energy dissipation rate changes with particle loadings. Can this be quantified and compared to the FLUENT model?	M		The plan is to use video cameras placed alongside the test vessel at two locations that will be used to track the movement of the free surface and the cloud height. This effects can then compared to the transient CFD model using animations placed side-by-side to the video.	There is no mention of a test in the test matrix that has no solids. Run PJM cycle with and without solids and compare height of free surface.
40	4.2.1	The test data is available only along or near the centerline, not near the outside wall where the heat exchangers are. Apparently, this document presumes … "that fluid velocities near the center of the vessel correlate well to the local wall fluid velocities." There is no evidence given, either experimentally or computationally, to support this assertion. Furthermore, even if they "correlate well" that implies that they differ by a constant factor, which could be very large.	M		As previously noted, CFD is no longer planned to be used for the cool-to-transfer vessel performance analysis.	Agreed

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Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
41	4.2.2	What are the values for suction line diameter, suction line inlet height and radial offset and suction line flow rate in WTP VSL?	M		This information is not easily obtained for all vessels but if necessary we will investigate	Why is this information not available or not important? This should be a critical piece of information. Response is not satisfactory
42	4.2.2	A range of particle size in TEST VSL is used to compare again the WTP VSL. However, it seems that in most experiments only a mean particle diameter is given. It is not clear from Table 6-22 whether a single particle size or a mixture with wide PSD is used. This information should be very clearly mentioned in the gap analysis since it is one thing to perform many experiments for different particle diameters and it is another to perform one experiment that encompasses the entire particle size and density distribution.	M		Agreed – the information will be clarified in the next revision of the report. Also note that the tests in the 8 foot diameter vessel will include 6 particle classes in each experiment (to represent WTP waste).	Agreed, as long as the same mixture composition is used for all experiments recommended in the the experimental test matrix document that NETL provided to WTP

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Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
43	4.2.3	Only a vessel with a single PJM is considered in the test so that the effect of multiple jets and the more complicated geometry are not included. Can BNI provide details to support the use of a single PJM.	M		The single PJM test is conducted to obtain data at plant scale PJM nozzle diameter and Reynolds number. Subsequent tests will be conducted with half-scale nozzles using prototype WTP plant PJM arrays.	Agreed, as long as the same set of PJM configurations are used for all the experiments recommended in the experimental test matrix document that NETL provided to WTP
44	4.3	The particle size distribution is an important parameter and should be considered through the solids loading, wt%, by constituent. However, it seems only the total solids loading is used in most analyses. What is the justification for not including this very important variable from the context of multiphase flows in the analysis?	M		The particle size distribution (PSD) will be considered in the V&V 8 foot vessel testing and is also clearly prescribed in the PJM vessel design calculations.	Agreed, as long as the same mixture composition is used for all experiments recommended in the experimental test matrix document that NETL provided to WTP provided to WTP

Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
45	4.3	The symbols used for non-dimensional numbers and even some of the terms used in the governing equations are different from those used in the V&V report. Can BNI make this consistent?	M		Yes – BNI will make sure these are consistent in the next revision of the V&V Plan and Data Gap Analysis.	NETL will need this updated document
46	4.3	What is the physical significance of the densimetric particle Reynolds number Re_p defined in this document? Reynolds number is the ratio of inertial to viscous forces. However, the particle Reynolds number defined here has no such significance. Why not just call it something other than a Reynolds number? A quick scholarly search of the term "densimetric particle Reynolds number" returns nothing.	M		Re_p is the particle Reynolds number as defined for use in the Shields relations for mobilization of settled solids beds (Cao, Z., Pender, G., and Meng, J., 2006: Explicit formulation of the Shields diagram for incipient motion of sediment, J. Hydraulic Eng., 132(10), pp. 1097-1099). It is also the square root of the Archimedes number used in the Karamanev correlation for the drag coefficient for settling particles (Green, D.W. and Perry, R.H., 2008: Perry's Chemical Engineers' Handbook, 8th Edition, McGraw Hill, p. 6-52). The addition of "densimetric" was used in the document to distinguish this definition of the particle Reynolds number from other common definitions in the particle transport community as pointed out in a visit to NETL.	NETL is reviewing this information

Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
47	4.3	The definition of densimetric particle Reynolds number is based on characteristic velocity for particle settling. It is not clear at all how this characteristic velocity is obtained. On non-dimensionalizing the particle trajectory equation for a particle settling in an infinite fluid medium, one can obtain two characteristic velocities. One is something similar to U_g but not identical. It is $U_g = (gD(\rho_p - \rho_f)/\rho_p)^{0.5}$(note the difference from your definition of U_g where submerged specific gravity $((\rho_p - \rho_f)/\rho_f)$ is used. Another characteristic velocity could be the terminal velocity. In any case, it is not clear how the characteristic velocity definition is arrived at and detailed derivation should be included or referenced.	M		The definition for Re_p is provided in reference Cao, Z., Pender, G., and Meng, J., 2006: Explicit formulation of the Shields diagram for incipient motion of sediment, J. Hydraulic Eng., 132(10), pp. 1097-1099. A motivation for this definition is the force balance for a settling particle at terminal velocity in a quiescent medium . There are three terms: weight of the particle, F_g, weight of the displaced fluid, F_b, and drag, F_d yielding the force balance $F_g - F_b - F_d = 0$. $Fg = V_p r_p g$, where V_p is the particle volume ($V_p = 4/3$ □ r_p^3 for a spherical particle), and g is the acceleration of gravity. $F_b = - V_p$ □$_f$ g. $F_d = - C_d A_p \frac{1}{2}$ □$_f$ u_t^2, where C_d is the drag coefficient, A_p is the particle cross-sectional area (Ap = □ r_p^2 for a spherical particle), and u_t is the terminal velocity. Algebraic manipulation yields $u_t = (4/3/C_d)^{0.5}$ Ug, where $U_g = (s\ g\ d_p)^{0.5}$. The submerged specific weight, s, is defined by $s = (r_p - r_f)/r_f$.	Agreed

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Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
48	4.3	What does the so defined Froude number tells us? What are the ranges of Froude number distinguishing special physical flow transitions? In the absence of a physical mechanism that is strongly dependent on Froude number, its use in the current context is hard to follow. Can BNI provide references their use of the Froude number for this application?	M		BNI will provide the requested references.	NETL will need this information

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Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
49	4.3	Solids momentum conservation equations are closed by invoking countless empirical correlations. A comprehensive non-dimensionalization analysis should consider each correlation that will be used in the study (rather than some hand-picked ones) in order to determine the dependence. Can BNI extend this to include all the closures?	M	Agreed. However, following BNI's response to this comment, the whole idea of this analysis is not clear in the first place. The CFD should be compared to the experimental tests to determine error. What does this analysis help with? If it has to be done then it has to be extended to all closures and equations used in the CFD model.	It is not clear why it is necessary to perform this analysis extension since the comparison between CFD and measurements for the various tests conducted in the 8 foot vessel will determine how well (i.e., error and uncertainty) the CFD model (and sub-model closures employed) accounts for these effects.	Agreed. However, following BNI's response to this comment, the whole idea of this analysis is not clear in the first place. The CFD should be compared to the experimental tests to determine error. What does this analysis help with? If it has to be done then it has to be extended to all closures and equations used in the CFD model.

Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
50	4.3	The dimensionless parameters in this effort are derived by normalizing the dependent variables of the differential equation using characteristic length, time and velocity scales that were arbitrarily chosen. This practice is usually always accompanied by problems because it generates dimensionless groups that are only a subset of what is truly needed. It neglects the fact that it is often necessary to scale the different terms in the transport equations using different length, time and velocity scales. It is best to apply an order of magnitude analysis on each term in the equations as they apply to the different regions of the flow field to see which terms dominate and which terms may be neglected in which region. An order of magnitude analysis will generate a better set of dimensionless groups.	M		The dimensionless parameters are derived from a non-dimensionalization of the governing equations based on reference values for mass, length, and time. The choice of reference values is not unique; however, the specific set of reference values used in the report was not arbitrarily chosen. In unsparged WTP PJM mixing vessels, the momentum flux responsible for all mixing effects is derived from the pulse tube nozzle momentum flux which depends on the pulse tube nozzle velocity, nozzle diameter, and discharged fluid properties. The peak nozzle velocity, U_0, and nozzle diameter, D_0, were chosen as reference quantities, because they determine the maximum kinematic momentum flux into the vessel. The carrier fluid properties were chosen as representative, because the carrier fluid properties do not depend on the degree of solids loading nor on a particular solids composition.	Please refer to the recommended experimental test matrix document NETL provided to WTP

Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
50 cont'd					The dimensionless parameter group identified by non-dimensionalization provides a means to assess whether the plant space is spanned by a set of experiments relative to the space to which the CFD model is sensitive. The experimental matrix (separate document) is formed based on the dimensional operating conditions of the plant, not the dimensionless operating conditions, to ensure that the dimensional parameters of the experimental dataset are directly relevant to plant conditions.	

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Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
51	4.3	It is also important to derive the set of dimensionless parameters using standard dimensional analysis. This is done using all known inputs including all geometrical and operational parameters and all know outputs including precise mathematical statements of all the important mixing requirements. This kind of analysis will generate all the dimensionless parameters without using the differential equations.	I		No response needed as this comment is informational.	Agreed, however, if the tests follow the Recommended Experimental Test Matrix document NETL provided to WTP, then the experimental data collected following the recommended approach might help support BNI's arguments on adequacy of dimensionless groups

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Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
52	4.3	The use of the jet velocity as a scaling parameter is questionable. The jet velocity is unsteady. It depends on the pressure over the free surfaces in both the PJM and the containment vessel, and also on the height of the free surfaces in the PJM and the containment vessel. These parameters are changing throughout the PJM cycle which will cause the jet velocity to be unsteady.	I		No response needed as this comment is informational.	This comment from NETL should have been stated "how is BNI sure that pressure and free surface height over both the PJM and containment vessel is not a leading order parameter".

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Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
53	4.4.1	The correlation chosen for this demonstration is for an isolated sphere settling in an infinite medium. Since the real application is not as simple as this correlation, the conclusion drawn in this section cannot be generalized. Also, what is the significance of Archimedes number here; it is just the particle Reynolds number wherein the slip velocity is substituted by the terminal velocity. This analysis should be done for a typical drag correlation used for dense multiphase flows.	M		The example correlations were included in the document solely to enhance confidence that the dimensionless parameter set is complete by showing that the parameters are sufficient to evaluate data-driven correlations from the literature that have been used, in part, to understand plant behavior. The Archimedes number is the particle Reynolds number squared. It was introduced in the document because the Karamanev correlation for the drag coefficient for settling particles is written in terms of it (Green, D.W. and Perry, R.H., 2008: Perry's Chemical Engineers' Handbook, 8th Edition, McGraw Hill, p. 6-52). It is not required to conduct additional analysis based on the drag correlations because the drag correlations are incorporated into the "CFD model" as sub-model selections in Fluent and this their adequacy and accuracy will be assessed as part of the V&V comparison with testing.	See resolution number 49

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Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
54	4.5	Why wt% is not included in the Table 4-9 since it has been demonstrated to be an important parameter?	M		Weight percent is an important parameter but it is not needed to evaluate the appropriateness of test vessel size selection since the testing in that vessel will be conducted at actual WTP plant solids weight percent loadings.	Agreed, but the same mixture composition should be used in the recommended experimental test matrix document NETL provided to WTP

Item No.	Section/ Paragraph	Comment	Significance[a]	"M" Comment Justification[B]	Response	Resolution
55	Section 5	The entire gap analysis presented here was conducted assuming that the set of dimensionless groups that define the parameter space is sufficient. Based on a review of how the dimensionless parameters were formulated in section 4.3 there are reasons to believe that the set of dimensionless parameters used may not be a complete set. If the set of dimensionless parameters is not sufficient then there exists a tremendous gap in the V&V effort of the CFD calculations. This should be investigated further	M	The dimensionless analysis done to justify the use of 8 ft vessel can only be conclusive if dimensionless group is proven to be sufficient and NETL review team has made several recommendations in this regard (example, calculation of ZOI in 4 ft and 8 ft vessels). Either this or the analysis in section 4 should have been extended to each governing equation and closure. However, the analysis in section 4 is not needed at all as the CFD governing equation do not change from test vessel to plant vessel scale. In any case, if the gap analysis is not based on dimensionless group, then it is recommended that the discussion in section 4 should be removed and only dimensional numbers should be used for data gap analysis for 8ft vessel. It is felt that the current practice of jumping between dimensional and dimensionless analysis without the obligation to prove the sufficiency of dimensionless group is risky and unscientific.	The Gap analysis is not based on dimensionless group analysis – rather the gap analysis is based on Dimensional analysis using a wide range of applicable WTP plant parameters. This is the approach recommended by external reviewers (ERT) and BNI Engineering Chiefs. The dimensionless analysis presented in Section 4 is used ONLY to justify the selection of an 8 foot diameter vessel for additional testing at significant scale. For that purpose the dimensionless analysis presented covers many of the key groups to support that conclusion. If the conclusion had not been clearly supported by the analysis conducted then more groups would have been considered.	Response in under "M" Comment Justification due to format issues with this document.

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55 contd…			M	Following this recommendation, it should become obvious that it is not possible to fill the data gap without resorting to dimensionless analysis and hence the need to prove the sufficiency of dimensionless group.		

[a] **Significance**: M = Mandatory; I = Improvement. Definitions for these terms are provided at the end of the form instructions and in Section 3.0 of procedure "*WTP Document Administration*".

[b] Justification required for Mandatory Comments.