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FINAL DESIGN REVIEW REPORT

Subcritical Experiments

Gen 2, 3-ft Confinement Vessel Weldment

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EFFECTIVE DATE: 9/26/17

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LANL Derivative Classifier

REVISION HISTORY

Revision	Date	Description of Change
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ACRONYMS

Term	Description
ASME	American Society of Mechanical Engineering
CJP	Complete Joint Penetration
DF	Design Feature
DYNEX	Dynamic Experiment
FDR	Final Design Review
Gen 2	Generation 2
HE	High Explosive
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
NNSS	Nevada National Security Site
NSTec	National Security Technologies, LLC
RFP	Request for Proposal
SCE	Subcritical Experiment
SS	Safety Significant
VDA	Vessel Design Authority

1.0 EXECUTIVE SUMMARY

A Final Design Review (FDR) of the Subcritical Experiments (SCE) Gen 2, 3-ft. Confinement Vessel Weldment was held at Los Alamos National Laboratory (LANL) on September 14, 2017. The review was a focused review on changes only to the confinement vessel weldment (versus a system design review). The changes resulted from lessons-learned in fabricating and inspecting the current set of confinement vessels used for the SCE Program. The baseline 3-ft. confinement vessel weldment design has successfully been used (to date) for three (3) high explosive (HE) over-tests, two (2) fragment tests, and five (5) integral HE experiments. The design team applied lessons learned from fabrication and inspection of these vessel weldments to enhance fit-up, weldability, inspection, and fitness for service evaluations. The review team consisted of five (5) independent subject matter experts with engineering design, analysis, testing, fabrication, and inspection experience. The review team identified the following findings and observations:

- Nine (9) Pre-start findings (must be completed before fabrication Request for Proposals (RFP))
- Zero (0) Post-start findings (must be completed before fabrication contract award)
- Four (4) Observations

The confinement vessel weldment design meets the specified requirements and is credible for SCE service given the design information presented and review team feedback. The current SCE plan is to initiate procurement of six (6) Gen 2, 3-ft Confinement Vessel weldments in late Q1FY18 with fabrication contract award in late Q2FY18.

Final system qualification will occur following successful execution of a hydrostatic over-pressure test meeting ASME Section VIII Division 3 requirements performed by the vendor (fabricator) and successful execution of a 125% HE system over-test performed by LANL to meet ASME Code Case 2564 requirements (which is consistent with DOE-STD-1212-2012, *Explosives Safety,* Section 13.4.a.1 over-test requirements).

2.0 INTRODUCTION

The National SCE portfolio requires new 3-ft. confinement vessel weldments to field and execute focused and integral SCEs at the Nevada National Security Site (NNSS). The confinement vessels are credited safety systems (safety significant, design feature) as they confine the blast effects and hazardous materials resulting from the detonation of a high explosive experimental device. The LANL design team incorporated lessons learned (design, fabrication, and inspection) from previous confinement vessel weldment designs (e.g., LANL DynEx Project and SCE Projects) for these new weldment designs.

3.0 BACKGROUND

National Security Technologies, LLC (NSTec) has procured and delivered a total of six (6) 3-ft. confinement vessel weldments for SCE Program use. These six confinement weldments are commonly referred to as the Lot 1 (i.e., first batch) vessels. These confinement vessel weldments have been, and will be, used for the execution of near-term SCEs. Appendix A shows the planned experiment usage for the Lot 1, Lot 2, and Lot 3 confinement vessels (18 total).

In FY16, the LANL Impulsively-loaded Vessel Design Authority (VDA) suggested to various SCE stakeholders (LANL, Lawrence Livermore National Laboratory (LLNL), and NSTec) an upgrade to the

current confinement vessel weldment design given lessons learned associated with fabricating and inspecting the Lot 1 vessels. The following identifies the resulting confinement vessel weldment upgrades:

1. Changing from as-formed to machined hemispherical heads
   - Enhances control of form and fit (port-to-shell and shell-to-shell)
   - Enhances inspection
2. Changing from a 30/70 Double-Bevel Weld Joint to a 50/50 Double U Stepped Weld Joint
   - Enhances control of port (nozzle)-to-shell fit
   - Enhances welding
3. Relocate Port-to-Shell Weld Joints (away from port)
   - Enhances welding accessibility
   - Enhances inspection accessibility
4. Increasing number of exit port bolt holes from 16 to 24
   - Enhances bolt strength for larger exit port cover
   - Aligns linear density of exit port bolt holes with both top and entry ports

The SCE stakeholders agreed to the proposed upgrade with the intent of implementing these design enhancements for the future Lot 3 procurement (as the Lot 2 (6 total) fabrication effort had already started at the time of this decision). LANL plans to initiate SCE Gen 2, 3-ft. Confinement Vessel Lot 3 procurement in late Q1FY18.

4.0 PURPOSE OF THE FINAL DESIGN REVIEW

The FDR is a graded multi-disciplined technical review to ensure that a system (in this case, weldment) can proceed into fabrication, qualification, and service meeting stated performance requirements. The FDR team includes subject matter experts independent of the design team who determine whether the design of the confinement vessel weldment satisfies defined requirements (i.e., meeting ASME Code Case 2564 strain limits and assessing design for manufacturability).

5.0 REVIEW TEAM

The FDR team consisted of the independent subject matter experts listed in Table 1.

First Name	Last Name	Organization	Confinement Vessel Skillset
Kelly	Bingham	LANL, QPA-IQ	Fabrication, Welding, & Inspection
Thomas	Duffey	LANL, J-EI	Analysis & Testing
Paul	Leslie	LANL, J-DO	Analysis & Testing
Rich	Lyons	LLNL, DTED	Design & Testing
Robert	Valdiviez	LANL, J-3	Design, Analysis, Fabrication, & Testing

Table 1. Final Design Review Team

6.0 DESIGN REQUIREMENTS

The design change requirements for this review are limited to:

1. ASME Code Case 2564, Revision 5 strain limit compliance (refer to Table 2 and Figure 1)

Plastic Strain Component	Parent Metal Limit	Weld Limit
Membrane (through thickness average)	0.2%	0.2%
Bending	2.0%	1.0%
Peak	5.0%	2.5%

Table 2. ASME Code Case 2564 Equivalent Plastic Strain Design Limits

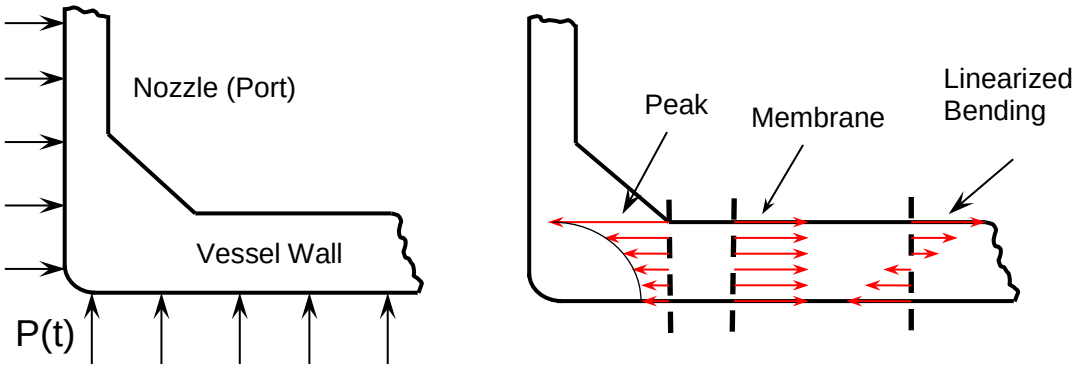

Figure 1. Plastic Strain Component Description

2. Assessing design for manufacturability (fabrication, welding, inspection)

7.0 FINAL DESIGN REVIEW

The FDR was held at LANL on September 14, 2017. Several stakeholders from LANL and LLNL participated in the review. Appendix B lists the attendees of the FDR. The following LANL briefings were provided to the review team:

1. *SCE, Gen 2, 3-ft Confinement Vessel Final Design Review*, Christopher Romero, LANL, J-EI
2. *SCE Gen 2, 3-ft. Confinement Vessel Design Changes*, Robert Gentzlinger, LANL, A-3
3. *SCE Gen 2, 3-ft. Confinement Vessel Structural Analysis*, Dallas Hill, LANL, AET-1

These briefings provided the minimum set of key design information and analysis results for the review team to discern whether the confinement vessel weldment design change requirements were appropriately met.

8.0 DESIGN INFORMATION

The following design information for the confinement vessel weldment upgrade (refer to Figure 2) was provided to the review team showing compliance to specified requirements:

- Engineering drawing set showing detailed product definition for fabrication

- Structural analysis results showing compliance with ASME Code Case 2564 strain limit requirements

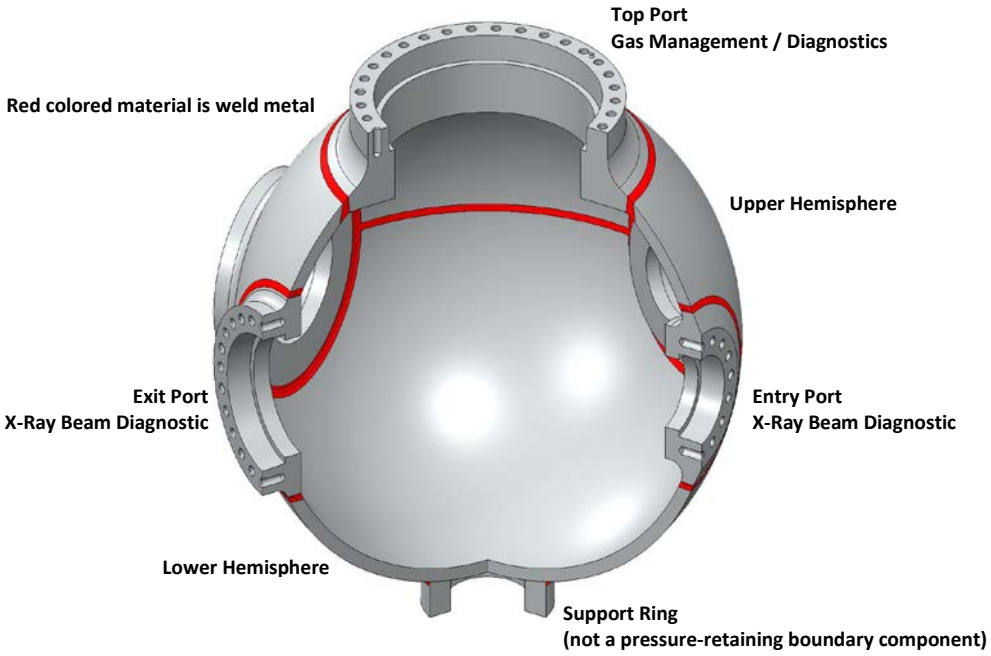

Figure 2. SCE Gen 2, 3-ft. Confinement Vessel Weldment

The engineering drawing set includes geometric dimensioning and tolerancing enhancements to improve form and fit for welding and machining operations and for final system assembly. The structural analysis results show full compliance with ASME Code Case 2564 requirements and shows that the confinement vessel weldment is robustly designed for the 1.9 kg TNT-Equivalent HE design load. It must be noted that the design limiting components of a typical confinement vessel system are the diagnostic covers and feed-throughs. These components are experiment-specific and are designed by experimental verification (i.e., a 125% HE over-test per ASME Code Case 2564 requirements). A formal structural analysis report of the confinement vessel weldment is being prepared, reviewed, and approved with release planned for late October 2017. Table 3 summarizes the maximum calculated plastic strains and locations of the confinement vessel weldment.

Equivalent Plastic Strain Component	ASME Parent Material Limit	ASME Weld Material Limit	Maximum Calculated Parent Material Plastic Strain	Maximum Calculated Parent Material Plastic Strain Location	Maximum Calculated Weld Material Plastic Strain	Maximum Calculated Weld Material Plastic Strain Location

Equivalent Plastic Strain Component	ASME Parent Material Limit	ASME Weld Material Limit	Maximum Calculated Parent Material Plastic Strain	Maximum Calculated Parent Material Plastic Strain Location	Maximum Calculated Weld Material Plastic Strain	Maximum Calculated Weld Material Plastic Strain Location
Membrane (through thickness avg)	0.2%	0.1%	**0.14%**	**Upper Hemisphere Between Entry Ports**	**0.05%**	**Top Port Weld Between Entry Ports**
Bending	2%	1%	**0.22%**	**Lower Hemisphere Between Entry Ports**	**0.17%**	**Top Port Weld Between Entry Ports**
Peak	5%	2.5%	**0.89%**	**Upper Hemisphere Between Entry Ports**	**0.48%**	**Top Port Weld Between Entry Ports**

Table 3. Maximum Calculated Plastic Strains

9.0 REVIEW FEEDBACK & DISPOSITION

The review team was instructed to assess the information presented and provide feedback using the following three (3) categories:

1. Pre-Start Finding (must be completed before fabrication RFP)
2. Post-Start Finding (must be completed before fabrication contract award)
3. Observations

As a result of the review, the following review team feedback was provided and includes design team comment disposition:

- **Pre-Start Findings (9)**

  1. **Paul Leslie, LANL, J-DO**

     It appears that LANL is required to meet the conditions described in DOE-STD-1212-2012, “Explosives Safety”. One requirement is a 20% factor of safety on the HE TNT equivalent. Has this requirement been incorporated in the 4.2 lb TNT equivalent loading utilized in the FE calculations reported by Dallas Hill, LANL, AET-1?

     Pre-start Finding (1) Disposition:

The SCE Gen 2, 3-ft. Confinement Vessels will be used at the NNSS U1a Facility and are credited as a safety significant (SS) design feature (DF) for loss of confinement control. The confinement vessels are designed to prevent loss of confinement during and after experiment execution. However, they are not designed for blast-protection of personnel or facility. Blast-resistant protection for personnel and facility is provided by the U1a Facility experiment room, which is considered a containment structure and exclusion area per DOE-STD-1212-2012. Therefore, the 20% safety factor increase in design load is not applicable for these confinement vessels.

The design code of record for these confinement vessels is the ASME Boiler and Pressure Vessel Code, Section VIII, Division 3, Alternative Rules for Construction of High Pressure Vessels, and ASME Code Case 2564, Impulsively Loaded Pressure Vessels, Section VIII, Division 3. The ASME Code Case requires the designer to meet two separate design conditions: (a) Global Instability State; and (b) Local Tearing Failure. The design and supporting analysis must ensure that with a 175% design basis impulse load, a global instability will not form, thus ensuring the vessel will not collapse and thereby remain intact. As such, ASME Code Case 2564 design requirements exceed DOE-STD-1212 guidance of 20% design safety factor increase. Moreover, per ASME Code Case 2564, final qualification of the confinement vessel weldment includes a hydrostatic over-pressure test and a 125% HE over-test. This ASME Code Case 2564 125% HE over-test is identical to over-test requirements specified in DOE-STD-1212-2012 (Section 13.4.a.1).

2. Kelly Bingham, LANL, QPA-IQ

Please check the specifications called out on drawing 180Y1801237, note 12 (ENG-TS-JEI-0078) and note 13 (W-14-AD-0004) for being the most current to cite.

Pre-start Finding (2) Disposition:

The material (plate, head, and forging) specifications, ENG-TS-JEI-0075 through 0077, which were developed for the SCE Gen 1, 6-ft. Confinement Vessel Weldment, will be used for the SCE Gen 2, 3-ft Confinement Vessel Weldment Lot 3 procurement. A new fabrication specification will be developed for the SCE Gen 2, 3-ft. Confinement Vessel Weldment. The engineering drawings will be updated, accordingly.

3. Robert Valdiviez, LANL, J-3

Please review for manufacturability the hemispherical head final profile detailed on drawing 180Y1801239. The review committee is of the opinion that this head can be manufactured by industry partners. However, their attention should be called to the final profile requirement to ensure that they account for this in their project bid and planning.

Pre-start Finding (3) Disposition

An additional note will be added to the hemispherical head drawing emphasizing that a 1-in. minimum wall shell thickness is required. This note will augment the geometric dimensioning and tolerancing requirements specified in the engineering drawing set.

4. Robert Valdiviez, LANL, J-3

The wall thickness of the hemispherical heads of the 3-ft vessel are being required to be 1.0-inch in thickness, with a 0.12-inch thicker wall total profile tolerance. This will result in a wall that is typically thinner than what has been used for past vessels. This fact is not a structural problem, but does need to be considered when citing past acceptance tests conducted to underpin this design. The discussion provided by the design team was satisfactory in closing this comment because additional acceptance testing will be conducted on this new vessel design once it is built into a first unit vessel.

Pre-start Finding (4) Disposition:

Final qualification of the SCE Gen 2, 3-ft. Confinement Vessel Weldment design will be based on both the structural analysis (which models a 1-in. minimum wall thickness), the vendor hydrostatic over-pressure test, and the final 125% HE over-test.

5. Richard Lyons, LLNL, DTED

Is a machined surface finish on all areas of the hemispheres a requirement? There may be cases where the drawing tolerances are met. However some areas may have an "as formed" surface finish instead of a machined surface. A machined surface specification or call-out was not observed on the fabrication drawing and should be added if that is the intent.

Pre-start Finding (5) Disposition:

A machined surface call-out (125 µ-inch) is specified in the title block tolerance table of the hemispherical head drawing (180Y1801239).

6. Richard Lyons, LLNL, DTED

Consider adding a small lead in chamfer on the top nozzle port. Personal experience has shown the top cover O-rings are hard enough to support the weight of the cover and experiment when the O-rings contact the top nozzle opening. The top cover must be gently forced down to compress and move the O-rings past the top shoulder of the nozzle.

Pre-start Finding (6) Disposition:

A small lead-in chamfer will be added to the engineering drawings for all ports to facilitate cover with o-ring installation.

7. Thomas Duffey, LANL, J-EI Contractor

Please comment on the manufacturability of the step between the two hemispheres. This comment was raised during the FDR on Thursday. Discussion and response by the Design Team was satisfactory. No additional response is required.

Pre-start Finding (7) Disposition:

The weld joint 'step' will facilitate fit-up of both hemispherical heads. The step is sized and dimensioned to ensure adequate structural strength during fit-up.

8. **Thomas Duffey, LANL, J-EI Contractor**

   Is the U-type weld in common use? This comment was raised during the FDR on Thursday. Discussion and response by the Design Team was satisfactory. No additional response is required.

   Pre-start Finding (8) Disposition:

   A U-type weld joint is a common weld joint used for joining similar thickness materials and will facilitate weld head positioning and weld metal deposit.

9. **Thomas Duffey, LANL, J-EI Contractor**

   Will the circumferential, double U-type weld and step result in a true full-penetration weld? This comment was raised during the FDR on Thursday. Discussion and response by the Design Team was satisfactory. No additional response is required.

   Pre-start Finding (9) Disposition:

   The weld joint 'step' will be removed (back-gouged) during welding operations to ensure a final and ASME-compliant complete joint penetration (CJP) weld.

- **Post-Start Findings (0)**
- **Observations (4)**

1. **Richard Lyons, LLNL, DTED**

   The review team was tasked to assess the confinement vessel weldment design changes (4 total) only. Assessment: The design changes are sound improvements and should be implemented. Changes 1 - 3 are based on fabrication and PAUT inspection lessons learned from the Lot 1 & 2 vessels. Design change 4 is proposed to increase the structural margin on exit port fasteners by increasing the number to be consistent with the entry and top cover fastener spacing.

2. **Richard Lyons, LLNL, DTED**

   Moving weld regions away from port nozzles will in general improve PAUT scanning but may make the weld region between the radiographic exit ports more difficult to scan. Should this prove to be true, it is my judgement the tradeoff is still justified due to the benefits gained in all other weld areas.

3. **Richard Lyons, LLNL, DTED**

   Observations of structural FEA analysis presented by Dallas Hill, LANL, AET-1: strain field, and therefore stress field, discontinuities along element edges are observed on slides 15, 17 & 18. It was not clear during the FDR if a review of the structural analysis by an appropriate SME is planned or already complete. Review or additional review is recommended.

   Observation (3) Response:

   An independent peer review of the structural analysis will be performed and documented in the final structural analysis report.

4. **Thomas Duffey, LANL, J-EI Contractor**

The structural analysis was especially detailed and thorough. Results presented clearly demonstrated that the ASME Code Case 2564 strain limits had been met.

10.0 CONCLUSION

A Final Design Review of the Subcritical Experiments (SCE) Gen 2, 3-ft. Confinement Vessel System was held at LANL on September 14, 2017. The review team consisted of five (5) independent subject matter experts with engineering design, analysis, testing, fabrication, and inspection experience. The review team identified nine (9) pre-start findings (must be completed before RFP); zero (0) post-start findings (must be completed before contract award); and four (4) observations. The nine (9) pre-start findings and four (4) observations will be appropriately addressed in the engineering/procurement package for vendor RFP. The weldment design meets the specified requirements and is credible for SCE service given the design information and review team feedback.

Final system qualification of the SCE Gen 2, 3-ft. Confinement Vessel weldment shall occur following successful execution of a hydrostatic over-pressure test meeting ASME Section VIII Division 3 requirements performed by the vendor (fabricator) and successful execution of a 125% high explosive over-test performed by LANL.

APPENDIX A - LOT 1, 2, AND 3 CONFINEMENT VESSEL USE MATRIX

LOT	VESSEL SERIAL NO.	LABORATORY	EXPERIMENT SERIES	EXPERIMENT DESCRIPTION	EXPERIMENT TYPE	EXPERIMENT EXECUTION DATE
1	3-1-5-SE-01*	LANL	Gemini	125% HE Vessel Over-test	HE Vessel Over-test	Jun '12
		LANL	Gemini	Castor	Confirmatory	Aug '12
		LANL	Leda	Leda	Confirmatory	Aug '14
		LANL	Lyra	125% HE Diagnostic Over-test	HE Diagnostic Over-Test	Jun '15
		LANL	Lyra	Fragment Mitigation Test	Fragment Test	Aug '15
		LANL	Lyra	Destructive Testing	Destructive Test	May '16
	3-1-5-SE-02*	LANL	Gemini	Pollux	SCE	Dec '12
	3-1-5-SE-03**	LANL	Lyra	Eurydice	Confirmatory	Mar '17
		LLNL	Sierra Nevada	Lamarck	Confirmatory	Sep '18
		LLNL	Pacific Coast	Big Sur***	Dynamic Plutonium Experiment	Nov '19
	3-1-5-SE-04	LANL	Lyra	Vega	SCE	Dec '17
	3-1-5-SE-05	LLNL	Sierra Nevada	Ediza	SCE	Dec '18
	3-1-5-SE-06**	LANL	Lyra	Orpheus	Confirmatory	Sep '15
		LLNL	Humphreys	Humphreys	HE Over-test	Sep '16
		LLNL	Sierra Nevada	Conness	Fragment/Integrated Test	Jul '17
2	3-1-5-SE-07**	LANL	Red Sage	125% HE Vessel / Window Over-test (Red Sage HE Load)	HE Vessel & Window Over-test	TBD
		LANL	Red Sage	Fragment Mitigation Test	Fragment Test	TBD
		LANL	Red Sage	Iris	Confirmatory	Sep '19
	3-1-5-SE-08	LANL	Red Sage	Nightshade A SCE	SCE	Dec '19
	3-1-5-SE-09	LANL	Red Sage	Nightshade B SCE	SCE	Mar '20
	3-1-5-SE-10	LANL	Red Sage	Nightshade C SCE	SCE	Jun '20
	3-1-5-SE-11	LLNL	Red Sage	Nightshade 'L' SCE	SCE	Sep '20
	3-1-5-SE-12	TBD		Lot 2 Contingency Vessel		
3 New Design	3-1-5-SE-13**	LLNL	Sierra Nevada II	125% HE Over-test (LLNL S-N HE Load)	HE Vessel Over-test	TBD
		LLNL	Sierra Nevada II	Tuolumne	Confirmatory	Jun '21
		LLNL	Sierra Nevada III	Owens Lake	Confirmatory	Sep '23
	3-1-5-SE-14	LLNL	Sierra Nevada II	Tuolumne (SCE)	SCE	Sep '21
	3-1-5-SE-15	LLNL	Sierra Nevada III	Owens Lake A	SCE	Dec '23
	3-1-5-SE-16	LLNL	Sierra Nevada III	Owens Lake B	SCE	Mar '24
	3-1-5-SE-17	LLNL	Sierra Nevada III	Owens Lake C	SCE	Jun '24

LOT	VESSEL SERIAL NO.	LABOR ATORY	EXPERIMENT SERIES	EXPERIMENT DESCRIPTION	EXPERIMENT TYPE	EXPERIMENT EXECUTION DATE
	3-1-5-SE-18	TBD	TBD	Lot 3 Contingency Vessel	TBD	TBD

NOTES:

1. *Out of Service.
2. **Re-use of Confirmatory Experiments vessels in this matrix assumes a 'passing' ASME-compliant Fitness for Service Evaluation (FFSE).
3. ***Acceptable risk given current experiment design information from LLNL; dependent on Eurydice & Lamarck fragment damage and resulting inspection and FFSE.

APPENDIX B - LIST OF FDR PARTICIPANTS

FIRST NAME	LAST NAME	INSTITUTION	ORGANIZATION	ROLE
REVIEW TEAM				
Kelly	Bingham	LANL	QPA-IQ	Quality Assurance Specialist
Thomas	Duffey	LANL	J-EI	LANL Contractor
Paul	Leslie	LANL	J-DO	Deputy Division Leader
Rich	Lyons	LLNL	DTED	R&D Engineer
Robert	Valdiviez	LANL	J-3	R&D Engineer
DESIGN TEAM				
Richard	Bingham	LANL	AET-6	Non-Destructive Examination
Robert	Gentzlinger	LANL	A-3	R&D Engineer
Dallas	Hill	LANL	AET-1	R&D Engineer
Kenneth	Hurtle	LANL	W-11	Designer/Drafter
Christopher	Romero	LANL	J-EI	Project Director / Vessel Design Authority
OBSERVERS				
Jeremy	Danielson	LANL	P-23	Diagnostic Coordinator
Todd	Jankowski	LANL	AET-1	Deputy Group Leader