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Technical Letter Report
TLR-RES/DE/CIB-2020-01

Compilation of Software Quality Assurance and Verification and Validation Documentation for the Fracture Analysis of Vessels – Oak Ridge (FAVOR) Software Product

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Prepared in response to Task 1.1 in User Need Request NRR-2017-007, by:

Andrew Dyszel
NUMARK Associates, Inc.

Terry Dickson
NUMARK Associates, Inc.

Marvin Smith
NUMARK Associates, Inc.

NRC Project Manager:

Patrick Raynaud
Senior Materials Engineer
Component Integrity Branch

Division of Engineering
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555–0001

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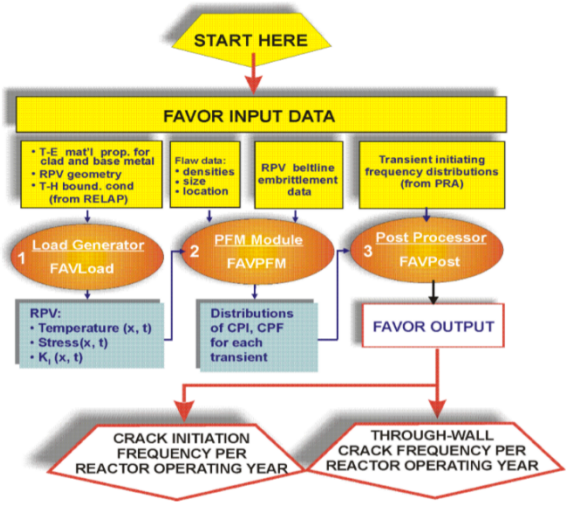
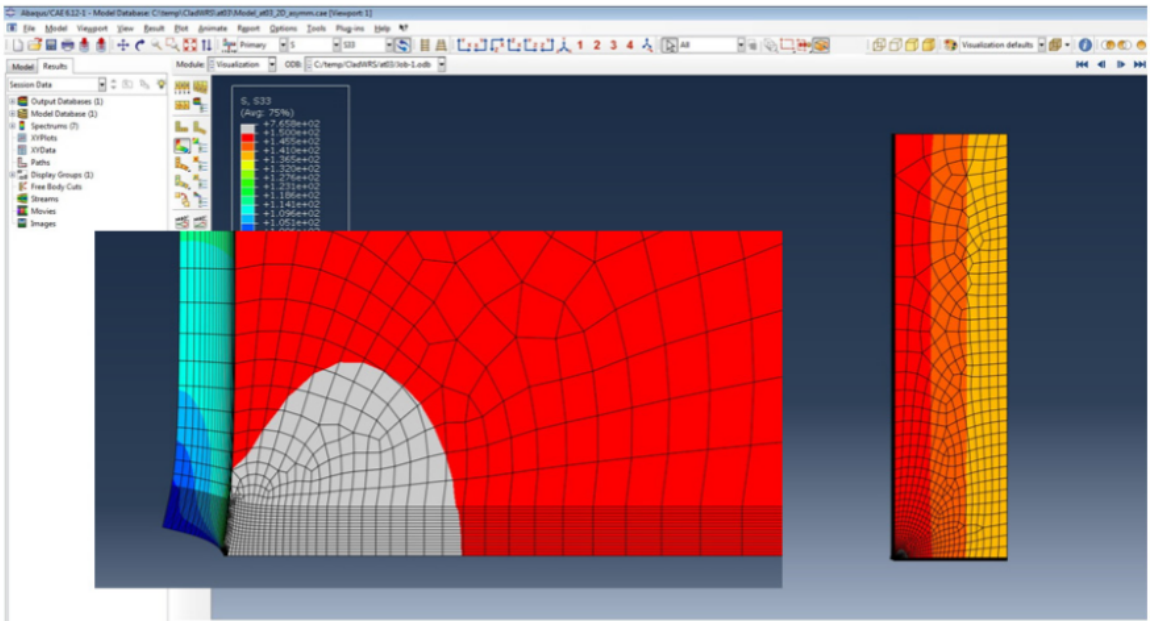
FAVOR PROJECT

Subtask 1.1

Technical Letter Report





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FAVOR Project Subtask 1.1 Objective

The objective under Subtask 1.1 of the Reactor Pressure Vessel Integrity and FAVOR Support, Contract (RC-HQ-25-14-E-0004) is to assemble all Software Quality Assurance (SQA) documentation previously created for the FAVOR code following the requirements of NUREG/BR-0167. The initial focus was to gather reports and papers listed in Attachments 1 and 2 that cover the history of Validation and Verification (V&V) efforts for FAVOR (Reference 2). This list includes both internal studies carried out by the FAVOR development team at ORNL and external studies performed by independent subject-matter experts with specialization in requirements of Nuclear Power Plant components. Under Subtask 1.1, a search was conducted to identify additional V&V documents (extending up through FAVOR 16.1) that support the NUREG/BR-0167 validation. The documentation was sorted into two categories:

- Category 1: from the first version of FAVOR through v6.1; and
- Category 2: all versions following FAVOR v6.1 up through v16.1.

Under Subtask 1.1, the deliverable would be an archive of all the documentation consistent with NUREG/BR-0167, including:

1. A ZIP file containing all documentation collected for the task, with a folder structure/substructure that clearly indicates which of the two categories each document belongs to; and

2. A tabulated list of all the documents in the ZIP file, including the following information: date, authors, title, report number, corresponding FAVOR version number, and any other relevant bibliographical information.

After discussion with the NRC COR, NUMARK proposed an alternative deliverable to the ZIP file of documents. As an alternative deliverable, NUMARK created file folders on both a NUMARK SharePoint site and the NRC SharePoint site with the following library and directory structure:

- Software Quality Assurance (SQA) Documentation [new library on NRC SharePoint site]
    - Category 1 SQA up to CFR 50.61a (through FAVOR v6.1)
    - Category 2 post 10 CFR 50.61a (FAVOR v6.1 to v16.1)
    - V&V Supporting Documents-References

This structure provides direct access to PDF files of all documents collected in subtask 1.1. For each document, the NUMARK and NRC SharePoint site Software Quality Assurance (SQA) Documentation library also provides metadata fields listing:

- Authors, Title, Date, Report Number and FAVOR Version
- Document Verification Topic
- Document Type and Validation Issue

This is the same information that is provided in the Tables 1, 2 and 3 lists below.

Subtask 1.1 Approach

Document searches of the NRC ADAMS database, the internet, and FAVOR expert personnel files were conducted using the key selection criteria of "FAVOR". In addition, references identified in Attachments 1 and 2, which come from the FAVOR theory manual (Reference 2), that could be located were retrieved and included. The documents were reviewed for applicability to V&V efforts for FAVOR and categorized into the following three categories:

- Category 1: Documents supporting V&V of FAVOR up through v06.1;
- Category 2: Documents supporting V&V of FAVOR from v06.1 through the current version, v16.1; and
- Category 3: Documents providing general background and applications of FAVOR.

These documents were then stored on the NRC SharePoint site in a special library created for FAVOR V&V documents. The documents were saved as Adobe pdf files or in the native format of the document. For documents that were only available as scanned pdf files, the documents were processed through Optical Character Recognition software and stored with file names containing the letters OCR at the end of the file name. For each document, the NRC SharePoint FAVOR V&V library also includes metadata fields listing:

- Authors, Title, Date, Report Number and FAVOR Version
- Document Verification Topic
- Document Type and Validation Issue

An Excel spreadsheet was created from the V&V validation library that lists the Subtask 1.1 SQA files along with the information listed above for each SQA document. This Excel spreadsheet can be automatically downloaded and updated from SharePoint whenever new SQA documents are identified and added to the SharePoint site.

Subtask 1.1 Deliverables

A consolidated listing of these V&V documents is provided in Tables 1, 2, and 3. Table 1 provides a listing of all the Category 1 documents (i.e., documents supporting V&V of FAVOR up through v06.1). Table 2 provides a listing of all the Category 2 documents (i.e., documents supporting V&V of FAVOR from v06.1 through the current version, v16.1). Finally, Table 3 provides a listing of all the Category 3 documents (i.e., documents providing general background and applications of FAVOR).

These SQA documents were copied from the NUMARK SharePoint site to the NRC SharePoint site with the same directory structure as the NUMARK site:

- Software Quality Assurance (SQA) Documentation [NRC SharePoint Library]
    - Category 1 SQA Documents published before 10 CFR 50.61a (through FAVOR v6.1) was issued.
    - Category 2 Documents published after 10 CFR 50.61a (FAVOR v6.1 to v16.1) was issued.
    - V&V Supporting Documents-References

PRECAUTIONARY NOTES:

1. A significant effort was made to gather FAVOR V&V documents from the public domain and from FAVOR developers and NRC personnel. However, some of documents listed in the FAVOR theory manual were not available from the sources searched during Subtask 1.1. These additional documents are not FAVOR V&V documents required by NUREG/BR-0167. However, they would be useful as Category 3 Supporting Reference documents and they will be added to the FAVOR V&V library Category 3 folder whenever they are obtained.

2. This Subtask 1.1 document gathering effort is in support of Subtask 1.2 of the Reactor Pressure Vessel Integrity and FAVOR Support Contract (NRC-HQ-25-14-E-0004) effort to assess the level of FAVOR V&V performed under NUREG/BR-0167 and the ASME Code standard for Software Quality Assurance (SQA). As stated in Appendix G of Reference 2:

   > **ORNL Internal Procedures and Controls**: At the time of its initial release in 2001, FAVOR was being developed under the aegis of the Software Quality Assurance (SQA) program at ORNL. Subsequent releases of FAVOR were subjected to periodic internal SQA audits; in all cases, the FAVOR code was judged to be in compliance with ORNL SQA procedures and requirements. As the ORNL consensus standard, the Laboratory's SQA Program is registered to and compliant with the ISO 9001:2008 standard. In 2012, a formal ORNL SQA exemption was granted to FAVOR due to the fact that the FAVOR software was being developed and maintained with funding from the US NRC. The NRC support required that FAVOR be compliant with the terms and conditions of NRC Management Directive 11.7 [G12], which requires that all software development, modification, or maintenance follow the general guidance provided in NUREG/BR-0167 [G13]. ASME Guides and Standards for Verification and Validation (V&V) studies [G14-G15] and other references [G16-G17] have provided more specific guidance (specific to scientific computing applications) during the development of FAVOR.

3. However, the ISO 9001:2008 SQA program as applied at ORNL did not include the additional FAVOR SQA documentation that would be required to meet the ASME Code standard for Software Quality Assurance. These additional SQA requirements include a comprehensive FAVOR SQA Software Requirements Document, FAVOR configuration control, requirements for identifying and reporting FAVOR code errors and resolving identified errors, and a defined set of FAVOR test problems to exercise all FAVOR functions whenever changes are made to the FAVOR code.

TABLE 1 - CATEGORY 1
HISTORICAL VALIDATION AND VERIFICATION EFFORTS FOR FAVOR (UP TO VERSION 06.1)

File Name	Authors, Title, Date, Report Number and FAVOR Version	Document Verification Topic	Document Type and Validation Issue
1994-1 Validation of FAVOR LEFM Solutions OCR.pdf	Bryson, John W. Dickson, Terry L. Keeney, Janis A., Validation of FAVOR Code Linear Elastic Fracture Solutions for Finite-Length Flaw Geometries, 1994, CONF-950740--16, 94.01	Verification of FAVOR KI solutions using SIFICs for axially and circumferentially oriented semielliptical inner surface breaking flaws; base and clad, R / t = 10, ABAQUS and other solutions.	Validation Paper on FAVOR LEFM solutions for finite-length flaws.
1999-1 Validation for Embedded Flaws.pdf	Bass B.R., Dickson T.L., Williams P.T., Validation of a Linear-Elastic Fracture Methodology for Postulated Flaws Embedded in the Wall of a Nuclear Reactor Pressure Vessel, 1999	Verification of FAVOR KI solutions for embedded flaws in RPV wall; comparison of FAVOR KI solutions with ABAQUS solutions.	Validation Paper on FAVOR LEFM solutions for embedded flaws.
2000-1 Comparison of K1 Factors for Embedded Flaws.pdf	Bass, B.R. Dickson, T.L., Giles, Jr. G.E., McAfee, W.J., Williams, P.T., Comparison of KI Factors for Embedded Flaws: FAVOR Implementation of ASME Section XI – Appendix A Methodology versus Three-Dimensional 2000, ORNL/NRC/LTR-99/26	Verification of FAVOR KI solutions for embedded flaws in RPV wall; comparison of FAVOR KI solutions with ABAQUS solutions.	Letter Report - Benchmark of KI Factors in FAVOR vs ABAQUS.
2002-1 Validation of the Treatment of Flaw Related Inputs.pdf	Simonen F.A., Validation of the Treatment of Flaw Related Inputs by the FAVOR Code, March 2002, Draft, FAVOR v02.01	Verification that FAVOR is correctly reading, interpreting, and processing the output from the VFLAW computer code.	Draft Verification Report of FAVOR by PNNL - Flaw Assignment.
2003-1 ERPI MRP90 Validation of FAVOR Ver 2.4.pdf	B. Bishop, R. Gamble, Materials Reliability Program: Validation and Verification of FAVOR v02.4(MRP-90), 2003	Verification of PFM algorithms and sampled variables in FAVOR by comparing them against independent calculations, based on the descriptions provided in the FAVOR Theory manual.	V&V Report - PFM Algorithms and Sampled Variables.
2003-3 INEEL Validation of FAVPOST 2.4 OCR.pdf	FAVOR v2.4 Validation Post Processing Module INEEL 1. INEEL TEST ACTIVITIES TASK (III), VALIDATION OF FAVPOST 2003	Verification (by INEEL) that the FAVPOST module correctly works (as described in the Theory manual) by comparing the results against independent calculations.	Validation Report - FAVPOST CFI and CFF vs SAS by INEEL.

TABLE 1 - CATEGORY 1
HISTORICAL VALIDATION AND VERIFICATION EFFORTS FOR FAVOR (UP TO VERSION 06.1)

File Name	Authors, Title, Date, Report Number and FAVOR Version	Document Verification Topic	Document Type and Validation Issue
2003-4 INEEL Embrittlement Parameter Sampling Validation OCR.pdf	INEEL TEST ACTIVITIES TASK(II) A and B VALIDATION OF EMBRITTLEMENT PARAMETER SAMPLING, 2003, FAVOR v2.4	Verification (by INEEL) of the sampling of embrittlement related parameters described in the theory manual by comparing the results against independent (SAS) calculations.	Validation Report - Embrittlement Parameter Sampling in FAVOR vs SAS by INEEL.
2004-1 EPRI MRP 125 Validation of FAVOR Ver 3.1.pdf	B. Bishop, R. Gamble, Materials Reliability Program: Validation and Verification of FAVOR v03.1(MRP-125), 2004	To perform verification of incremental changes between FAVOR version 03.1 and version 02.4 with respect to sampling of embrittlement related parameters.	V & V Report - PFM Algorithms and Sampled Variables.
2004-2 Large-Scale Pressurized Thermal Shock Experiment Assessment.pdf	Dickson T.L., Kirk M.T., Assessment of Large-Scale Pressurized Thermal-Shock Experiments Using the FAVOR Fracture Mechanics Computer Code, 2004	Verification of FAVOR by comparing results against data generated during large scale pressurized thermal shock experiments performed at ORNL.	Application Paper - FAVOR comparison to large-scale PTSE.
2004-6 FAVOR 3.1 Modifications for Embrittlement Sampling OCR.pdf	Appendix C. FAVOR 3.1 Modifications for Embrittlement Sampling Validation. Upper Shelf Embrittlement Parameter Sampling--INEEL, 2/27/2004, FAVOR v3.1	Incremental verification of new algorithms and associated sampled variables in version 04.1 for the evaluation of vessel failure due to ductile flaw extension.	Installation of FAVOR 03.1 and installation verification. FAVOR modifications and output from the validation calculations discussed.
2004-8 INEEL FAVOR Ver 3-1 Upper Shelf Energy Validation.doc	INEEL Test Activities Validation of Unirradiated Upper-Shelf Energy Embrittlement Parameter Sampling –INEEL, 2/27/2004, FAVOR v3.1	Test Plan for validation of unirradiated upper-shelf energy embrittlement sampling using independent (SAS) calculations.	Validation Test Report - Unirradiated Upper-Shelf Energy Embrittlement Parameter Sampling in FAVOR vs SAS by INEEL.
2004-9 Deterministic Load Variables Validation.pdf	B.R. Bass, T.L. Dickson, P.T. Williams, A.-V. Phan, and K.L. Kruse, Verification and Validation of the FAVOR Code—Deterministic Load Variables, ORNL/NRC/LTR-04/11, FAVOR v2.2	Computation study of Deterministic Load Variables against independent ABAQUS calculations.	Verification and Validation Report – Deterministic Load Variables against independent ABAQUS calculations.
2004-10 Flaw Distribution Input Validation.pdf	F.A. Simonen, PNNL, Validation of the Treatment of Flaw Related Inputs by the FAVOR Code, Draft Report 2004, FAVOR v2.3	Verification that FAVOR correctly assigns the number, size, and locations of flaws to the weld and base metal regions of an RPV using independent PPNL calculations.	Draft Validation Report - FAVOR Flaw Distribution comparisons to independent PPNL calculations.

TABLE 1 - CATEGORY 1 HISTORICAL VALIDATION AND VERIFICATION EFFORTS FOR FAVOR (UP TO VERSION 06.1)			
File Name	**Authors, Title, Date, Report Number and FAVOR Version**	**Document Verification Topic**	**Document Type and Validation Issue**
2005-1 NUREG-1795 FAVOR 2.4 AND 3.1.pdf	Shah N.M Malik, NUREG-1795 FAVOR Code Versions 2.4 and 3.1 Verification and Validation Summary Report, 2005	NUREG-1795 FAVOR Code Versions 2.4 and 3.1 Verification and Validation Summary Report 2005	Verification and Validation Summary Report on FAVOR Code Versions 2.4 and 3.1
2005-2 FAVOR 04.1 Validation and Verification.pdf	B. Bishop, R. Gamble, Materials Reliability Program: Validation and Verification of FAVOR v04,1, 2005, EPRI MRP-171	Incremental verification of new algorithms and associated sampled variables in version 04.1 for the evaluation of vessel failure due to ductile flaw extension.	Validation and Verification Report on FAVOR v 04.1(MRP-171).
2007-3 FAVOR v06.1 Validation and Verification MRP-226.pdf	B. Bishop, R. Gamble, Materials Reliability Program: Validation and Verification of FAVOR v06,1, 2005, EPRI MRP-171.	Incremental V&V testing of FAVOR, v06.1 including testing of new PFM sampling strategies and computational algorithms for upper-shelf and radiation-embrittlement-related variables and uncertainties.	Validation and Verification Report on FAVOR v06.1(MRP-226).

TABLE 2 - CATEGORY 2 HISTORICAL VALIDATION AND VERIFICATION EFFORTS (AFTER FAVOR VERSION 06.1)			
File Name	**Authors, Title, Date, Report Number and FAVOR Version**	**Document Verification Topic**	**Document Type and Validation Issue**
2010-1 Load Module New Capability Verification.pdf	Bass B.R., Dickson T.L., Shengjun Yin, Williams P.T., Verification of New Capabilities of Deterministic Load Module of Favor 09.01, 2010, PVP2010-25439, FAVOR v09.01	ASME paper describing verification of FAVOR KI solutions versus ABAQUS solutions for internal surface breaking flaws, external surface breaking flaws, and embedded flaws in BWR geometries.	Comparison Paper using FAVOR and ABAQUS.
2011-1 Verification and Validation of the FAVOR 9.1 Code.pdf	Adams G., Simonen F., Wilt T. Verification and Validation of the Version 09.1 Code, 2011, FAVOR v09.1	Incremental verification of 09.1 version of FAVOR relative 06.1 version of FAVOR. Performed by(Southwest Research Institute). Scope is limited to: new warm pre-stress options, new embrittlement trend curves.	V & V Report.
2016-7 FAVOR v16.1 Verification and Validation Studies.pdf	P.T. Williams, T.L. Dickson, B.R. Bass. H.B. Klasky, Fracture Analysis of Vessels - Oak Ride FAVOR, v16.1, Computer Code: Appendix G Verification and Validation Studies	Procedures and processes used to ensure that FAVOR meets its software requirements.	Verification and Validation Studies - focusing on improvements made in the 16.1 versions of FAVOR for KI(t) solutions of internal surface breaking flaws.
2017-1 Fracture Mechanics Computer Code Analysis of Nuclear Reactor Pressure Vessels.pdf	Bass B.R., Dickson T.L., Klasky Hilda B. Williams P.T., FAVOR Version 16.1-A Computer Code for Fracture Mechanics Analyses of Nuclear Reactor Pressure Vessels, 2017, PVP2017-65262, FAVOR v16.1	FAVOR v16.1 computer code for fracture mechanics of nuclear reactor pressure vessels.	Paper summarizing FAVOR v16.

TABLE 3 – SUPPORTING REFERENCES FOR HISTORICAL FAVOR VALIDATION AND VERIFICATION			
File Name	**Authors, Title, Date, Report Number and FAVOR Version**	**Document Verification Topic**	**Document Type and Validation Issue**
1987-1 Reg Guide 1.99 Rev 2.pdf	NRC OFFICE OF NUCLEAR REGULATORY RESEARCH (RES), Rev 2 to reg guide 01.099, task ME 305-4, "Radiation Embrittlement of Reactor Vessel Materials."1987, REGGD-1.099	General Reference Regulatory Guide.	REGULATORY GUIDE (REG GUIDE), REGULATORY GUIDES & STD. REVIEW PLANS-TEXT.
1993-1 Stress Intensity Factor Influence Coefficients.PDF	Dickson, T.L., Keeney, T.L., Heavy-Section Steel Technology (HSST) Program Engineering Technology Division, 1993, ORNL/NRC/LTR-93/33	Stress-Intensity-Factor Influence Coefficients for Axially Oriented Semielliptical Inner-Surface Flaws in Clad Pressure Vessels (R i/t=10).	Letter Report.
1999-2 Tech Bases Development Activities for PTS.pdf	Terry L. Dickson, Review of FAVOR Probabilistic Fracture Mechanics (PFM) Analysis Methodology, 1999	General Reference document that discusses the NRC Meeting on Tech Bases for PTS.	General Reference - NRC Meeting on Tech Bases for PTS.
2000-2 ACRS Meeting Minutes on Rx Vessel and FAVOR OCR.pdf	Noel Dudley, Certification of ACRS meeting minutes subcommittee meeting on materials and metallurgy concerning pressurized thermal shock technical basis reevaluation, 2000	General Reference document discussing ACRS meeting minutes on Rx Vessel and FAVOR.	General Reference - Comparison Paper on LEFM KI Methodologies (EDF, EPRI, ABAQUS).
2001-1 Fracture Mechanics Methodologies Comparison.pdf	Bass B.R., Dickson T.L., Williams P.T., Comparison of Fracture Mechanics Methodologies for Postulated Flaws Embedded in the Wall of a Nuclear Reactor Pressure Vessel, 2001	Verification of FAVOR KI solutions for embedded flaws in RPV wall; comparison of FAVOR KI solutions with ABAQUS solutions and other investigators.	General Reference - Comparison Paper on LEFM KI Methodologies (EDF, EPRI, ABAQUS).
2001-2 BEAVER_FLuence_Maps.xls	A. Aronson, J.F. Carew, K. Hu, W.R. Jones (project manager), A. Prince, G. Zamonsky, PWR and BWR Pressure Vessel Fluence Calculation Benchmark Problems and Solutions, 2001, NUREG/CR-6115 BL-NUREG-52395	Supplemental Excel spreadsheet that is a part of NUREG-CR-6115 BLN.	Excel spreadsheet with relevant data.

TABLE 3 – SUPPORTING REFERENCES FOR HISTORICAL FAVOR VALIDATION AND VERIFICATION			
File Name	**Authors, Title, Date, Report Number and FAVOR Version**	**Document Verification Topic**	**Document Type and Validation Issue**
2001-2 NUREG-CR-6115 BLN Fluence Calculations.pdf	A. Aronson, J.F. Carew, K. Hu, W.R. Jones (project manager), A. Prince, G. Zamonsky, PWR and BWR Pressure Vessel Fluence Calculation Benchmark Problems and Solutions, 2001, NUREG/CR-6115 BL-NUREG-52395	General Reference NUREG report on PWR and BWR Pressure Vessel Calculation Benchmark Problems and Solutions.	Report providing detailed specification and corresponding numerical solutions for a set of PWR and BWR pressure vessel fluence benchmark problems.
2003-2 Dickson et al comparison of fracture mechanics OCR.pdf	B. Richard Bass, Terry L. Dickson, Paul T. Williams, A Comparison of Fracture Mechanics Methodologies for Postulated Flaws Embedded in the Wall of a Nuclear Pressure Vessel, 2003	Verification of FAVOR KI solutions for embedded flaws in RPV wall; comparison of FAVOR KI solutions with ABAQUS solutions and other investigators.	General Reference - Comparison Paper on LEFM KI Methodologies (EDF, EPRI, ABAQUS).
2004-4 embrittlement parameter sampling 4192004 OCR.pdf	Process for Validation of Embrittlement Parameter Sampling in FAVOR 2004, FAVOR v3.1	General reference document dated 4/19/2004-Process for Validation of Embrittlement Parameter Sampling in FAVOR.	Validation process instructions for Embrittlement parameter sampling in FAVOR 3.1.
2004-5 embrittlement parameter sampling 4212004 OCR.pdf	Process for Validation of Embrittlement Parameter Sampling in FAVOR v2004, FAVOR v3.1	General reference document dated 4/21/2004-Process for Validation of Embrittlement Parameter Sampling in FAVOR.	Validation process instructions for Embrittlement parameter sampling in FAVOR v3.1.
2004-7 FAVOR embrittlement parameter sampling OCR 2004.pdf	Process for Validation of Embrittlement Parameter Sampling in FAVOR, 4/21/2004, FAVOR v3.1	General reference document dated 4/21/2004-Process for Validation of Embrittlement Parameter Sampling in FAVOR and FAVOR Post-Processor.	Validation process instructions for Embrittlement parameter sampling in FAVOR v3.1.
2006-1 Sensitivity Studies of Probabilistic Fracture Mechanics in FAVOR.pdf	M. ErickKirk, T. Dickson, T. Mintz, F. Simonen, Sensitivity Studies of the Probabilistic Fracture Mechanics Model Used in FAVOR, 2006, NUREG-1808	General Reference-Sensitivity Studies of the Probabilistic Fracture Mechanics Model Used in FAVOR.	Report describing the sensitivity studies performed on the probabilistic failure mechanics model.

TABLE 3 – SUPPORTING REFERENCES FOR HISTORICAL FAVOR VALIDATION AND VERIFICATION			
File Name	**Authors, Title, Date, Report Number and FAVOR Version**	**Document Verification Topic**	**Document Type and Validation Issue**
2006-2 NUREG-1806, Vol. 1 Chpt 1-7 OCR.pdf	Kirk, Arcieri, Bass, Bessette, Chang, Dickson, Fletcher, Kolaczkowksi, Malik, Mintz, Pugh, Simonen, Siu, Whitehead, Williams, Woods, Yin, Technical Basis for Revision of the PTS Screening Limit for the PTS Rule (10 CFR 50.61), 2007. NUREG 1806 Vol.1, 04.1	General Reference-Technical Basis for Revision of the Pressurized Thermal Shock (PTS) Screening Limit in the PTS Rule (10 CFR 50.61).	Report summarizing documents describing procedures used and results obtained in probabilistic risk assessment, thermal hydraulic, and probabilistic fracture mechanics studies conducted.
2006-2 NUREG-1806, Vol. 1 Chpt 8-13 OCR.pdf	Vessel Failure Frequencies Estimated for Oconee Unit 1, Beaver Valley Unit 1, and Palisades, 2004, NUREG-1806	General Reference - Technical Basis for PTS revision.	General Reference - Technical Basis for PTS revision.
2006-3 NUREG-CR-6854 FAVOR Theory and Implementation OCR.pdf	P.T. Williams, T.L Dickson, Fracture Analysis of Vessels-Oak Ridge FAVOR v04.1, Computer Code: Theory and Impletion of Algorithms, Methods, and Correlations. 2007.NUREG/CR-6854 ORNL/TM-2004/244, FAVOR v04.1	Report on FAVOR v04.1 Computer Code: Theory and Implementation of Algorithms, Methods, and Correlations.	General Reference report on FAVOR v04.1 computer code theory and algorithm implementation, methods and correlations.
2006-4 Prob Fracture Mechanics- Models, Parameters, and Uncertainty Favor 04.1 OCR.pdf	M. Erickson Kirk, B.R. Bass, T. Dickson, C. Pugh, T. Santos, P. Williams, Probabilistic Fracture Mechanics-Models, Parameters, and Uncertainty Treatment Used in FAVOR Version 04.1, 2007, NUREG-1807, FAVOR v04.1	General Reference-Models, Parameters, and Uncertainty Treatment Used in FAVOR Version 04.1.	Background technical discussion of the models, parameters, and uncertainty treatment used in FAVOR v04.1.
2007-1 NRC - ORNL - Risk Informed 10CFR50 App G.pdf	Mark Erickson Kirk, NRC/ORNL Work on Risk-Informing 10 CFR Part 50 Appendix G, 2007, FAVOR v06.1	NRC Status Meeting PowerPoint Presentation.	NRC Status Meeting.
2007-2 Recommended Screening Limits for Pressurized Thermal Shock (PTS).pdf	Mark Erickson Kirk, Terry L. Dickson, Recommended Screening Limits for PTS, 2007, NUREG-1874, FAVOR v05.1 and v06.1	NUREG-1874 report on screening limits for pressurized thermal shock.	Report on PTS using FAVOR.
2008-1 Nonlinear Analyses for Embedded Cracks Under PTS - Comparisons Weibull OCR.pdf	B. Wasiluk, X. Qian, and R. Dodds, Jr. Nonlinear Analyses for Embedded Cracks Under PTS: Comparison with FAVOR and Weibull Stress Approaches, 2008, NUREG/CR-6956	US NRC report covering comparisons with FAVOR and Weibull Stress Approaches.	Development Report using FAVOR.

TABLE 3 – SUPPORTING REFERENCES FOR HISTORICAL FAVOR VALIDATION AND VERIFICATION			
File Name	**Authors, Title, Date, Report Number and FAVOR Version**	**Document Verification Topic**	**Document Type and Validation Issue**
2009-1 Stress Intensity Factor Influence Coefficients.pdf	Bass B.R., Dickson T.L., Shengjun Yin, Williams P.T. Stress Intensity Factor Influence Coefficients for External Surface Flaws in Boiling Water Reactor Pressure Vessels, 2009, PVP 2009-77143	ASME paper describing extension of FAVOR SIFIC database to include external surface breaking flaws for BWR geometries (R / t = 20).	Development Paper using FAVOR.
2009-2 Favor Code Generalizations.pdf	Dickson Terry, Williams Paul, Shengjun Yin, A Generalization of the FAVOR Code to Include BWR Geometries and Heat-Up Transients, 2009, PVP-77106	ASMR paper describing generalization of FAVOR to include BWR geometries and heat up transients (included external surface breaking flaws and embedded flaws in outer half of RPV wall).	Development Paper using FAVOR.
2012-1 Probabilistic Fracture Mechanics Sensitivity Study.pdf	Adams G., Simonen F., Wilt T., A Probabilistic Fracture Mechanics Sensitivity Study Using FAVOR Version 09.01, 2012	Study performed by SWRI to evaluate sensitivities (on the probability of RPV failure) considering the effect of RPV geometry, EFPY, and flaw type, as predicted by the 09.1 version of FAVOR.	Sensitivity Report using FAVOR.
2015-1 ORNL Evaluation of Electrabel Safety Cases for Doel 3 Tihange 2.pdf	Bass, Richard B., Dickson, Terry L., Gorti, Sarma B., Hilda B. Klasky, Randy K. Nansted. Miikhail A. Sokolov, Paul T. Williams, ORNL Evaluation of Electrabel Safety Cases for Doel 3/Tihange 2: Final Report(R1),2015, ORNL/TM-2015/59349	Appendix D provides illustrations of excellent agreement between FAVOR and ABAQUS XFEM solutions for axial and circumferentially oriented embedded flaws.	Application Report using FAVOR.
2015-2 Material-Orientation Toughness Assessment (MOTA) OCR.pdf	Elliot J. Long, Mota for the Purposes of Mitigating BTP 5-3 Uncertainties, 2015, PWROG-15003-NP	Summary Report on MOTA for the Purposes of Mitigating BTP 5-3 Uncertainties.	General Reference Report by PWROG - Westinghouse.
2015-3 Draft NUREG-2163 Basis for Alternate PTS Rule.pdf	Mark T. Kirk, Mohammad Modarres, Gary L. Stevens, Technical Basis for Regulatory Guidance on the Alternate Pressurized Thermal Shock Rule, 2014, NUREG-2163	Technical Basis guide draft report submitted to the NRC for comment.	This report is a draft.

TABLE 3 – SUPPORTING REFERENCES FOR HISTORICAL FAVOR VALIDATION AND VERIFICATION			
File Name	**Authors, Title, Date, Report Number and FAVOR Version**	**Document Verification Topic**	**Document Type and Validation Issue**
2016-1 Theory and Implementation of Algorithms, Methods and Correlations.pdf	P.T. Williams, T.L. Dickson, B.R. Bass. H.B. Klasky, Fracture Analysis of Vessels - Oak Ride FAVOR, v. 16.1, Computer Code: Theory and Implementation of Algorithms, Methods, and Correlations, 2016, ORNL/LTR-2016/309, FAVOR v16.1	Appendix G provides through documentation of verification of FAVOR KI solutions (versus ABAQUS solutions) for internal breaking flaw geometries over a range of vessel geometries.	Report on FAVOR supporting Software Requirements and Software Design.
2016-2 FAVOR Code - V16.1 User Guide.pdf	B.R. Bass, T.L. Dickson, H.B. Klasky, P.T. Williams, FAVOR, v16.1, Computer Code. 2016, ORNL/LTR-2016/310. FAVOR v16.1	Oak Ridge FAVOR, v16.1, Computer Code: User's Guide (Reference Material).	Report on FAVOR supporting Software Implementation and User Documentation.
2016-3 Summary Report on FAVOR v 15-3.pdf	Summary Report on FAVOR v15.3 NRC/ORNL ProSAMM Program, Meeting to Discuss Pressure Vessel Issues and 10 CFR Appendix H Rulemaking, 2016. FAVOR v15.3	General Reference- Summary Report on FAVOR v 15.3. NRC/ORNL ProSAMM Program, Meeting to Discuss Pressure Vessel Issues and 10 CFR Appendix H Rulemaking, 2016.	NRC Meeting on FAVOR v15 versus v12.
2016-4 Effect of Shallow Inside- Surface-Breaking Flaws - Status Report.pdf	Bass, Dickson, Klasky, Williams, Effect of Shallow Inside-Surface-Breaking Flaws on the Probability of Brittle Fracture of Reactors Subjected to Postulated and Actual Operational Cooldown Transients: Status Report, 2016, ORNL/TM-2015/59531/REV-01	Appendix B illustrates verification of FAVOR and ABAQUS thru wall stress distributions at various times in cool down.	Annual NRC Meeting.
2016-5 August 2016 Annual NRC and Industry Materials Tech Exchange.pdf	Drew Odell, Annual NRC and industry Materials Technical Exchange Meeting, 2016	Annual NRC and Industry Materials Technical Exchange Meeting –August 4, 2016 Chicago.	Annual NRC Meeting.
2016-6 NRC Public Meeting Jan 2016 - ORNL Update - FAVOR.pdf	Richard Bass, Terry Dickson, Impact of using stress free temperature of 364 F on Shallow Flaw issue. 2016, ORNL/NRC Staff meeting Rockville, Maryland	General Reference- Presentation on the Impact of using stress free temperature of 364 F on Shallow Flaw Issue.	NRC Meeting on Shallow Flaw Issue.
2017-2 NUREG-0800 Revision on Fracture Toughness.pdf	David L. Rudland, Closure Memorandum Supporting the Limited Revision of NUREG-0800 Branch Technical Position 5-3, "Fracture Toughness Requirements, 2017	General Reference on Fracture Toughness Requirements.	General Reference on Fracture Toughness Requirements.

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ATTACHMENT 1
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