

U.S. Department of Energy
Office of River Protection

P.O. Box 450, MSIN H6-60
Richland, Washington 99352

08-WTP-131

JUL 23 2008

Mr. L. J. Simmons, Project Manager
Bechtel National, Inc.
2435 Stevens Center Place
Richland, Washington 99354

Dear Mr. Simmons:

CONTRACT NO. DE-AC27-01RV14136 – TRANSMITTAL OF THE U.S. DEPARTMENT OF ENERGY (DOE), OFFICE OF RIVER PROTECTION (ORP) DESIGN OVERSIGHT ASSESSMENT REPORT D-08-DESIGN-066: COMPUTATIONAL FLUID DYNAMICS (CFD) ANALYTICAL PROCESS ASSESSMENT

This letter forwards the results of the ORP assessment of the CFD analytical process and requests your actions to correct the assessment Findings and Observations. The assessment evaluated the Bechtel National, Inc. (BNI) application of CFD in design activities, including the use of the commercially-available software application FLUENT¹. The primary objectives of this assessment were to determine if BNI is correctly applying the CFD methodologies and also to determine if the software quality requirements have been correctly applied.

The assessment identified issues regarding the procurement of the FLUENT software, software configuration control, and the software verification and validation process. In addition, the Assessment Team identified technical issues regarding the application and completeness of CFD analyses. The assessment resulted in six Findings and three Observations. DOE acknowledges and supports the BNI self-imposed Management Stoppage of Work on CFD activities while developing its plan to initiate the corrective actions to resolve these issues.

Within 30 days of receipt of this letter you should respond to the assessment Findings. For the Findings, your response must include:

- The causes of the findings;
- The corrective actions that have been taken to control or remove any adverse impact from noncompliant conditions (remedial actions) and the results achieved;
- The corrective actions that will be taken to identify the extent of condition, correct the cause(s), and prevent further findings; and
- The date when all corrective actions will be completed, verified, and compliance to applicable requirements achieved.

¹ FLUENT is a registered trademark of Ansys, Inc

Mr. L. J. Simmons
08-WTP-131

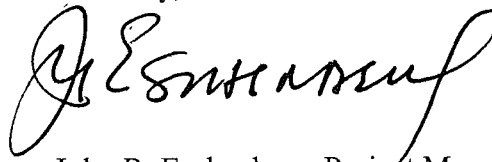
-2-

JUL 23 2008

This letter is not considered to constitute a change to the Contract. In the event the Contractor disagrees with this interpretation, it must immediately notify the Contracting Officer orally, and in writing within five working days in accordance with the Contract (Section H, Clause H.1 "Technical Direction").

If you have any questions, please contact me, or your staff may contact James H. Wicks, Acting Assistant Manager, Engineering and Nuclear Safety, (509) 376-3522.

Sincerely,



John R. Eschenberg, Project Manager
Waste Treatment and Immobilization Plant Project

WTP:AAK

Attachment

cc w/attach:
D. Kammenzind, BNI
P. Snider, BNI
BNI Correspondence

U.S. Department of Energy, Office of River Protection

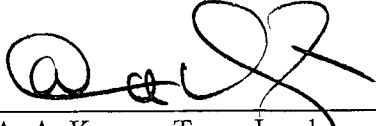
**ASSESSMENT OF THE BECHTEL NATIONAL, INC. (BNI)
COMPUTATIONAL FLUID DYNAMICS ANALYTICAL
PROCESS**

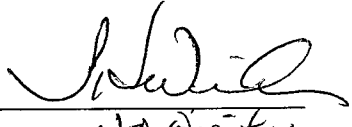
ORP Design Oversight Report

June 2008

Design Oversight: D-08-DESIGN-066

Team Lead:


A. A. Kruger, Team Lead
WTP Engineering Division


WTP Director

Team Members:

Donna Post Guillen, PhD, P.E., Idaho National Laboratory
David H. Brown, Project Assistance Corporation
Fred B. Hidden, Jr., ELR Consulting, Inc.

EXECUTIVE SUMMARY

The U.S. Department of Energy, Office of River Protection conducted a design oversight assessment of the Waste Treatment and Immobilization Plant (WTP) Computational Fluid Dynamics (CFD) analytical process. The specific objectives of this oversight were to:

1. Determine if Bechtel National, Inc. (BNI) is applying CFD methodologies correctly.
2. Determine if BNI is applying software quality requirements correctly.

In addition, the Assessment Team evaluated how BNI conducts analyses using CFD methodologies and how effectively the CFD application contributes to the WTP Project's ability to meet the design and operational criteria identified in the project baseline documentation.

The scope of this assessment included the review of BNI technical documents, procedures, manuals, plans, forms, and quality assurance records; technical literature and reference materials; technical journals; and online reference materials. In addition, the Assessment Team conducted meetings and interviews with BNI staff and contacted software technical support personnel for assistance.

Conclusions

The Assessment Team identified six findings and three observations:

Finding	Description
1. D-08-DESIGN-066-F01	The FLUENT license was not purchased from a Quality Assurance Requirements for Nuclear Facility Applications supplier and the requirements for "otherwise acquired software" were not followed.
2. D-08-DESIGN-066-F02	BNI did not perform the required supplier evaluation of the vendor for the FLUENT software licenses.
3. D-08-DESIGN-066-F03	The verification and validation (V&V) report for FLUENT 6.2 did not state the basis for some acceptance criteria.
4. D-08-DESIGN-066-F04	BNI issued a confirmed calculation for which the FLUENT 6.2 V&V report did not provide verifying or validating test cases for two software routines.

5. D-08-DESIGN-066-F05 BNI did not establish configuration control over the FLUENT software in accordance with BNI requirements.
6. D-08-DESIGN-066-F06 BNI did not control the identification and resolution of software errors.

Observation

Description

1. D-08-DESIGN-066-O01 CFD analysis using FLUENT was applied to issues that may have been solved more effectively with other calculation tools or methods.
2. D-08-DESIGN-066-O02 CFD design analyses are not sufficiently detailed such that a person technically qualified in the subject can review and understand the analyses and verify the adequacy of the results without recourse to the originator.
3. D-08-DESIGN-066-O03 Computer code in an engineering calculation document should have been run as part of the verification and validation process.

TABLE OF CONTENTS

1.0	INTRODUCTION	1
2.0	BACKGROUND	1
3.0	OBJECTIVES, SCOPE, AND APPROACH.....	1
3.1	Objectives	1
3.2	Scope.....	1
3.3	Approach.....	1
4.0	RESULTS	2
4.1	Application of CFD Methodologies	2
4.2	Application of Software Quality Requirements.....	4
5.0	Recommendations.....	9
6.0	References.....	10

ACRONYMS

ASME NQA-1	Quality Assurance Requirements for Nuclear Facility Applications
BNI	Bechtel National, Inc.
CFD	computational fluid dynamics
DOE	U.S. Department of Energy
FEA	finite element analysis
ISO	International Standards Organization
IS&T	Information Systems and Technology Department
IT	information technology
ORP	Office of River Protection
PPS	project program sponsor
QAM	quality assurance manual
QAS	quality affecting software
UDF	user defined function
V&V	verification and validation
WTP	Waste Treatment and Immobilization Plant

1.0 INTRODUCTION

The U.S. Department of Energy (DOE), Office of River Protection (ORP) conducted a design oversight assessment of the Waste Treatment and Immobilization Plant (WTP) Computational Fluid Dynamics (CFD) analytical process. The purpose of the oversight was to determine if Bechtel National, Inc. (BNI) is applying CFD methodologies correctly and if BNI is applying software quality requirements correctly. The scope of the assessment included evaluation of documentation related to WTP procedures and design requirements. Assessment activities began in April 2008 and were completed in June 2008.

2.0 BACKGROUND

The ORP mission is to retrieve and treat Hanford Site tank waste and close the tank farms to protect the Columbia River. To complete one major component of this mission, ORP awarded BNI a contract to design, construct, and commission the WTP at the Hanford Site in Richland, Washington. As part of their role as WTP Contractor, BNI conducts analyses using CFD methodologies in their design process.

3.0 OBJECTIVES, SCOPE, AND APPROACH

3.1 Objectives

The specific objectives of this oversight were to:

1. Determine if BNI is applying CFD methodologies correctly.
2. Determine if BNI is applying software quality requirements correctly.

In addition, the Assessment Team evaluated how BNI conducts analyses using CFD methodologies and how effectively the CFD application contributes to the WTP Project's ability to meet the design and operational criteria identified in the project baseline documentation.

3.2 Scope

The scope of this assessment included the review of BNI technical documents, procedures, manuals, plans, forms, and quality assurance records; technical literature and reference materials; technical journals; and online reference materials. In addition, the Assessment Team conducted meetings and interviews with BNI staff and contacted software technical support personnel for assistance.

3.3 Approach

This oversight assessment was conducted within the guidelines of ESQ-OA-IP-01, *Integrated Assessment Program*, Rev. 0, and WTP-OA-DI-01, *Conduct of Design Oversight*, Rev. 0.

ORP transmitted a letter to BNI on April 15, 2008, to inform them of the ORP-planned assessment activity and to provide them with the *Assessment of the Bechtel National, Inc (BNI) Computational Fluid Dynamics Analytical Process Design Oversight Plan* (Appendix A). An entrance meeting was held on April 22, 2008, that included the ORP Assessment Team members and BNI representatives.

In evaluating the application of CFD methods, the Assessment Team reviewed BNI technical documents (two separate CFD calculation reports), reference literature, subject-related technical journals, and online reference materials provided by FLUENT.¹ In addition, information was gathered from personal communication with ANSYS² technical support personnel.

To evaluate the application of software quality requirements, the Assessment Team reviewed a variety of documents and versions of those documents associated with CFD, including the Software Project Plan for the FLUENT software package, software verification and validation (V&V) plans, software V&V reports, installation plans, Quality Affecting Software (QAS) Application Forms, corrective action reports, condition reports, and Project Issues Evaluation Reports. The assessor compared these to the requirements of the BNI Quality Assurance Manual (QAM) and Information Systems and Technology Department (IS&T) procedures, including 24590-WTP-GPP-IT-001 *Acquisition, Development, and Management of Quality Affecting Software*, Rev. 6, 24590-WTP-GPP-IT-008, *Software Life Cycle Management*, Rev. 3, and 24590-WTP-3DP-G04B-00037, *Engineering Calculations*, Rev. 13. The assessor interviewed the Project Program Sponsor (PPS) for FLUENT, interviewed other persons involved with these documents, and compared the documents to the requirements governing them. The Assessment Team reviewed one calculation and interviewed personnel involved in preparing and checking it. The team also reviewed the procurement documentation and license agreements for several releases of FLUENT.

After the review process, the Assessment Team members provided a review summary to the Assessment Team Leader. The draft report was assembled and reviewed by the ORP Design Oversight Review Board. The report was then provided to BNI for factual accuracy review and comments. After incorporating the changes deemed necessary from the BNI factual accuracy review, this oversight report will be finalized, and entered into the system for concurrence routing.

4.0 RESULTS

The results of the assessment activities for each of the primary objectives are summarized in Sections 4.1 and 4.2.

4.1 Application of CFD Methodologies

The Assessment Team noted two observations regarding the technical application of CFD methodologies. Observation details are described in the following paragraphs.

¹ FLUENT is a registered trademark of Ansys, Inc. Prior to the acquisition of FLUENT by Ansys, Inc, FLUENT was a registered trademark of Fluent, Inc

² ANSYS is a registered trademark of Ansys, Inc

Observation D-08-DESIGN-066-001: CFD analysis using FLUENT was applied to issues that may have been solved more effectively with other calculation tools or methods.

Requirements: 24590-WTP-QAM-QA-01-001, *Quality Assurance Manual*, Policy Q-03.1, "Design Control," Section 2 states "Items and systems/processes will be designed using sound engineering/ scientific principles, and appropriate standards."

Discussion:

CFD Calculation 24590-HLW-M8C-C5V-00001 Revision B, "HLW Pour Tunnel CFD Analysis, Normal and Accident Condition"

The use of FLUENT in this calculation was not necessarily wrong; however, it was certainly more complex than required. The parameters of interest are the structural temperatures and not the details of the coolant flow. This problem, as described in the calculation, does not exhibit complex flow effects (e.g., hot streaking, etc.) that would warrant a high fidelity simulation of the air flow. A correlation from the literature to obtain the free convection heat transfer coefficient would be satisfactory. It would be more correct to model this phenomenon using a tool expressly developed to solve thermal-type problems.

CFD analyses should be performed for nominal operating and design conditions, as well as worst-case bounding conditions. The bounding calculations may be overly conservative for design purposes because they focused primarily on worst-case scenarios. Temporary excursions above nominal conditions may be tolerated for the materials and systems in the design.

CFD Calculation 24590-WTP-M6C-M11T-00006, Revision 0, "Determination of Static Equivalent Loads Due to Hydrogen Explosions in WTP Vessel Piping"

The physical phenomena occurring in this problem (i.e., deflagration to detonation transition; shock waves; multi-component, multi-phase mixtures; slurry/gas interface; and reacting flow) make this an extremely complicated problem. The FLUENT code would not be considered the code of choice by those with an expertise in this area to model these interrelated phenomena. Codes such as those developed and applied by the DOE Weapons Laboratories may have a higher probability of success because they have been developed and extensively verified and validated for these types of problems. Similar types of problems have also been previously encountered in the pipeline industry. Such computer codes are extremely complex and not as user-friendly, nor robust, as FLUENT. However, if it is important to understand the complex behavior of the radioactive slurry then such an approach may be warranted.

At first glance, the problem in calculation 24590-WTP-M6C-M11T-00006 appears almost untenable. However, it has been simplified and a conservative solution obtained. Rather than computing shock waves and reacting flow, a pressure pulse obtained from the pressure-time history curve for the hydrogen explosion (documented in 24590-WTP-M6C-M11T-00005 Rev. 0) is applied to the gas phase. The analysis does not consider the complex transient coupling phenomena between the pressure loading and flexural waves. Although, the analysis claims on p. 27 that "the first ejection creates the bounding loads," the potential for subsequent resonant excitation is neglected. The cellular structure of the detonation creates an oscillation in

the pressure loading which raises the possibility of resonant excitation of flexural oscillations by the pressure oscillations in the detonation (Belman and Shepherd, 2002).

Observation D-08-DESIGN-066-O02: CFD design analyses are not sufficiently detailed such that a person technically qualified in the subject can review and understand the analyses and verify the adequacy of the results without recourse to the originator.

Requirements: 24590-WTP-QAM-QA-01-001, *Quality Assurance Manual*, Policy Q-03.1, “Design Control,” Section 3.5.2 states “Design analyses shall be sufficiently detailed such that a person technically qualified in the subject can review and understand the analyses and verify the adequacy of the results without recourse to the originator.” This requirement is also incorporated, verbatim, into BNI procedure 24590-WTP-3DP-G04B-00037, *Engineering Calculations*, Rev. 13.”

Discussion: Sections 6.1.2 - 6.1.5 of calculation 24590-WTP-M6C-M11T-00006, *Determination of Static Equivalent Loads due to Hydrogen Explosions in WTP Vessel Piping*, detail the assumptions used in the CFD analysis. The large number of assumptions (28 total) used in the calculation dismissed many of the intrinsic variables worthy of consideration. Given the nature and technical complexity of this calculation, the assumptions made should be thoroughly justified. Section 6.2, “Assumptions Requiring Verification,” states “There are no assumptions that require verification.” For example, this calculation should have included a vibration-type analysis to determine if any of the reflected shock waves would excite a resonant frequency (akin to a water hammer analysis). The rationale for excluding water hammer and acoustics effects was not properly justified. By assuming only the worst-case static load, the problem has potentially been overly simplified.

4.2 Application of Software Quality Requirements

The Assessment Team noted six findings and three observations regarding the application of software quality requirements. The findings and observation are detailed below.

Finding D-08-DESIGN-066-F01: The FLUENT license was not purchased from a Quality Assurance Requirements for Nuclear Facility Applications (ASME NQA-1) supplier and the requirements for “otherwise acquired software” were not followed.

Requirements:

- a. 24590-WTP-QAM-QA-01-001, “*Quality Assurance Manual*,” Policy Q-03.2, “Software Quality,” Section 3.12.1 states “Individuals or organizations developing and supplying software shall be required to have policies and procedures that meet the applicable requirements of this policy as specified in procurement documents.”
- b. 24590-WTP-QAM-QA-01-001, “*Quality Assurance Manual*,” Policy Q-03.2, “Software Quality,” Section 3.13, states “Unqualified software in which the history of the software is not known, but the software is required to be used in quality activities shall meet the following requirements . . . The user organization shall perform, document and provide

for an independent review and evaluation ... [including] test plans and test cases required to validate the software for acceptability”

Discussion: Contrary to these requirements, the FLUENT software package was not purchased from a supplier with an ASME NQA-1 program. Instead, the V&V plan justified the use of an International Standards Organization (ISO) 9000 supplier based on an informal assessment that the program was used widely in industry for CFD work. While use of the code could be justified under the provisions in the BNI QAM and ASME NQA-1 for “otherwise acquired software,” BNI had not performed the activities required to meet the requirements specified for this approach. The assessment team based its conclusions on the following:

- The Fluent, Inc. quality assurance program implemented ISO 9000 and TickIT software quality standards, not ASME NQA-1.
- BNI based its acceptance of the Fluent, Inc. quality assurance processes on the unsubstantiated statement in the V&V plan, “...FLUENT uses well tested models and numerical methods that are generally accepted by outstanding CFD research academicians and scientists.”
- Several of the test cases BNI used to accept FLUENT during V&V testing were provided by the ISO 9000 vendor and were not independently and formally validated under an ASME NQA-1 program.

Finding D-08-DESIGN-066-F02: BNI did not perform the required supplier evaluation of the vendor for the FLUENT software licenses.

Requirements:

- a. 24590-WTP-QAM-QA-01-001, *Quality Assurance Manual*, Policy Q-07.1, “Control of Purchased Items and Services,” Section 3.3.1 states “Prior to awarding a contract, the purchaser shall evaluate the supplier’s capability to provide items or services in accordance with the requirements of the procurement documents. Supplier evaluation and selection and the results shall be documented...”
- b. 10 CFR 830.122(g)(2) states “Evaluate and select prospective suppliers on the basis of specified criteria.”
- c. 10 CFR 830.122(g)(3) states “Establish and implement processes to ensure that approved suppliers continue to provide acceptable items and services.”

Discussion: Contrary to these requirements, BNI did not document an evaluation of the capability of either Fluent, Inc. or Ansys, Inc. to provide CFD software at the required level of quality. The assessment team based its conclusions on the following:

- BNI had no evidence that the original DOE WTP contractor, British Nuclear Fuel Limited, Inc., had evaluated the vendor that initially provided the FLUENT software.

- The Assessment Team could find no evidence of a formal supplier evaluation in the initial BNI procurement document package for FLUENT, even though FLUENT was used to prepare calculations for safety systems.
- The Assessment Team could find no evidence BNI had conducted re-evaluations of the software vendor for any of the subsequent purchases of annual license agreements from Fluent, Inc. and Ansys, Inc.
- BNI did not apply the software acceptance requirements for “otherwise acquired software” to the FLUENT software.

Finding D-08-DESIGN-066-F03: The V&V report for FLUENT 6.2 did not state the basis for some acceptance criteria.

Requirements:

- a. 24590-WTP-QAM-QA-01-001, *Quality Assurance Manual*, Policy Q-03.2, “Software Quality,” Section 3.7, states “Test requirements and acceptance criteria shall be provided or approved by the organization responsible for the design or use of the program... Test requirements and acceptance criteria shall be based upon applicable design or other pertinent technical documents.”
- b. 24590-WTP-GPP-IT-001, *Acquisition, Development, and Management of Quality Affecting Software*, Appendix 6, Item 3.0, states “Describe the documentation that the test requirements are based on.”

Discussion: Contrary to these requirements, 24590-WTP-VV-HS-03-001, *Verification and Validation Report for Fluent*, did not identify the basis for several test requirements and acceptance criteria. For example, Section 3.8.3, “Simulation Setup,” identified boundary conditions with external radiation temperatures of 603K and 303K, but did not identify the basis for these values. BNI engineering personnel said that values like these are often based on judgment, but these judgments must still be justified.

(*N.B.*, Calculation 24590-WTP-M6C-M11T-00006 uses design inputs that were determined by the Finite Element Analysis (FEA) software program ANSYS. In light of issues identified during this assessment, it is suspected that the test cases used in the ANSYS V&V report may not include the bounding conditions for design elements used in the FEA structural analysis. The review of the ANSYS V&V test plan was not investigated because it was considered to be outside the scope of this CFD assessment.)

Finding D-08-DESIGN-066-F04: BNI issued a confirmed calculation for which the FLUENT 6.2 V&V report did not provide verifying or validating test cases for two software routines.

Requirements:

- a. 24590-WTP-3DP-G04B-00037, *Engineering Calculations*, Section 3.5.1, states “When quality-affecting software is used, the originator shall qualify its use in the calculation in

accordance with 24590-WTP-GPP-IT-001, Rev. 6, *Acquisition, Development, and Management of Quality Affecting Software...*”

- b. 24590-WTP-3DP-G04B-00037, *Engineering Calculations*, Section 2.2, identifies QAS to include “...any application, routine, or macro listed on the *Approved Project Software Distribution List* ... or approved for project use using a change request...”
- c. 24590-WTP-QAM-QA-01-001, *Quality Assurance Manual*, Policy Q-03.1, “Design Control,” Section 3.5.7 states “The computer program shall be verified to show that it produces correct solutions for the encoded mathematical model within defined limits for each parameter employed. The encoded mathematical model shall be shown to produce a valid solution to the physical problem associated with the particular application.”
- d. 24590-WTP-GPP-IT-001; *Acquisition, Development, and Management of Quality Affecting Software*, Section 5.6.1, states “The PPS will initiate life cycle activities[,] ... will record these activities in a life cycle document[, and] ... will ensure testing of the custom software is planned, executed, and reported.”

Discussion: Contrary to these requirements, BNI issued calculation 24590-WTP-M6C-M11T-00006, *Determination of Static Loads due to Hydrogen Explosions in WTP Vessel Piping*, using two software routines that were not documented, reviewed, and tested in accordance with BNI procedures. The calculation analyzed phenomena occurring subsequent to hydrogen explosions in WTP piping.

The two routines were locally developed, reusable User-Defined Functions (UDF) named “compress.c” and “force.c.” They were not addressed in the FLUENT 6.2 V&V test plan or report prepared prior to performing calculation 24590-WTP-M6C-M11T-00006. Both UDFs called a vendor-supplied header file named “udf.h” for inclusion in the object code at compile-time. Based on the following, the assessment team concluded the calculation results produced by the UDFs were not subject to adequate verification and validation:

- The complexity of the calculation prohibited the verification of the result, such as through an alternate calculation. BNI was, therefore, required to verify the routines produced correct results prior to using them in the calculation. This could not be done by inspection, so testing was required.
- The validity of “udf.h” could not be demonstrated without testing because it was supplied by the vendor and relied on the vendor’s knowledge of FLUENT.

Finding D-08-DESIGN-066-F05: BNI did not establish configuration control over the FLUENT software in accordance with BNI requirements.

Requirements:

- a. 24590-WTP-QAM-QA-01-001, *Quality Assurance Manual*, Policy Q-03.2, “Software Quality,” Section 3.10, states “A labeling system for configuration items shall be implemented includes: A definition of the baseline elements of each software baseline .. Uniquely identifies each configuration item... Identifies changes to configuration items

by Rev ... Provides the ability to uniquely identify each configuration of the revised software...”

- b. 24590-WTP-GPP-IT-001, *Acquisition, Development, and Management of Quality Affecting Software*, Section 5.3.1, states “The PPS ensures that a software configuration management plan is created to control the software once it is received from the supplier.”
- c. 24590-WTP-GPP-IT-001, *Acquisition, Development, and Management of Quality Affecting Software*, Appendix 4, Item 4.4, states “Provide a definition of configured items including documentation of the unique identification of those items for each baseline.”

Discussion: Contrary to these requirements, the configuration management section of the project plan did not identify the configuration items for the FLUENT software. Other documents purported to identify configuration items were incomplete and referenced outdated documents.

BNI procedure 24590-WTP-GPP-IT-001 identified the configuration management plan as the document identifying the configuration items, but IS&T management stated this information was also contained in the Information Technology (IT) Change Request document. Neither of these documents correctly identified the configuration items. The assessment team based its conclusions on the following:

- Section 7.0, “Configuration Management,” of 24590-WTP-PL-ENS-02-001, *Project Plan for CFD Computer Code Fluent*, did not identify the configuration items for FLUENT as required by 24590-WTP-GPP-IT-001. 24590-WTP-GPP-IT-001 required the project plan to incorporate all specified features of the configuration management plan, but the project plan did not include features such as listing the configuration items.
- The IT Change Request form for FLUENT identifies 24590-WTP-RPT-G-01-004, *Requirements Document for Fluent, FIDAP, and Airpak*, as the Software Requirements Specification for FLUENT version 6.2, but this document addresses FLUENT version 5.5.14. BNI retired FLUENT 5.5.14 several years ago.
- 24590-WTP-RPT-ENG-03-004, *Fluent Life Cycle Documentation*, was not listed on the IT Change Request for FLUENT 6.2 as a configuration item.

Finding D-08-DESIGN-066-F06: BNI did not control the identification and resolution of software errors.

Requirements:

- a. 24590-WTP-QAM-QA-01-001, *Quality Assurance Manual*, Policy Q-03.2, “Software Quality,” Section 3.11.2 states “Software defect reporting and resolution systems shall include the following controls: Problems are identified, evaluated, documented, and, if required, corrected.”
- b. 24590-WTP-GPP-IT-001, *Acquisition, Development, and Management of Quality Affecting Software*, Section 5.10.1, states “If an error is discovered by suppliers, developers, or software users, the discoverer must notify the PPS of any errors

encountered... The PPS completes the error impact part of 24590-IT-F00004, *Software Error Notification (SEN)*...”

- c. 24590-WTP-QAM-QA-01-001, *Quality Assurance Manual*, Policy Q-03.2, “Software Quality,” Section 3.12, states “Software errors and failures shall be reported between the supplier and purchaser.”
- d. 24590-WTP-GPP-IT-001, *Acquisition, Development, and Management of Quality Affecting Software*, Section 5.3.1 states “The PPS ensures that procurement documents (generated by WTP and provided by the vendor) for software shall ... Identify the process vendors and/or subcontractors will follow for error notification.”

Discussion: Contrary to these requirements, BNI was not documenting and formally evaluating the effects of software errors. In interviews, BNI personnel stated they had occasionally found errors in the software during their work and watched for error notices posted on the vendor’s web site; however, these were not documented and resolved in accordance with BNI procedures. As a result, it was not clear that all errors had been properly evaluated and their effect on in-process and completed calculations determined. The assessment team based its conclusions on the following:

- The BNI Engineering Group did not document errors or error evaluations using the Software Error Notification form required by BNI procedures.
- The BNI material requisition and purchase order for FLUENT did not contain the required error reporting provisions.

Observation D-08-DESIGN-066-O03: Computer code in an engineering calculation document should have been run as part of the verification and validation process.

Discussion: Calculation 24590-WTP-M6C-M11T-00006, *Determination of Static Loads due to Hydrogen Explosions in WTP Vessel Piping*, included 17 pages of code written for Wolfram Mathematica. The analyst who developed the calculation and the individual who checked it both said the code was not used to provide calculation results, nor did they say the Mathematica code was used as an alternate calculation as described in 24590-WTP-3DP-G04B-00037, *Engineering Calculations*. Instead, they said the code was used to provide confidence that FLUENT was producing reasonable results. In the view of the Assessment Team, this is an activity appropriate to the V&V process, not as part of a calculation.

This approach did not unambiguously violate any BNI procedures, and it did not bring into question the accuracy of the calculation.

5.0 RECOMMENDATIONS

The assessment identified issues regarding the procurement of the FLUENT software, configuration control, and the V&V process. In addition, the Assessment Team identified technical issues regarding the application of CFD methodologies. The assessment resulted in six findings and three observations. As a result of the number and seriousness of the issues

discovered during the assessment activities, it is recommended that a future assessment be conducted to re-assess the BNI CFD analytical process and verify that the issues have been effectively resolved.

6.0 REFERENCES

- 10 CFR 830.122, "Quality Assurance Criteria," *Code of Federal Regulations*, as amended
- 24590-HLW-M8C-C5V-00001, *HLW Pour Tunnel CFD Analysis, Normal and Accident Condition*, Rev. B, Bechtel National, Inc.
- 24590-WTP-3DP-G04B-00027, *Design Verification*, Rev. 9, Bechtel National, Inc.
- 24590-WTP-3DP-G04B-00034, *Off-Project Design Review*, Rev. 5, Bechtel National, Inc.
- 24590-WTP-3DP-G04B-00037, *Engineering Calculations*, Rev. 13, Bechtel National, Inc.
- 24590-WTP-GPP-IT-001, *Acquisition, Development, and Management of Quality Affecting Software*, Rev. 6, Bechtel National, Inc.
- 24590-WTP-GPP-IT-008, *Software Life Cycle Management*, Rev. 3, Bechtel National, Inc.
- 24590-WTP-M6C-M11T-00005, *DDT Near a Closed End Pressure Time Histories*, Rev. 0, Bechtel National, Inc.
- 24590-WTP-M6C-M11T-00006, *Determination of Static Equivalent Loads Due to Hydrogen Explosions in WTP Vessel Piping*, Rev. 0, Bechtel National, Inc.
- 24590-WTP-PL-ENS-02-001, *Project Plan for CFD Computer Code Fluent*, Rev. 1, Bechtel National, Inc.
- 24590-WTP-QAM-QA-01-001, *Quality Assurance Manual*, Rev. 7b, Bechtel National, Inc.
- Policy Q-03.1, "Design Control"
 - Policy Q-03.2, "Software Quality"
 - Policy Q-07.1, "Control of Purchased Items and Services"
- 24590-WTP-RPT-ENG-03-004, *Fluent 6, 2 Computational Fluid Dynamic Software Life Cycle Documentation*, Rev. 1, Bechtel National, Inc.
- 24590-WTP-RPT-G-01-004, *Requirements Document for Fluent, FIDAP, and Airpak*, Rev. 0, Bechtel National, Inc.
- 24590-WTP-VV-HS-03-001, *Verification and Validation Report for Fluent*, Rev. 4, Bechtel National, Inc.
-

Beltman, W.M and J.E. Shepherd, 2002, "Linear Elastic Response of Tubes to Internal Detonation Loading," *Journal of Sound and Vibration*, Vol. 252, Issue 4, pp. 617-655

DE-AC27-01RV14136, Bechtel National, Inc. *Design, Construction, and Commissioning of the Hanford Tank Waste Treatment and Immobilization Plant*, August 31, 2000, Bechtel National, Inc. Richland, Washington

ESQ-OA-IP-01, *Integrated Assessment Program*, Rev. 0, U. S. Department of Energy, Office of River Protection, Richland, Washington

Jaluria, Y., 2008, *Design and Optimization of Thermal Systems*, Second Edition, CRC Press

ORP DI WTP-OA-DI-01, *Conduct of Design Oversight*, Rev. 0, May 2008, U.S. Department of Energy, Office of River Protection, Richland, Washington

Appendix A

Design Oversight Plan



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

08-WTP-089

APR 15 2008

Mr. L. J. Simmons, Project Manager
Bechtel National, Inc.
2435 Stevens Center Place
Richland, Washington 99354

Dear Mr. Simmons.

CONTRACT NO. DE-AC27-01RV14136 – TRANSMITTAL OF THE U.S. DEPARTMENT OF ENERGY (DOE), OFFICE OF RIVER PROTECTION (ORP) DESIGN OVERSIGHT ASSESSMENT PLAN D-08-DESIGN-066: COMPUTATIONAL FLUID DYNAMICS (CFD) ANALYTICAL PROCESS ASSESSMENT

The purpose of this letter is to notify Bechtel National, Inc. (BNI) that ORP intends to perform an assessment of BNI's application of CFD in design activities, including use of the Fluent¹ computer code, as outlined in the attached assessment plan. The objectives of this assessment are to determine if BNI is applying CFD methodologies correctly, and determine if BNI is applying software quality requirements correctly. In addition, the Assessment Team will evaluate how BNI conducts analyses using CFD methodologies and the effectiveness of the application of the analyses to the Waste Treatment and Immobilization Plant (WTP) Project's ability to meet the design and operational criteria identified in the project baseline documentation.

The DOE Assessment Team will include team members from ORP. BNI is requested to schedule the availability of the appropriate engineering support personnel during this assessment to interact with Assessment Team members, including providing material as requested, scheduling interviews, and providing programmatic overview of the temporary modification design. An entrance meeting with BNI management and assessment support personnel will be scheduled on April 22, 2008, preliminary feedback on assessment is due May 15, 2008, and an exit meeting will be scheduled during May 2008.

If you have any questions, please contact me, or your staff may contact James H. Wicks, Director, WTP Engineering Division, (509) 376-3522.

Sincerely,

John R. Eschenberg, Acting Assistant Manager
Waste Treatment and Immobilization Plant Project

WTP:AAK

Attachment

(see Page 2 for cc's)

¹ Fluent is a registered trademark of Ansys, Inc

Mr. L. J. Simmons
08-WTP-089

-2-

APR 15 2008

cc w/attach:
D. Kammenzind, BNI
P. Snider, BNI
BNI Correspondence

U.S. Department of Energy, Office of River Protection

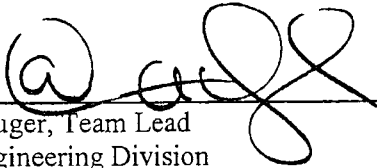
DESIGN PRODUCT OVERSIGHT PLAN

ASSESSMENT OF THE BECHTEL NATIONAL, INC. (BNI) COMPUTATIONAL FLUID DYNAMICS ANALYTICAL PROCESS

April 2008

Design Oversight: D-08-DESIGN-066

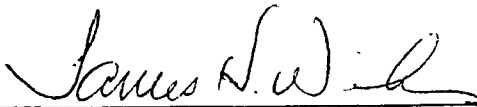
Submitted by:



A. A. Kruger, Team Lead
WTP Engineering Division

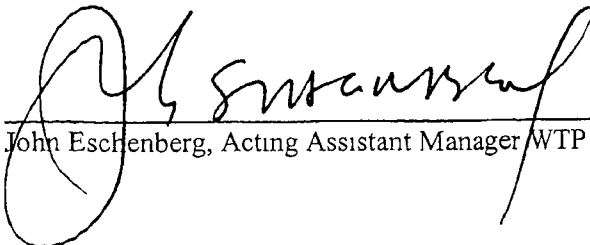
Date 10 Apr 2008

Concurrence:



J. H. Wicks, Director
WTP Engineering Division

Date 11 Apr 2008



John Eschenberg, Acting Assistant Manager WTP

Date 4/15/08

1.0 BACKGROUND, PURPOSE, AND OBJECTIVES

1.1 Background

The U.S. Department of Energy (DOE), Office of River Protection's (ORP) mission is to retrieve and treat Hanford Site tank waste and close the tank farms to protect the Columbia River. In order to complete one major component of this mission, ORP awarded Bechtel National, Inc. (BNI) a contract for the design, construction, and commissioning of the Waste Treatment and Immobilization Plant (WTP) at the Hanford Site in Richland, Washington. As part of their role as WTP Contractor, BNI conducts analyses using Computational Fluid Dynamics (CFD) methodologies in their design process.

1.2 Purpose

The WTP Engineering Division (WED) has responsibility for design oversight at the WTP. The purpose of this review is to evaluate BNI's application of CFD in design activities, including use of the Fluent¹ computer code.

1.3 Objectives

The following are the specific objectives of this oversight:

1. Determine if BNI is applying CFD methodologies correctly
2. Determine if BNI is applying software quality requirements correctly

2.0 SCOPE

The Assessment Team will evaluate documentation in relation to WTP procedures and design requirements (see Table 1). During ORP's evaluation, criteria review and approach documents (CRAD) and/or lines of inquiry (LOI) will be documented and given to BNI's point of contact (POC) for resolution. BNI's responses to LOI questions will be utilized as reference information during the Assessment Team's evaluation.

The Assessment Team will be comprised of one Office of River Protection (ORP) WTP Engineering Division (WED) staff member and three subcontractors:

- A. A. Kruger, WED, Team Lead
- Donna Post Guillen, PhD, P.E., Idaho National Laboratory
- David H. Brown, Project Assistance Corporation
- Fred B. Hidden, Jr., ELR Consulting, Inc.

This oversight shall be conducted within the guidelines of ORP M 220.1, *Integrated Assessment Plan*, Rev. 5, and the WTP DI 5.2, "Conduct of Design Oversight," as amended.

¹ Fluent is a registered trademark of Ansys, Inc

3.0 PREPARATION

1. Identify the Assessment Team involved in the review.
2. Notify BNI that ORP will be conducting this assessment plan.
3. Identify relevant and appropriate design documents, including procedures, associated implementation paperwork, regulatory requirements, and any vendor requirements.
4. Identify contract requirements and contractor design requirements.
5. Prepare and implement schedule of assessment activities.

Table 1 – Requested Documentation and Information

1	Contractor point of contact for the assessment: Dawn Kammenzind
2	<p>Technical Documents:</p> <ul style="list-style-type: none"> • 24590-HLW-M8C-C5V-00001, <i>HLW Pour CFD Analysis, Normal and Off-Normal Condition</i> • 24950-WTP-MVC-50-00003, <i>Hydrodynamic Loads in a Fluid/Structural Analysis of Mixing Vessels Equipped with Pulse Jet Mixers</i> • Project Technical Note - CCN: 177200, "CFD Analysis of HLP-22 Mixing and Re-suspension" • To be added to existing LAW Melter Lid Calc, "LAW Melter Lid Cooling design analysis" • 24590-HLW-M6C-M11T-00009, <i>HPAV Vessel Internal Loads based on CFD Analysis with Comparison against Overblow Test Data</i>
3	<p>Procedures and Requirements:</p> <ul style="list-style-type: none"> • 24590-WTP-QAM-QA-01-001, Rev. 6, <i>Quality Assurance Manual</i> • 24590-WTP-GPP-IT-001, Rev. 6, <i>Acquisition, Development, and Management Of Quality Affecting Software</i> • 24590-WTP-3DP-G04B-00038, Rev. 2, <i>Computer Program Error Reporting</i> • 24590-WTP-3DP-G04B-00037, Rev. 12, <i>Engineering Calculations</i> • 24590-WTP-GPP-IT-008, Rev. 3, <i>Software Life Cycle Management</i>

4.0 REPORTING

The Assessment Team Lead will periodically brief ORP management and provide the contractor POC the opportunity for a daily briefing as necessary during the assessment. The Team Lead, with assistance from the team, will prepare a final assessment report that summarizes review activities, results, issues, conclusions, and recommendations

5.0 SCHEDULE OF ACTIVITIES

Table 2 lists the schedule of assessment activities. The Assessment Team will adhere to the schedule to the maximum extent practicable.

Table 2 – Schedule

Activity Description	Responsibility	Complete By
Develop Assessment Plan	Brown	04/07/08
Identify Team members	Kruger	04/07/08
Obtain approved plan	Kruger	04/09/08
Team members prepare CRAD, checklists, and/or lines of inquiry, submit to Team Lead	Team	04/09/08
Obtain initial information defined in Table 1 above to support review and provide to team members	Kruger	04/09/08
Qualify Team members	Wicks	04/09/08
Review documents from ORP and provide oversight strategy, lines of inquiry, and interview requests to Team Lead	Team	04/11/08
Conduct entrance meeting with contractor and team to outline objectives, scope, schedule, and establish points of contact	Kruger / Team	04/22/08
Complete fieldwork, conduct exit meeting with the contractor	Kruger / Team	05/06/08
Prepare draft Design Assessment Report, provide draft report to the contractor for factual accuracy review	Kruger / Team	05/15/08
Resolve comments and place final report into concurrence including factual accuracy review with contractor	Kruger	05/23/08
Issue Final Report	Kruger	05/29/08

6.0 DOCUMENTATION

The final assessment report shall contain the sections and content as summarized in WTP DI 5.2 Rev 0, "Conduct of Design Oversight." The final report will be formally issued once draft review comments have been resolved. Any Findings, Assessment Follow-up Items, or Open Issues identified in the report will be assigned a number, and tracked to resolution through the Corrective Action Reporting System (CARS) by DOE ORP. These assigned numbers shall also be tracked to resolution by the Contractor through the Correspondence Control Number (CCN) that will be assigned to the transmittal of the report from ORP to the Contractor.

7.0 CLOSURE

The Assessment Team Leader shall confirm that Findings, Assessment Follow-up Items, and/or Open Items from this review are adequately resolved.