

S

ENGINEERING CHANGE NOTICE

H

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1. ECN 648984

Proj. ECN

2. ECN Category (mark one) <input type="radio"/> Supplemental <input checked="" type="radio"/> Direct Revision <input type="radio"/> Change ECN <input type="radio"/> Temporary <input type="radio"/> Standby <input checked="" type="radio"/> Supersedure <input type="radio"/> Cancel/Void	3. Originator's Name, Organization, MSIN, and Telephone No. Duane Bogen, BWHC, T2-12 373-2685		4. USQ Required? <input checked="" type="radio"/> Yes <input type="radio"/> No	5. Date
	6. Project Title/No./Work Order No. Tank 241-Z-361		7. Bldg./Sys./Fac. No. TK-241-Z-361/PFP	8. Approval Designator S.O.E. D
	9. Document Numbers Changed by this ECN (includes sheet no. and rev.) HNF-2024, Rev 1		10. Related ECN No(s). None	11. Related PO No. N/A
12a. Modification Work <input type="radio"/> Yes (fill out Blk. 12b) <input checked="" type="radio"/> No (NA Blks. 12b, 12c, 12d)	12b. Work Package No. N/A	12c. Modification Work Completed N/A Design Authority/Cog. Engineer Signature & Date	12d. Restored to Original Condition (Temp. or Standby ECNs only) N/A Design Authority/Cog. Engineer Signature & Date	

13a. Description of Change
Supersedure of HNF-2024, Rev. 1, "Justification for Continued Operations for Tank 241-Z-361" to reflect Phase II characterization activities.

13b. Design Baseline Document? Yes No

14a. Justification (mark one) <input checked="" type="radio"/> Criteria Change <input type="radio"/> Design Improvement <input type="radio"/> Environmental <input type="radio"/> Facility Deactivation <input type="radio"/> As-Found <input type="radio"/> Facilitate Const. <input type="radio"/> Const. Error/Omission <input type="radio"/> Design Error/Omission	14b. Justification Details The Tank 241-Z-361 "Justification for Continued Operations is being developed" in phases. This justification for continued operations addresses the second phase ... tank characterization.
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15. Distribution (include name, MSIN, and no. of copies)
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1. ECN (use no. from pg. 1)

648984

16. Design Verification Required

Yes
 No

17. Cost Impact

ENGINEERING

Additional \$ N/A
Savings \$ _____

CONSTRUCTION

Additional \$ N/A
Savings \$ _____

18. Schedule Impact (days)

Improvement N/A
Delay _____

19. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 13. Enter the affected document number in Block 20.

<p>SDD/DD <input type="checkbox"/></p> <p>Functional Design Criteria <input type="checkbox"/></p> <p>Operating Specification <input type="checkbox"/></p> <p>Criticality Specification <input checked="" type="checkbox"/></p> <p>Conceptual Design Report <input type="checkbox"/></p> <p>Equipment Spec. <input type="checkbox"/></p> <p>Const. Spec. <input type="checkbox"/></p> <p>Procurement Spec. <input type="checkbox"/></p> <p>Vendor Information <input type="checkbox"/></p> <p>OM Manual <input type="checkbox"/></p> <p>FSAR/SAR <input type="checkbox"/></p> <p>Safety Equipment List <input type="checkbox"/></p> <p>Radiation Work Permit <input checked="" type="checkbox"/></p> <p>Environmental Impact Statement <input type="checkbox"/></p> <p>Environmental Report <input type="checkbox"/></p> <p>Environmental Permit <input type="checkbox"/></p>	<p>Seismic/Stress Analysis <input type="checkbox"/></p> <p>Stress/Design Report <input type="checkbox"/></p> <p>Interface Control Drawing <input type="checkbox"/></p> <p>Calibration Procedure <input type="checkbox"/></p> <p>Installation Procedure <input type="checkbox"/></p> <p>Maintenance Procedure <input type="checkbox"/></p> <p>Engineering Procedure <input type="checkbox"/></p> <p>Operating Instruction <input type="checkbox"/></p> <p>Operating Procedure <input type="checkbox"/></p> <p>Operational Safety Requirement <input type="checkbox"/></p> <p>IEFD Drawing <input type="checkbox"/></p> <p>Cell Arrangement Drawing <input type="checkbox"/></p> <p>Essential Material Specification <input type="checkbox"/></p> <p>Fac. Proc. Samp. Schedule <input type="checkbox"/></p> <p>Inspection Plan <input type="checkbox"/></p> <p>Inventory Adjustment Request <input type="checkbox"/></p>	<p>Tank Calibration Manual <input type="checkbox"/></p> <p>Health Physics Procedure <input type="checkbox"/></p> <p>Spares Multiple Unit Listing <input type="checkbox"/></p> <p>Test Procedures/Specification <input type="checkbox"/></p> <p>Component Index <input type="checkbox"/></p> <p>ASME Coded Item <input type="checkbox"/></p> <p>Human Factor Consideration <input type="checkbox"/></p> <p>Computer Software <input type="checkbox"/></p> <p>Electric Circuit Schedule <input type="checkbox"/></p> <p>ICRS Procedure <input type="checkbox"/></p> <p>Process Control Manual/Plan <input type="checkbox"/></p> <p>Process Flow Chart <input type="checkbox"/></p> <p>Purchase Requisition <input type="checkbox"/></p> <p>Tickler File <input type="checkbox"/></p> <p><u>TK 241-Z-361 Work</u> <input checked="" type="checkbox"/></p> <p><u>Packages</u> <input type="checkbox"/></p>
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20. Other Affected Documents: (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.

Document Number/Revision

Document Number/Revision

Document Number/Revision

21. Approvals

	Signature	Date		Signature	Date
Design Authority	<u>A. L. Ramble</u> <i>[Signature]</i>	<u>5/20/99</u>	Design Agent	_____	_____
Cog. Eng.	<u>D. M. Bogen</u> <i>[Signature]</i>	<u>5/19/99</u>	PE	_____	_____
Cog. Mgr.	<u>P. E. Roege</u> <i>[Signature]</i>	<u>5/20/99</u>	QA	_____	_____
QA	<u>S. Zeller</u> <i>[Signature]</i>	<u>5/25/99</u>	Safety	_____	_____
Safety	<u>S. Nunn</u> <i>[Signature]</i>	<u>5/25/99</u>	Design	_____	_____
Environ.	_____	_____	Environ.	_____	_____
Other	<u>M. Talbot</u> <i>[Signature]</i>	<u>5/25/99</u>	Other	_____	_____

DEPARTMENT OF ENERGY

Signature or a Control Number that tracks the Approval Signature

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ADDITIONAL

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DWS

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Title: ECN 6489484⁸⁴ Revision 2, HNF-2024, "Justification For Continued Operation For Tank 241-Z-361"

DESCRIPTION: Tank 241-Z-361 is an inactive, underground storage tank located within the protected area of the Plutonium Finishing Plant (PFP). The tank is a reinforced concrete, rectangular underground structure located near the east end of the south fence line of PFP between Building 241-Z and the retention basin.

On October 15, 1997 the Department of Energy declared an unreviewed safety question (USQ) existed for Tank 241-Z-361 based upon the discovery that the potential hazards associated with the tanks had not been previously evaluated in the development of the PFP authorization basis. The USQ noted the potential for flammable gas build up in the tank, unevaluated structural condition, and the potential for time-related phenomena to invalidate prior criticality analysis.

As part of the October 15, 1997 declaration of the USQ, the Department of Energy also accepted PFP's recommendations for interim operating restrictions. The controls were replaced by controls approved in Revisions 0A and 1 of this justification for continued operations (JCO).

The work completed under the previous revisions to this JCO resulted in a weight test being performed. This test showed there has been no significant degradation of the tank top load bearing capacity up to 4000 lbs. The tank has also been vented and a passive filter has been installed to ensure there is no build up of flammable gas within the tank. Vapor samples have been drawn and are undergoing analysis. The interior of the tank has been videographed. These activities have eliminated or mitigated two key hazards potentially associated with the tank: steady-state flammable gas build up and tank pressurization.

A step-wise approach has been adopted to developing an authorization basis for this tank. This second revision of the JCO has been developed to support characterizing the tank. The purpose of this USQ evaluation is to determine if the revision to the JCO prepared to support Tank 241-Z-361 characterization activities requires approval by the Department of Energy - Richland Operations.

INTRODUCTION: The revision to the JCO evaluates PFP-unique hazards associated with the planned characterization activities. The specific activities considered include:

1. Shortening risers and replacing flanges.
2. Moving fence lines, associated security systems, and power lines.
3. Installing truck sampling foundation piers.
4. Truck sampling bridge construction.
5. Preparing risers for push-mode sampling.
6. Opening risers for video monitoring.
7. Establishing grounding/bonding termination point.
8. Establishing contamination control area.
9. Installing push-mode core sampling riser equipment.
10. Position push-mode-sampling truck on bridge.
11. Stage push-mode core sampling equipment.
12. Ground/bond equipment.
13. Raise and level sampling truck and assemble drill string.
14. Collect push-mode core segment.
15. Seal core segment in onsite transfer cask.
16. Package wastes and clean up area.
17. Store onsite transfer cask

The revision to the JCO also evaluated potential natural phenomena hazards associated with tank characterization activities.

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Hazard Analysis

A hazard analysis has been performed for Tank 241-Z-361 tank characterization activities. Tank 241-Z-361 has many of the same potential hazards as other TWRS tanks. Many of the activities being performed are the same as those performed by TWRS. Accordingly, the hazard analysis that was used to develop the TWRS authorization basis was not repeated. The hazard analysis performed identifies PFP-unique hazards (e.g., the structural condition of the tank) that may warrant additional controls that were not considered in the development of the TWRS authorization basis.

The principal hazard types and controls that resulted from the hazards analysis are summarized below:

1. Events that result in ignition of a quantity of flammable gas in the tank head space, that involve major damage to the tank roof, and result in a significant release of radioactive aerosols to the atmosphere.

As a result of Phase I activities the tank is now passively and continuously vented. Monitoring shows the tank is less than 25% of the lower flammability limit. During Phase II activities, flammable gas release events are only postulated to potentially occur as a result of the push-mode core sampling activity.

The applicable controls for this event include:

Control of access to the tank roof and general vicinity, determination of maximum allowable roof loading, control of roof loading when access is required, use of the Hanford rigging manual. These controls are intended to prevent collapse that could result in a spark and subsequent ignition of flammable gas.

A set of ignition controls similar to the TWRS ignition controls that specify bong requirements, allowed tools, allowed instrumentation, and procedures to minimize the likelihood of producing a spark.

2. Events that result in collapse of the tank roof or failure of the risers in the tank roof that cause significant release of toxic vapors and radioactive aerosols and possibly gross contamination of workers.

The applicable controls for this event include:

Control of access to the tank roof and general vicinity, determination of maximum allowable roof loading, control of roof loading when roof access is required, and the use of the Hanford Rigging Manual.

Control of mechanical forces on the risers.

Construction of the truck sampling bridge to prevent loads being applied to the tank from the sampling activity. Designing the bridge such that it can safely handle the static and dynamic loads that may be applied during operations. Also, construction of the bridge such that the sampling truck cannot be inadvertently driven off the edge of the bridge.

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3. Events that result in minor releases of toxic vapors and radioactive aerosols with no damage to the basic tank structure.

The applicable controls for these events include:

Institutional controls for working in an area where aerosols and vapors could be present. These may include protective clothing, greenhouses, drapes, radiation monitoring and respiratory protection.
4. Events that result in a criticality occurring in the tank.

Criticality controls will be established through implementation of the PFP criticality safety program.
5. Events postulated to result in an ignition of nitrate compounds in the tank with subsequent release of toxic vapors and radioactive aerosols.

The applicable controls for these events include:

Control of vehicle access to the tank to prevent vehicle impacts into risers that could dump burning fuel into the tank. Control to stop operations on the tank when lightning is detected within a 50-mile radius of the tank.

Preventing flame cutting/welding in the tank unless approved by the PHMC President.
6. Events involving normal industrial hazards or small quantities of radioactive contamination.

Implementation of existing institutional control programs is sufficient to control the hazards identified.
7. Leaks to the soil column from the tank.

Video taken in the tank during Phase I has identified there is little free liquid in the tank. Accordingly leaks to the soil column from tank leaks during this phase would be small and not pose a risk to workers. For Phase II, the tank characterization hazards for soil leak events will be controlled by procedure.

The applicable controls for these events include:

Only permitting hand digging or the use of the "guzzler" in the vicinity of the tank.

Limiting down force on the push mode drill string.

Limiting the torque on the installation of the helical piers.
8. Events that result in pressurized releases from the tank.

Because the tank was vented during Phase I and no pressure was detected, there are no events in this category for tank characterization activities proposed in this revision.

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9. Events that result in radioactive releases within or from, the OTC weather enclosure.

The applicable controls for these events include:

Ensure the weather enclosure is passively ventilated. Apply ignition controls during venting. Conduct airborne radioactive particulate sampling before entry. Post warning signs.

SCOPE: The scope of this USQ is the evaluation of the hazards presented by the Tank 241-Z-361 characterization activities as described in Revision 2 of HNF-2024, "Justification For Continued Operation For Tank 241-Z-361."

AUTHORIZATION BASIS: The USQ evaluation is done against HNF-2024, Rev. 1, "Justification For Continued Operations For Tank 241-Z-361," which incorporates specifically identified PFP operational safety requirements. (See Section 5.0) This authorization basis for Tank 241-Z-361 was specified in the Safety Evaluation Report approving Phase I activities (DOE/RL 99-TPD-054).

CONCLUSION: This revision to the authorization basis for Tank 241-Z-361 will require DOE approval because Tank 241-Z-361 characterization activities had not been evaluated in previous revisions of this JCO.

REFERENCES:

1. HNF-2024, Revisions 1 and 2, "Justification For Continued Operations For Tank 241-Z-361," 1999, B&W Hanford Company, Richland, Washington.
2. RL Letter, J.D. Wagoner to R.D. Hanson, 99-TPD-054, "Justification For Continued Operation (JCO) For Hanford Underground Storage Tank 241-Z-361," dtd. December 21, 1998.

Instructions: Respond to each question and provide justification for each response. A restatement of the question does not constitute a satisfactory justification or basis. An adequate justification provides sufficient explanation such that an independent reviewer could reach the same conclusion based on the information provided [DOE 5480.21, 10.e.1].

QUESTIONS

1. Does the PROPOSED CHANGE, test, experiment or DISCOVERY increase the probability of occurrence of an accident previously evaluated in the AUTHORIZATION BASIS documentation?

No Yes/Maybe

BASIS: The probability of occurrence of accidents was not determined as part of the JCO. However, the qualitative likelihood was assigned to each hazardous event during the performance of the hazards analysis.

Comparison of Appendix B for Revisions 1& 2 of the JCO does not reveal any previously analyzed hazardous event for which the probability of occurrence has increased.

2. Does the PROPOSED CHANGE, test, experiment or DISCOVERY increase the consequences of an accident previously evaluated in the AUTHORIZATION BASIS documentation?

No Yes/Maybe

BASIS: Revision 2 of the JCO identifies that as a result of Phase I activities a continuous, passive, filtered ventilation path has been established. As a result, the tank is known to be unpressurized and be less than

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25% of the lower flammability limit. The hazard analysis (Appendix B) shows that for similar accidents during Phase II the consequences are generally less and in no case greater. This resulted from elimination of the potential for the tank headspace to have a detonable or flammable level of hydrogen present.

3. Does the PROPOSED CHANGE, test, experiment or DISCOVERY increase the probability of occurrence of a malfunction of EQUIPMENT IMPORTANT TO SAFETY (ITS EQUIPMENT) previously evaluated in the AUTHORIZATION BASIS documentation?

No Yes/Maybe

BASIS: The probability of equipment failure was not determined as part of the JCO. However, the likelihood of failure can be inferred from failure modes identified in the hazards analysis.

Revision 1 of the JCO identified that Tank 241-Z-361 was designated as a safety significant structure. Revision 2 of the JCO identifies that a sampling platform will be constructed over the tank to carry the weight of the sampling truck. This prevents over-stressing the tank due to the weight of the sampling truck. The hazards analysis for Revision 2 (Appendix B) identifies several hazardous events where failure of the sampling platform leads to failure of the tank. These failure modes were not present during the analysis in Revision 1 of the JCO. Accordingly, it can be inferred that the probability of the tank failing has increased.

4. Does the PROPOSED CHANGE, test, experiment or DISCOVERY increase the consequences of a malfunction of ITS EQUIPMENT previously evaluated in the AUTHORIZATION BASIS documentation?

No Yes/Maybe

BASIS: Revision 2 of the JCO identifies that as a result of Phase I activities a continuous, passive, filtered ventilation path has been established. As a result, the tank is known to be unpressurized and be less than 25% of the lower flammability limit. The hazard analysis (Appendix B) shows that for similar accidents during Phase II the consequences are generally less and in no case greater. This resulted from elimination of the potential for the tank headspace to have a detonable or flammable level of hydrogen present. No hazardous event was identified where failure of the equipment caused a greater consequence than previously analyzed.

5. Does the PROPOSED CHANGE, test, experiment or DISCOVERY create the possibility of an accident of a different type than any previously evaluated in the AUTHORIZATION BASIS documentation?

No Yes/Maybe

BASIS: Section 3.2.2 of Revision 2 of the JCO identifies that the onsite transfer cask may be stored in a weather enclosure at PFP. The hazard analysis (Appendix B) identifies hazardous events that could lead to release of radioactive aerosols from that weather enclosure. Revision 1 of the JCO only described potential radioactive aerosol releases from Tank 241-Z-361. As such, this set of potentially hazardous events associated with the weather enclosure is a possible accident not previously evaluated in Revision 1, but which is addressed in Revision 2.

6. Does the PROPOSED CHANGE, test, experiment or DISCOVERY create the possibility of a malfunction of ITS EQUIPMENT of a different type than any previously evaluated in the AUTHORIZATION BASIS documentation?

No Yes/Maybe

BASIS: Revision 2 of JCO establishes the sampling platform as a safety significant structure. The basis for this designation was that its failure could lead to a tank failure. (The tank had been previously designated as safety significant.) The hazard analysis (Appendix B) in Revision 2 of the JCO postulates failure mechanisms

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for the sampling platform. Structural failure of the sampling platform had not been considered in Revision 1 of the JCO because that JCO did not authorize installation of the sampling platform and tank characterization activities

7. Does the PROPOSED CHANGE, test, experiment or DISCOVERY reduce the margin of safety as defined in the basis for any Technical Safety Requirement?
 No Yes/Maybe

BASIS: The controls established in the JCO do not address margin to safety for Tank 241-Z-361 activities.

8. Does the PROPOSED CHANGE, test, experiment or DISCOVERY require a new or revised Technical Safety Requirement?
 No Yes/Maybe

BASIS: The JCO does not impose TSR. However, as specified in Section 5.0 of the JCO, "The control requirements for performing characterization activities in Tank 241-Z-361 are administrative in nature...They will be considered equivalent to OSR for the Plutonium Finishing Plant."

To control potential hazards associated with the new activity of shortening risers (Section 3.2.2(1), an additional control was necessary that prevents flame cutting or welding in the tank unless a waiver is granted by the PHMC President and a debris catch is used (Section 5.3.3.4). This control was necessary to prevent ignition of nitrate compounds potentially in the tank, which could lead to releasing significant amounts of toxic and radioactive aerosols from the tank.

To control potential hazards associated with the new activity of storing the onsite transfer cask at PFP in a weather enclosure, additional controls were needed to prevent radioactive releases from, or within, the weather enclosure. These controls are derived from the potential for hydrogen to be generated in the onsite transfer cask during storage that pressurizes the onsite transfer cask. This hydrogen will be periodically vented. Ignition of the hydrogen or releases from the onsite transfer cask could potentially result in releasing significant radioactive aerosols. Leaks from a pressurized onsite transfer cask could similarly release radioactive aerosols. As specified in Section 3.2.2, storage of the core samples in the transfer cask is part of the transfer cask safety and analysis report and outside the scope of this JCO. As such, the controls associated with establishing the frequency of venting are outside the scope of this USQ.

Push mode core sampling activities will apply about 1000 lbs. or more vertical load to the riser being sampled. Previous analysis had limited these loads to lower vertical loads consistent with the activities being performed. The new analysis performed to support this JCO (Appendix I) show the risers can accept the loads that will be applied during sampling. On the basis of this revised analysis, the previous load limits for the risers have been modified in Table 5-6.2.

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USQE #1 <u>Alan Rumble</u> (Print Name)	USQE #2 <u>J.T. King</u> (Print Name)
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<u>Alan Rumble</u> Signature	Date: <u>5/21/99</u>	<u>J.T. King</u> Signature	Date: <u>5/24/99</u>
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PRC REVIEW (If Required)

Meeting No.: <u>99-14</u>	Date: <u>6/17/99</u>
PRC Chairman Concurrence: <u>ND Rudeboy</u> Signature	Date: <u>6/17/99</u>

Record Note: This ECN required a PRC to concur with submitting the ECN to DOE-RL for approval. The ECN was submitted and approved prior to PRC approval. The PRC reviewed and concurred with the submitted and this record note explains why the dates differ. The late PRC review + approval had no impact on the decision made.

ND Rudeboy
6/17/99

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Justification For Continued Operation For Tank 241-Z-361

D. M. Bogen
BWHC
Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-96RL13200

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Org Code: 15C00 Charge Code: 101387
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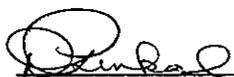
Key Words: Justification For continued Operation, Tank 241-Z-361, Unreviewed safety Question, Preliminary Hazard Assessment

Abstract: Tank 241-Z-361 was identified as an Unreviewed Safety Question in October, 1997. This Justification for Continued Operation provides an authorization basis for sampling the tank.

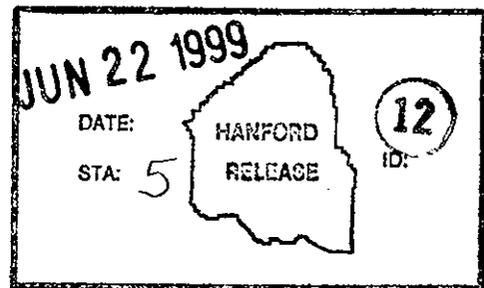
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JUSTIFICATION FOR CONTINUED OPERATION FOR TANK 241-Z-361

May 1999

Prepared by:
The PHMC Companies and



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EXECUTIVE SUMMARY

This justification for continued operations (JCO) summarizes analyses performed to better understand and control the potential hazards associated with Tank 241-Z-361. This revision to the JCO has been prepared to identify and control the hazards associated with sampling the tank using techniques developed and approved for use in the Tank Waste Remediation System (TWRS) at Hanford.

Tank 241-Z-361 is an inactive, underground storage tank located within the protected area of the Plutonium Finishing Plant (PFP). The tank is a reinforced-concrete, rectangular underground structure located near the east end of the south fence line of PFP between Building 241-Z and the retention basin. This settling tank received all low-salt, liquid effluent from the plant processes from 1949 to May 1973. As such, the tank contents are expected to include constituents from nearly all PFP processes used during that period, and be dominated by those from Buildings 234-5Z, 236-Z, and 232-Z. After 1973, the liquid from the tank was pumped leaving about 75 cubic meters of sludge in the tank. In 1985 the tank was sealed, including sources of ventilation.

On October 15, 1997 the Department of Energy declared an unreviewed safety question (USQ) existed for Tank 241-Z-361 based upon discovery that the potential hazards associated with the tank had not been previously evaluated in the development of the PFP authorization basis. The USQ evaluation noted the potential for flammable gas build up in the tank, unevaluated structural condition, and the potential for time-related phenomena to invalidate prior criticality analysis.

As part of the October 15, 1997 declaration of the USQ, the Department of Energy also accepted PFP's recommendations for interim operating restrictions. The controls were replaced by the controls approved in Revisions 0A and 1 of this JCO. This revision to the JCO is the second part of a phased-authorization to conduct activities to characterize this tank in preparation for remediation.

The previous revisions of this JCO indicated that the principal hazards of this tank are potential flammable gas build-up from radiolysis and structural degradation of the tank. The potential for inadvertent criticality has been shown to be extremely unlikely. Moreover, because the tank had almost 2,000,000 gallons of water flowing through it each year, it is very unlikely significant chemical reactants remain, but the potential for an organic-nitrate reaction cannot yet be excluded. Under previous revisions of the JCO the tank has been vented. As a result, the principal potential immediate hazard posed by this tank, flammable gas build-up, has been eliminated.

Newly authorized activities associated with this JCO include shortening the height of risers, installation of a truck bridge over the tank, and conducting core sampling (push-mode) of the Tank 241-Z-361.

Structural analysis of the tank has been performed to determine if undisturbed tank collapse is likely or if collapse is likely during the range of activities proposed in this JCO. There is uncertainty in the rebar condition and the rebar-concrete bond. As a result, a load test was completed to ensure adequate load capacity was available to complete Phase I activities. This test showed there has been no significant degradation of the tank top load bearing capacity up to 4000 lbs. Also, analysis has been performed of the load applied to the tank during past snowfall and by the past practice of parking an armored vehicle next to the tank. This analysis forms the basis for the load limits surrounding the tank established in this JCO.

The load limits established by previous testing and analysis are insufficient to allow placement of the TWRS sampling truck (32,000 lbs) directly on top of the tank. Based on previous analysis, placing the truck directly on top of the tank could potentially result in structural damage to the tank. As a result, this JCO authorizes the placement of a bridge over the top of the tank to bear the weight of the sampling truck. The load-bearing piers for the bridge are being installed sufficiently deep and in a configuration such that the load applied to the tank when the sampling truck is on the bridge will be within the limits stated in this JCO.

Prior analyses (see Section 2.3.2) indicated that this tank contained between 26 and 75 kg of plutonium. Material accountability records indicated that the tank contained about 31.2 kg of plutonium. Using the sampling data generated in the mid-1970's, the criticality hazard associated with this tank has been re-evaluated. This analysis shows the average plutonium density is 0.38 grams plutonium per liter (g Pu/l) -- 29 kg plutonium total inventory. This is below the minimum critical density of 4.7 g Pu/l for a waste sphere with a diameter of 86 inches. The 99% upper bound confidence interval for the average plutonium concentration is 0.61 g Pu/l, still well below the minimum critical density. Using the upper bound plutonium density, the plutonium areal density is 136 g/ft², which is below the minimum critical areal density of 240 g/ft². The k_{eff} for the tank was determined to be 0.13 and, even in the case of the worst-case hypothetical compaction and drying, k_{eff} was still very subcritical at 0.75.

Review of tank characterization data also shows that the plutonium is distributed relatively evenly throughout the tank. This makes the likelihood of finding a pocket with a sufficiently high plutonium concentration to achieve criticality extremely unlikely. As a result, this assessment concludes that the qualitative likelihood of criticality in this tank is extremely unlikely during sampling and storage activities, including the consequences of natural phenomena hazards. Even though extremely unlikely, controls for criticality have been proposed that will protect key assumptions, reduce residual risks, and address key areas of uncertainty.

Analysis of samples taken in the 1970's indicate the tank sludge solids are inorganic materials largely comprised of aluminum, calcium, and iron and other inorganic materials. Analysis for carbon content was generally under 1%, but one sample had 6% carbon. The source of the carbon is unknown but may be a combination of ash from the incinerator operations, carbonate from scrubbers, or small amounts of organic materials, such as tri-butyl phosphate. Although the

waste was reportedly neutralized to pH 8 prior to being placed in the tank, a March 1975 tank pH sample was measured at pH 4. This acidic tank pH may have been due to incomplete neutralization during operations, the discharge to Tank 241-Z-361 of un-neutralized nitric acid flushes of Tank D-7, or both. The potential for large, energy-releasing reactions within this tank was found to be extremely unlikely during the PFP chemical hazard assessment. Sampling is needed to confirm that an organic-nitrate reaction is not possible.

Although the tank contents do not appear to be capable of bulk or localized chemical reactions that can cause a significant hazard, hydrogen gas generation is expected because of the radiolytic decomposition of water. This hydrogen is being released through the vent installed on the tank during Phase I activities, and the tank atmosphere has been shown to be less than 25% of the lower flammability limit (LFL). Based on the analysis in this JCO, Tank 241-Z-361 will be treated as a Flammable Gas Category 3 tank for the purposes of establishing the appropriate flammable gas controls. In general, Flammable Gas Category 3 means the tank atmosphere is not flammable, but the tank is potentially capable of a localized gas release event (GRE) during waste disturbing events such as push-mode core sampling.

The substantial experience developing Tank Waste Remediation System (TWRS) controls for flammable gas has been used to develop flammable gas and other hazard controls for this tank. The TWRS flammable gas controls are applicable because the flammable gas hazard is similar to that found in TWRS tanks. Tank farm control development considered both the steady-state and episodic release of flammable gas. Tank farms controls were developed from the conservative standpoint that a flammable gas concentration could exist and therefore ignition sources must be prevented, and the atmosphere will be monitored and maintained below lower flammability limits where possible. The activities being undertaken for Tank 241-Z-361 are the same as those conducted within the tank farms. Moreover, the process history, sampling data, and preliminary hazard analysis (PHA) do not indicate that a hazard exists in Tank 241-Z-361 that was not contemplated in the development of the TWRS controls. As such, use of the TWRS controls during Tank 241-Z-361 activities offers the same accepted degree of hazard control that is achieved in tank farm operations. The hazard and accident analysis provided in the TWRS authorization and safety basis are not repeated in this JCO.

For unique hazards associated with activities associated with Tank 241-Z-361 a preliminary hazards analysis (PHA) has been performed to systematically evaluate the hazards. The PHA postulates four principal hazards to the public and on-site workers associated with this tank: flammable gas ignition, structural collapse, pressurized releases from the tank, and inadvertent criticality. The PHA identifies the types of controls needed to prevent or mitigate these hazards. This PHA also identifies controls needed to protect facility workers during the proposed work. All controls to will be implemented through the PFP work planning and control process, and reviewed by the PFP Plant Review Committee (PRC).

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1.0 INTRODUCTION

Tank 241-Z-261 is an underground inactive settling tank within the protected area of the Plutonium Finishing Plant (PFP). It is approximately 240 feet south of Building 236-Z. (Figure 1-1) This settling tank received all low-salt (caustic) liquid effluent discharged from plant processes from 1949 to May 1973. As such, the tank contents are expected to include constituents from nearly all PFP processes used during that period, and be dominated by those from Buildings 234-5Z, 236-Z, and 232-Z.

As part of the 1997 PFP chemical hazard assessment (Ref 1-1), the tank was evaluated to decide whether the hazards present were evaluated and controlled within the current PFP authorization basis. This review identified that the potential hazards associated with the tank, primarily that associated with a potential hydrogen concentration increase, had not been evaluated in the formulation of the current PFP authorization basis. Also, concerns were raised regarding the structural integrity as a result of corrosion and the potential for inadvertent criticality. Accordingly, a potential inadequacy in the PFP authorization basis was identified per DOE Order 5480.21, "Unreviewed Safety Question" (Ref 1-2). After completing its evaluation, on September 24, 1997, PFP recommended to DOE-RL that an unreviewed safety question (USQ) be declared (Ref 1-3). In this letter PFP also transmitted to the Department the operating restrictions imposed. On October 15, 1997, the Department of Energy accepted the recommendation that a USQ existed and agreed to the interim controls (Ref 1-4).

In its October 15 letter, the Department further directed the preparation of a Justification for Continued Operations (JCO). Phase I of this JCO provided a basis for DOE to approve the controls needed to open the tank safely. The tank is currently being managed using the controls provided in Revision 1 to this JCO.

This phase of the JCO (Revision 2) addresses characterization. This two-phased approach allowed resolving flammable gas concerns and assessing the physical condition of the sludge (dry or wet) before characterization activities were authorized. This phased approach limited the need for overly-conservative speculative hazard controls.

Once the tank is characterized, further steps to establish a final authorization basis may be undertaken. This phased approach to establishing an authorization basis is consistent with DOE Order 5480.23, "Nuclear Safety Analysis" and DOE Standard 3011-94, "Guidance for Preparation of DOE 5480.22 (TSR) and DOE 5480.23 (SAR) Implementation Plans."

The hazard categorization of this tank has also been determined to evaluate the types of safety analysis appropriate for this facility. Appendix A documents an initial hazard categorization of this tank per DOE-STD-1027-92. If this tank were a stand-alone facility, it would be designated Hazard Category 2. This classification is consistent with that of the overall PFP complex. Accordingly, this tank requires performance of a formal nuclear safety analysis to define and control potential hazards.

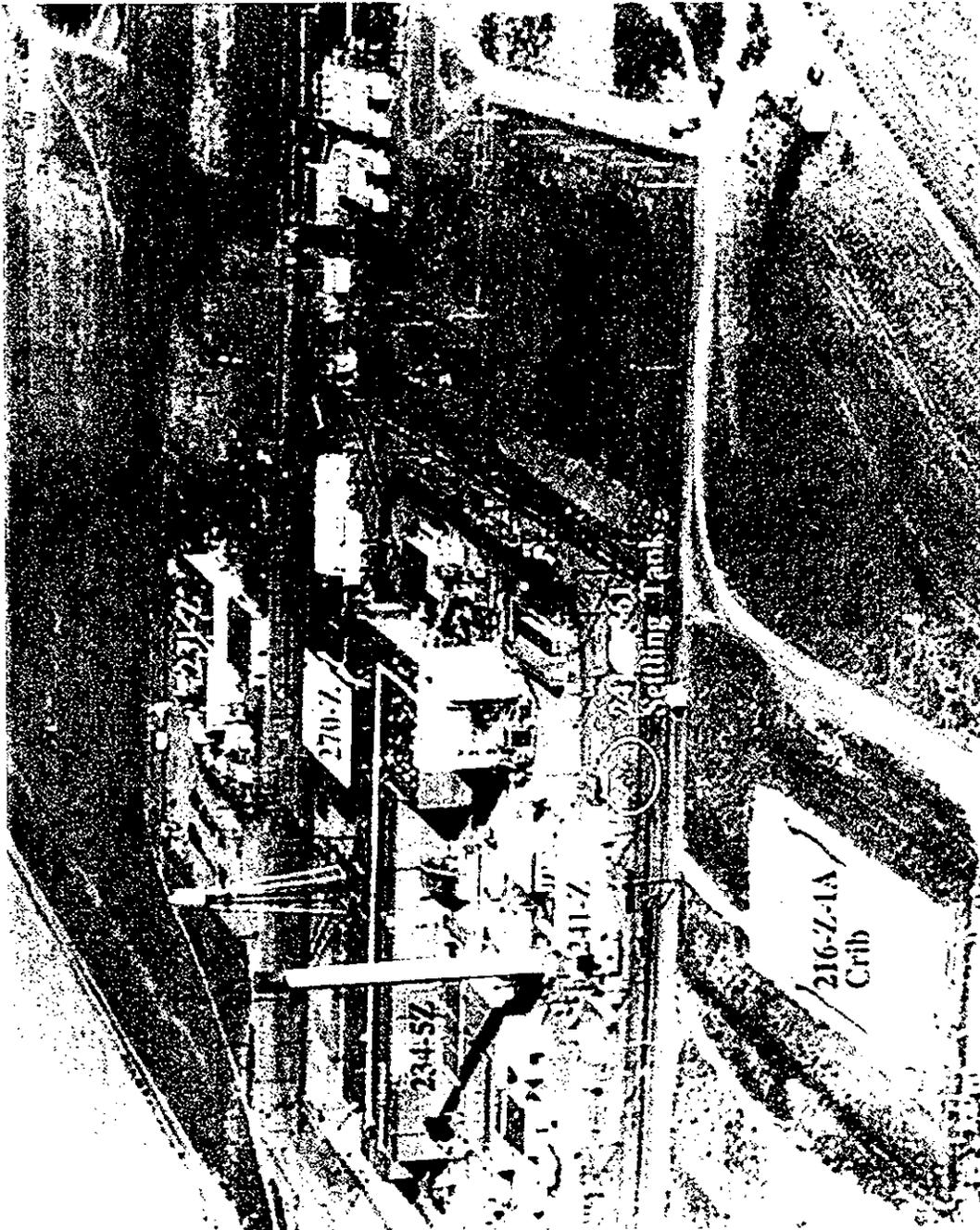


Figure 1.1-1 PFP Facility

1.1 References

- 1-1. Weiss, E.V. and Wittman, G.R., August 1997, *Plutonium Finishing Plant Chemical Hazard Assessment*, HNF-SD-CP-HA-001, Richland WA.
- 1-2. USQ, 1997, *TK-241-Z-361 -- Potential Discovery*, ID No. PFP-97-12, Unreviewed Safety Question Screening and Evaluation.
- 1-3. Redekopp, *Unreviewed Safety Question (USQ) Discovery for Tank 241-Z-361*, BWHC-9757164 R2, September 24, 1997.
- 1-4. Wagoner, John D., 1997, *Contract No. DE-AC06-96RL13200- Unreviewed Safety Question (USQ) Regarding Plutonium Finishing Plant (PFP) Tank 241-Z-361*, DOE-RL Letter 97-TPD-193, October 15, 1997.

2.0 BACKGROUND

2.1 TANK LOCATION AND DESCRIPTION

Tank 241-Z-361 is constructed of reinforced concrete, and is a rectangular underground structure located near the east end of the south fence line of the PFP between Building 241-Z and the retention basin, 240' south of 236-Z. The tank is 26 feet long and 13 feet wide and varies in depth between 17 feet deep at the inlet (north end) and 18 feet deep at the outlet (south end). The base mat is 9 inches thick with grout and waterproofing added for a total thickness of 12 inches. All walls are 12 inches thick and the roof is 10 inches thick. The top of the tank was sealed with 1/4" mastic and approximately 4 inches of concrete were poured over the mastic with 2"x 2" 14 gauge reinforcement mesh. The elevation of the top of the tank is 672' 6". (Figure 2.1-1) Grade level elevation is 674' 6".

The interior of the tank was lined with 3/8" carbon steel on the bottom and up the sides to within 6" of the roof. A protective coating was placed between the liner and the concrete as a corrosion barrier. Two 6" stainless steel pipes lead into the tank (from the retention basin and 241-Z) at the north end of the tank and one 8" stainless steel pipe forms the discharge at the south end of the tank. Baffle boxes were installed around the inlet and discharge pipes, and attached to the liner. The bottom of the inlet piping is elevation 669' and the bottom of the discharge pipe is elevation 668'.

The tank roof has three large penetrations and eight riser penetrations (Figures 2.1-2, 2.1-3). A three foot manhole exists at the north end on the tank on the centerline, centered 2' 8" from the outside wall of the tank. A second manhole is centered 1' 3" west of the centerline, 2' 8" from the south outside wall of the tank. The third large penetration is a four foot diameter concrete plug in the geometric center of the tank roof. There are two 8" risers, one 2" riser and one 3" riser built into the south west corner of the tank, and one 3" riser built into the northeast corner of the tank. One 6" riser penetration was installed through the concrete plug, and two 8" riser penetrations were installed north of the center plug.

Figure 2.1-1 - Side View Tank 241-Z-361

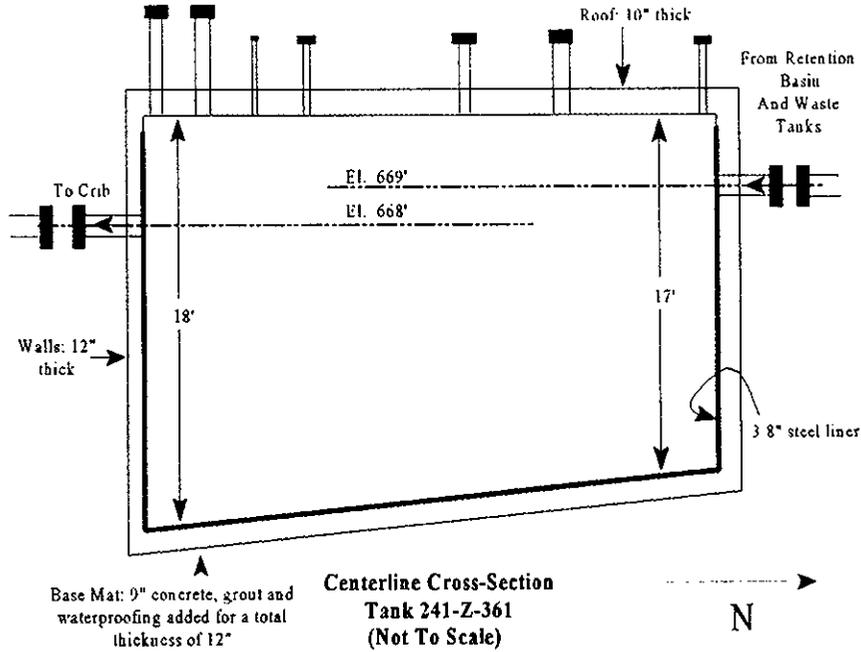
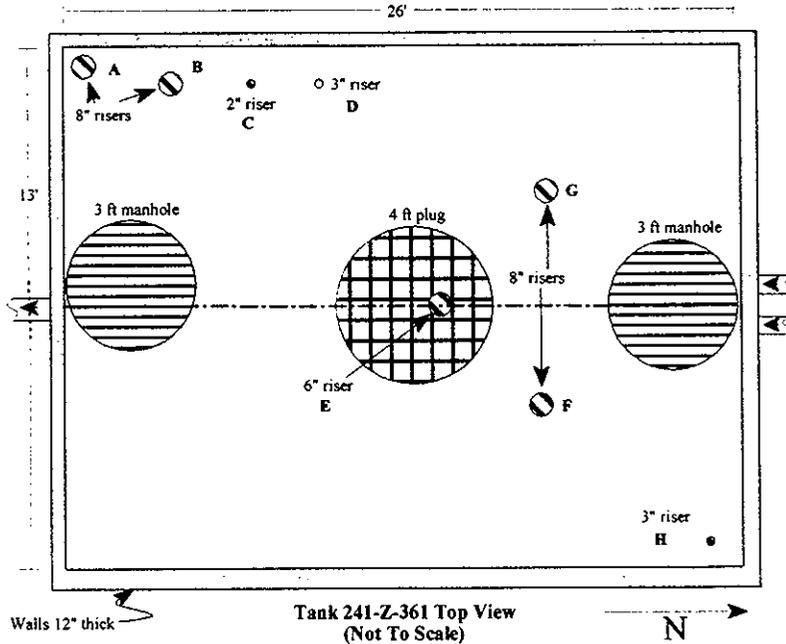


Figure 2.1-2 - Top View Tank 241-Z-361



Previous photographs show the liner plate (elevation 668') appears to be corroded away down to the sludge (Figure 2.1-4). More recent videographs (Phase I of this JCO) suggest the liner plate is in better condition than anticipated. Unexpectedly, the video revealed that 5 dry wells are installed in the tank, although historical information indicated their removal. Dry wells appear to be installed in both 3-ft concrete manholes (See Figure 2.1-2). Dry wells are also installed in risers F and G. The recent video also shows the tank walls to be in apparently good condition. The tank top showed more cracking than was expected.

The sludge is approximately 94 inches deep. One of the south end 8" risers had a dry well installed, and it is removed or corroded away. The inlet and outlet pipes have been isolated and plugged or flanged two feet from the outer wall of the tank. The reinforced concrete poured over the top of the tank has been removed over the two manholes and the tank was opened for sampling in the mid 1970's. The manhole covers were subsequently reinstalled, covered with weather covers and buried. The tank is covered with approximately two feet of soil.



Figure 2.1-3 - Risers for Tank 241-Z-361



Figure 2.1-4 Tank 241-Z-361 Interior

2.2 PROCESS SOURCES OF TANK CONTENTS

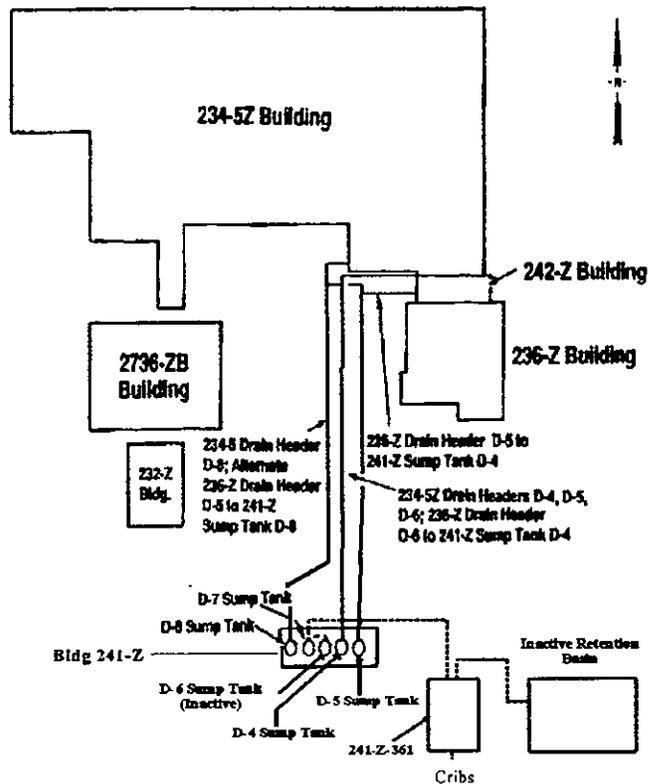
A study has been completed of the processes that resulted in effluent to Tank 241-Z-361 (Ref 2.2-1) in order to evaluate the contents of the tank for potential hazards and to determine the range of potential contents for planned characterization activities. Records of transfers into the tank, past characterization efforts, and scientific experience/judgement were used to estimate the current condition of Tank 241-Z-361 and its contents.

2.2.1 Background

The Plutonium Finishing Plant was built in 1948 and began processing plutonium in mid-1949 with Tank 241-Z-361 as part of the low-salt waste disposal path from all PFP processes including the Incinerator, the Plutonium Reclamation Facility and the Waste Treatment Facility. The Incinerator (232-Z) operated from December 1961 until May 1973. The Plutonium Reclamation Facility (PRF, 236-Z) began operation in May 1964. The Waste Treatment Facility (242-Z) operated from August 1964 until August 1976. Waste from some processes and laboratories went through transfer lines to Building 241-Z sump tanks. High salt and organic waste under normal operation were sent to the Z-9 or Z-18 cribs.

The transfer lines to Building 241-Z were numbered D-4 to D-6 as represented in Figure 2.2-1. (Note: there were several different configurations of the PFP drain system, Figure 2.2-1 identifies the general flow path to Tank 241-Z-361 and then to the cribs.) The 241-Z sump tanks were numbered D-4 through D-8. The D-4, 5, and 6 drains went to the D-6 sump tank. When D-6 tank was full it was transferred to D-7 tank. The D-6 sump tank eventually failed and D-7 was used in its place. Prior to transfer to cribs, the D-7 tank contents were sampled. If the plutonium content was analyzed to be more than 10 g per batch, the material was generally sent to be reprocessed. Below the plutonium discard limit, caustic was added and the material was sent to the cribs via Tank 241-Z-361 where solids settled out and the liquid overflowed by gravity to the cribs. Accordingly, the materials discharged via Tank 241-Z-361 would be expected to generally have been low in plutonium concentration.

Figure 2.2-1 - PFP Drain System



In addition to drain lines, an unquantified (but large) amount of process water was discharged from the retention basins to the cribs via Tank 241-Z-361.

Waste liquids that passed through the Tank 241-Z-361 settling tank flowed from PFP to ground in the following sequence: Processes to D-4, D-5, D-6 Drains to D-6 Sump Tank to D-7 or D-8 Sump Tank to 241-Z-361 Settling Tank to cribs.

2.2.2 Processes

Low-salt waste going through Tank 241-Z-361 generally consisted of large volumes of water containing relatively low concentrations of chemicals in contrast to the "high-salt" waste that went to Cribs Z-9 or Z-18. Process streams volumes and plutonium mass contributing to the low-salt waste for a typical year (1969) are listed in Table 2.2-1.

- Each of these process streams contributed some unique waste constituents and would only be discharging to Tank 241-Z-361 while that process was in use. Cooling water was sanitary water in closed lines that did not come in contact with chemicals or radioactive material.
- Laboratory wastes may have contained almost anything, and there is virtually no information about its constituents. The small volume coupled with large dilutions with the process streams make it unlikely they contributed enough material to be of concern.
- The incinerator burned a variety of materials including organic chemicals, paper and plastic. A caustic off-gas scrub solution was used to trap acid fumes, combustion products and fine particles. The incinerator operated intermittently from December 1961 to May 1973. It was estimated that 600 grams of the 870 grams of plutonium sent in 1969 to Crib Z-12 via Tank 241-Z-361 were from the incinerator.

Table 2.2-1 Typical Low-Salt Aqueous Process Streams in the Plutonium Finishing Plant (Circa 1969) [Ref 2.2-1]

Stream	Drain	Source	Thousands of Gallons/Yr.	Plutonium Grams/Yr.	Chemical Contaminant
Uncontaminated lab wastes	D-4,5	Cooling water for equipment in labs	127	0	None
Contaminated lab wastes	D-4,5	Lab drains	174	100	Miscellaneous lab chemicals
Waste treatment aqueous waste	D-6	Ion exchange process	86	60	Principally Al, Ca, Mg, nitrate
Incinerator scrubber solution	D-6	Spent caustic from scrubber	6	600	Considerable Na
Reclamation condensate	D-6	Process concentrators	54	12	Slight
Fluorinator off-gas jet	D-6	Water for vacuum jet	1906	100	hydrogen fluoride
Total			2353	872	

- There is little known about reclamation condensate except that the chemical contaminants were considered "slight".
- Fluorinator off-gas jet and scrubber solutions from hood HC-9A and HC-9B on the "Button Lines" contributed the largest volume of waste to D-6. These were responsible for failure of D-6 due to corrosion. The HF concentration was approximately 0.06 M.

Large amounts of water were flushed through Tank 241-Z-361. The discharges to the tank were generally dilute. Accordingly, even slightly soluble materials and suspended materials were likely flushed from Tank 241-Z-361 and discharged to the cribs. Moreover, materials sent to Tank 241-Z-361 were steam jetted. Compounds with low boiling points would be expected to have been vaporized and released through vents then existing in the tank. Other than the laboratories, there are no processes that discharged reactants that would be reasonably capable of generating large, exothermic reactions. The laboratory chemicals discharged would be small quantities and well diluted, and therefore not likely to present a significant hazard. Combined these factors suggest there should be very little if any significant chemical reactants in this tank. However, some of the organic materials used are heavier than water (but not the sludge-water density) and may exist in layers. As such, the potential for organic or organic-nitrate reactions cannot be completely excluded.

From the foregoing example typical of when the incinerator operated, the principal source of plutonium in Tank 241-Z-361 was the incinerator. Extrapolating that single year example, the plutonium inventory would be expected to be on the order of 20 kg.

Material Unaccounted For (MUF) records can be used to refine this estimate. These records identify material that was discharged to various PFP cribs. There was no measurement performed at the cribs that provides the actual plutonium received in the cribs. If instead we assume that plutonium settled in Tank 241-Z-361 and none got to the cribs, then the records of discharges with Tank 241-Z-361 in the flow path provides a conservative estimate of the plutonium in Tank 241-Z-361 based on MUF records. Using this assumption that all plutonium settled in Tank 241-Z-361, then about 31.2 kg of plutonium is in this tank, as shown below (Ref 2.2-2):

Discharges With Tank 241-Z-361 In The Flow Path	
<u>Crib Recorded As Having Received The Discharge</u>	<u>Plutonium (grams)</u>
Z-1 & Z-2	199
Z-3	5,698
Z-12	<u>25,300</u>
Total	31,197

As will be seen in Section 4.2, this 31.2 kg plutonium closely matches the estimate of 29 kg plutonium established during the criticality analysis.

How that plutonium is deposited within the tank is also important, particularly to determine the likelihood of inadvertent criticality. If the sludge deposition rate is assumed to be proportional to the volume discharge, these discharge records can be further developed into annual plutonium discharges as a function of sludge depth in Tank 241-Z-361 as shown in Table 2.2-2 (Ref 2.2-2).

Table 2.2-2. Calculated Plutonium Concentration in Tank 241-Z-361 if Sludge Deposition Is Assumed Proportional To Volume Discharged ^a

Year	Volume Percent	Plutonium, g		Plutonium Concentration (g Pu/L)	Layer Top (cm from bottom)
		Estimated ^b	Adjusted ^c		
1949 - 1958	8.4 ^d	2,000	2,302	0.357	20.5
1959	13.7	1,276	1,469	0.140	54.0
1960	14.5	2,508	2,887	0.260	89.4
1961	13.7	3,592	4,135	0.394	122.7
1962	8.2	2,844	3,274	0.519	142.8
1963	7.5	3,842	4,422	0.772	161.1
1964	6.2	3,199	3,682	0.772	176.2
1965	5.7	1,864	2,145	0.495	190.0
1966	5.0	767	883	0.232	202.2
1967	3.9	1,035	1,191	0.396	211.8
1968	2.0	680	783	0.517	216.6
1969	2.2	517	595	0.360	221.9
1970	1.2	650	748	0.842	224.7
1971	2.8	1,067	1,228	0.583	231.4
1972	3.9	939	1,081	0.359	241.0
1973	1.2	327	376	0.421	243.8
Total or Average	100.0	27,100	31,200	0.408	243.8

^a Solids deposited assumed proportional to total waste passing through tank

^b This column is for wastes routed to Crib Z-12.

^c Plutonium quantities adjusted to make total equal to estimated total discharged to Tank 241-Z-361 from all sources.

^d Volume of solids for 1949-1958 chosen to make plutonium concentration equal to measured value of 0.36 g/L.

Table 2.2-3 has been prepared to help compare the expected values from Table 2.2-2 and the values measured during prior tank characterization activities (Section 2.3). The measured values were grouped and averaged for 20-inch intervals. Similarly, the estimated concentrations were grouped and averaged for 20-inch intervals.

Table 2.2-3 Plutonium Concentrations in 20-inch Increments above the Floor of Tank 241-Z-361

Layer in.	Average From Records Pu g/l	Average Measured Pu g/l
0-20	0.25	0.35
20-40	0.29	0.38
40-60	0.52	0.52
60-80	0.56	0.35
80-top	0.46	0.21

This comparison is graphically represented in Figure 2.2-2 (Ref 2.2-2). This shows the expected values compare well with the measured values. Furthermore, Figure 2.2-3 (Ref 2.2-2) demonstrates the horizontal distribution of the plutonium is also reasonably uniform. Together, these tables strongly suggest that the sludge has been deposited in reasonably simple layers with Pu concentrations varying within a factor of 2 of the average.

Table 2.2-4 (Ref 2.2-1) shows a broad range of chemical constituents that could potentially be present in Tank 241-Z-361 based on laboratory and process reviews. Although process history strongly suggests any reactants of concern would have been flushed to the cribs, the existence of organic-nitrate reactants cannot yet be excluded. Moreover, some of the potential sludge components represent materials with specific exposure limits (Cd, Pb) under occupational health requirements. Exposure will need to be controlled accordingly. An estimate of the mass of chemicals in the low salt waste from all sources in 1969 is given in Table 2.2-5 (Ref 2.2-1).

Figure 2.2-2 - Average Pu Concentration at Given Depth
Tank 241-Z-361

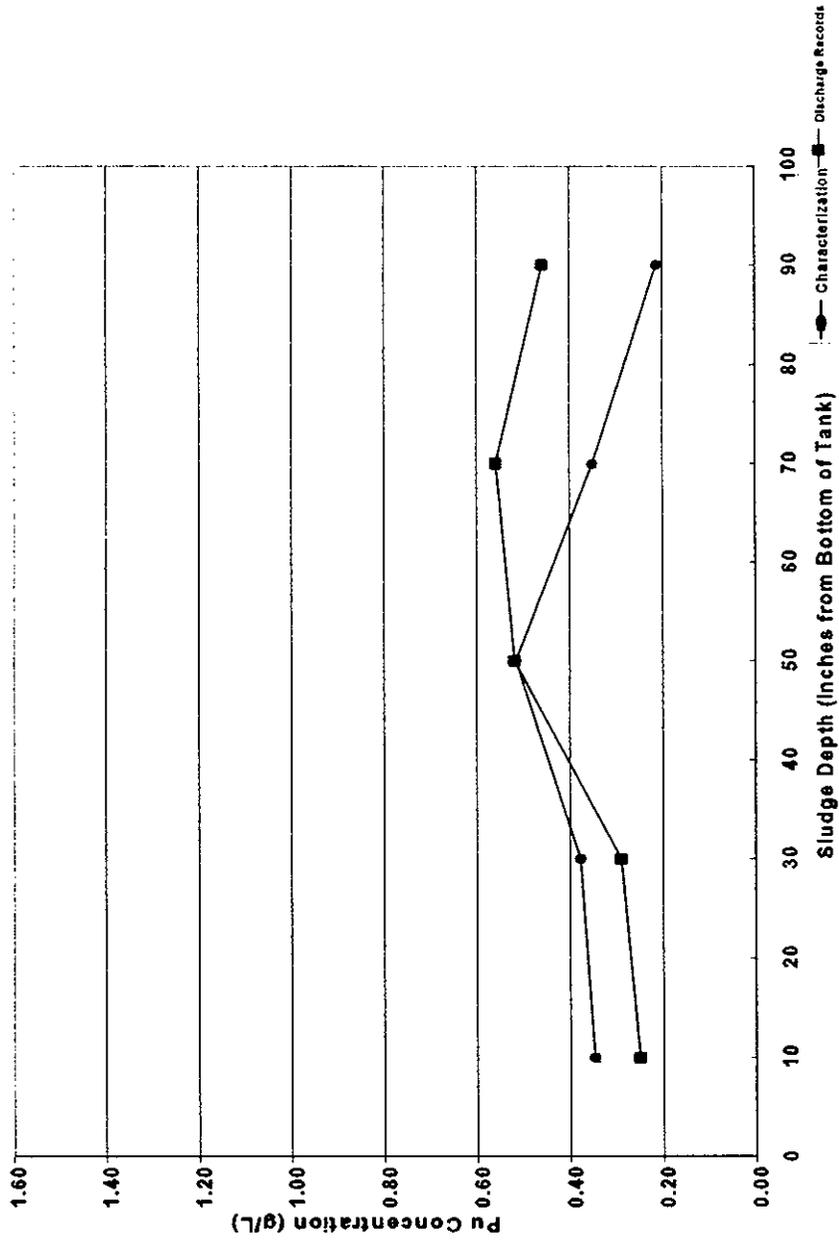


Figure 2.2-3 Average Pu Concentration vs Location
Tank 241-Z-361

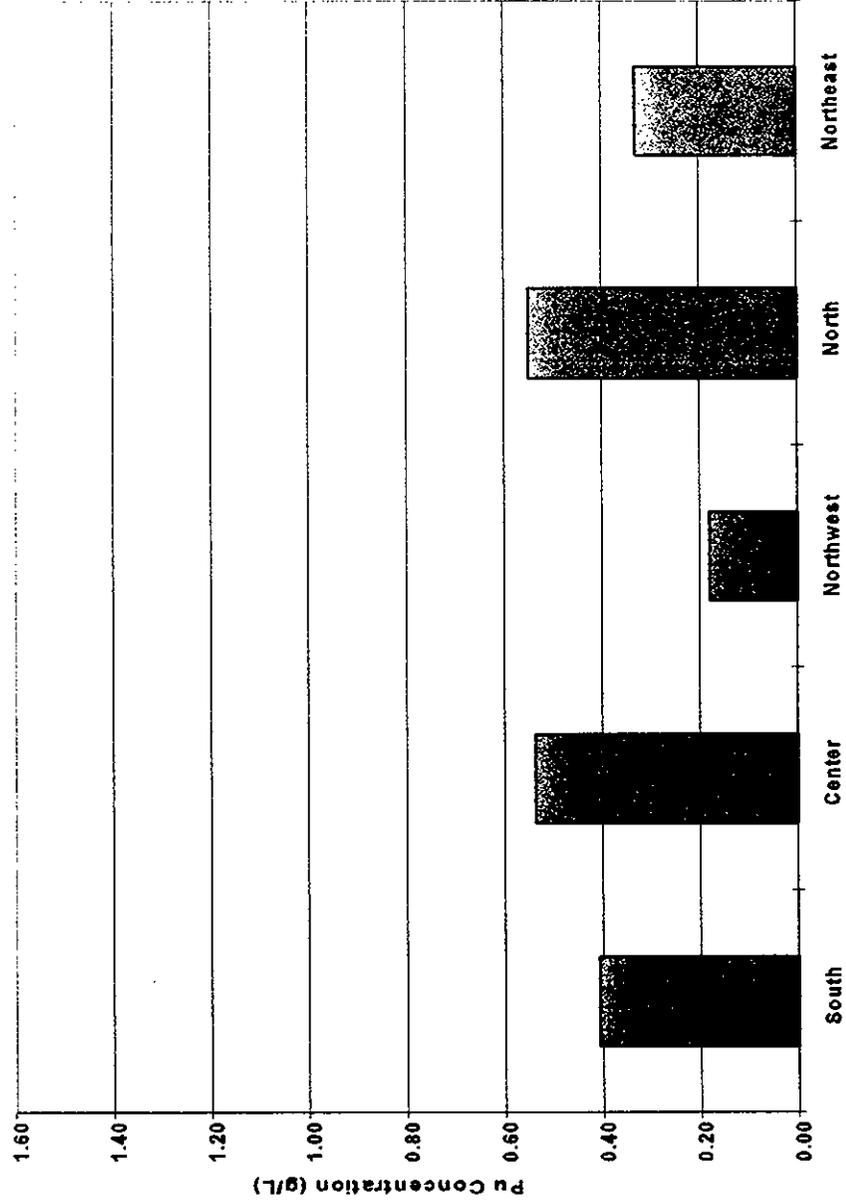


Table 2.2-4. Known and Probable Components of 241-Z-361 Tank Sludge.

Type of Component	Component	Probable Source
Known Metals	Al	Waste Treatment
	Na	Incinerator Off-gas Treatment
	Ca	Waste Treatment
	Si	Incinerator Off-gas Treatment
	Cd	Most likely an analytical artifact
Known Non-Metals	F ⁻	Hydrogen Fluorinator
	Cl ⁻	Waste Treatment
	C (organic or total?)	Incinerator Off-gas Treatment
	H ₂ O	All
	H ⁺	All
Probable Metals	Pb	Incinerator Off-gas Treatment
	Mg	Waste Treatment
	Mn	Waste Treatment
	Cr	Corrosion of SS Equipment
	Ni	Corrosion of SS Equipment
	Ag	Lab Film Processing
Probable Non-Metals	NO ₃ ⁻	Waste Treatment
	NO ₂ ⁻	Radiolysis of NO ₃ ⁻
	SO ₄ ²⁻	Waste Treatment
	PO ₄ ³⁻	Degradation of TBP
	CO ₃ ²⁻	Incinerator Off-gas Treatment
Probable Organics	CCl ₄	Waste Treatment
	DBBP	Waste Treatment
	TBP	Waste Treatment
	DBP	Degradation of TBP
	MBP	Degradation of TBP
	Butanol	Degradation of TBP
	Urea	Incinerator Off-gas Treatment
	Lard Oil (Triolein)	Waste Treatment
	Oxalic Acid	Waste Treatment
	Acetic Acid	Incinerator Off-gas Treatment
	Benzene	Incinerator Off-gas Treatment
Phthalic Acid	Incinerator Off-gas Treatment	
Known Radionuclides	Pu	All
	Am	Decay of Pu ²⁴¹
	U	Waste Treatment

Table 2.2-5. Chemicals from Processes that Discharged to Low-Salt Waste in 1969

Chemical	Weight/year	Chemical	Weight/year
Plutonium	870 g	Aluminum	96 kg
Calcium	320 kg	Sodium	7,394 kg
Magnesium	128 kg	Fluoride	6,100 kg
Manganese	13 kg	Nitrate	19,904 kg

2.2.3 References

- 2.2-1 Jones, S.A., BWHC, 1997, *Tank 241-Z-361 Process and Characterization History*, HNF-1989, Richland, Washington.
- 2.2-2 Lipke, E.J., Rogers, C.A., Miller, E.M., et al., 1997 *Engineering Study Of The Criticality Issues Associated With Hanford Tank 241-Z-361*, HNF-2012, Rev. 0, Richland, Washington.

2.3 CHARACTERIZATION HISTORY

2.3.1 Characterization

Tank 241-Z-361 was characterized in the mid-to-late 1970's as described in HNF-1989 (Ref 2.3-1) and HNF-2012 (Ref 2.3-2). The main focus of that characterization was on the Pu content of the sludge, the distribution of Pu, and the presence of various nuclear poisons.

The sludge was found to vary greatly in solids content, but to be on average 30 percent solid material with the rest being liquid (mostly water). The sludge was deposited in layers from the various operating campaigns, and exhibits considerable variability in consistency. Tables 2.3-1 (Ref 2.3-1) and 2.3-2 (Ref 2.3-2) portray the sludge appearance and non-radioactive content based upon core sampling.

Little is known regarding the routine acidity of the wastes sent to the settling tank, other than the general guidance that the waste was to be neutralized. However, one pH sample was measured at 4.0 in March 1975. The corroded carbon steel liner indicates that some wastes were not completely neutralized or the acidic flushes of Tank D-7 caused a low tank pH, or more likely both. Likewise, while some organic materials have likely entered the tank, carbon has not been found except for in a few samples. Most carbon detected was about 1%, but the carbon concentration was as high as 6% in one sample. This could be as carbon from fly ash in the incinerator scrubber solution, carbonate from neutralization and absorption into caustic solution, or from organic compounds. Most likely it is from a combination of all of these sources. There has been no separate organic phase identified in the tank.

Table 2.3-1. Sample Descriptions for 1977 Sludge Sample.

	Sample Description
NW-1	Dark Brown -almost Black - loose -wet
NW-2	Color of Sample 1 - thicker
NW-3	Small amount of free liquid on top Color of sample 1 - thicker than 2
NW-4	Dark brown -lighter than 2- thinner
NW-5	Lighter color than 4 - very watery - thin soup
NW-6	Thicker than 5 - lighter color than 5 - gritty - sandy
NW-7	Thicker than 6 - dark tan color - pasty, creamy consistency
NW-8	Same as 7 except lighter color
NW-9	Free liquid on top - only slightly darker color than 8 - same consistency
NW-10	Same as 9
NW-11	Tan-brown Same as 10 - slightly darker
NW-12	Lot of liquid on top. Lt. brown darker than the five samples above

Table 2.3-2 Component Concentrations in Air Dried Tank 241-Z-361 Solids

Component	Northeast Core g/L	Southwest Core g/L	Center Manhole Bottle g/L	
			Sample #8	Sample #9
Aluminum	71.8	304.0	---	290.3
Calcium	345.0	460.0	322.4	213.6
Cadmium	< 3.8	< 3.4	< 0.4	0.9?
Iron	230.9	562.2	59.0	74.0
Sodium	18.6	40.5	6.3	200.4
Silicon	10.5	10.4	4.4	8.3
Oxygen	20.	200.	---	---
Hydrogen	0.6	60.	---	---
Carbon	46.	87.2	---	---
Chloride	---	34.2	---	---
Fluoride	---	3.9	---	---

2.3.2 Plutonium Contents

Extensive work was done to determine the plutonium concentration in Tank 241-Z-361 between 1974 and 1978. Efforts included making estimates of the plutonium in the liquid waste streams released from PFP to the tank; chemically analyzing grab samples of liquid and sludge taken with bottles; full height and partial height core sludge samples taken with 2 and 3-inch diameter core drills at five locations at each end and center of the tank; and measurements by foils and BF₃ neutron detectors at four locations. The data from all sources showed a consistently low plutonium concentration.

Two families of sample data have been generated for the contents of this tank: 1975 and earlier and 1977 and later. Plutonium concentrations for 1975 data are more than twice as high as data from 1977 and later. In 1976 corrected plutonium concentrations were calculated. The correction involved recalculating the percent volume solids. This recalculation of the earlier results yielded 17 to 86 percent reductions in the plutonium concentrations. The recalculated plutonium concentrations still have a significant error that yields values that are high by about a factor of two. This error arises from the fact that the volume of water evaporated from the filtered solids was not accounted for in the calculated sludge volume.

The plutonium concentration and neutron measurements for 1977 data are more consistent. Discharge records and material accountability records are also more consistent with measured plutonium inventories for the 1977 data. Accordingly, the 1977 data has been evaluated as the most reliable.

Section 4.2 and its references describes in detail the analysis of the 1977 data. In summary, this analysis identified that the average plutonium concentration is 0.38 g Pu/l. The 99% confidence interval density is 0.61 g Pu/l. The average plutonium concentration translates to a total plutonium inventory of 29 kg, and the 99% confidence interval concentration equates with 46 kg. This inventory range is consistent with the inventory expected from review of the discharge records.

2.3.3 Recent Atmosphere Samples

When Tank 241-Z-361 was opened to install passive, filtered ventilation, initial samples were collected. These samples did not identify any significant hydrogen or organic vapors of concern. A larger sample has been drawn and is undergoing more detailed analysis.

2.3.4 References

- 2.3-1 Jones, S.A., BWHC, 1997, *Tank 241-Z-361 Process and Characterization History*, HNF-1989, Richland, Washington.

- 2.3-2 Lipke, E.J., Rogers, C.A., Miller, E.M., et al., 1997 *Engineering Study Of The Criticality Issues Associated With Hanford Tank 241-Z-361*, HNF-2012, Rev. 0, Richland, Washington.

2.4 SUMMARY

Tank 241-Z-361 is known or suspected to have received waste in large volume from all of the sources identified above. The waste was very dilute, with upwards of 2,000,000 gallons per year flowing through the tank. The sludge represents a small portion of that large volume stream, with potential constituents shown in Table 2.2-4. Significant amounts of highly reactive or combustible materials are not expected, and no controls are proposed specifically for them. However, even if encountered, the controls applied for flammable gas safety (Section 5.0) are at least as restrictive as those that would be applied to control chemical reaction hazards.

As noted in the characterization sections, the predicted tank constituents from process chemistry analysis match reasonably well the measured tank contents, particularly with respect to plutonium. The characterization data supports an average plutonium concentration of about 0.38 g Pu/l, also consistent with process history records. Accordingly, there is a strong basis to judge that the plutonium inventory of Tank 241-Z-361 is on the order of 30 kg and that the plutonium has been distributed in relatively uniform layers across the tank.

3.0 PLANNED OPERATIONS UNDER JCO

The planned approach to accessing and characterizing Tank 241-Z-361 has involved the use of a two-phased authorization in order to ensure that certain of the potential hazards are properly understood and controlled prior to undertaking the more complex characterization activity. This approach was developed based on the initial hazard evaluation conducted. (Ref. 3-1.) This approach reduced the level of speculative hazards analysis and contingency planning that must be done, and has been more conserving of the scarce PFP resources while preserving the level of safety provided.

During Phase I activities, the tank has been load tested, vented, vapor sampled, been inspected with video, and had a continuous, filtered vent installed on Riser H of Figure 2.1-2. Load testing has shown that the tank top can safely carry 4000 lbs a 2000 lbs load limit for the tank top was selected to be conservative. Phase I efforts have relieved any potential build-up of flammable gases in the tank. With passive ventilation through the filtered vent, the tank is no longer potentially pressurized and will remain less than 25% of the lower flammability limit (LFL). This condition for the tank is the assumed beginning condition for the work activities described in this section for Phase II of this JCO.

3.1 INTERFACES

The planned work will involve more than one work force, performing work in series so that no confusion exists regarding field work control. All work forces will be operating under the same PFP work release process. The PFP Shift Manager will release the work.

This JCO will serve as authorization basis for all work forces, and will be administered under the PFP administrative controls for authorization bases. Access controls will be used to administer all the controls specified in Section 5.0. Access will only be permitted under an approved work instruction, and the review and approval of those work instructions will be the mechanism for ensuring application of the controls associated with work activities described in this JCO. All work controls, including radiological, industrial hygiene, criticality, job hazards analysis and application of JCO controls to work processes involving the tank will be implemented through the work control procedures. As specified in Section 5.2.2, work procedures will be reviewed by the PFP PRC on PRC clearance to ensure implementation of the controls specified in this JCO, and they will be released by the PFP Shift Manager through the PFP work control process.

3.2 WORK DESCRIPTION AND LOGIC

Phase II activities have been established to complete the characterization of the tank. The desired tank samples have been specified using the data quality objectives process (Ref 3-6). This process systematically develops an agreed set of samples and sample locations that will ensure sampling objectives are satisfied. The primary purpose of these samples is to gather the data needed to

develop a remediation plan for the tank. In some cases, the information developed will help reduce uncertainty regarding some tank hazards, such as the potential for unplanned criticality.

Section 3.2.1 describes the activities that were conducted during Phase I. In some cases, the analysis of these activities has been used to support performance of like activities that will be performed during Phase II. As a result the descriptions of the activity and the associated analysis have been retained in this revision to the JCO. Those elements of Phase I activities necessary to complete Phase II activities remain authorized, e.g., riser flange asbestos abatement, and they may be implemented using the flammable gas controls specified in Section 5.0. Since the flammable gas hazard has been eliminated or controlled, the risk associated with the activities approved for Phase I has been reduced from that identified in previous revisions of this JCO. Section 3.2.2 describes the activities that will be performed during Phase II.

3.2.1 Phase I Work Activities

This section describes activities that were analyzed during Phase I of the JCO (Revision 1) and the planned order they were conducted in to perform Phase I activities.

- 1) Radiological survey and toxic vapor survey of the risers to be opened were performed, and neutron and gamma measurements obtained from the exterior at one or more risers. No flammable gases were detected. No radiological dose rates above background were detected
- 2) The risers were inspected and prepared for opening. This included taking measurements for riser adapters, fabrication of required hardware, staging adapter and filter assemblies at, or over, the riser, staging asbestos abatement and riser preparation tools, and all other qualified tools required to safely open the riser.
- 3) A glovebag was installed around the riser with HEPA filtration to control contamination upon tank opening. The bolts holding the riser flange were replaced one at a time with bolts made of non-sparking materials. Inert gas was staged to provide a purge for the glovebag and the tank if needed.
- 4) Any pressure in the tank was then relieved and the riser flange removed. The flange was raised by slowly loosening the riser flange bolts in incremental steps. To prevent excessive rates of tank venting, the tank was vented through a small orifice. The rate of venting was controlled through controlled loosening of the flange bolts. The flow rate was controlled to prevent over-pressurization of the glovebag, damage to the HEPA filters, or ripping the glovebag due to high flow rates. The atmosphere in the glove bag was continuously monitored while work was in progress until the breather filter is installed. Once the tank was vented and a relief path was verified, a non-sparking insert was slid between the riser and the flange to prevent inadvertent contact between them. The flange was then lifted off

the riser. To ensure the local region of the tank was less than 25% of the LFL, an inert purge was applied to the tank through the riser via a hose. All of this work was performed in appropriate confinement, with worker protection provided that was consistent with the potential hazards.

- 5) Asbestos abatement was conducted where needed, and the riser flange was prepared to receive the breather filter adapter using non-sparking tools. The breather filter was lowered onto the open riser. An inert gas purge was used in the glovebag to ensure the flammable gas concentration around the riser less than 25% of the LFL.
- 6) A second larger riser was opened to insert the video camera and videograph inside the tank.
- 7) Although not performed during Phase I, a zip-cord measurement of the waste height was authorized during the internal inspection of the tank. Waste height measurements using a zip-cord will be obtained during Phase II. Camera equipment (still and/or video) was installed into an open riser, and the tank internals and the sludge were video-taped. This was done with equipment and methods compliant with the controls specified in Section 5.0.
- 8) The tank was vapor sampled in accordance with the Data Quality Objectives and Tank Sample Analysis Plan (TSAP).
- 9) Although not performed during Phase I, a grab sample was authorized to be collected from the top surface of the sludge in the tank.
- 10) The tank and nearby grounds were surveyed with civil survey and ground penetrating radar techniques as needed to ensure that the tank elevation was well known and buried conduits or piping were located in preparation for excavation to the top corners of the tank to evaluate tank structural integrity or as otherwise needed.
- 11) Although not performed during Phase I, the tank corners were authorized to be excavated to about 3 feet by hand or by use of a "guzzler," a vacuum excavation device with filtered exhaust. The exterior of the side face of the tank roof and the top of the tank sidewall were authorized to be cleaned off in preparation for structural evaluation.
- 12) Although not performed during Phase I, additional structural evaluations were authorized (e.g. ground penetrating radar and ultrasonic) to evaluate the tank structural condition for Phase II or other activities. Ultrasound transducers were authorized to be connected and an ultrasonic shear wave non-destructive examination of the tank roof and sidewall performed.

Using the controls identified in this JCO, each of these steps and additional contingency actions analyzed in the hazard analysis was authorized to be repeated as necessary.

3.2.2 Phase II Work Activities

This section describes the activities within Phase II for which this JCO provides a basis. Controls for these activities are specified in Section 5.0.

The first four steps to be performed install the inspection platform bridge necessary to keep the weight of the sampling truck off of Tank 241-Z-361 and protect the tank's structural integrity.

- 1) Two of the risers (Risers A and B of Figure 2.1-2. See also Figure 2.1-3) are approximately 48-inches high. To accommodate the truck bridge, these risers must be shortened to approximately 12 to 18-inches high. The risers will be cut off using a portable bandsaw or similar equipment. The spark production will be minimized, and the sparks will not produce a high thermal energy slag that could ignite organic nitrate compounds. If the old riser cover gaskets are removed, asbestos abatement will be conducted if necessary. New riser gaskets and flange covers will then be installed to re-seal these risers. The new flange covers will not require welding inside the tank during installation. This activity is not waste intrusive and is minimally dome intrusive. The flammable gas controls of Section 5.3.3 will be applied during the performance of this work. As such, during all of these activities the tank atmosphere will be monitored to ensure it remains < less than 25% of the LFL.

Video examination during Phase I has revealed pipes installed in the tank at risers desired for conducting sampling. These pipes may be moved or removed to accommodate sampling or videography. As risers are opened, these dry wells may be removed or moved out of the way. No flame cutting will be conducted to remove/move the risers. This activity is done intrusive and minimally waste disturbing. Flammable gas controls of Section 5.3 will be applied to this activity. The pipes may be moved/removed at any time during Phase II. If the pipes are dry wells, then they may be logged using gamma and/or neutron technique to assist in characterizing the tank.

- 2) The power lines and communication lines must be removed/relocated to provide room for the truck bridge and supports. If necessary, fences and associated security systems will also be removed temporarily. This activity is not waste intrusive and is not dome intrusive. Flammable gas controls for an ex-tank intrusive activity apply as required in Section 5.3.3. Dome loading controls of Section 5.6 will apply during the performance of this activity, including load lift restrictions.
- 3) Piers will then be installed to support the inspection platform bridge. About 42 helical piers will be screwed into the soil surrounding Tank 241-Z-361 as indicated in Ref 3-2 to

a minimum depth of about 23 feet. The helical piers may be installed manually, or with powered turning equipment. This activity is not waste intrusive and is not dome intrusive. Flammable gas controls for an ex-tank intrusive activity apply as required in Section 5.3.3. The helical coils will be screwed in to minimize the application of force to the tank, prevent damaging the tank walls, and to minimize any soil disturbance. During the installation of the piers, the dome load limits of Table 5.6-1 will apply. Because the piers will proceed to a depth beneath the tank, vertical load applied to the piers will not affect the tank. Angled helical anchors will also be installed to prevent any lateral loads from being applied to the helical piers and potentially to the tank walls. Dome loading controls of Section 5.6 will apply during the performance of this activity, including load lift restrictions. The bridge and piers are further described in Section 4.6 and Appendix H.

- 4) Bridges will then be installed on the piers. The bridge and pier foundation support system are further described in Section 4.6 and Appendix H. The construction of the foundation support system is also described in Ref 3-2. This activity is not waste intrusive and is not dome intrusive. Flammable gas controls for an ex-tank intrusive activity apply as required in Section 5.3.3. Dome loading controls of Section 5.6 will apply during the performance of this activity, including load lift restrictions. Appendix H provides the calculations demonstrating the bridge and pier design is adequate for bearing the design load.

The next series of steps are those required to perform push-mode sampling of the tank using the TWRS sampling truck. Conducting push-mode sampling of the tank is locally waste disturbing and dome intrusive. These steps will be repeated as needed to collect the three full-depth core samples desired to meet data quality objectives (Ref 3-6). Throughout these steps the flammable gas controls of Section 5.3 and the dome loading controls of Section 5.6 will be applied. Other controls from Section 5.0 will be applied as applicable. TWRS Procedures, TO-020-453, Setup and Takedown of Core Sample Equipment at 241-Z-361 (Ref 3-7), and TO-080-520, Core Sampling at 241-Z-361 (Ref 3-8), will be prepared specifically for the core sampling of 241-Z-361. These procedures will be adapted from existing TWRS procedures, TO-020-451, Setup and Takedown of Core Sampling Systems, and TO-080-503, Push Mode Sampling With Truck #1 (Ref. 3-3 and 3-5). Steps 5-18 represent general types of actions necessary to push-mode sample. These steps may be altered for specific Tank 241-Z-361 applications.

- 5) The risers to be sampled (Risers B, E, and F on Figure 2.1-2) will be prepared. The activities include removing the riser covers, conducting asbestos abatement, and then the bolts in the riser covers will be replaced. A zip-cord reading will also be obtained from at least one of the sampling risers. If the waste level data under the other sampling risers is required to support core sampling, then zip-cord data from the other risers may also be obtained. If an obstruction is encountered and a full core sample cannot be obtained from a sampling riser, then an additional core sample may be obtained from an alternate riser. Taking the waste height reading is dome intrusive, but is not waste intrusive.

- 6) To assist in monitoring the sampling drill string, other risers may be prepared for opening. In these risers a video camera may be inserted. A separate video van and generator will be placed outside the controlled area to support operation of the video camera in this case.
- 7) Grounding/bonding termination points will be established.
- 8) Contamination control equipment will be established around the riser to be sampled.
- 9) The riser equipment will then be installed. This includes the riser sleeve, riser adapter, spray wash assembly, foot clamp, "frisbee," and "frisbee" plug.
- 10) The push mode sampling truck will be positioned on the bridge.
- 11) Sampling support equipment will be staged. The equipment to be staged around the tank includes the distribution trailer, inert gas trailer, diesel generator, support truck, cask stands, and on-site transfer casks (OTC).
- 12) Equipment will be grounded and bonded as specified in the flammable gas controls (Section 5.3.3).
- 13) The sampling truck will be raised and leveled. Final measurements from the riser to the quill rod on the sampling truck will be taken to determine the drill string makeup, i.e., length and number of pieces.
- 14) The sampler is installed into the core barrel and the drill string is lowered into the tank down to the waste surface. The sampler will be pushed up to 19-inches using the sampling truck hydraulic ram into the waste to collect a core segment. (See Ref 3-6, 3-7 and 3-8 for additional details.)
- 15) The sampler is then recovered from the drill string. The sampler is then placed in the OTC, and the OTC is then sealed. A new sampler is then placed in the drill string.
- 16) Drill string is washed to remove contamination and the drill string is packaged as waste. Up to 1000 gallons of Lithium Bromide (Li Br) solution may be added to the tank during drill string washing operations.
- 17) Steps are repeated until a full depth core is obtained. Then this overall process is repeated at each of the three risers to be sampled.
- 18) At the completion of sampling, all equipment will be removed and the areas surveyed for contamination and released. Each riser opened will be sealed after sampling or opening to perform video monitoring of the drill string.

After the samples are collected, they are stored and then transported to the analytical laboratory in the OTC. Samples may be stored in the OTC at Tank 241-Z-361 after push mode sampling is complete. If storage at the tank or outside the laboratory is required for an extended period (e.g., >30 days), then a weather cover with passive ventilation may be erected and the OTC will be placed in it. Controls for storage of the OTC at PFP in a weather enclosure are provided in Section 5.7. The authorization basis and controls for the storage of samples and transport to the analytical laboratory is provided in the SARP for the OTC (Ref 3-4). These activities are outside the scope of this JCO and separately authorized.

3.3 REFERENCES

- 3-1 HNF-SD-CP-CN-003, *Hazard Analysis of Tank Z361*, Fluor Daniel Northwest, 1997, Richland, WA.
- 3-2 Drawing H-2-829739, *Civil Foundation Supports For Inspection Platform*, Fluor Daniel Northwest, March 1999, Richland, WA.
- 3-3 Procedure TO-080-503, current revision, *Push Mode Sampling With Truck #1*, Lockheed Martin Hanford Corporation, 1998, Richland, WA.
- 3-4 WHC-SD-TP-SARP-002, current revision, *Safety Analysis Report for Packaging (Onsite) Onsite Transfer Cask*, Waste Management Federal Services, Northwest Operations.
- 3-5 TO-020-451, current revision, *Setup and Takedown of Core Sampling Systems*, Lockheed Martin Hanford Corporation, 1998, Richland, WA.
- 3-6 BWHC 1995, *241-Z-361 Sludge Characterization Sampling and Analysis Plan*, April 1999, B&W Hanford Company, Richland, WA.
- 3-7 Procedures TO-020-453, *Setup and Takedown of Core Sampling Equipment at 241-Z-361*, Lockheed Martin Hanford Corporation, 1999, Richland, WA. (Draft)
- 3-8 Procedure TO-080-520, *Core Sampling at 241-Z-361*, Lockheed Martin Hanford Corporation, 1999, Richland, WA. (Draft)

4.0 HAZARD ASSESSMENT

Section 4.0 provides a summary of the process used to systematically identify the hazards associated with Tank 241-Z-361 and the activities proposed within this JCO. An initial hazard categorization of this facility has been performed and is provided in Appendix A. That analysis indicates that if this facility were stand-alone it would be defined as Hazard Category 2. That broad class of facilities includes those with the potential for significant on-site consequences if an adverse event were to occur. Hazard Category 2 facilities require formal safety analysis. This hazard categorization is consistent with the overall PFP hazard categorization.

A preliminary hazards analysis (PHA) was performed to systematically evaluate the hazards of the tank for Phase I activities, and it and other analysis performed in support of this JCO were used as the basis for the designation of safety functions and the controls specified in Section 5.0.

Subsequently, this PHA was modified to address unique aspects of Phase II characterization activities. The push-mode sampling activities have not been addressed in this PHA. The hazard analyses and accident analyses associated with these activities are addressed in the TWRS authorization basis, and these analyses are not repeated in this JCO except where unique hazards associated with Tank 241-Z-361. Where appropriate, the hazard analysis from Phase I activities has been used to evaluate similar Phase II activities.

A key difference in Phase II activities is the starting condition of the tank. During Phase II, the tank is known to be vented, unpressurized, and have a flammable gas concentration less than 25% of the LFL. The only flammable gas releasing events postulated for this type of tank are associated with locally-waste disturbing activities such as push-mode core sampling. As such, principle hazards of concern have been eliminated or mitigated by Phase I activities. The preliminary hazards analysis (PHA) results have been incorporated into this JCO as Appendix B.

Section 4.1 describes how the PHA was conducted for Tank 241-Z-361. Sections 4.1.2 and 4.1.2.1 describe the process. Section 4.1.2.2 describes which activities were considered. Section 4.1.2.3 describes how each activity was further broken down into component parts. Section 4.1.3 describes the methodology used to group the results from the PHA. Section 4.1.4 describes how the controls were tied to the hazards identified so that each hazard could be systematically controlled.

Section 4.2, 4.3, 4.4, and 4.5 describe the more in-depth analysis performed on the four principal hazards identified within the PHA: inadvertent criticality, tank structural failure, tank pressurization, and flammable gas ignition. Section 4.6 describes the sampling bridge that will be constructed to prevent structural damage to the tank during characterization activities. These sections also define the bases for the controls proposed for these specific hazards. These controls

will be further delineated in Section 5.0.

4.1 PRELIMINARY HAZARDS ANALYSIS

4.1.1 Introduction

The activities to vent Tank 241-Z-361 and to characterize and remediate the tank waste contents will be performed in phases. This PHA identifies the potential hazards associated with Phase I and Phase II activities. The Phase I activities are those necessary to load test the tank, gather information about the structural integrity of the tank, open the tank, passively ventilate the tank, obtain video and/or still photographs of the interior of the tank, obtain vapor space samples, and take waste surface (grab) samples from the tank if desired. Phase II activities are those associated with characterizing the contents of the tank using push-mode sampling.

An earlier PHA, HNF-SD-CP-CN-003 (Ref 4.1-1), evaluated the hazards associated with the tank being in a state of isolation and inactivity. The PHA presented in this document is the follow-on step in evaluating hazards associated with Tank 241-Z-361. In the interest of completeness, the hazardous conditions identified in the earlier HNF-SD-CP-CN-003 have been incorporated into the current PHA. Moreover, some contingent activities have also been evaluated.

4.1.2 Methodology

Hazard identification is the process of highlighting material, system, process, and facility characteristics with the potential to initiate accidents having undesirable consequences. The hazardous events that are of primary concern for this PHA are:

- Events that can result in the airborne release of radiological or toxicological material from the tank.
- Events that can result in operator exposures to elevated levels of ionizing radiation.
- Industrial type accidents that can result in severe injuries to plant workers.

The primary method of hazard identification/hazard evaluation used for the Tank 241-Z-361 was a PHA. In this systematic approach, the basic elements of the system and the hazards of interest for postulated activities are identified, potential causes and effects are evaluated, and possible corrective and/or preventive measures are proposed.

A PHA is a technique that is derived from the U.S. Military Standard System Safety Program Requirements. A PHA focuses in a general way on hazardous materials and major processes. In a PHA, a team of individuals with experience in process safety and with extensive knowledge of the operation or process to be evaluated are assembled. The team's collective experience is

elicited in "brainstorming" sessions to discover the potential hazards posed by a given operation or process. The team members involved in the performance of this PHA were: Gary R Franz, J. Michael Grigsby, Brett Hall, Keith E. Myers, Milton V. Shultz, Alan L. Ramble, and Duane M. Bogen. Subsequent entries into the PHA tables have been developed by John D. Williams.

4.1.2.1 PHA Table Structure. PHA is a form driven technique. The form used in the performance of this PHA is shown in Table 4.1-1. The PHA was structured primarily based on planned Phase I activities. Each Phase I activity was broken down into significant sub-activities or procedural steps for analysis. An alphanumeric system was used to designate the severity, with the following "S" rankings characterizing safety consequences:

- S0 no effect outside the facility confinement systems and no safety concerns for the facility worker, the onsite worker, or members of the general public
- S1 potential industrial injury, radiological dose consequences or chemical exposure to the facility worker; limited environmental discharge of hazardous material outside the facility,
- S1* potential severe harm or potential death from industrial injury, radiological dose consequences or chemical exposure to the facility worker,
- S2 potential significant radiological dose consequences or chemical exposure to the maximum onsite worker outside the facility; environmental discharge of hazardous material within the plant site boundary, and
- S3 potential significant radiological dose consequences or chemical exposure to the offsite population; environmental discharges of hazardous material outside the Hanford site boundary or to the groundwater.

The frequency ranking column is a "first cut," qualitative, consensus estimate of the frequency of the consequences. This frequency estimate is based on a "no controls present" character of the accident. An alphanumeric system was used to designate the frequency, with the following "F" rankings characterizing safety consequences:

- F0 Events not expected to occur and categorized as beyond extremely unlikely. The frequency range is $<1E-06/yr$,
- F1 Events not expected to occur within the lifetime of a typical facility and categorized as extremely unlikely. The frequency range is $1E-06/yr$ f $< 1E-04/yr$,
- F2 Events which could occur during the lifetime of the facility and categorized as unlikely. The frequency range is $1E-04/yr$ f $< 1E-02/yr$, and

F3 Events which are expected to occur one or more times during the lifetime of the facility and categorized as anticipated. The frequency range is $1E-02\text{yr}^{-1} < f < 0.1/\text{yr}$.

Table 4.1-1. Preliminary Hazards Analysis Table

Item #	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Engineered Features	Administrative Controls	Cons Rank	Freq Rank	Remarks
Activities									
Passive Tank--Prior to Phase 1 Activities									
Passive Tank--After Phase 1 (Breather Filters Installed)									
Natural Phenomena Hazards									
External Events									

Table 4.1-2. Phase I Tank 241-Z-361 Operations/Conditions

1.	Civil Survey and Load Test - Check to Determine Ground Level and Soil Depth and Verify Capability of Tank to Support Personnel and Equipment for Riser Opening
2.	Ground Penetrating Radar (Optional) - Determine Outline of Tank Top and Location of Buried Lines near Tank
3.	Excavate Small Area next to Tank to Permit Ultrasound Wall and Roof Check (Optional)
4.	Perform Ultrasound Check - Attempt to Verify Tank Wall and Top Integrity (Optional)
5.	Install People Bridge (Optional Depending on Tank Load Test Results)
6.	Radiological Survey of Risers (Activity Preliminary to Any Further Actions to Enter Tank)
6.A	External Gamma and Neutron Scans (Optional) - Attempt to Determine If Criticality Event Has Occurred
7.	Inspect Riser [Procedure Item - Riser Prep] (It Is Assumed That a People Bridge Is in Place or it Has Been Determined That One Is Not Required for Access on the Tank Roof)
8.	Open Riser - Replace Bolts, Install Glovebag, Relieve Pressure, Remove Flange
9.	Install Breather Filter On Open Riser
9.A	Purge Tank [This Is a Contingency and the Only Way Tank Can Be Accessed If Atmosphere Is Determined to Be Flammable]
10.	Take Pictures/video Inside Tank (Requires Entry Through 8-inch Riser)
11.	Perform Vapor Sampling (This Data Is for Characterization)
12.	Take Hard Gamma/test for Mixed Fission Products (Optional) - Further Testing to Determine If Criticality Has Occurred
13.	Take Waste Grab Sample (Optional)

Table 4.1-3 Phase II Tank 241-Z-361 Operations/Conditions

1.	Shortening risers and replacing flanges.
2.	Moving fence lines, associated security systems, and power lines.
3.	Installing truck sampling foundation piers.
4.	Truck sampling bridge construction.
5.	Preparing risers for push mode sampling.
6.	Opening risers for video monitoring (Optional).
7.	Establishing grounding/bonding termination point.

8.	Establishing contamination control area.
9.	Install push-mode core sampling riser equipment.
10.	Position push mode sampling truck on the bridge.
11.	Stage push-mode core sampling equipment.
12.	Ground/bond equipment.
13.	Raise and level sampling truck and assemble drill string.
14.	Collect push-mode core segment.
15.	Seal core segment into On-site Transfer Cask.
16.	Package waste and clean-up area.
17.	Store Onsite Transfer Cask.
18.	Natural phenomena hazards.

4.1.2.2 Activities/Conditions Evaluated. The activities to be performed in Phase I and Phase II were determined by cognizant engineers at the PFP responsible for ultimately dispositioning the waste in Tank 241-Z-361 and by the PHA team. In some cases, insights gained from performing the PHA resulted in the reordering or modification of planned activities to enhance benefit or reduce risks. This is one of the advantages provided by the structured PHA approach. In addition some activities were incorporated into the PHA to address contingencies and options that may be exercised during the performance of the work. The activities covered in the PHA are listed in Tables 4.1-2 and 4.1-3. In Appendix B, Phase I and Phase II activities have been separated in the PHA tables.

In addition to the hazardous events that can occur during the Phase II activities, hazardous events can occur while the tank is in an isolated, passive condition prior to the initiation of Phase II activities (e.g., spurious collapse of the tank due to long term structural degradation). After Phase II activities are completed, Tank 241-Z-361 will be left to passively ventilate through installed breather filters before future remediation activities are initiated. Certain hazardous events can be postulated for the tank during this time period, e.g., criticality due to dry out and subsidence of the tank sludge. These passive time periods for the tank were evaluated separately and are shown as items 14 through 15 for Phase I activities in Appendix B. These hazards are unchanged by Phase II activities. The PHA entries for the passive isolated tank prior to Phase II activities are essentially those from the prior hazards analysis performed on the tank (Ref 4.1-1), except that the likelihood of flammable gas deflagration has been largely eliminated because of the passive ventilation that was installed during Phase I.

A PHA structured to look at operational steps or activities is not designed to highlight accidents initiated by natural phenomena (e.g., earthquakes) or external events (vehicle accidents). The general effects of natural phenomena and external hazards on facilities are to cause process upsets

and/or to challenge the integrity of facility confinement systems. In some cases, external events can add hazardous material to the system (such as fuel from a truck crash) which might initiate a unique accident. Natural phenomena and external events are treated separately in the PHA table (Appendix B) for both Phase I and Phase II activities. Phase I natural phenomena hazards have not been altered, however the likelihood of flammable gas deflagration, and therefore the consequences, have been reduced because the tank is now passively ventilated.

4.1.2.3 Brainstorming Approach. Each activity was broken down into significant sub-activities or procedural steps to ensure a comprehensive review. The TWRS procedures for activities similar to those planned for Phase I and Phase II were reviewed to determine the significant sub-activities and procedural steps associated with each major activity.

The PHA team brain stormed potential hazards associated with the sub-activities and procedural steps. Brainstorming was based on the team's general collective experience, the team members' knowledge of hazards identified for similar activities in other safety basis documents, and on logical "what if" type questions posed by PHA team members--"what if" questions such as: "what if the activity is not performed or performed out of order," "what if the activity takes longer than desired," "what can go wrong during the performance of the activity," etc. For hardware systems, the safety functions performed by those systems were identified and functional failures were simply postulated to determine potential hazardous outcomes. Finally, a hazard/energy checklist from DOE 76-4519, "Job Safety Analysis" (Ref 4.1-2) was reviewed for each activity to aid in the brainstorming process.

4.1.3 PHA Results

The qualitative consequence and likelihood estimates for the various hazardous events (columns 8 and 9 of the PHA table) were generated based on the PHA team members' experience and judgment. The selection of accidents for further treatment to identify equipment and controls important to safety is accomplished by a binning process. The initial accident screening criteria used in the binning process is based entirely on *qualitative consequence rankings*. Any accident postulated in the S2 and S3 consequence categories is a potential candidate for the application of specific administrative controls or adding engineered features. This results in a broad spectrum of candidate accidents being considered and provides for consideration of a broad enough spectrum of representative and unique accidents to furnish adequate technical justification for the choice of engineered features and administrative requirements.

All the accidents having S2 or S3 consequences are classified by type. The type of accident relates to the accident phenomena such as leak, fire, explosion, etc.

The hazardous events identified in this PHA can be grouped into eight categories. These categories are:

1. Events that result in ignition of a quantity of flammable gas in the tank headspace, that involve major damage to the tank roof, and that result in a significant release of radioactive aerosols to the atmosphere.

2. Events that result in collapse of the tank roof or failure of the risers in the tank roof that cause a significant release of toxic vapors and radioactive aerosols and possibly gross contamination of a worker or workers.
3. Events that result in minor releases of toxic vapors and radioactive aerosols with no damage to the basic tank structure.
4. Events that result in a criticality occurring in the tank waste.
5. Events postulated to result in an ignition of nitrate compounds in the tank with subsequent release of toxic vapors and radioactive aerosols.
6. Events involving normal industrial hazards or small quantities of radioactive contamination.
7. Leaks to the soil column due to general tank degradation. Also, events that result in localized flooding above the tank and intrusion of water into the tank, exacerbating a tank leakage condition.
8. Events that result in pressurized releases from the tank.
9. Events that result in radioactive releases within, or from, the OTC weather enclosure

Natural phenomena and external events were found in general to be initiators for the hazardous conditions specified above. Controls identified to minimize risk during Phase I and Phase II activities for the above hazardous conditions will in most cases also be adequate for natural phenomena initiators. However, the natural phenomena hazards may dictate certain design requirements.

4.1.4 Controls Identification

The following controls are proposed for the seven general categories of events identified for JCO activities. The controls are grouped according to the preceding categories of hazardous events. The controls established for the significant hazardous event categories are discussed in more detail in Section 5.0.

1. Events that result in ignition of a quantity of flammable gas in the tank head space, that involve major damage to the tank roof, and that result in a significant release of radioactive aerosols to the atmosphere.

General Controls:

(Note: as a result of Phase I activities the tank is now passively and continuously vented. Monitoring shows the tank is less than 25% of the LFL. During Phase II activities,

flammable gas release events are only postulated to potentially occur as a result of the push-mode core sampling activity.) Control of access to the tank roof and general vicinity (includes crane and vehicle controls), determination of maximum allowable roof loading, control of roof loading when roof access is required, and use of crane critical lift procedures where required by the Hanford Rigging Manual. These controls are intended to prevent collapses that could result in a spark and subsequent ignition of flammable gas.

A set of ignition controls similar to TWRS ignition controls that specify bonding requirements, allowed tools, allowed instrumentation, and procedures to minimize the likelihood of producing a spark.

Administrative controls to halt operations on the tank when lightning is detected within a 50 mile radius from the tank.

2. Events that result in collapse of the tank roof or failure of the risers in the tank roof that cause a significant release of toxic vapors and radioactive aerosols and possibly gross contamination of a worker or workers.

General Controls:

Control of access to the tank roof and general vicinity (includes crane and vehicle controls), determination of maximum allowable roof loading, control of roof loading when roof access is required, and use of crane critical lift procedures where required by the Hanford Rigging Manual.

Control of mechanical forces on a riser to prevent failure of a degraded riser.

Institutional controls for emergency response to earthquakes - reduces number of individuals potentially exposed to radioactive material. (See Section 5.0 for the PFP operational safety requirements (OSR) and other institutional controls relied upon in this JCO.)

Construction of the truck sampling bridge such that significant lateral loads to the tank walls are prevented.

Construction of the bridge such that it can safely handle static and dynamic loads that may be applied during operations.

Construction of the bridge such that the sampling truck cannot be inadvertently driven off the edge of the bridge.

3. Events that result in minor releases of toxic vapors and radioactive aerosols with no damage to the basic tank structure.

General Controls:

Institutional controls for working in an area where aerosols and vapors could be present. These may include protective clothing, greenhouses, drapes, radiation monitoring and respiratory protection.

4. Events that result in a criticality occurring in the tank waste.

General Controls:

Controls to prevent inadvertent criticality are identified in Section 4.2.

5. Events postulated to result in an ignition of nitrate compounds in the tank with subsequent release of toxic vapors and radioactive aerosols.

General Controls:

Control of vehicle access to the tank to prevent vehicle impacts into risers that could dump burning fuel into the tank. Control to stop operations on the tank when lightning is detected within a 50 mile radius of the tank.

Preventing flame cutting/welding in the tank unless approved by the PHMC President.

6. Events involving normal industrial hazards or small quantities of radioactive contamination.

General Controls:

No special controls beyond what are imposed by the normal institutional requirements for this type of work.

7. Leaks to the soil column due to general tank degradation. Also, events that result in localized flooding above the tank and intrusion of water into the tank, exacerbating a tank leakage condition.

General Controls:

Only hand digging or excavation using the "guzzler" machine should be allowed near the tank to minimize the possibility of breaking water lines. Ground penetrating radar will be used to identify the location of water lines near the tank. The concrete cap poured on top of the tank limits potential intrusion. Should a water tank be used to load test the tank a limited water source will be used to fill the tank to limit the volume of water potentially spilled on the tank.

Limiting down force on the push-mode core sample drill string.

Installation of the helical piers with appropriate torque limits such that the tank walls are

not damaged by the helical piers.

8. Events that result in pressurized releases from the tank.

General Controls:

(Note as a result of Phase I activities the tank is passively and continuously vented. As such, this general type of hazard is no longer present. This section is retained for reference purposes.) A glovebag will be installed around the first riser to be opened to confine and mitigate any potential release of radioactive particulate matter when the riser is opened. The riser should be opened in a manner that controls the blow down rate of the tank and prevents ejection of the flange. The glovebag HEPA filter(s) should be sized large enough to accommodate the controlled blow down flow without failing the glovebag or HEPA filters from pressurization. Moreover, the flow rate needs to be sufficiently low that the glovebag is not damaged by the hydrodynamic forces associated with flow through the glovebag. If purging is used, controls on purge flow are needed to ensure glovebag and filter integrity are maintained. A control is also needed to ensure installed breather filters are not valved out during purging to prevent tank pressurization or unfiltered releases through HEPA filter assembly seal loops. Ignition and spark source controls need to be established for glovebag activities to ensure hydrogen released from the tank into the glovebag is not ignited.

9. Events that result in radioactive releases within, or from, the OTC weather enclosure.

General Controls:

Ensure weather enclosure is passively ventilated to reduce likelihood that the hydrogen can build up or airborne radioactive concentrations will be significant. Apply ignition controls during venting. Conduct airborne radioactive particulate sampling before entry. Post warning signs identifying the presence of flammable gas.

4.1.5 References

- 4.1-1 HNF-SD-CD-CN-003, 1997, *Hazard Analysis of 241-Z-361 Tank*, Rev. 0, Fluor Daniel Northwest Inc., Richland, Washington.
- 4.1-2 DOE 76-4519 *Job Safety Analysis*, U.S. Department of Energy, Washington D.C.

4.2 CRITICALITY SAFETY

Tank 241-Z-361 has been the subject of three prior criticality analyses (Ref 4.2-1,4.2-2,4.2-3). Each has found the tank substantially subcritical but with somewhat differing conclusions, and in some cases used data now believed suspect. Accordingly, another criticality assessment has been performed in support of this JCO and is documented in "Engineering Study Of The Criticality Issues Associated With Hanford Tank 241-Z-361" (Ref 4.2-4). This analysis is an integral part of this JCO and is summarized within this section.

For the purpose of evaluating the very limited activities proposed under this JCO, "Engineering Study Of The Criticality Issues Associated With Hanford Tank 241-Z-361" provides the initial basis to evaluate the criticality safety of the proposed activities. Criticality analysis is being continued, including independent evaluation, so that a criticality safety evaluation report (CSER) may be completed. The CSER will provide the basis for developing criticality prevention specifications (CPS).

Two conditions are required to achieve criticality. The minimum areal density of plutonium must exceed about 240 g/ft², and the minimum critical concentration must be exceeded. Tank 241-Z-361 does not likely meet either condition. As a result, the qualitative likelihood of criticality in this tank has been found to be extremely unlikely during storage and sampling, including the consequences of natural phenomena hazards.

Two families of sample data have been generated for the contents of this tank: 1975 and earlier and 1977 and later. Plutonium concentrations for 1975 data are more than twice as high as data from 1977 and later. In 1976 corrected plutonium concentrations were calculated. The correction involved recalculating the percent volume solids.

The 1977 family of data was used for the analysis. The plutonium concentration and neutron measurements for 1977 data are more consistent. Discharge records and material accountability records are also more consistent with measured plutonium inventories for the 1977 data.

The two different families of data does generate some uncertainty. But the differences in plutonium concentration reported in the 1975 family of data (higher Pu concentrations) would not alter the conclusions drawn. The margin to criticality would be reduced from that found when using the 1977 data. Even so, there would remain enough margin that the tank would remain subcritical during evaluated storage and upset conditions even with the higher plutonium concentrations.

Several additional conclusions using the 1977 sample results have been reached as a result of this criticality safety assessment:

- Even if the plutonium concentration were much greater than postulated, the plutonium concentration would be well below the minimum critical plutonium concentration. The average of all samples was calculated to be 0.38 g Pu/l, corresponding to a total tank plutonium inventory of about 29 kg. The upper bound for the 99% confidence interval for

the average plutonium concentration is 0.61 g Pu/l, corresponding to a total tank plutonium inventory of about 46 kg. If all free water has been lost, but bound water and a small amount of interstitial water remains, the maximum average concentration (99% confidence) would be 0.69 g Pu/l. For a tank inventory of 30 kg, the minimum critical concentration is 4.7 g Pu/l, much greater than any of the concentrations noted above. Moreover, even if the inventory were postulated to be 70 kg, the minimum critical concentration would still be above 4.0 g Pu/l.

- The estimated upper limit of plutonium areal density is 136 g/ft² (based on the upper bound of the 99% confidence interval for plutonium concentration). This is well below the 240 g/ft² minimum critical areal density. As such, there is no postulated condition where this second necessary condition for criticality can be achieved.
- Tank samples show the plutonium settled roughly uniformly across the surface of the tank in layers consistent with expectations from plant operation campaigns and activities. (See Figures 2.2-2 and 2.2-3) The characterization data suggests that it is unlikely that regions exist with a plutonium concentration more than twice the average plutonium concentration. Accordingly, it is extremely unlikely that there is a non-homogenous area with a plutonium concentration sufficient to achieve criticality.
- The k_{eff} for this tank was calculated to be substantially subcritical at approximately 0.13. Increasing the sludge depth by a foot, such as might happen if sludge were dropped during sampling or removal, left the k_{eff} unchanged. In addition, flooding the space above the sludge with water would not increase k_{eff} .
- The greatest effect on k_{eff} comes from drying the sludge. Even when worst case accident scenarios are considered, including drying and compression, there is a wide margin of safety. The accident conditions evaluated did not cause k_{eff} to increase beyond 0.75.

The criticality safety assessment supports the conclusion that activities conducted to open, sample, and characterize the tank can be done without causing an inadvertent criticality.

- Opening the tank and applying ventilation can cause increased drying of the sludge. The drying that could result, even from forced ventilation, would not eliminate the bound water. If dried in the field, the sludge volume is expected to decrease by about 88%. The plutonium concentration would only increase by about 14%. Accordingly, criticality is extremely unlikely as a result of passive or active ventilation being applied to this tank for an indefinite period of time.
- Push mode core sampling (a Phase II activity) could result in compression, redistribution of plutonium, and changes in the neutron reflection. Furthermore, during sampling there is the possibility for sludge to be dropped on top of other sludge. Modeling of compression, increased sludge depth, drying and increased reflection show that core sampling would not reduce the margin of subcriticality below a safe level. As such, the grab sampling or push-mode sampling can be completed without causing inadvertent criticality.

- Because of hydrogen generation in the tank, the possibility of tank deflagration occurring during a tank intrusive activity is evaluated in the JCO. If a hypothetical deflagration occurred in the tank, compression of the waste would occur. To achieve criticality would require the sludge to be completely dry and the density to be more than doubled. No credible degree of compaction would be capable of increasing the density this much. Accordingly, criticality is extremely unlikely to occur from a deflagration occurring within the tank.

Subsequent analysis has been performed to evaluate the to potential consequences for adding drill rinse solution during push mode core sampling. (Ref 4.2-5) This analysis shows up to 1000 gallons of the aqueous solution can be added into the tank.

Even though the likelihood of criticality is remote, controls are needed to protect key assumptions used in this analysis, to reduce residual risks, and to address key areas of uncertainty. Those controls will include:

- Fissile material should not be added to the tank.
- Large scale mixing, such as that which would result from the use of mixer pumps or sluicers, is prohibited. (The minor amount of mixing resulting from characterization operations and upsets has been shown to be acceptable.)
- No more than 5 liters of chemical or organic solvents should be added to the tank. (Note, however, that the accidental spill of hydraulic fluid into the tank was analyzed and concluded to be acceptable.)
- No more than 1000 gallons of aqueous solution (e.g. push mode core sampling rinse solution) should be added to the tank.

HNF-PRO-334 (Ref 4.2-6) designates Tank 241-Z-361 as a limited control facility. This designation means the tank contains greater than one-third of a critical mass of fissile material, but that material is in a form that precludes the potential for a criticality. This more recent criticality safety assessment of Tank 241-Z-361 (HNF-2012) confirms the extreme unlikelihood of criticality in the tank, which was the basis for the earlier designation of the tank as a limited control facility. Accordingly this facility will continue to be designated a limited control facility.

4.2.1 Safety Functions

The potential for inadvertent criticality has been assessed to be extremely unlikely. All of the controls specified are administrative and will be implemented through the existing PFP criticality prevention program. No safety systems, structures or components (SSC) have been identified for the criticality hazard.

4.2.2 References

- 4.2-1 Carter, R.D., and D.J. Brown, 1976, Letter to R.E. Isaacson, *Criticality Potential of 241-Z-361 Tank*, Atlantic Richfield Hanford Co., Richland, Washington, February 20, 1976.
- 4.2-2 Davenport, L.C., W.C. Maculas, and C.L. Brown, 1977, *Second Party Criticality Safety Review of Settling Tank 241-Z-361*, Letter to G.C. Oberg, Battelle Pacific Northwest Laboratory, Richland, Washington, April 5, 1977.
- 4.2-3 Altschuler, S.J., and R.D. Carter, 1980, *Deactivated Cribs and Settling Tanks*, CSAR 80-024, WHC-SD-SQA-CSA-20240, Rev. 0, Released January 19, 1990, by D.E. Friar.
- 4.2-4 Lipke, E.J., Rogers, C.A., Miller, E.M., et al., 1997, *Engineering Study Of The Criticality Issues Associated With Hanford Tank 241-A-361*, HNF-2012, Rev. 0, Richland, Washington.
- 4.2-5 Letter, Fluor Daniel Northwest, D.P. Hughes to A .L. Ramble, *Addition of Core Drill Rinse Solution to Tank 241-Z-361, Contract 915, Release 3*, March 30, 1999, Richland, Washington.
- 4.2-6 HNF-PRO-334, *Criticality Safety General, Requirements*, 1997, Rev. 0, Fluor Daniel Hanford, Richland, Washington.

4.3 STRUCTURAL INTEGRITY ASSESSMENT

A structural analysis (Ref 4.3-1) was performed of Tank 241-Z-361. Because of the potential for chemical degradation of the rebar, analysis has been performed of both the as-built condition and a condition assuming that 50% of the interior rebar has been degraded. Stress calculation were performed using American Concrete Institute (ACI) load combinations and load factors. To gain a better understanding of likely actual tank conditions "best estimate" load conditions have also been evaluated.

Analysis shows that using ACI load combinations and load factors with a uniform subgrade reaction model and for the as-built and as designed (not degraded) condition:

- The tank is adequate for 100 pounds per square foot (psf) distributed load or 5,000 lbs concentrated load applied above the tank at grade.
- The tank is also adequate for 0.25g seismic induced loads.
- Tables 4.3-1 and 4.3-2 show that as the live load on the tank is increased the stress in the wall increases. At 200 psf live load, the wall is predicted to be over stressed.

Analysis shows that using ACI load combinations and load factors with a uniform subgrade reaction model and for an assumed 50% degraded rebar condition in the interior wall:

- Tables 4.3-3 and 4.3-4 show that with an assumed degraded rebar in the interior wall (degraded carrying capacity), the mid-wall is over-stressed. From this it can also be seen that hydrostatic plus dead load is the governing load combination for this tank.
- Table 4.3-5 through 4.3-8 assess the tank condition if it is assumed that a hinge joint has formed. A hinge joint is possible from over stress and since the tank has been in a liquid environment for almost 50 years. Over-stress conditions in the side wall are developed for large dead and hydrostatic loads.

An elastic subgrade reaction model was also evaluated (Tables 4.3-9 through 4.2-12).

Although the margins improve, the same basic conclusions may be drawn. The governing load combination is hydrostatic plus dead. With a 50% degraded rebar, the tank wall is predicted to be over-stressed.

Analysis for the "best estimate" loads (Tables 4.3-13 and 4.3-14), using an elastic subgrade reaction model and assuming a 50% degraded rebar condition in the interior wall, show that the bottom slab and the wall do not appear to be over-stressed in the present state.

The conclusions drawn are based on an assumed degradation of the rebar. The rebar condition is not known and may be difficult to verify. There are also uncertainties associated with concrete degradation that may effect the rebar-concrete bond. As such, it is not known

whether the 50% degradation assumed is conservative. Three-dimensional modeling calculations might also reveal some additional non-conservative features in the two-dimensional modeling performed.

However, there is no evidence of tank failure. The at-grade surface is not sagging and is not settling as would be expected if significant tank cracking had occurred. The tank has received significant snow and rain loads. Prior to establishing the access restriction, there have been multiple people on top of the tank, and heavy vehicles have operated near the tank edge. This recent operational history suggests the tank has received loads as large as those contemplated for Phase I JCO activities without adverse consequence. Based on the analysis and these operational factors, engineering judgement is that access over the tank by a limited number of people carrying hand-carried equipment is likely to be safe.

As a result of this uncertainty, a load test has been conducted using an approved test plan. This load test applied 4000 lbs to the tank top and 600 lbs (moving) to the regions outside the tank. Following completion of the load testing, the data measured was evaluated (Ref 4.3-5). This evaluation concludes that the tank response to increasing load was linear and the maximum deflection observed was well within acceptable values. The load test confirmed that the tank top is structurally adequate for a working load up to 2000 lbs anywhere above the tank. No sagging or other failure mechanisms were observed as a result of the 600 lbs load test performed outside the tank top area.

In addition to analysis of tank structural integrity, analysis has been performed to define acceptable load carrying capacity for the tank risers. The analysis documented in "Engineering Load Evaluation of the Riser on Tank 241-Z-361," (Ref. 4.3-3) was performed to ensure that the risers would have a minimum load carrying capacity. The assessed load capacity is sufficient to allow safely working in the vicinity of the risers. An additional analysis was performed (Ref. 4.3-4) to examine in greater detail the load carrying capacity of the risers that may have breather filters installed on them. This analysis has been incorporated into this JCO as Appendix F.

Subsequently, another analysis has been performed of the risers that will be used for push-mode core sampling. This analysis shows that Risers B and F (See Figure 2.1-2) are adequate to with stand the load of the sampling equipment (1500 lbs). The strength of Riser E is indeterminate, and additional support will need to be installed around this riser to perform push-mode core sampling through it. (Ref. 4.3-5) This analysis has been incorporated into this JCO as Appendix I. The specific limits for each riser resulting from this set of analyses are provided in Table 5.6-2.

After the successful load testing of the tank and regions around the tank, new analysis has been performed (Appendix G) to compare stresses induced by snow load and an armored personnel carrier that was formerly parked in the vicinity of the tank. Prior analysis showed that the region of concern was about 8-feet down the walls or lower. The load tests show the integrity of the upper portions of the wall. Comparison of the previously applied snow load and

armored personnel carrier shows that a margin of greater than 2.0 for the load to be applied in Phase I can be maintained (in the tank wall regions of concern) with greater loads than the initial very conservative limits established for the region outside the tank. Based on this analysis, and the successfully completed load test, the load limit for regions outside the tank is being increased as specified in Section 5.0. These increased loads in the regions external to the tank will enable the balance of Phase I and Phase II activities to be completed with reduced risk of contamination spread.

Table 4.3-1. ACI Code-Based Analysis Results for Live Load, L = 100 psf (Uniform Subgrade Reaction Model)

C A S E	Load Combinations	TOP SLAB (5, 7) ⁴			WALL (9, 12) ⁴			BASE SLAB (1, 3) ⁴		
		Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin
1	As-Designed, As-Built 1.4D + 1.7L ³	6,466 9,532	18,921 18,921	1.71 0.98	7,089 ¹ 4,786	27,767 23,661	2.91 3.94	7,089 ¹ 12,632 ¹	13,802 13,802	0.94 0.09
3	1.05D + 1.28L + 1.4E _o	8,267 3,744	18,921 18,921	1.29 4.05	8,709 ¹ 4,647	27,767 23,661	2.18 4.09	8,709 ¹ 6,096 ¹	13,802 13,802	0.58 1.26
6	1.4D + 1.7L + 1.7H	12,209 3,789	18,921 18,921	0.55 3.99	11,892 ¹ 10,594	27,767 23,661	1.33 1.23	11,892 ¹ 5,694 ¹	13,802 13,802	0.16 1.42
3	Assuming 50% Rebar Corroded Inside Face of Concrete Tank Wall 1.05D + 1.28L + 1.4E _o		Not Applicable	*	8,709 ¹ 4,647	27,767 12,136 ²	2.18 1.61	8,809 ¹ 6,096 ¹	13,802 7,078 ²	0.58 0.16
6	1.4D + 1.7L + 1.7H		Not Applicable	**	11,892 ¹ 10,594	27,767 12,136 ²	1.33 0.14	11,822 ¹ 5,694 ¹	13,802 7,078 ²	0.16 0.24

Table 4.3-2. ACI Code-Based Analysis Results for Live Load, L = 200 psf (Uniform Subgrade Reaction Model)

C A S E	Load Combinations	TOP SLAB (5, 7) ^a			WALL (9, 12) ^a			BASE SLAB (1, 3) ^a		
		Demand (M) lb-in/in	Capacity (M _j) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _j) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _j) lb-in/in	Safety Margin
5	As-Designed, As-Built 1.4D + 1.7L + 1.7H	13,854	18,921	0.37	15,600 ¹	27,767	0.78	15,600 ¹	13,802	-0.11
		6,314	18,921	1.99	9,248	23,661	1.55	8,157 ¹	13,802	0.69
5	Assuming 50% Rebar Corroded Inside Face of Concrete Tank Wall 1.4D + 1.7L + 1.7H	Not Applicable			15,600 ¹	27,767	0.78	15,600 ¹	13,802	-0.11
					9,248	12,136 ²	0.31	8,156 ¹	7,078 ²	-0.13

Table 4.3-3. ACI Code-Based Analysis Results for Seismic Loading with No Live Load (Uniform Subgrade Reaction Model)

C A S E	Load Combinations	TOP SLAB (5, 7) ^a			WALL (9, 12) ^a			BASE SLAB (1, 3) ^a		
		Demand (M) lb-in/in	Capacity (M _j) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _j) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _j) lb-in/in	Safety Margin
2	As-Designed, As-Built 0.9D + 1.7H	14,994	18,921	0.26	16,929 ¹	27,767	0.64	16,929 ¹	13,802	-0.18
		9,288	18,921	1.04	16,165 ⁵	26,540 ⁵	0.64	9,313 ¹	13,802	0.48
7	1.05D + 1.4E _s	6,247	18,921	2.03	6,880 ¹	27,767	3.03	6,880 ¹	13,802	1.00
		2,629	18,921	6.19	3,767	23,661	5.28	4,967 ¹	13,802	1.78
2	Assuming 50% Rebar Corroded Inside Face of Concrete Tank Wall 0.9D + 1.7H	Not Applicable			16,929 ¹	27,767	0.64	16,929 ¹	13,802	-0.18
					16,165 ⁵	13,760 ⁵	-0.14	9,313 ¹	7,078 ²	-0.24

C A S E	Load Combinations	TOP SLAB (5, 7)*			WALL (9, 12)*			BASE SLAB (1, 3)*		
		Demand (M) lb-in/in	Capacity (M _j) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _j) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _j) lb-in/in	Safety Margin
7	1.05D + 1.4E _o			* **	6,880' 3,767	27,767 12,136 ²	3.03 2.22	6,880' 4,967'	13,802 7,078 ²	1.00 0.42

Table 4.3-4. ACI Code-Based Analysis Results for Live Load, L = 10 psf (Uniform Subgrade Reaction Model)

C A S E	Load Combinations	TOP SLAB (5, 7)*			WALL (9, 12)*			BASE SLAB (1, 3)*		
		Demand (M) lb-in/in	Capacity (M _j) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _j) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _j) lb-in/in	Safety Margin
9	As-Designed, As-Built 1.05D + 1.28L + 1.4E _o	6,447 2,742	18,921 18,921	1.94 5.90	7,065' 3,852	27,767 23,661	2.93 5.14	7,065' 5,086'	13,802 13,802	0.95 1.71
10	1.4D + 1.7L + 1.7H	10,731 1,520	18,921 18,921	1.76 11.45	12,553' 11,803	27,767 23,661	1.22 1.00	12,553' 3,624'	13,802 13,802	0.10 2.81
9	Assuming 50% Rebar Corroded Inside Face of Concrete Tank Wall		Not Applicable	* **	7,065' 3,852	27,767 12,136 ²	2.93 2.15	7,065' 5,086'	13,802 7,078 ²	0.95 0.39
10	1.4D + 1.7L + 1.7H			* **	12,553' 11,803	27,767 12,136 ²	1.21 0.03	12,553' 3,624'	13,802 7,078 ²	0.09 0.95

Table 4.3-5. ACI Code-Based Analysis Results with Assumed Hinge at Wall-to-Base Slab Interface for Live Load, L = 100 psf (Uniform Subgrade Reaction Model)

C A S E	Load Combinations	TOP SLAB (5, 7) ⁴			WALL (14, 11) ⁴			BASE SLAB (1, 3) ⁴		
		Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin
3	As-Designed, As-Built 1.05D + 1.28L + 1.4E _o	10,538	18,921	0.79	10,588	23,661	1.23	---	---	---
		1,529	18,921	11.38	10,171	23,661	1.32	14,794 ¹	13,802	-0.06
6	1.4D + 1.7L + 1.7H	15,867	18,921	0.19	15,867	23,661	0.49	---	---	---
		3,869	18,921	3.80	21,276	23,661	0.11	16,718 ¹	13,802	-0.17
3	Assuming 50% Rebar Corroded Inside Face of Concrete Tank Wall	Not Applicable			10,588	23,661	1.23	---	---	---
		Not Applicable			10,171	12,136 ²	0.19	14,794 ¹	7,078 ²	-0.52
6	1.4D + 1.7L + 1.7H	Not Applicable			15,867	23,661	0.49	---	---	---
		Not Applicable			21,276	12,136 ²	-0.43	16,718 ¹	7,078 ²	-0.57

Table 4.3-6. ACI Code-Based Analysis Results with Assumed Hinge at Wall-to-Base Slab Interface for Live Load, L = 200 psf (Uniform Subgrade Reaction Model)

C A S E	Load Combinations	TOP SLAB (5, 7) ⁴			WALL (14, 11) ⁴			BASE SLAB (1, 3) ⁴		
		Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin
5	As-Designed, As-Built 1.4D + 1.7L + 1.7H * **	17,697	18,921	0.06	17,697	23,661	0.33	---	---	---
		2,571	18,921	6.35	20,679	23,661	0.14	23,721 ¹	13,802	-0.42
5	Assuming 50% Rebar Corroded Inside Face of Concrete Tank Wall 1.4D + 1.7L + 1.7H	Not Applicable								
				*	17,697	23,661	0.33	---	---	---
				**	20,679	12,136 ²	-0.41	23,721 ¹	7,078 ²	-0.70

Table 4.3-7. ACI Code-Based Analysis Results with Assumed Hinge at Wall-to-Base Slab Interface for Seismic Loading with No Live Load (Uniform Subgrade Reaction Model)

C A S E	Load Combinations	TOP SLAB (5, 7) ⁴			WALL (14, 11) ⁴			BASE SLAB (1, 3) ⁴		
		Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin
2	Assuming 50% Rebar Corroded Inside Face of Concrete Tank Wall 0.9D + 1.7H	Not Applicable								
				*	19,740	23,661	0.19	---	---	---
				**	42,591	12,136 ²	-0.71	10,149 ¹	7,078 ²	-0.30
7	1.05D + 1.4E _s	Not Applicable								
				*	8,175	23,661	1.894	---	---	---
				**	8,421	12,136 ²	0.44	9,389 ¹	7,078 ²	-0.25

Table 4.3-9. ACI Code-Based Analysis Results for Live Load, L = 100 psf (Elastic Subgrade Reaction Model)

C A S E	Load Combinations	TOP SLAB (5, 7) ⁴			WALL (9, 12) ⁴			BASE SLAB (1, 3) ⁴		
		Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin
1	As-Designed, As-Built 1.4D + 1.7L ³	7,566	18,921	1.50	1,385 ¹	27,767	19.04	1,385 ¹	13,802	8.96
		8,432	18,921	1.24	3,092	23,661	7.65	2,548 ¹	13,802	4.42
		9,092	18,921	1.08	2,669 ¹	27,767	9.40	2,669 ¹	13,802	4.17
3	1.05D + 1.28L + 1.4E _o	2,919	18,921	5.48	6,637	23,661	2.56	455	13,802	29.30
		13,308	18,921	0.42	4,726 ¹	27,767	4.87	4,726 ¹	13,802	1.92
6	1.4D + 1.7L + 1.7H	2,690	18,921	6.03	13,246	23,661	0.79	1,776 ¹	13,802	6.77
3	Assuming 50% Rebar Corroded Inside Face of Concrete Tank Wall									
			Not Applicable	*	2,669 ¹	27,767	9.40	2,669 ¹	13,802	4.17
				**	6,637	12,136 ²	0.83	455	7,078 ²	14.56
6	1.4D + 1.7L + 1.7H			*	4,726 ¹	27,767	4.87	4,726 ¹	13,802	1.92
				**	13,246	12,136 ²	-0.08	1,776 ¹	7,078 ²	1.98

Table 4.3-10. ACI Code-Based Analysis Results for Live Load, L = 200 psf (Elastic Subgrade Reaction Model)

C A S E	Load Combinations	TOP SLAB (5, 7) ⁴			WALL (9, 12) ⁴			BASE SLAB (1, 3) ⁴		
		Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin
5	As-Designed, As-Built 1.4D + 1.7L + 1.7H	15,084	18,921	0.25	5,922 ¹	27,767	3.68	5,922 ¹	13,802	1.33
		5,084	18,921	2.72	12,215	23,661	0.93	1,694 ¹	13,802	7.15
5	Assuming 50% Rebar Corroded Inside Face of Concrete Tank Wall 1.4D + 1.7L + 1.7H	Not Applicable			5,922 ¹	27,767	3.69	5,922 ¹	13,802	1.33
		Not Applicable			12,215	12,136 ²	-0.006	1,694 ¹	7,078 ²	3.18

Table 4.3-11. ACI Code-Based Analysis Results for Seismic Loading with No Live Load (Elastic Subgrade Reaction Model)

C A S E	Load Combinations	TOP SLAB (5, 7) ⁴			WALL (9, 12) ⁴			BASE SLAB (1, 3) ⁴		
		Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin
2	As-Designed, As-Built 0.9D + 1.7H	15,617	18,921	0.21	5,396 ¹	27,767	4.15	5,396 ¹	13,802	1.56
		9,911	18,921	0.91	16,165 ⁵	26,540 ⁵	0.64	4,277 ¹	13,802	2.28
7	Assuming 50% Rebar Corroded Inside Face of Concrete Tank Wall 1.05D + 1.4E _s	6,973	18,921	1.71	1,573 ¹	27,767	16.65	1,573 ¹	13,802	7.77
		1,902	18,921	16.33	5,520	23,661	3.27	268 ¹	13,802	50.50
2	Assuming 50% Rebar Corroded Inside Face of Concrete Tank Wall 0.9D + 1.7H	Not Applicable			5,396 ¹	27,767	4.15	5,396 ¹	13,802	1.56
		Not Applicable			16,165 ⁵	13,760 ^{1,5}	-0.14	4,277 ¹	7,078 ²	0.65

C A S E	Load Combinations	TOP SLAB (5, 7) ⁴			WALL (9, 12) ⁴			BASE SLAB (1, 3) ⁴		
		Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin
7	1.05D + 1.4E _o			* **	1,573 ¹ 5,520	27,767 12,136 ²	16.65 1.19	1,573 ¹ 268 ¹	13,802 7,078 ²	2.28 50.50

Table 4.3-12. ACI Code-Based Analysis Results for Live Load, L = 10 psf (Elastic Subgrade Reaction Model)

C A S E	Load Combinations	TOP SLAB (5, 7) ⁴			WALL (9, 12) ⁴			BASE SLAB (1, 3) ⁴		
		Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin
9	As-Designed, As-Built	7,184 2,004	18,921 18,921	1.63 8.44	1,687 ¹ 5,629	27,767 23,661	15.46 3.20	1,687 ¹ 287 ¹	13,802 13,802	7.18 49.10
10	1.4D + 1.7L + 1.7H	11,713 2,524	18,921 18,921	0.61 6.50	3,437 ¹ 14,173	27,767 23,661	7.08 0.67	3,437 ^{1,2} 1,580 ¹	13,802 13,802	3.02 7.73
9	Assuming 50% Rebar Corroded Inside Face of Concrete Tank Wall		Not Applicable	* **	1,687 ¹ 5,629	27,767 12,136 ²	15.46 1.16	1,687 ¹ 2,871 ¹	13,802 7,078 ²	7.18 23.66
10	1.4D + 1.7L + 1.7H			* **	3,437 ¹ 14,173	27,767 12,136 ²	7.08 -0.14	3,437 ¹ 1,580 ¹	13,802 7,078 ²	1.01 3.48

Table 4.3-13. Best-Estimate Analysis Results for Dead Load + Soil Pressure + Live Load, L = 100 psf (Elastic Subgrade Reaction Model)

C A S E	Load Combinations	TOP SLAB (5, 7) ⁴			WALL (9, 12) ⁴			BASE SLAB (1, 3) ⁴		
		Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin
12	As-Designed, As-Built 1D + 1H + 1L * **	8,427 2,475	18,921 18,921	1.24 6.65	4,641 ¹ 7,336 ⁵	27,767 26,540 ⁵	4.98 2.62	2,743 ¹ 795 ¹	13,802 13,802	4.03 16.30
12	Assuming 50% Rebar Corroded Inside Face of Concrete Tank Wall 1D + 1H + 1L		Not Applicable	* **	4,641 ¹ 9,083	27,767 13,760 ^{2,5}	4.93 0.87	2,743 ¹ 795 ¹	13,802 7,078 ²	4.03 7.90

Table 4.3-14. Best-Estimate Analysis Results for Dead Load + Soil Pressure (Elastic Subgrade Reaction Model)

C A S E	Load Combinations	TOP SLAB (5, 7) ⁴			WALL (9, 12) ⁴			BASE SLAB (1, 3) ⁴		
		Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin	Demand (M) lb-in/in	Capacity (M _u) lb-in/in	Safety Margin
11	As-Designed, As-Built 1D + 1H * **	10,784 2,330	18,921 18,921	0.75 7.12	6,839 ¹ 9,508 ³	27,767 26,540 ⁵	3.06 1.79	3,363 ¹ 2,120 ¹	13,802 13,802	3.10 5.51
11	Assuming 50% Rebar Corroded Inside Face of Concrete Tank Wall 1D + 1H		Not Applicable	* **	6,839 ¹ 9,508 ³	27,767 13,760 ^{2,5}	3.06 0.44	3,363 ¹ 2,120 ¹	13,802 7,078 ²	3.10 2.33

Legend for Tables 4.3-1 through 4.3-14:

D = Dead Load

L = Live Load

H = Earth Pressure

E_o = Soil earthquake load (0.25 g)

Safety Margin = Capacity/Demand - 1

* Demand moment at intersection of wall and slab.

** Demand moment near middle of wall or slab.

¹ Sludge weight on base slab has been considered to modify moment from ANSYS computer run which did not include sludge weight.

² Reduced capacity due to corroded rebar at inside face of concrete.

³ Load case applicable during construction.

⁴ Denotes elements from ANSYS model (see Figure 1).

⁵ Includes 2-way action of load distribution because of lateral earth pressure and respective capacity in each direction. It does not take into account the moment effect due to vertical earth pressure. This computation is based on an approximate and simplified analytical approach in lieu of a 3-directional analysis which would have provided a more realistic load distribution resulting from the 2-way action.

4.3.1 Safety Functions

Although consequence analysis has not been performed, Tank-241-Z-361 serves the safety function of being a barrier to prevent significant worker radiological exposure, i.e. the tank does not collapse. As an interim measure the tank will be designated safety significant because of this function.

4.3.2 References

- 4.3-1 Islam, M. A., *Structural Integrity Assessment For PFP Tank 241-Z-361*, Fluor Daniel Northwest, December 1997, Richland WA.
- 4.3-2 Julyk, L.J. letter report, *Tank 241-Z-361 Dome Load Test Results Summary*, October 1998, Fluor Daniel Northwest, Richland WA.
- 4.3-3 McShane, D.S., letter report, *Engineering Load Evaluation of the Riser on Tank 241-Z-361*, January 1998, Fluor Daniel Northwest, Richland WA.

- 4.3-4 McShane, D.S., letter report, *Re-Evaluation of 3-inch and 8-inch Risers for Breather Filter Mounting on Tank 241-Z-361*, June 1998, Fluor Daniel Northwest, Richland WA.
- 4.3-5 McShane, D.S., letter report, *Evaluation Of Tank 241-Z-361 Nozzles B, E, And F For Load Induced By Sampling Equipment*, April 1999, Fluor Daniel Northwest, Richland, WA.

4.4 FLAMMABLE GAS SAFETY

The following is a general discussion of flammable gas production, behavior and control as developed for the wastes and tanks of the Hanford Tank Farm, with clarifications interjected to relate more directly to Tank 241-Z-361. Within the Tank Farm, there is a great variability in the generation rate of flammable gas, the waste conditions and gas hold-up, and the ventilation for the tank head spaces. Due to some uncertainty in the actual conditions within Tank 241-Z-361, the discussion has been kept broad to ensure all for the potential hazards and complexities. A more detailed discussion is included in control Appendix C. Relevant conditions that are factors in flammable gas production and are thought to exist in this tank include:

- The supernate was removed in 1975 and no known liquid additions have occurred since.
- The heat source from the nuclides in the tank is on the order of 100 watts in 75 cubic meters of waste. Elevated temperatures were not measured in the mid-1970's.
- The tank has no intentional ventilation path but some hydrogen is expected to be removed through diffusion.
- The organic contents are lower than that in most Hanford Tank Farm tanks. The sludge has been effectively washed by the large volume through-put.
- The liner corrosion has in all likelihood already been accomplished so that it is not contributing additional flammable gas.

Since these factors are difficult to quantify, the approach to the hazards will be to assume a higher degree of hazard exists until conditions can be verified to be acceptable.

Radioactive waste generates hydrogen through the radiolysis of water, thermolytic decomposition of organic components, and corrosion of a tank's carbon steel walls. Radiolysis and thermolytic decomposition also generate ammonia. Non-flammable gases such as nitrogen, which act as diluents, are also produced. Additional flammable gases, such as methane and an oxidizer, nitrous oxide, are generated by chemical reactions between various degradation products of organic chemicals originally present in the tank. Volatile or semi-volatile organic chemicals may also produce organic vapors.

The gases generated by the waste have the potential to accumulate in flammable concentrations in

the tank vapor spaces or within the waste.

This section summarizes the understanding regarding flammable gases generated by Hanford tank wastes including hazard phenomenology and control strategies. This understanding and control strategy has been developed based on extensive study of the flammable gas hazards present in the TWRS Tank Farms and is adapted for the hazards present in Tank 241-Z-361.

The flammable gas control strategy for TWRS facilities, and its application to Tank 241-Z-361 is designed to prevent a flammable gas accident by: (1) maintaining the head space concentration below 25% of the LFL for gases that are released in a steady manner; and, (2) preventing ignition sources when and where flammable gases may be present due to gas retention within the waste and gas release events (GRE)s or accumulation within waste intruding equipment.

When and where ignition controls are required is determined by three factors affecting the nature and extent of postulated flammable gas hazards: (1) waste behavior postulated as defined by the facility group assignment (Section 4.4.3); (2) the type of operational activity that may be performed (i.e., waste disturbing or non-waste disturbing); and, (3) the region or location within the tank that will be accessed (i.e., dome intrusive, waste intrusive, or ex-tank intrusive).

4.4.1 Vapor Space Flammable Gas Concentration Because of Steady State Releases

Steady state releases are managed by diluting and removing the gases from the tank headspace through passive ventilation. This prevents a steady accumulation of gas from reaching flammable concentrations.

Passive ventilation consists of atmospheric breathing combined with a convective flow through tank openings caused by the buoyancy effects from gas temperature differences, and Bernoulli flow caused by wind blowing past the tank exhausts. Diffusion of hydrogen through the porous concrete wall and top, however, is also an important mechanism for diluting the hydrogen released from the waste.

4.4.1.1 Controls for Steady State Releases. Tank 241-Z-361 now has a continuous passive ventilation system. Monitoring shows the tank atmosphere is being maintained less than 25% of the LFL.

4.4.2 Gas Retained Within the Waste

Some generated gas is retained in the waste. Because retained gases can include fuel (for example, hydrogen, ammonia, methane) and an oxidizer (for example, nitrous oxide), the gases can be in flammable concentrations. Retained gas presents a flammability hazard in the following ways:

- It is theorized that the retained gas could burn below the waste surface if ignited; and the amount of gas, bubble type, size, and distribution could enable flame

propagation.

- Gases can be released from the waste in a gas release event (GRE) and burn in tank domes, connected vapor spaces such as ventilation systems, and outside of tank openings such as ventilation inlet paths or open risers if the released gas remains above 100% of the LFL.
- The retained gases can be released and ignited inside equipment inserted into the waste, such as core sample drill strings.

4.4.2.1 Deflagrations Below the Waste Surface. The original USQ declaration for the TWRS Tank Farm flammable gas hazard acknowledged that a flammable mixture of gases may exist in the waste thereby creating the possibility of a combustion event below the waste surface. Further study of this potential has indicated that such a scenario is at best very unlikely since the waste must be porous to allow flame propagation. However, a porous material also allows the flammable gas to diffuse out of the waste and into the tank head space. This issue has not been completely resolved, and, therefore, this JCO specifies ignition source controls to be used with waste intruding equipment in Tank 241-Z-361. Data regarding the amount of gas that may have accumulated in the waste in this tank has not yet been obtained, and thus these controls have been adopted to address the potential for subsurface combustion.

4.4.2.2 Gas Release Events (GREs). Gases that are released from the waste in a nearly continuous manner can be managed effectively by ventilation. Less straight forward, however, is the situation where a significant amount of the gas is retained within the waste and released relatively rapidly in a GRE.

The large GREs that occurred in Tank 241-SY-101 before the mixer pump was installed were unique in size and frequency in TWRS double-shell tanks. None of the gas releases in the other double shell tanks (DSTs) have been large enough to have created flammable mixtures after mixing in the tank headspace. The mechanism for large gas releases in these DSTs is thought to be a buoyant displacement instability (sometimes referred to as a rollover). This occurs when a waste sludge is stored with a large supernate liquid layer above it. Gas is retained in the sludge, the gas void builds until the sludge becomes less dense than the supernate, and then a glob of waste breaks free from the sludge layer and rises to the waste surface. The expansion of the gas bubbles as the waste rises breaks apart the sludge/bubble matrix and releases some of the gas to the tank headspace.

The TWRS single shell tanks (SSTs), like Tank 241-Z-361, do not have large supernate liquids and therefore buoyant displacement GREs are not possible in these tanks. The ongoing study of gas retention behavior of SST waste forms has narrowed the number of plausible spontaneous release mechanisms to only a few possibilities that are capable of only small releases. Observation of a number of the most notable flammable-gas-retaining SSTs indicates that no large GREs are occurring and only a few SSTs experience small spontaneous GREs. The typical spontaneous GRE in a SST has a small release volume of tens of cubic feet of hydrogen.

Gas releases can be induced by waste disturbing operations, but local disturbances do not trigger a general, large-scale gas release. Rather, gas is released only from the volume of waste actually disturbed.

4.4.2.3 Controls for Preventing Ignition During GREs. To manage the risks associated with retained gases and GREs, specific ignition source controls and continuous monitoring requirements are applied on a graded basis depending on (1) the tank's flammable gas facility group status (Section 4.4.3) which defines when and where flammable conditions resulting from a GRE are a concern, and (2) the nature of the work performed.

Prevention of ignition sources involves the use of two sets of ignition source controls that are each invoked depending on the type of activity performed and where the activity may create sparks. The ignition source controls address electrical equipment requirements, non-electrical equipment and materials requirements, and work practices. "Set 1" primarily applies to activities and locations that involve direct contact with waste and undiluted waste gases. "Set 2" primarily applies to circumstances where flammable gas conditions may be postulated to occur in the dome space or ex-tank locations. To ensure consistent application and interpretation of industry standards used by these control sets, a TWRS Flammable Gas Advisory Board (FGEAB) has been formed to oversee the implementation of the ignition source controls.

Monitoring is used prior to work activities to prevent work when gas concentrations resulting are in excess of 25% of the LFL.

4.4.3 Flammable Gas Facility Group Approach

Tank 241-Z-361 is similar to other tanks under TWRS control. The same control strategy approved for use with TWRS tanks will serve as the starting point for identifying flammable gas controls for Tank 241-Z-361. For the purpose of applying controls, each facility in TWRS has been placed in one of four facility groups. The placement depends on whether the waste is postulated to present a hazard from large or small GREs, whether the GREs may be spontaneous or only induced during waste disturbing operations, or no GREs are postulated at all. Ignition source controls and monitoring requirements are applied at times when, and in locations where, flammable conditions resulting from GREs can be present, as appropriate to this grouping scheme. Facilities that have had significant GREs are conservatively postulated to have the potential for large spontaneous and large induced GREs. These tanks have been assigned to Facility Group 1 (FG1). Five TWRS DSTs have been placed in this category.

If a facility is postulated to have the potential for a large induced GRE but only a small spontaneous GRE, it is assigned to Facility Group 2 (FG2). The remainder of the 28 TWRS DSTs have been placed in this category along with a number of SSTs that indicated a significant amount of gas retention.

Facilities that show no propensity for spontaneous GREs but may produce a small induced GRE, are assigned to Facility Group 3 (FG3). The majority of TWRS SSTs have been placed in this category. Facilities with little or no waste solids capable of retaining gases are categorized as

non-GRE. All facility groups assume that the subject tanks undergo steady state gas generation at all times.

The grouping of facilities reflects a conservative approach even in light of uncertainties in the underlying methodology. It also enables a graded application of controls based on perceived hazards and frees less hazardous tanks from unnecessarily restrictive or burdensome controls. This method also enables a degree of simplicity in applying control sets to specific tanks.

Because many of the TWRS Inactive Miscellaneous Underground Storage Tanks (IMUST) contain waste similar in composition to SST waste, it is postulated that flammable gas behavior (gas generation, retention, and release) is analogous to that in SSTs, but on a much smaller scale because of the small amount of waste present.

The facility group control sets for TWRS IMUST were assigned based on the amount of waste solids and overlying supernate known or suspected to be contained in the tank. The IMUST with significant solids but little supernate (less than 378.5 L (100 gal) or less than 1% of the tank capacity) were assigned to FG3. Conversely, IMUST with significant solids and a large supernate layer were assigned to FG2. If the waste solid and liquid volumes of an IMUST were unknown, the tank was assigned to FG2 as a prudent measure until better knowledge of the waste contents is obtained. Finally, those IMUST containing mostly liquids with only a small amount of solids (less than 378.5 L [100 gal]) were classified as non-GRE tanks.

Based on a comparison of Tank 241-Z-361's configuration and contained waste (a large amount of sludge with little or no supernate liquid) controls used for FG3 facilities are appropriate. But, Appendix D postulates the possibility of flammable hydrogen concentrations in the tank. Moreover, there are uncertainties in the actual tank conditions upon which this facility group determination was made. Accordingly, until the conditions are shown to be safe (i.e., less than 25% of the LFL) and consistent with FG 3, more restrictive controls will be applied. Phase I activities have shown the tank to be safe, i.e., less than 25% of the LFL. Accordingly, the controls appropriate for a FG 3 tank will be applied during Phase II.

4.4.4 Application of Flammable Gas Controls to Tank 241-Z-361

Table 4.4.4-1 summarizes the application of the control strategies to address each flammable gas hazard discussed above. More details regarding the control strategies are described in Appendix C. Specific control requirements for Tank 241-Z-361 are included in Section 5.0.

Table 4.4.4-1. Summary of Flammable Gas Controls Strategy for 241-Z-361 (FG 3). (1 sheet)

Flammable Gas Hazard	Control Strategy
Steady state accumulation in head spaces	<ol style="list-style-type: none"> 1. Dilution by ventilation, and 2. Gas monitoring (characterization sampling and work activity entry gas monitoring) 3. If adequate ventilation has not been verified, apply ignition source controls (Set 1) or de-energize
Accumulation in sealed risers	<ol style="list-style-type: none"> 1. Ignition source controls (Set 1) for installed equipment until low concentrations are verified. 2. Work activity entry gas monitoring to verify low concentrations when opening riser
Ignition of flammable gas retained within the waste	<ol style="list-style-type: none"> 1. Ignition source controls (Set 1) at all times
Large spontaneous GREs	Not postulated for 241-Z-361 as a FG 3 tank.
Small spontaneous GREs	Not postulated for 241-Z-361 as a FG 3 tank.
Large induced GREs. (Only postulated in Tank 241-Z-361 during globally waste disturbing operations -- post-Phase II.)	<ol style="list-style-type: none"> 1. Ignition source controls (Set 2) in ex-tank and dome intrusive locations during waste disturbing operations and activities and 2. Continuous gas monitoring during manned waste disturbing activities
Small induced GREs (Only postulated in Tank 241-Z-361 during locally waste disturbing operations.)	<ol style="list-style-type: none"> 1. Ignition source controls (Set 2) for dome intrusive locations during waste disturbing operations and activities and 2. Continuous gas monitoring during manned waste disturbing activities
Accumulation in waste intruding equipment (e.g., inside core sampler drill string) -- Phase II	<ol style="list-style-type: none"> 1. Purge or flush before energizing equipment and during use of equipment or 2. Ignition controls (Set 1) at all times

4.4.5 Exceptions to Ignition Source Control Requirements

The performance of work activities in Tank 241-Z-361 requires the use of some equipment and materials that do not meet the ignition source control requirements and do not have safety equivalency with ignition source controls (Set 1 or Set 2) established by the FGEAB. Most of these items are used throughout TWRS tank farm field activities and are needed to perform important characterization activities in Tank 241-Z-361. Therefore, the exceptions described in Appendix C (Table C-2) are required to perform the activities that are, or will, be covered in this JCO for Tank 241-Z-361.

4.4.6 Adequacy of Flammable Gas Controls

The three-pronged control strategy (ventilation, monitoring, and ignition source control) has been judged to be a practical means for preventing the accumulation of flammable gases where ignition sources may be present or to eliminate ignition sources where flammable gases may be present in TWRS. This same strategy and controls are proposed for use within the Tank 241-Z-361 JCO. The strategy and specific controls have been reviewed and approved for use in TWRS Facilities by RL based on the following findings (TWRS-RT-SER-02, Revision 1). In summary, the SER on the TWRS JCO stated:

- The JCO provides a valid formalized process for selecting controls to minimize the risk of activities where the flammable gas hazard is likely to be present, and
- The control suite represents the best available knowledge on how to practically minimize the hazard of flammable gas presence and minimize potential for ignition if present.

4.4.7 Safety Functions

TWRS equipment has been previously evaluated for its classification under these hazards, and because of the similarity of hazard, this JCO does not repeat that effort. However, as part of Phase I activities, a breather filter was installed on Tank 241-Z-361. That breather filter provides a filtered, passive ventilation path for the tank that will maintain the atmosphere less than 25% of the LFL. Even though a consequence analysis has not been performed, as an interim measure, the breather filter is being designated safety significant.

4.4.8 References

- 4.4-1 HNF-SD-CP-CN-003, 1997, *Hazard Analysis of 241-Z-361 Tank*, Rev. 0, Fluor Daniel Northwest Inc., Richland, Washington.
- 4.4-2 DOE 76-45/19, SSDC-19, 1979, *Job Safety Analysis*, U.S. Department of Energy, Washington D.C.

4.5 TANK PRESSURIZATION

Even small cracks or holes in Tank 241-Z-361 on the order of 1/16 inch would keep the tank from significantly pressurizing and allow atmospheric breathing. Since the tank is about 50 years old, such cracks and holes are expected. However, the existence of relief paths for the tank could not be assured. Accordingly, Appendix E was prepared to evaluate the potential for tank pressurization and the resulting hydrogen concentration. Furthermore, this appendix evaluates the expected flow rate as the tank is vented from this pressurized condition. This appendix formed the basis for developing the controls needed to safely vent Tank 241-Z-361 during Phase I. As a result of Phase I activities the tank has a continuous vent path established, and it therefore cannot be pressurized any longer. Appendix E is retained for reference purposes.

4.6 SAMPLING TRUCK BRIDGE

This section discusses the truck sampling bridge and the basis for its functional classification. The truck sampling bridge is being installed to prevent structural damage to the tank resulting from the weight of the sampling truck. However, the installation and use of the truck sampling bridge introduce hazards that must be appropriately controlled through bridge design features and operating limits. A detailed description of the design basis for the bridge is provided in Appendix H.

4.6.1 Bridge Foundation And Bridge Design

There were six failure modes associated with the bridge and its installation identified during the hazards analysis that could cause damage to Tank 241-Z-361:

The installation of load support piers in the proximity of the tank could potentially cause damage to the tank by excessive weight being applied during the installation process, or the insertion of the piers could potentially damage the walls of the tank with mechanical force leading to a potential leak to the soil column from the tank.

The weight of the sampling truck could be applied in areas external to the tank as it approaches the tank potentially causing structural damage to the tank.

The heavy members associated with the bridge construction could be dropped onto the tank during installation and potentially cause tank structural damage.

The bridge could collapse due to dynamic or static loads applied when the sampling truck is positioned onto the sampling bridge. The collapsing bridge and truck could potentially cause structural damage to the tank. Alternatively, the loads could be applied above the bottom of the tank because the piers were not installed sufficiently deep, leading to potential tank damage. Also, the static and dynamic loads associated with positioning the truck on the sampling bridge could cause excessive forces to be transferred to the tank walls potentially causing structural damage to the tank.

The sampling truck could inadvertently be driven off the sampling bridge and fall onto the tank potentially causing structural damage.

Although collapse of the tank is unlikely even if damaged, this cannot be assured. As a result, events leading to significant overstress of the tank walls or tank top were conservatively considered to be events that could lead to tank collapse. Tank collapse could cause grievous injuries to multiple workers and significant facility worker contamination.

The tank has been vented and is being maintained less than 25% of the LFL with passive breathing through the vent. As indicated in Section 4.4, the tank is not subject to large episodic gas release events. Accordingly, these tank collapse events in Phase II are not postulated to lead to deflagrations that could affect the onsite worker or the public.

The approach to the design and installation of the bridge has been structured to address failures that could potentially lead to tank structural damage. These failures include errors during installation that lead to tank collapse and overstress conditions during sampling. Other features of the bridge have been installed to address operational requirements and to ensure worker safety while working on the platform.

The method chosen to install the foundation for the sampling bridge has been developed to address several potential hazards. The use of helical piers that are inserted by rotation minimizes soil disturbance. The torque control on the rotation of the helical piers reduces the likelihood that the walls will be damaged by mechanical force, thereby reducing the likelihood of potential leaks to the soil column from this activity. Installation of the helical piers does not require use of heavy equipment that would likely apply excessive weight to the areas surrounding the tank. During the installation of the piers, the dome loading controls of Section 5.6 will be applied to ensure the tank walls are not over-stressed by weights applied in the area surrounding the tank.

To ensure the sampling truck weight is not applied in the areas external to the tank except on the sampling bridge, the bridge has been extended about 22-feet from the tank walls. Outside this distance, any load applied would not be seen by the tank walls.

The dome loading controls of Section 5.6 require the use of the Hanford Rigging Manual during lifts. These controls also limit the load lift height. In combination these controls reduce the likelihood that heavy members will be dropped on the tank during construction of the bridge.

The bridge foundation and the bridge structure were designed and evaluated for the expected loading in accordance with AISC allowable stress criteria for steel components and in accordance with manufacturer recommendations for helical pier foundation components. Figures 4.6-1 and 4.6-2 provide the general layout of the foundation for the bridge that has been developed. The vertical piers will be installed to a minimum depth of about 23-feet. As such, load applied to the piers is transmitted to a depth beneath the tank and will not affect the tank. Angled helical piers are installed to a minimum insertion length of about 22-feet. These angled anchors in combination with the bridge structure prevent lateral stresses from being transferred to the tank walls resulting from the dynamic load applied by the truck being positioned on the sampling bridge and from the

wind force on the sampling truck. Specific design features and tolerances are provided in the design media.

Included in the dynamic load evaluated was the wind force potentially being applied to the sampling truck. Seismic loads were not evaluated. Because of the short duration of the sampling activity, and that it is a one-time activity, the likelihood of a large earthquake occurring while sampling was judged remote. Accordingly, the bridge was not designed to accommodate seismic loads from a design basis earthquake.

Although the truck is positioned at very low speeds on the bridge (<2 mph), operator error or failure of the truck could lead to events where the truck is inadvertently driven off the bridge. To prevent this event, the bridge has had edge guards (bumpers) installed that will restrain the truck in this event.

4.6.2 Bridge Load Limit

The analysis provided in Appendix H evaluated load combinations that might be applied to the bridge as static loads and the dynamic loads associated with the force of wind on the sampling truck and that associated with the stopping of movement of the truck as it is repositioned. This analysis provides the basis for the bridge foundation support design specified in drawing H-2-829739. (Ref. 4.6-1) As a result of the analysis of the design of this bridge, an aggregate load limit for the sampling bridge of 35,000 lbs has been established.

4.6.3 Safety Functions

Since the potential for flammable gas deflagration has largely been eliminated by providing a passive, continuous ventilation path for the tank, collapse of the tank no longer would likely result in a large deflagration that could spread contamination that could affect the onsite worker or the public. Collapse of the tank could result in grievous injuries and ingestion of significant amounts of contamination for multiple facility workers. The collapse of the tank could also cause a tank splash. This splash could loft radioactive material that could potentially contaminate onsite workers. The function of the bridge is to prevent structural collapse of the tank during tank characterization to prevent injury to facility workers and potential contamination of onsite workers. Accordingly the bridge is designated a safety significant structure including the edge rails that prevent the truck from inadvertently falling off the bridge.

4.6.4 References

- 4.6-1 Drawing H-2-829739, *Civil Foundation Supports For Inspection Platform*, Fluor Daniel Northwest, March 1999, Richland, WA.

Figure 4.6-1 Plan View -- Tank 241-Z-361 Sampling Bridge Pier Installation
(Not To Scale)

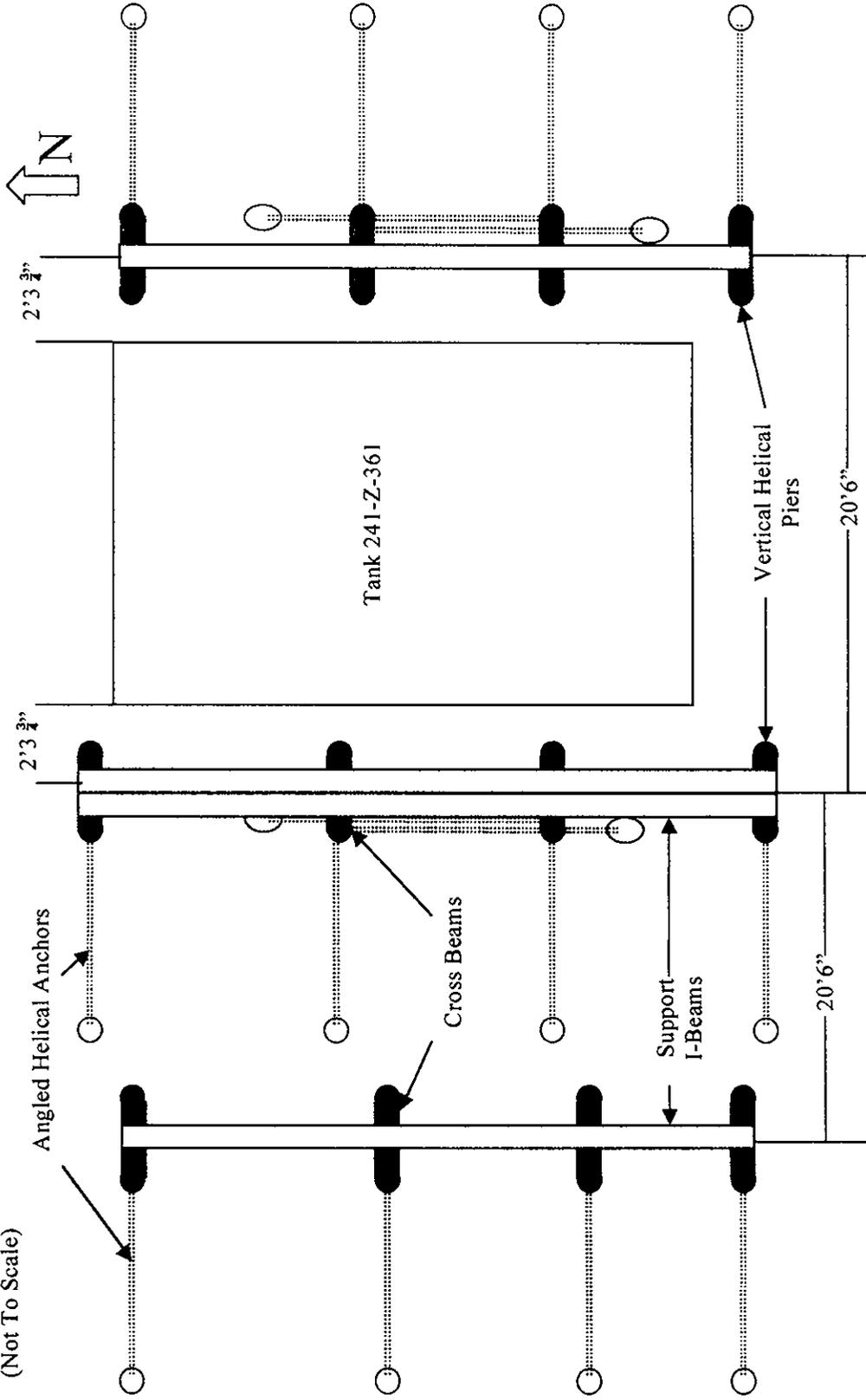
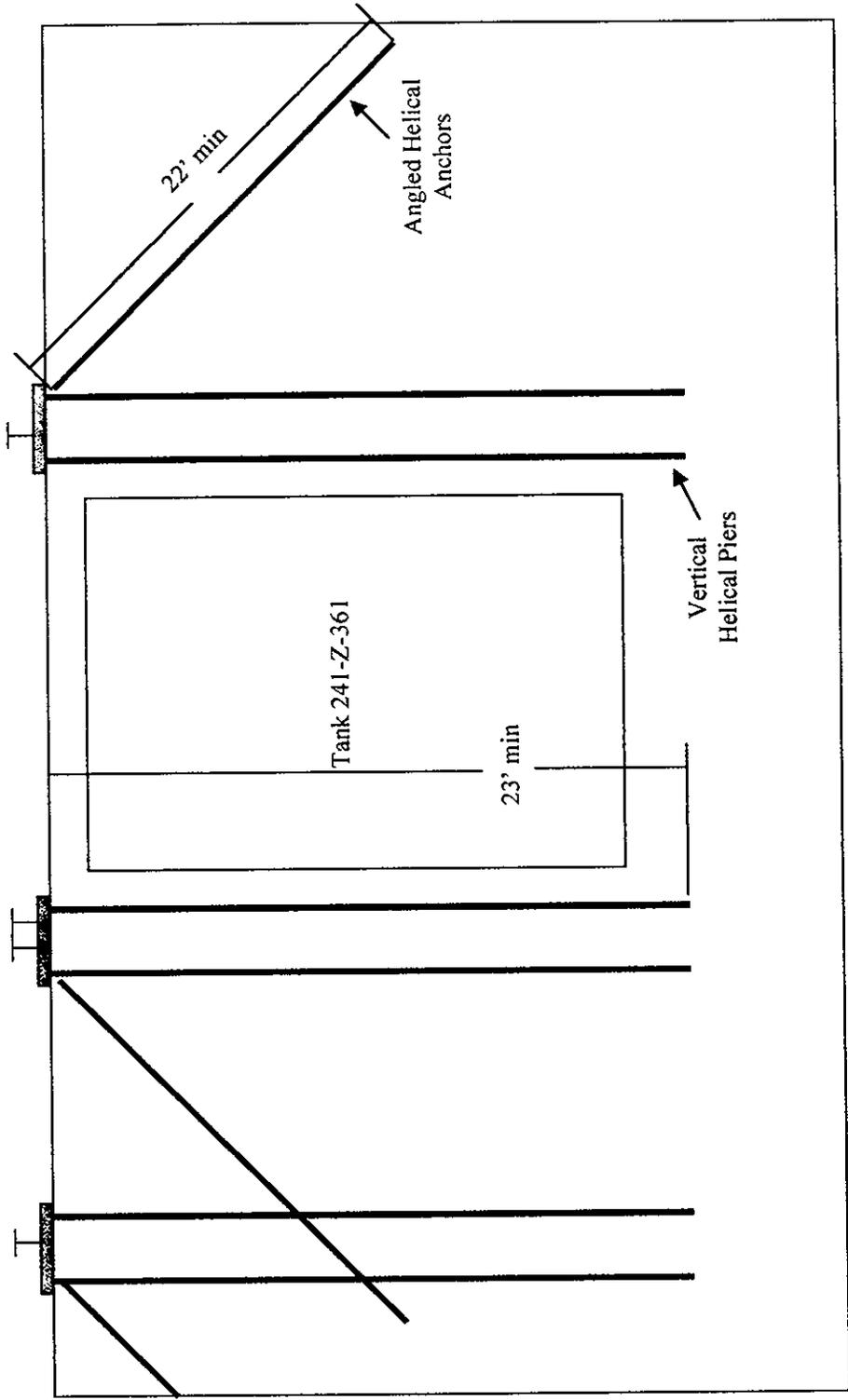


Figure 4.6-2 Sectional View -- Tank 241-Z-361 Sampling Bridge Pier Installation
(Not To Scale)



5.0 HAZARD CONTROL REQUIREMENTS

The initial plant screening for the Unreviewed Safety Question (USQ) identified that the potential for significant hazards and lack of an authorization basis would constitute a potential discovery. As a result, the PRC imposed operating restrictions on activities near the tank, including an expanded exclusionary boundary and a CPS posting around the tank. A formal USQ evaluation was then performed and additional controls instituted, including prohibition of flammable gases, liquids, oxygen or combustible storage, open flames or sources of ignition within 25 feet of the tank risers and flammable gas posting. These controls have been replaced by those approved by DOE in Revision 1 to this JCO. .

In general the controls necessary for Phase II activities are similar to those imposed for Phase I activities. The controls for Phase II activities will become effective prior to commencement of the activities being authorized (Section 3.0) and after receipt of approval from DOE-RL to use these controls. The controls implemented will be those defined in this JCO and any additional controls specified by DOE-RL in their agreement to this authorization basis. These controls will remain effective until replaced by another approved authorization basis document.

Violations to the authorization basis controls approved for Tank 241-Z-361 activities will be reported in accordance with the existing PFP administrative control -- Administrative Control 5.4 - Operational Safety Requirement Violations.

Exemptions to the requirements specified in this JCO may be implemented in an emergency under the provisions of existing PFP Limiting Condition for Operation (LCO) 3.0.7 - Emergency Exceptions. Other non-emergency exemptions may be gained following the procedures, as applicable, provided in the existing PFP Administrative Controls: 5.6 - Revision To Operational Safety Requirements; 5.7 - Operational Safety Requirement Basis Control; and 5.11 - Unreviewed Safety Questions.

The controls identified in the PHA will be administered through the access restriction that is the same as that already in place. Work performed within 25 feet of the tank risers must be reviewed by the PFP PRC and released through the PFP Shift Manager. Thus, the work planning and control process will ensure that these controls are incorporated into the work that is being released for the tank, and the PRC will approve the work planning process and approve JCO control incorporation. This control administration mechanism is suitable because of the short duration of the work, the transitory nature of some of the controls, and the relative simplicity of the controls given the TWRS experience applying the flammable gas controls.

Another aspect of controls that must be considered are the institutional controls for this work. In the hazards analysis process, personnel familiar with work done around the Tank Farm tanks were present to ensure that the hazards were all recognized and that the mechanisms for mitigating personnel hazards were identified. The work that was anticipated and the mechanisms for control of hazards were then reviewed by personnel familiar with the institutional programs at PFP to ensure that the expected or postulated control would exist. Examples of areas where controls on day-to-day work were evaluated include industrial safety and hygiene, radiological control,

environmental protection, excavation control, conduct of operations, work planning and release, criticality program administration, and emergency planning.

Existing PFP institutional programs will be relied upon to control hazards identified in the hazards analysis. The programs include: industrial safety, industrial health, criticality safety, radiological control, work control, fire protection (range fire control), and quality assurance. The existing PFP programs can provide the control specified in the hazard analysis. Where necessary (e.g., emergency preparedness) program implementing procedures will be modified to cover JCO activities, and they will directly cover TWRS personnel working at PFP. These procedure changes will be implemented prior to commencing any Phase I JCO activities. As such, this JCO relies upon and incorporates existing PFP authorization basis administrative controls and other existing institutional programs.

In addition to the controls specified in this JCO in Sections 5.2 through 5.6, the specific PFP Operational Safety Requirements (OSR) included within the terms and conditions for this effort are: LCO 3.0.7 - Emergency Exceptions; Administrative Control (AC) 5.2 - Contractor Responsibility; AC 5.3 - Compliance; AC 5.4 - Operational Safety Requirement Violations; AC 5.5 - Occurrence Reporting; AC 5.6 - Revision To Operational Safety Requirements; AC 5.7 - Operational Safety Requirement Basis Control; AC 5.9 - Procedures; AC 5.10 - Facility Change Control; AC 5.11 - Unreviewed Safety Questions; AC 5.12 - Personnel Qualifications And Training; AC 5.13 - Facility Reviews And Audits; AC 5.14 - Audit Records Requirements; AC 5.15 - Nuclear Criticality Safety; AC 5.16 - Radiation Protection; AC 5.19 - OSR Interfaces With Other Facilities; AC 5.20 - Fire Protection; and AC 5.23 - OSR Compliance Program.

Elements of the TWRS authorization basis are also being adopted while performing push-mode core sampling activities. Those elements of the TWRS authorization basis that are applicable and relevant to push mode sampling at PFP have been incorporated into Section 5.2 through 5.6.

A health and safety plan has been prepared to address specific hazards potentially associated with the sampling activities. The health and safety plan has been provided in Appendix C to "241-Z-361 Characterization Sampling and Analysis Plan, HNF-4371 (Ref 5.3-5). This plan also identifies emergency planning requirements associated with this activity.

The activities at Tank 241-Z-361 will utilize HNF-IP-0263-PFP, "Building Emergency Plan for Plutonium Finishing Plant Complex." (Ref 5.3-6). The PFP emergency plan will be implemented by PFP procedures, and work packages will specify applicable emergency preparedness and response activities. All TWRS field staff working on Tank 241-Z-361 will attend a PFP emergency response briefing and will be trained on emergency response provisions in the work packages. That training includes:

- facility layout and location;
- energy signals, notification, and communications;
- routes of egress and staging areas;
- plant-specific safety requirements; and
- plant emergency response procedures

Specific emergency response notifications and their actions are specified in Z-plant casualty response procedures (ZCR). These procedures identify actions for a broad range of potential emergencies.

The following subsections provide the detailed control requirements for the hazards identified and evaluated in performing the PHA and preparing this JCO. The control requirements for performing characterization activities in Tank 241-Z-361 are administrative in nature and are therefore provided in the form of administrative controls. They will be considered equivalent to OSR for the Plutonium Finishing Plant. Flammable gas controls being used are the set that were developed for the Tank Farm and approved as the TWRS authorization basis controls.

5.1 DEFINITIONS

DOMe INTRUSIVE A **DOMe INTRUSIVE** region is one that is within the tank between the top of a riser and the surface of the waste. Because the filter housing and connecting ducting extends the riser, the **DOMe INTRUSIVE** region extends to the open-air inlet/outlet of breather filters or active ventilation system inlet filters, or bags/sleeving around an open riser. The **DOMe INTRUSIVE** region includes regions above the riser, such as vapor sample streams that may contain undiluted dome space gases.

EX-TANK INTRUSIVE An **EX-TANK INTRUSIVE** region is one that includes all vapor spaces with a direct connection to the tank dome space but does not meet the definition of either **DOMe INTRUSIVE** or **WASTE INTRUSIVE**.

The **EX-TANK INTRUSIVE** region includes the environment outside a tank opening, which is directly connected to the dome space, out to the shortest of the following distances:

- 18 opening diameters
- 15 ft
- The boundary of temporary containment devices.

INTRUSIVE **INTRUSIVE** tank regions include **EX-TANK INTRUSIVE**, **DOMe INTRUSIVE**, and **WASTE INTRUSIVE**.

WASTE DISTURBING **WASTE DISTURBING** operations and activities include all work that may result in significant motion under the waste surface. **WASTE DISTURBING** operations and activities include **GLOBAL WASTE DISTURBING** and **LOCAL WASTE DISTURBING**

defined as follows:

- **GLOBAL WASTE DISTURBING**: Operations and activities that cause a large global disturbance of the waste.

Examples of GLOBAL WASTE DISTURBING operations and activities include waste sluicing and retrieval or mixing as with a mixer pump. (These operations are not anticipated in Phase I or Phase II of this JCO.)
- **LOCAL WASTE DISTURBING**: Operations and activities that disturb only a small, local portion of the waste.

Examples of LOCAL WASTE DISTURBING operations and activities include waste grab sampling and core sampling.

WASTE-INTRUDING EQUIPMENT

WASTE-INTRUDING EQUIPMENT includes open-ended or breached objects that are inserted below the waste surface and create an unvented vapor space where flammable gases retained in the waste may accumulate. An example of WASTE-INTRUDING EQUIPMENT is a core sample drill pipe.

WASTE INTRUSIVE

The **WASTE INTRUSIVE** region is the region below the waste surface.

5.2 ACCESS RESTRICTIONS

5.2.1 Requirement for Access Restrictions

Limit access to the zone surrounding Tank 241-Z-361 to control potential hazards associated with flammable gas ignition, structural collapse, criticality or burning fuel in the tank.

5.2.2 Program Key Elements

1. Establish and post a Controlled Area surrounding and over Tank 241-Z-361 out to 25 ft. from the tank risers.
2. No personnel or vehicles shall access the Controlled Area except as allowed by an approved work package.
3. Work packages allowing work within the Controlled Area shall be reviewed by the PFP PRC to ensure implementation of the controls of this JCO.

5.3 FLAMMABLE GAS SAFETY

The purpose of the flammable gas safety controls is: to ensure that gas volumes are controlled to be less than 25% of the LFL; that ignition sources are controlled where potentially flammable gases exist; and, that monitoring is performed to evaluate potentially flammable gas conditions. This set of controls is consistent with industry practice and was justified and approved in the TWRS Basis for Interim Operation (BIO) (Ref 5.3-1).

5.3.1 Ventilation, Purging And Pressure Relief

Ventilation shall be provided to Tank 241-Z-361 after opening such that the head space gas concentrations resulting from the steady release of the gas generated in the tank are maintained below 25% of the LFL.

If the initial flammable gas concentration exceeds 25% of the LFL, then the adequacy of the ventilation shall be verified by monthly measuring the concentration in the head space and verifying that concentrations are less than 25% of the LFL subsequent to initial riser opening.

If purge gas is applied to the tank or a confinement (i.e., glovebag) or pressurized gas will be vented from the tank, HEPA-filtered ventilation path(s) shall be operating and filter this air flow prior to release to the environment. These filtered vent path(s) shall be sized to accommodate the sum of the expected vent flow rate and the purge flow rate while preventing excessive tank pressurization, confinement failure due to pressurization or flow-induced forces, or excessive filter differential pressure.

The rate of tank venting and purge application shall be controlled so that the confinement (i.e., glovebag) and HEPA filters are not damaged.

5.3.2 Flammable Gas Ignition Controls

5.3.2.1 Ignition Source Control Applicability. Ignition source controls are required as shown in Table 5.3-1

5.3.2.2 Ignition Source Control Requirements.

Ignition Source Control Set #1

The Ignition Source Control Set #1 is used for equipment that is installed or used during work activities for that portion of the work in a WASTE INTRUSIVE region or inside WASTE-INTRUDING EQUIPMENT.

1. Mechanical tooling, equipment, and materials (including lubricants, adhesives, gaskets, corrosion inhibitors, epoxies, etc.) shall be constructed of spark-resistant material, or shall be rendered incapable of sparking with sufficient energy to combust hydrogen, or shall have been analyzed and evaluated to be incapable of sparking with sufficient energy to combust hydrogen under the applied conditions. Material compatibility shall be evaluated

- for thermite reaction potential. For the first flange opened, the flange bolts shall be replaced with bolts made of spark-resistant material. Also, for the first riser opened, an insert made of a spark resistant material shall be inserted between the flange and riser while the flange is being lifted off the riser.
2. Electrostatic ignition sources shall be controlled by providing bonding or grounding according to NFPA 77, *Recommended Practice on Static Electricity*. (Ref 5.3-2)
 3. Exposed polymer materials shall be rendered incapable of electrostatic charge or discharge potential with sufficient energy to combust hydrogen either by design, through acceptable work around practices, or by evaluation of the applied conditions (NFPA 77).
 4. The surface temperatures of heat-generating devices (this includes potential compression heating and open flames) shall not exceed 780 °F. The surface temperature is limited to a maximum of 320 °F if the device can contact the waste and cause ignition by triggering exothermic reactions in the waste (i.e., organic salt-nitrate reactions). Internal temperatures of heat-generating devices may exceed these temperatures (NFPA 70, *National Electric Code, Articles 500 - Hazardous [Classified] Locations and 501 - Class I Locations*) [Ref 5.3-3] if the heat source is either isolated (pressurized) from the gas environment, or if the design of the device enclosure meets the requirements for explosion-proof housings.
 5. Electrical equipment shall be designed to meet NFPA 70, Class I, Division 1, Group B criteria or provide equivalent safety. As a minimum, this shall be interpreted to mean that no single point failure of energized equipment can result in an arc, spark, or gas burn propagation to the environment external to the source enclosure (NFPA 70). In the case of waste-submerged equipment containing potential ignition sources, demonstration by design that the equipment is non-sparking under normal operation and is designed to be isolated from the waste environment is an acceptable alternative.
 6. Shutdown of purged and pressurized electrical equipment, and purged and pressurized heat-generating equipment, on loss of protective gas pressure or flow, shall be automatic by design as defined by NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*. (Ref 5.3-4)
 7. Interlocked startup of purged and pressurized electrical or purged and pressurized heat-generating equipment shall only be allowed when the system senses preset limits (e.g., adequate protective gas pressure established as defined by NFPA 496). If pressurized enclosures are used to isolate energized components, a minimum of four enclosure volumes shall be purged through the enclosure for energized components, and/or ten volumes shall be purged for enclosed motors before controlled startup of the system components (NFPA 70, NFPA 496).

Ignition Source Control Set #2

The Ignition Source Control Set #2 is applied to vapor space regions (EX-TANK INTRUSIVE and DOME INTRUSIVE) when a gas release event (GRE) is postulated to create flammable conditions.

1. Mechanical tooling, equipment, and materials (including lubricants, adhesives, gaskets, corrosion inhibitors, epoxies, etc.) shall be constructed of spark-resistant material, or shall be rendered incapable of sparking with sufficient energy to combust hydrogen, or shall have been analyzed and evaluated to be incapable of sparking with sufficient energy to combust hydrogen under the applied conditions. Material compatibility shall be evaluated for thermite reaction potential.
2. Electrostatic ignition sources shall be controlled by providing bonding or grounding according to NFPA 77.
3. Exposed polymer materials shall be rendered incapable of electrostatic charge or discharge potential with sufficient energy to combust hydrogen either by design, through acceptable work around practices, or by evaluation of the applied conditions (NFPA 77).
4. The surface temperatures of heat-generating devices (this includes potential compression heating and open flames) shall not exceed 780 °F. The surface temperature is limited to a maximum of 320 °F if the device can contact the waste and cause ignition by triggering exothermic reactions in the waste (i.e., organic salt-nitrate reactions). Internal temperatures of heat-generating devices may exceed these temperatures (NFPA 70) if the heat source is either isolated (pressurized) from the gas environment, or if the design of the device enclosure meets the requirements for explosion-proof housings.
5. Electrical equipment shall be designed to meet NFPA 70, Class I, Division 2, Group B criteria or provide equivalent safety. As a minimum, this shall be interpreted to mean the equipment is non-sparking under normal operation or, if normally sparking, the sparking component(s) shall be continuously isolated (purged and pressurized) from the potentially flammable gas environment, or the design of the device enclosure shall be of sufficient strength (explosion-proof) to prevent propagation of a gas burn to the environment external to the enclosure (NFPA 70).
6. Either automatic shutdown or alarming with manual shutdown is required upon loss of protective gas pressure or flow as defined by NFPA 496 Type Z pressurization. In EX-TANK INTRUSIVE region applications, electrical equipment that does not meet Class I, Division 2, Group B may be used, if it is automatically shutdown by combustible gas detection systems.

7. Automatic or manual startup controls of purged and pressurized electrical or purged and pressurized heat-generating equipment shall only be allowed on system sensing of preset limits (e.g., adequate protective gas pressure established as defined by NFPA 496). If pressurized enclosures are used to isolate energized components, at least four enclosure volumes shall be purged through the enclosure for energized components, and/or ten volumes shall be purged for enclosed motors before controlled startup of the system components (NFPA 70, NFPA 496). When combustible gas detection shutdown systems are employed, startup of equipment shall only be allowed once measured acceptable flammable gas levels are indicated.

5.3.2.3 Deviations From Flammable Gas Ignition Controls. Deviations from Ignition Source Control Sets #1 and #2 are permitted provided the equipment, materials or work practices: (1) provide equivalent ignition source control safety, as approved by a TWRS Flammable Gas Advisory Board, or (2) is an approved exception listed in Table 5.3-3.

Deviations from Ignition Source Control Sets #1 and #2, or from the DOE-approved list of exceptions listed in Table 5.3-3 are subject to the unreviewed safety question (USQ) process.

Table 5.3-1. Flammable Gas Ignition Source Control Set Application Requirements

Tanks	During Non-WASTE DISTURBING Activities		During LOCAL WASTE DISTURBING Activities		During GLOBAL WASTE DISTURBING Activities		WASTE INTRUSIVE or Inside WASTE-INTRUDING EQUIPMENT
	EX-TANK INTRUSIVE	DOME INTRUSIVE	EX-TANK INTRUSIVE	DOME INTRUSIVE	EX-TANK INTRUSIVE	DOME INTRUSIVE	
241-Z-361 (Facility Group 3)*†	2B	2B	2B	2A	2B	2A	I

Notes:

- 1 - Ignition Source Control Set #1 applies at all times
- 2A - Ignition Source Control Set #2 applies only for the duration of the WASTE disturbance
- 2B - Ignition Source Control Set #2 applies to activity-related equipment and materials until work activity entry monitoring requirements (5.3.3) are met. Ignition Source Controls are not required by 2B (ignition source controls during entry monitoring) in the EX-TANK INTRUSIVE region defined as the environment outside of tank openings that are directly connected to the headspace out to a distance of 18 opening diameters; 4.92 m (15 ft); or the boundary of temporary containment devices, whichever is shorter.
- When installing equipment (e.g., cameras, videos, lights) with hot filaments, a method shall be used to prevent these hot sources from falling on the waste surface.
- † Flame cutting/welding in this tank is not permitted unless the PHMC President's approval is received. This approval requirement cannot be delegated. If flame cutting/welding is authorized and performed where debris could fall onto the waste surface, a barrier or device shall be used to prevent hot metal/slag from falling onto the waste surface.

5.3.3 Flammable Gas Work Activity Monitoring Controls

The following flammable gas monitoring controls shall be performed during work activities to monitor flammable gas concentrations to prevent deflagrations.

5.3.3.1 Work Activity Entry Monitoring Verify that flammable gas concentrations in INTRUSIVE tank regions are $\leq 25\%$ of the Lower Flammability Limit (LFL) prior to commencing any work. If flammable gas concentrations are $> 25\%$ of the LFL, do not start manned work activities. This entry monitoring does not require the monitoring of the EX-TANK INTRUSIVE region.

This requirement shall be applied to all manned work activities in waste containing vessels (i.e., when the manned work activity is near an opening in the vessel containment) to ensure that flammable conditions in the work space are not present because of steady-state accumulation and/or recent gas release events (GREs), subsequent to initial riser opening.

For manned activities on this tank, the entry monitoring requirements are:

1. Monitor at breather filter (passive ventilation) or vent duct (active ventilation) prior to start of activity, subsequent to initial riser opening.
2. For work in pits or enclosures, monitor inside of pit prior to start of pit or enclosure work.
3. Monitor inside riser (passive or active ventilation) or allow for a one minute pause with riser opened (active ventilation only) prior to start of operations and activities in DOME INTRUSIVE regions.
4. For DOME INTRUSIVE work, follow 1 through 3 above, plus monitor below bottom of riser (passive or active ventilation) or in vent duct upstream of the first mixing point (active ventilation only) prior to start of activity.
5. For manned activities involving WASTE- INTRUDING EQUIPMENT, monitor in the vapor space prior to start of activity.

The flammable gas entry monitoring requirements are also shown on Table 5.3-2.

5.3.3.2 Work Stops

1. If flammable gas concentrations are $> 25\%$ of the LFL, manned work activities shall be stopped except for gas sampling, taking necessary actions to reduce gas concentrations, and discontinuing use of ignition sources that do not meet Section 5.3.2, "Ignition Controls." Installed equipment that meets Section 5.3.2 may continue to be used (not be de-energize) if $> 25\%$ of the LFL.
2. If lightning is detected within 50 miles of the Hanford site, all work on Tank 241-Z-361

shall be halted.

3. Secure equipment in lowest position (e.g., lay down equipment elevated above the tank and lower crane boom) if lightning is identified within a 50-mile radius of the Hanford site.

5.3.3.3 Continuous Monitoring For GRE During the performance of manned work activities there is the possibility of flammable conditions developing as a result of a GRE, therefore, work space (EX-TANK INTRUSIVE or DOME INTRUSIVE) flammable gas monitoring is continued as indicated in Table 5.3-2. Continuous monitoring means use of a continuous monitor (e.g., Standard Hydrogen Monitoring System [SHMS]) or use of portable combustible gas monitors (CGMs) that monitor continuously and alarm at $\leq 25\%$ LFL. It is acceptable to disconnect a CGM or similar instrument during continuous monitoring to permit the temporary connection of alternate measurement devices such as organic vapor monitors (OVMS) or Drager tubes.

Continuous monitoring requirement applicability is shown in Table 5.3-2.

Stop manned work activities if flammable gas concentrations are $> 25\%$ of the LFL with an exception for gas sampling, necessary actions to reduce gas concentrations, and discontinuing use of ignition sources that do not meet the ignition source controls in Section 5.3.2.

5.3.3.4 Welding/Flame Cutting Welding and flame cutting are not authorized on this tank unless the PHMC President's approval is received. This approval requirement cannot be delegated. If flame cutting/welding is authorized and performed where debris could fall onto the waste surface, a barrier or device shall be used to prevent hot metal/slag from falling onto the waste surface.

Table 5.3-2. Flammable Gas Monitoring Requirements for 241-Z-361

Tanks	During Manned* Non-WASTE DISTURBING Activities		During Manned* LOCAL WASTE DISTURBING Activities		During Manned* GLOBAL WASTE DISTURBING Activities		Inside WASTE-INTRUDING EQUIPMENT
	EX-TANK INTRUSIVE & DOME INTRUSIVE (Riser or Duct only)	DOMES INTRUSIVE in Dome Space	EX-TANK INTRUSIVE	DOMES INTRUSIVE	EX-TANK INTRUSIVE	DOMES INTRUSIVE	
241-Z-361 (Facility Group 3)	A1	B	none	C	none	C	D

Notes:

- A1 - 1. Monitor at breather filter (passive ventilation) or vent duct (active ventilation) when present or in the vicinity of the risers prior to start of activity.
- 2. Monitor inside riser (passive or active ventilation) or allow for a one minute pause with riser opened (active ventilation only) prior to start of operations and activities in DOME INTRUSIVE regions. This entry monitoring does not require the monitoring of the EX-TANK INTRUSIVE region defined as the environment outside of tank openings that are directly connected to the headspace out to a distance of 18 opening diameters; 4.92 m (15 ft); or the boundary of temporary containment devices, whichever is shorter.
- B - A1 above, plus monitor below bottom of riser (passive or active ventilation).
- C - B above, plus continuous monitoring in DOME INTRUSIVE regions where work is being performed such as below bottom of riser (passive or active ventilation), inside of breather filters, inlet filters or temporary glove bags, or in vent duct upstream of first mixing point (active ventilation only) during activity.
- D - Monitor inside WASTE-INTRUDING EQUIPMENT vapor space prior to entry. Monitoring outside of WASTE-INTRUDING EQUIPMENT (e.g., open drill string) is not required.

* Manned refers to personnel performing work related to activity only.

Table 5.3-3. Exceptions to Ignition Source Control Requirements. (3 Sheets)

Item #	Authorized Activities
1	Personal Protection Equipment (i.e., raingear, airline respirator hoses, rubber/plastic and canvas gloves, respirator masks, rubber/plastic boots, masking tape, Tyvek [®] coveralls) are authorized for use in ex-tank locations, but may be used in a minimally dome intrusive location (e.g., at the plane of a riser).
2	Wearing of plastic badges, badge holders, and dosimeters.
3	Installation of, removal of, working on, or extended presence of nonconductive lead blankets in ex-tank regions. Lead blankets shall not be used in a vapor trapping configuration.
4	Installation, removal, or extended presence of nonconductive adhesive tape (e.g., green tape, white tape) in ex-tank regions, Dome Intrusive regions, and in Waste Intruding Equipment.
5	Use of Portable Alpha Monitor (PAM) in ex-tank regions, Dome Intrusive regions, and in Waste Intruding Equipment.
6	Use of nonconductive poly bottles in ex-tank and Dome Intrusive regions.
7	Use of zip cords in ex-tank regions and Dome Intrusive regions.
8	Use of nonconductive plastic ropes in ex-tank regions.
9	Use of nonconductive plastic tubing in ex-tank regions and Dome Intrusive regions (e.g., aerosol testing). Nonconductive plastic tubing shall not be used below the plane of a riser.
10	Installation and removal of Garlock gaskets in ex-tank regions.
11	Use of nonconductive plastic garden type sprayer (approximately 5 gallons, hand pump pressurizer and brass spray wand) in ex-tank regions.
12	Use of grab sample cap, sampling and sludge weight retrieval device and coated steel cable in ex-tank and Dome Intrusive regions.
13	Installation and removal of PVC riser liners in Dome Intrusive regions.

Table 5.3-3. Exceptions to Ignition Source Control Requirements. (3 Sheets)

Item #	Authorized Activities
18	Installation of, removal of, working with, or extended presence of the pipe wiper (Frisbee) during push mode core sampling (PMCS) with Truck 1, 2, and 3, in ex-tank and Dome Intrusive regions.
18	Installation of, removal of, or extended presence of plastic Kamlock caps during push mode core sampling with Trucks 1, 2, or 3 in ex-tank and Dome Intrusive regions.
19	The presence of extension cords in ex-tank regions. Power strips (and outlet strips) are not allowed in these regions. Energized lines shall not be connected or disconnected in an ex-tank region.
21	Electrical bonding is not required for removal or installation of fittings on openings less than or equal to 2.54 cm (1 in.) inside diameter during intrusive location entry.
22	Use of Type 4 vapor sampling head in ex-tank and Dome Intrusive regions. Conductive plastic sleeving shall be used during Type 4 vapor sampling.
24	Use of Type 4 vapor cart in ex-tank and Dome Intrusive regions.
25	Open riser work related equipment (e.g. Pike Poles, T-Bars, Sockets, Chokers, Shackles, and Bull Hooks) in ex-tank regions. Installation and removal of vapor seal in ex-tank regions. Continuous monitoring in the tank dome and the ex-tank region required during use of this exception.
27	Installation, removal, presence of, or movement of cover blocks, riser flanges, shield plugs, tank installed waste and non waste intrusive equipment items (e.g. heated vapor probes, corrosion probes, water lances, void fraction meter, core sampling drill string, cameras/lights, viscometer, auger, sampler) each as used in ex-tank or dome intrusive or waste intrusive regions. Work packages and procedures will include practical measures to reduce the likelihood of a mechanical spark when equipment movement performed as part of an operation or activity can create mechanical sparks. Such measures may include: limiting insertion speeds, water bathing of equipment, prevention of contact with other non-spark resistant materials by use of collars or bumpers, use of critical lift procedures where appropriate. This exception does not cover the operation of large mixer pumps that might cause significant motion of installed equipment. Any other ignition source hazards (other than mechanical spark source potential) must comply with this JCO's requirements for ignition source controls.

Table 5.3-3. Exceptions to Ignition Source Control Requirements. (3 Sheets)

Item #	Authorized Activities
31	Use of Continuous Air Samplers in ex-tank regions. CAS shall be shutdown if 10% of the LFL is exceeded in the ex-tank area. Motor shall be placed outside the ex-tank region. Continuous monitoring in the tank dome and the pit is required during use of this exception.

5.3.4 References

- 5.3-1 HNF-SD-WM-BIO-001, Rev. 0, *Tank Waste Remediation System Basis For Interim Operations*, Fluor Daniel Hanford, 1997, Richland Washington.
- 5.3-2 NFPA, 1993a, *Recommended Practice on Static Electricity*, NFPA 77, National Fire Protection Association, Quincy, Massachusetts.
- 5.3-3 NFPA, 1996, *National Electric Code, Articles 500 - (Classified) Locations and 501 - Class I Locations*, NFPA 70, National Fire Protection Association, Quincy, Massachusetts.
- 5.3-4 NFPA. 1993b, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*, NFPA 496, National Fire Protection Association, Quincy, Massachusetts.
- 5.3-5 BWHC 1999, HNF-4371, *241-Z-361 Sludge Characterization Sampling and Analysis Plan*, April 1999, B&W Hanford Company, Richland, WA.
- 5.3-6 BWHC 1998, HNF-IP-0263-PFP, Rev. 5, *Building Emergency Plan for Plutonium Finishing Plan Complex*, 1998 B&W Hanford Company, Richland, WA.

5.4 VEHICLE FUEL FLAMMABILITY SAFETY

The following controls shall be in place prior to use of vehicles in the Controlled Area for Tank 241-Z-361 to prevent vehicle accidents that could cause burning fuel in the tank.

1. Vehicle access within the Controlled Area shall be limited to vehicles whose fuel systems are protected from damage to the integrity of the fuel systems caused by potential collisions with tank structures (e.g., mechanical protection such as a skid plate on the fuel tank or reservoir tanks physically located higher than risers or vehicle axles).
2. Vehicle speeds shall be limited to 5 mph.

5.5 NUCLEAR CRITICALITY SAFETY

The purpose of the Nuclear Criticality Safety control is to ensure that criticality safety analyses are performed and approved and resulting administrative controls are applied for Tank 241-Z-361.

5.5.1 Requirement for Nuclear Criticality Safety

The PFP Nuclear Criticality Safety Program shall be maintained for ensuring waste in Tank 241-Z-361 remains subcritical.

5.5.2 Program Key Elements Applicable to Tank 241-Z-361

1. Criticality limits and controls shall be documented and implemented.
2. Procedures shall be established for recovery from a CPS nonconformance.
3. Criticality safety training shall be provided for operations and technical personnel.

5.5.3 Specific Requirements for Work Activities in Tank 241-Z-361

Specific requirements applicable to Tank 241-Z-361 shall be administered through the PFP Criticality Control program.

5.6 DOME LOADING CONTROLS

The purpose of the dome loading controls is to ensure that distributed or concentrated loads applied to Tank 241-Z-361 are within the analyzed limits to prevent structural failure.

5.6.1 Requirement for Dome Loading Controls

Limit loads so waste is not released from Tank 241-Z-361 due to accidental equipment drops or excessive loads leading to tank structural failure.

5.6.2 Program Key Elements

1. For mechanical lifts within 20 ft of Tank 241-Z-361, the lower equipment boundary of the lifted item (e.g., bottom of the breather filter) shall be less than 10 ft above surface grade, or above the waste storage tank (covered or uncovered).
2. Use the *Hanford Site Hoisting and Rigging Manual* (DOE/RL-92-36) for lifts.
3. Dome loading shall be managed to limit distributed and concentrated loads above waste storage tank per Table 5.6-1 and Table 5.6-2.

4. Only hand digging or excavation using a “guzzler” machine (i.e., a vacuum soil extraction system) shall be used in the vicinity of the tank to remove soil. This control shall not limit the installation of piers and foundations that use minimally soil disturbing installation methods (e.g., screwing in helical piers).
5. The weight applied to the sampling bridge shall be limited to 35,000 pounds.

5.7 OTC WEATHER ENCLOSURE

The purpose of the OTC weather enclosure controls are to minimize the likelihood of a spread of contamination from an OTC that is placed within a weather enclosure.

5.7.1 Requirement for OTC Weather Enclosure Controls

Provide passive ventilation in the OTC weather enclosure to reduce the likelihood of significant concentration hydrogen or radioactive contamination build up during OTC storage in a weather enclosure.

5.7.2 Program Key Elements

1. If the OTC is stored in a weather enclosure, the weather enclosure shall have passive ventilation.
2. Ignition controls, grounding/bonding and spark free tools, shall be used during OTC venting in the weather enclosure.
3. Radiological control requirements shall be implemented under the PFP radiological control program.
4. When an OTC is present in the weather enclosure, the weather enclosure shall have warning signs on the outside that identify the presence of flammable gas and prohibit smoking or open flames within 25 feet of the weather enclosure.

Table 5.6-1. Authorized Tank Dome Loads For Tank 241-Z-361

Location	Applied Maximum Total Load Above Nominal ^{1, 5, 7, 9}
Tank Top Area	2000 lbs total
Restricted Access Area Outside of the Tank Top Area (For each tank wall) ^{2, 3}	Load patterns where, ^{4, 6, 8} $\sum_{i=0}^N \frac{Q_i}{957 + 163.6D_i + 8.14D_i^2} \leq 1$

- ¹ Nominal conditions consist of the existing soil overburden without significant snow or rain load present i.e. accumulated moisture in the previous 72 hours is less than 0.1 inches.
- ² One-half of the load applied outside of the tank top area but within 2 ft of a tank wall (as measured from a vertical extension of the tank wall) shall be considered as being applied to the tank top.
- ³ Loads applied beyond 20 ft from the tank walls (as measured from a vertical extension of the tank wall) are not restricted.
- ⁴ For the load evaluation criteria,
 Q_i = the discrete load in lbs.
 D_i = the distance in ft from the tank wall as measured from a vertical extension of the tank wall.
- ⁵ Work may proceed to next safe stopping point (as determined by the PIC) if rain or snow commences during work.
- ⁶ Loads applied with the angle subtended by the orthogonal wall (outside the tank top area) will be applied 50% to each wall.
- ⁷ The load associated with snow may be removed by removing the snow from the ground, i.e. shoveling.
- ⁸ The following table provides examples of the approximate largest single load that may be applied versus distance from the tank using this control.

Load (Q _i)	Distance (D _i)
950 lbs	0 ft
1900 lbs	5 ft
3400 lbs	10 ft
5200 lbs	15 ft
7400 lbs	20 ft

⁹ The limits identified in this table do not apply to loads applied to piers installed in accordance with this JCO. These piers have been installed sufficiently deep (23-feet for vertical piers and a minimum insertion of 22-feet for angled piers) that the load is not significantly applied to the tank walls.

The following controls shall be applied to ensure tank risers do not fail from applied loads. Such controls shall be maintained until the risers are found to be capable of receiving greater loads:

Table 5.6-2 Authorized Tank Riser Loads

Tank 241-Z-361 Riser Load Limits				
Riser ⁺	Vertical Load Limit (lbs)	Side Load Limit (lbs)	Torque Load Limit (ft-lbs)	Additional Limitations And Comments
A - 8-inch	500 ²	250	100	Only one of these two risers should be loaded at a time.
B - 8-inch	1500 ²	250	100	
C - 2-inch	100	100	50	Adequate to work around. However, if necessary to use, then a load test should be conducted.
D - 3-inch	100	100	50	
E - 6-inch	100 ^{1,2}	100	50	Insufficient design detail to fully analyze.
F - 8-inch	1500 ²	100	50	
G - 8-inch	1500 ²	250	100	
H - 3-inch	500	250	100	

¹ The riser vertical load limit can be increased to 1500 lbs if an equivalent method (riser clamp) such as that identified in Appendix I is applied to the riser to bear the load.

² See calculations provided in Appendix I.

⁺ See the load riser designations provided in Figure 2.1-2 and Appendices F and I.

APPENDIX A
INITIAL HAZARD CATEGORIZATION ANALYSIS FOR TANK 241-Z-361

A.1 Introduction

This analysis determines the initial hazard categorization for Tank 241-Z-361. A facility's hazard categorization determines the level of DOE oversight required for the facility and the level and type of safety analyses required for the facility.

DOE-STD-1027-92 provides the requirements and guidance for performing facility hazard categorizations. Hazard Category 1 facilities are defined in DOE Order 5480.23 as those with the potential for "significant offsite consequences." According to DOE-STD-1027, Hazard Category 1 facilities are limited to Category A reactors and facilities designated by the DOE Program Secretarial Officer (PSO). Category A reactors are those that have a steady-state power level greater than 20 MWt, as defined in DOE Order 5480.6. The Hazard Category 1 designation is not applicable to Tank 241-Z-361. Tank 241-Z-361 does not have the radiological inventory or inherent energy source potential to produce dose consequences comparable with a Category A reactor under worst case accident scenarios.

Hazard Category 2 facilities are defined as those with the potential for significant on-site consequences. The interpretation in DOE-STD-1027-92 is that Hazard Category 2 facilities are those with the potential for nuclear criticality events or with sufficient quantities of hazardous material and energy such that on-site emergency planning activities are required.

Hazard Category 3 facilities show the potential for significant but localized consequences. The Hazard Category 3 designation is intended to capture facilities such as lab operations, low level waste handling facilities, and research machines which possess less than the Category 2 quantities of material and are considered to represent a low hazard.

The primary manner for determining whether a facility is Hazard Category 2 or 3 is to compare the facility's radiological inventory with the threshold quantities (TQ) listed in Table A-1 of DOE-STD-1027-92. The bases for the Hazard Category 2 and 3 threshold quantities are provided in Attachment 1 to DOE-STD-1027-92. A comparison of the estimated Tank 241-Z-361 radiological inventory with the Hazard Category 2 TQs from DOE-STD-1027 is provided below. This comparison shows that the tank warrants designation as a Hazard Category 2 facility.

A.2 Comparison of Tank Isotopic Inventories with Hazard Category 2 Threshold Quantities

The primary radiological constituents in Tank 241-Z-361 are plutonium (various isotopes) and Am-241. Based on previous sludge sample results, the total plutonium content of the tank was estimated to range from 26 kg to 75 kg (WHC-SD-EN-040,1994). Material unaccounted for (MUF) indicates there is approximately 31 kg of plutonium in the tank. For this analysis, the conservative maximum value of 75 kg is assumed.

The isotopic makeup of the plutonium in the tank is unknown. However, it can be reasonably assumed not to exceed in specific activity the isotopic makeup of the plutonium currently being stored within the PFP. The isotopic distribution of plutonium in PFP is characterized in Table 9-44 of the *Plutonium Finishing Plant Final Safety Analysis Report*, WHC-SD-CP-SAR-021 (1996). Two distributions are provided in the FSAR: one for the portion of the PFP inventory containing less than 10% Pu-240; and one for PFP Pu material containing greater than 10% Pu-240. The bulk of the material processed through PFP was weapons-grade, containing less than 10% Pu-240 (BNWL-CC-925, 1974). The isotopic distribution shown in Table 9-44 of the PFP FSAR for the portion of the PFP Pu material containing less than 10% Pu-240 is therefore used in this analysis.

Table A-1 (attached) compares the plutonium isotopic inventory values predicted for Tank 241-Z-361 with the Hazard Category 2 and 3 thresholds. Column 1 of the table provides the list of isotopes considered in this analysis. The second column gives the weight percent estimated for each isotope based on Table 9-44 of the PFP FSAR. The third column of the table gives the total inventory estimate for each isotope, in g, based on the maximum estimated total plutonium quantity (all isotopes) of 75 kg for the tank and the isotopic weight distribution given in column 2. The fourth column provides the specific activities of each isotope, in Ci/g. The fifth column converts inventory estimates from a gram to a Curie basis by multiplying the elements in the third and fourth columns together. The sixth column in the table gives the DOE-STD-1027 Hazard Category 2 TQs for each isotope, in Ci. The last column of the table ratios (divides) the isotopic inventory estimates in the fifth column by the TQ values in the sixth column. The last column of the table therefore gives the fraction (ratio) of the TQ taken up by each radioisotope.

Where there are combinations of radionuclides in a facility, DOE-STD-1027 requires that the hazard category be determined based on the summation of the radionuclide threshold ratios. This summation is provided at the bottom of the last column in Table A-1. The sum of the threshold ratios for Tank 241-Z-361 is shown to be 111. Since this sum exceeds 1, a Hazard Category 2 designation is warranted.

A.3 Fissile Material Inventory And Criticality Potential

Facilities with fissile material in quantities in excess of the theoretical minimum critical mass limits specified in ANSI 16.1 are considered to be Hazard Category 2 facilities (whether or not the Hazard Category 2 TQs are exceeded), unless material form or segmentation preclude the possibility of a criticality. From Table A-1, Tank 241-Z-361 may contain approximately 70 kg of Pu-239. The minimum critical mass limit for Pu-239 is 450 g (Table A-1, DOE-STD-1027).

HNF-PRO-334 (1997) designates Tank 241-Z-361 as a limited control facility. This designation means the tank contains greater than one-third of a critical mass of fissile material, but that material is in a form that precludes the potential for a criticality. The most recent criticality safety assessment of Tank 241-Z-361 (HNF-2012) confirms the extreme unlikelihood of criticality in the

tank, which was the basis for the earlier designation of the tank as a limited control facility. Accordingly, the fissile material inventory therefore does not factor into the hazard category assignment for the tank.

A.4 Conclusion

Tank 241-Z-361 is designated Hazard Category 2 based on the inhalation dose potential radionuclide inventory.

A.5 References

- DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance With DOE Order 5480.23, Nuclear Safety Analysis Reports*, 1992, U.S. Department of Energy, Washington, D.C.
- BNWL-CC-925, *The Ecological Behavior of Plutonium and Americium in a Fresh Water Ecosystem: Phase II, Implication of Differences in Transuranic Isotopic Ratios*, 1974, Pacific Northwest Laboratory, Richland, Washington.
- HNF-PRO-334, *Criticality Safety: General Requirements*, Rev. 0, 1997, Project Hanford Policy And Procedure System, Richland, Washington.
- HNF-2012, *Engineering Study of the Criticality Issues Associated With Hanford Tank 241-Z-361*, 1997, Richland, Washington.
- WHC-SD-EN-ES-040, *Engineering Study of 50 Miscellaneous Inactive Underground Radioactive Waste Tanks Located at the Hanford Site, Washington*, Rev. 0, 1994, Golder Associates, Inc., and Engineering-Science, Inc., for Westinghouse Hanford Co., Richland, Washington.
- WHC-SD-CP-SAR-021, *Plutonium Finishing Plant Final Safety Analysis Report*, Rev. 1, 1996, Westinghouse Hanford Company, Richland, Washington.

Table A-1. Comparison of Tank 241-Z-361 Isotopic Inventory With Hazard Category 2 Thresholds

Isotope	weight%*	Isotopic+ Inventory (g)	Specific Activity (Ci/g)	Isotopic Inventory (Ci)	Std. 1027 Cat 2 Threshold** (Ci)	Fraction of Threshold (unitless)
Pu-238	1.0E-04	7.5E+00	1.71E+01	1.28E+02	6.20E+01	2.06E+00
Pu-239	9.37E+01	7.03E+04	6.20E-02	4.36E+03	5.60E-01	7.79E-01
Pu-240	6.05E-02	4.54E+03	2.27E-01	1.03E+03	5.50E+01	1.87E-01
Pu-241	2.0E-03	1.50E+02	1.03E+02	1.55E+04	2.90E+03	5.34E+00
Pu-242	3.0E-04	2.25E+01	3.88E-03	8.73E-02	5.50E+01	1.59E-03
Am-241	1.5E-03	1.13E+02	3.43E+00	3.88E+02	5.50E+01	7.05E+02
Sum-of-fractions:						1.11E-02
<p>* From Table 9-44 of WHC-SD-CP-SAR-021, mass-weighted isotopic distribution for Pu Inventory at PFP containing <10% Pu-240</p> <p>+ Basis: 75kg of total Pu</p> <p>** From Attachment 1 of DOE-STD-1027-92. Thresholds for unspecified alpha emitters Pu-240 and Pu-242 set at 55 Ci per footnote 1 at end of attachment</p>						

APPENDIX B
HAZARD ANALYSIS OF TANK 241-Z-361

B.1.0 INTRODUCTION

The activities to vent Tank 241-Z-361 and to characterize and remediate the tank waste contents will be performed in phases. Phase I activities are those necessary to safely approach the tank, perform a load test of the tank, gather information about the structural integrity of the tank, relieve tank pressure, open the tank, passively ventilate the tank, obtain video and photographs of the interior of the tank, and to obtain vapor space and waste surface grab samples from the tank. Phase II activities are those associated with characterizing the tank for subsequent remediation. This PHA has been revised to address both phases.

An earlier PHA, HNF-SD-CP-CN-003, *Hazard Analysis of Tank 241-Z-361* (1997), evaluated the hazards associated with the tank being in a state of isolation and inactivity. The PHA presented in this document is the follow-on step in evaluating hazards associated with Tank 241-Z-361. In the interest of completeness, the hazardous conditions identified in HNF-SD-CP-CN-003 have been incorporated into the current PHA.

B.2.0 METHODOLOGY

Hazard identification is the process of highlighting material, system, process, and facility characteristics with the potential to initiate accidents having undesirable consequences. The hazardous events that are of primary concern for this PHA are:

- Events that can result in the airborne release of radiological or toxicological material from the tank.
- Events that can result in operator exposure to elevated levels of ionizing radiation.
- Industrial-type accidents that can result in severe injuries to plant workers.

The primary method of hazard identification/hazard evaluation used for Tank 241-Z-361 is a PHA, a systematic approach in which the basic elements of the system and the hazards of interest for postulated activities are identified, potential causes and effects are evaluated, and possible corrective and/or preventive measures are proposed.

A PHA is a technique derived from the U.S. Military Standard System Safety Program requirements. A PHA focuses, in a general way, on hazardous materials and major processes. To prepare a PHA, a team of individuals with experience in process safety and with extensive knowledge of the operation or process to be evaluated are assembled. The team's collective experience is elicited in "brainstorming" sessions to discover the potential hazards posed by a given operation or process. Several revisions of the PHA have been prepared over the course of this JCO, and not all team members participated in each revision of the PHA.

The team members involved in the performance of this PHA and their qualifications are:

- Duane M. Bogen M.S., Nuclear Technology. Principal Engineer, PFP Transition Engineering, B&W Hanford Company. More than 20 years experience at Hanford: 2 years, Plutonium Finishing Plant; 9 years, Westinghouse Hanford Company, including Manager B Plant/WESF; 4 years UNC Nuclear Industries; 4 years Department of Energy, Richland, WA.
- Gary R. Franz B. S., Physics. Member, The Chiron Group, LLC. Twenty-three years experience in ES&H and engineering analysis and management. Performed and managed safety analyses for Hanford, INEL, and WIPP for a total of 18 years, with 2 years on TWRS, including forming the FSAR project team. Managed the Safety Analysis and Nuclear Engineering Department for WHC. Authored the N Reactor Safety Issues Resolution Report, the Special Isotope Separation Project Siting Analysis, and the FFTF Control Room Habitability Design Basis Evaluation.
- J. Michael Grigsby B.S., Mechanical Engineering. Senior Consultant, G&P Consulting, Inc. Seven years experience at Hanford performing or managing safety evaluations and safety analysis of TWRS tank farm operations and activities, including investigation of safety issues relating to ferrocyanide, organic complexant and organic solvent combustion, and flammable gas hazards and accidents. Co-author of safety analyses that lead to the closure of USQs involving ferrocyanide and organic solvent in the tank farms. Lead author of the TWRS flammable gas JCO. Eleven years experience in commercial nuclear power safety analysis and licensing.
- Brett Hall B. S., Chemical Engineering. Process Engineer, FDNW Safety Analysis and Risk Assessment Group. Over 8 years experience at Hanford. Seven years of experience in performing and documenting safety analyses for various Hanford facilities, including the TWRS tank farms and the Plutonium Finishing Plant (PFP). One year experience in tank waste characterization.
- Keith E. Myers B.S., Production Management. Senior Project Manager, E2 Consulting Engineers. Twelve years experience working in Tank Farm Operations. Began as a nuclear process operator performing all forms of field activities. Promoted to exempt position as a first-line supervisor overseeing day-to-day tank farm operations. Formed the single-shell tank stabilization organization to pump interstitial liquid from aging tanks. Operations Manager for Tank Characterization Project. This group was tasked with performing various tank intrusive activities to obtain samples in support of

overall program goals. Independent consultant for the last 2 years, primarily supporting tank farm tasks.

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| Alan L. Ramble | Mr. Ramble is currently the Criticality Safety Representative, the cognizant engineer for the Safety Analysis Report, and project manager for the Solution Stabilization Project at the Plutonium Finishing Plant. As the Criticality Safety Representative Mr. Ramble has responsibility for implementation of the criticality safety program at PFP, including approval of Criticality Safety Evaluation Reports, Criticality Prevention Specifications, operating procedures, initial training and annual retraining of fissile material handlers, and inspection for compliance with criticality safety requirements of PFP. Mr. Ramble is also responsible for the annual Safety Analysis Report, revision and any amendments required by new processes. In Mr. Ramble's previous position as Manager of Safety Analysis and Nuclear Engineering he prepared safety documentation for PFP, B-Plant/WESF, and Tank Farms as well as serving on the EFCOG Safety Analysis Working Group board of directors. Mr. Ramble successfully completed the milestone to design, construct and cold test a direct denitration vertical calciner at the PFP. Completion of this milestone is key to overall completion of the PFP 94-1 mission. |
| Milton V. Shultz | B. S., Nuclear Engineering Technology. Senior Process/ Specialty Engineer, FDNW Safety Analysis and Risk Assessment. More than 22 years experience at Hanford: 1 year, N Reactor fuel fabrication QA; 3 years, N Reactor maintenance QA; 4 years, N Reactor process standards; 5 years, N Reactor independent safety; 9 years, probabilistic risk assessment and risk evaluation. |
| John D. Williams | B.A. Mathematics. Graduate Naval Nuclear Propulsion Training Programs. President, Xron Associates, Inc. More than 19 years experience in the nuclear industry: 11 years Naval Nuclear Propulsion Program, 3 years DOE Deputy Director Advanced Reactor Program; 2 Years State Department; 3 years Hanford experience with PFP and TWRS. |

B.2.1 PHA Table Structure

PHA is a form driven hazards evaluation technique. The form used in the performance of this PHA is shown in Table B-1 (see tables provided at end of report). The PHA was structured primarily based on planned Phase I and Phase II activities. Each Phase I and Phase II activity was broken down into significant subactivities or procedural steps for analysis. The first column in see Table B-1, "Item Number," is a numeric identifier for each hazardous event postulated by the

PHA team. The second column, "Operating Steps/Procedures," identifies the significant operating steps or procedures associated with each general activity that was considered in the analysis. The third column, "Hazardous Event," describes the postulated condition or combination of events that can produce undesired consequences. The fourth column, "Cause," lists the potential cause or causes of the hazardous condition. The fifth column, "Consequences," contains a consensus description of the uncontrolled result of the hazardous event. The sixth column, "Engineered Features," lists potential hardware means by which the consequences of the hazardous event could be mitigated. The seventh column, "Administrative Controls," lists potential administrative features that could prevent or limit the consequences of the hazardous event. Administrative features include procedures, institutional control programs, operator training, etc.

The eighth and ninth columns are "Cons Rank" and "Freq Rank," respectively. These columns are used to capture a code designator for the level of consequence and frequency associated with the hazardous event. The Consequence Ranking column is a "first cut," qualitative, consensus estimate of the safety severity of the consequences. An alphanumeric system was used to designate the severity, with the following "S" rankings characterizing safety consequences:

- S0 No effect outside the facility confinement systems; no safety concerns for the facility worker, the onsite worker, or members of the general public.
- S1 Potential industrial injury, low to moderate radiological dose consequences, or low to moderate chemical exposure to the facility worker; limited environmental discharge of hazardous material outside the facility.
- S1* Potential severe harm or potential death from industrial injury, radiological dose consequences, or chemical exposure to the facility worker.
- S2 Potential significant radiological dose consequences or chemical exposure to the onsite workers located outside the facility; significant environmental discharge of hazardous material within the plant site boundary.
- S3 Potential significant radiological dose consequences or chemical exposure to the offsite population; significant environmental discharges of hazardous material outside the Hanford site boundary.

The Frequency Ranking column is a "first cut," qualitative, consensus estimate of the frequency of the consequences. The frequency estimate is based on a "no controls present" character of the accident. By estimating the accident frequency on only the initiating event characteristics (including consideration of real world physical effects, i.e., a motor vehicle can be assumed to not be able to penetrate a 2-foot thick reinforced concrete wall), the importance of the various postulated engineered and administrative preventers/mitigators can be evaluated. An

alphanumeric system was used to designate the frequency, with the following "F" rankings characterizing safety consequences:

- F0 Events not expected to occur and categorized as beyond extremely unlikely. The frequency range is $<1E-06/\text{yr}$.
- F1 Events not expected to occur within the lifetime of a typical facility and categorized as extremely unlikely. The frequency range is $1E-06/\text{yr} \leq f < 1E-04/\text{yr}$.
- F2 Events that could occur during the lifetime of the facility and categorized as unlikely. The frequency range is $1E-04/\text{yr} \leq f < 1E-02/\text{yr}$.
- F3 Events that are expected to occur one or more times during the lifetime of the facility and categorized as anticipated. The frequency range is $1E-02/\text{yr} \leq f < 0.1/\text{yr}$.

The "Remarks" column contains information that requires documentation. This includes, but is not limited to, assumptions about facility operation and recommendations for changes in the planned design or operation.

The first portion of the Table B-4 is the original portion of the PHA table prepared for Phase I activities. Additional entries have been prepared to address Phase II activities. Several of the activities associated with push mode sampling have been analyzed as part of the TWRS authorization and safety basis. This analysis is not repeated in this JCO.

In addition to the TWRS authorization basis documents, a USQ evaluation (TF-97-0236) was performed to evaluate push-mode sampling activities in single-shell tanks and double-shell tanks except for Tank 101-SY. This evaluation identified that about 95 hazardous conditions associated with push mode core sampling had been evaluated during the development of the TWRS authorization basis. This analysis concluded that push mode core sampling was within the TWRS authorization basis for the identified tanks. The discussion in Section 4.4 and Appendix C of this JCO identifies that hazards associated with Tank 241-Z-361 are generally the same the same as those for a TWRS Flammable Gas Category 3 tank. Several of the tanks for which TWRS authorizes push mode core sampling are significantly more hazardous, particularly from a flammable gas perspective, than Tank 241-Z-361. Accordingly, the approach taken in this JCO for Phase II activities is to provide hazard analysis for the potentially unique hazards (structural failure) associated with push mode core sampling in Tank 241-Z-361, and to make use of the previous analysis for typical push mode core sampling performed by TWRS.

B.2.2 Activities/Conditions Evaluated

The activities to be performed were determined by cognizant engineers at the PFP and TWRS responsible for ultimately dispositioning the waste in Tank 241-Z-361 and by the PHA team. In

some cases, insights gained from performing the PHA resulted in the reordering or modification of planned activities to enhance benefit or reduce risks. This is one of the advantages provided by the structured PHA approach. In addition some optional or contingency activities have been incorporated to enable flexibility during the performance of the work. The activities covered in the PHA are listed in Tables B-2 and B-3.

In addition to the hazardous events that can occur during Phase I and Phase II activities, hazardous events (e.g., spurious collapse of the tank due to long-term structural degradation) can occur while the tank is in an isolated, passive condition prior to the initiation of Phase I activities. After Phase II activities are completed, Tank 241-Z-361 will passively ventilate through installed breather filters until Phase II characterization activities are initiated. Certain hazardous events can be postulated for the tank during this time period (e.g., criticality due to dry out and subsidence of the tank sludge) given the lack of characterization information available for the tank. The PHA entries for the passive isolated tank following Phase I and Phase II activities are essentially those from the prior hazards analysis performed on the tank (HNF-SD-CP-CN-003), except that following Phase II the tank is known to be passively ventilated at a rate that flammable gas build-up and pressurization cannot occur.

A PHA is structured to look at operational steps or activities but is not designed to highlight accidents initiated by natural phenomena (e.g., earthquakes) or external events (vehicle accidents).

The effects of these natural phenomena and external hazards on facilities are to cause process upsets and/or to challenge the integrity of facility confinement systems. In some cases, external events can add hazardous material to the system (such as fuel from a truck crash) which might initiate a unique accident.

B.2.3 Brainstorming Approach

Each activity was broken down into significant subactivities or procedural steps to ensure a comprehensive review. The TWRS procedures for activities similar to those planned for Phase I and Phase II were reviewed to determine the significant subactivities and procedural steps associated with each major activity. The TWRS procedures reviewed as part of this PHA include:

Phase I Activities

- T0-020-006, Perform Riser Prep
- T0-020-930, Perform MCCS Survey of Single-Shell or Double-Shell Waste Storage Tanks
- T0-080-627, Perform Vapor Sampling of Waste Tanks Using In-Situ Vapor Sampling System

Phase II Activities

- TO-080-503, Push Mode Sampling With Truck #1
- TO-020-451, Setup And Takedown Of Core Sampling Systems
- TO-020-452, Setup And Takedown Of Core Sample Equipment At 241-SY-101

For each primary activity, the PHA team brain stormed potential hazards associated with the subactivities and procedural steps. Brainstorming was based on the team's general collective experience, the team members' knowledge of hazards identified for similar activities in other safety basis documents, and on logical "what if" type questions posed by PHA team members. Examples of what if questions are: "What if the activity is not performed or is performed out of order?" "What if the activity takes longer than desired?" "What can go wrong during the performance of the activity?" For hardware systems, the safety functions performed by those systems were identified and functional failures were postulated to determine potential hazardous outcomes. Finally, a hazard/energy checklist from DOE 76-4519, "Job Safety Analysis," was reviewed for each activity to aid in the brainstorming process. The hazard/energy checklist is provided in Table B-4.

B.3.0 PHA RESULTS

The hazardous events identified in this PHA were grouped into the following eight categories based on accident phenomenology and consequence severity. The accidents having S1*, S2, or S3 consequences are candidates for JCO controls and specific engineered features. Accidents having S1 severity need to have controls provided by institutional programs such as radiological protection and industrial safety. Accidents having an S0 severity or estimated to have a frequency beyond extremely unlikely do not need specific controls.

1. Events that result in ignition of a quantity of flammable gas in the tank head space causing damage to the tank roof and a release of radioactive aerosols to the atmosphere.

During Phase I, the events encompass quantities of flammable gas that range from the entire tank head space being flammable to gas release events involving small pockets of flammable gas. These events have the potential to produce S3 consequences. The ignition sources include postulated static and mechanical sparks generated in the tank vapor space or glovebag during riser entry, sparks from electrical equipment lowered into the tank, lightning strikes into the tank or connecting piping, vehicle impacts into tank risers that result in a spill of burning fuel into the tank, mechanical sparks due to wind generated missile impact into tank riser (highly unlikely), mechanical sparks generated during a seismic event, sparks generated due to micro-cracking of concrete during the load test, and mechanical sparks generated due to collapse of the tank roof in various overloading scenarios. Postulated scenarios for collapsing the tank roof are discussed in the next category.

During Phase II, flammable gas initiating events are less likely. The tank has been vented during Phase I and a passive, filtered ventilation path established that maintains the tank atmosphere less than 25% of the LFL. As a result, the principal gas release mechanism is associated with the locally waste disturbing push mode core sampling activity. During this activity, gas would only be expected to be released from that small pocket of waste disturbed by the sample drill string.

2. Events that result in collapse of the tank roof or failure of the risers in the tank roof that cause a significant release of toxic vapors and radioactive aerosols to the atmosphere and possibly gross contamination of a worker or workers. The collapse can range from the entire tank roof to failure of a riser. This category excludes flammable gas deflagrations potentially ignited by mechanical sparks produced in the roof collapses (which are covered in the previous hazardous event category). The events in this category have the potential to produce S1* through S3 consequences.

During Phase I, postulated causes for failing the tank roof or risers include putting too much load (people or equipment) on the tank, inadvertently driving a vehicle/crane onto or

too close to the tank, various crane or winch load drop events, application of excessive lateral load or torque during riser entry activities (with riser potentially significantly weakened first by long-term corrosion), collapse of degraded riser due to weight of installed Y-adaptor and breather filter, and pull out of riser with crane or winch due to failure to disconnect rigging before withdrawing rigging. The tank may also fail during the load test, if the test is not properly controlled.

During Phase II, several events associated with the truck sampling bridge have been identified that can lead to overstress conditions for the tank that potentially results in tank collapse. These events include: improper bridge installation, inadvertently driving the truck off from the sampling bridge, applying excessive weight surrounding the tank during construction, dropping heavy bridge members onto the tank during construction. However, the consequences of a tank collapse are likely less than those postulated for Phase I since there is not likely to be any significant concentration of flammable gas in the tank to deflagrate at the time the tank collapse might occur.

3. Events that result in minor releases of toxic vapors and radioactive aerosols with no damage to the basic tank structure. The events in this category produce only S1 consequences. This includes releases of contamination due to wind effects or atmospheric pressure changes when opening risers. Also includes minor contamination events when withdrawing equipment from the tank. During Phase II, the contaminated drill string and related equipment will be removed from the tank on several occasions.
4. Events postulated to result in a criticality occurring in the tank waste. Criticalities are six of the events evaluated. Postulated causes for a criticality include inadvertent addition of solvents to the tank and potential long-term chemical changes in the tank waste.
5. Events postulated to result in an ignition of organic nitrate compounds in the tank with subsequent release of toxic vapors and radioactive aerosols. The events in this category have the potential to produce S3 consequences. For an organic/nitrate reaction to occur, the waste must be very dry and ignited by a very energetic heat source. Postulated initiators are highly unlikely and include lightning strike and vehicle impact into riser resulting in a spill of burning fuel into the tank. During Phase II additional potential initiators include the activity to cut off the risers.
6. Events involving normal industrial hazards or small quantities of radioactive contamination (e.g., skin contaminations, excavation accidents, asbestos exposure, worker electrocution, falls and tripping hazards, etc.). These events pose only S1 potential consequences.
7. Leaks to the soil column due to general tank degradation. Also, events such as water line breaks that result in localized flooding above the tank and intrusion of water into the tank exacerbating a tank leakage condition. Leaks to the soil column are S0 events since the

release stays confined to the soil. During Phase I, large spills of water on top of the tank may overload the tank roof causing roof collapse and S3 consequences. During Phase II events that might cause leaks to the soil column include striking the tank walls during installation of the foundation for the tank sampling bridge.

8. Events that result in pressurized releases from the tank. The events in this category have the potential to produce S1* consequences due to worker injury (caused by ejected blind flange) or unfiltered release of plutonium particulate from the tank. During Phase I, pressurized releases are postulated during the opening of the first riser due to the potential buildup of hydrogen (produced by radiolysis) in the tank. The tank is assumed to have no vent paths prior to opening the first riser because of prior efforts to "seal" the tank. Pressurized releases can also occur during purging of the tank (if performed) due to excessive purge supply or blocked vents on the tank. Pressurized releases of flammable gases from the tank can result in ex-tank regions with flammable gas concentrations above the LFL. Pressurized release events are therefore a concern both from a flammable gas hazard standpoint and from a direct worker injury and inhalation dose hazard standpoint. During Phase II pressurized releases from the tank are not postulated to be present because the tank has a continuous vent path established through the HEPA filter.
9. Events that result in contamination releases within, or from, the OTC weather enclosure. The events in this category have the potential to produce S2 consequences because they can cause particulate plutonium to be released to the atmosphere in certain unlikely events. The OTC contain hydrogen that is produced by radiolysis. There is a possibility of this hydrogen deflagrating within the enclosure. This deflagration could damage the weather enclosure and loft particulate plutonium.

B.4.0 PROPOSED CONTROLS

The following general controls are proposed for the JCO activities. The controls are grouped according to the preceding categories of hazardous events. The controls for the significant hazardous event categories are discussed in more detail in the body of the JCO report (Section 5.0).

1. Category Description: Events that result in ignition of a quantity of flammable gas in the tank headspace, that involve major damage to the tank roof, and that result in a significant release of radioactive aerosols to the atmosphere.

General Controls: (Note: as a result of Phase I activities the tank is passively and continuously vented. Monitoring shows the tank is less than 25% of the LFL. During Phase II activities, flammable gas release

events are only postulated to occur as a result of the push-mode core sampling activity.) Control of access to the tank roof and general vicinity (includes crane and vehicle controls), determination of maximum allowable roof loading, control of roof loading when roof access is required, and use crane critical lift procedures where required by the Hanford Rigging Manual. These controls are intended to prevent collapses that could result in a spark and subsequent ignition of flammable gas.

Control of mechanical forces on a riser to prevent spark creation from failure of a degraded riser when inspections or riser cap removals are attempted.

A set of ignition controls similar to TWRS ignition controls that specify bonding requirements, allowed tools, allowed instrumentation, and procedures to minimize the likelihood of producing a spark during riser entry.

Administrative controls to halt operations on the tank when lightning is detected within a 50 mile radius from the tank.

2. Category Description: Events that result in collapse of the tank roof or failure of the risers in the tank roof that cause a significant release of toxic vapors and radioactive aerosols and possibly gross contamination of a worker or workers.

General Controls: Control of access to the tank roof and general vicinity (includes crane and vehicle controls), determination of maximum allowable roof loading, control of roof loading when roof access is required, and use of crane critical lift procedures where required by the Hanford Rigging Manual.

Control of mechanical forces on a riser to prevent failure of a degraded riser when inspections or riser cap removals are attempted.

Institutional controls for emergency response to earthquakes - reduces number of individuals potentially exposed to radioactive material.

Construction of the truck sampling bridge such that significant lateral loads to the tank walls are prevented.

Construction of the bridge such that it can safely handle static and dynamic loads that may be applied during operations.

Construction of the bridge such that the sampling truck cannot be inadvertently driven off the edge of the bridge.

3. Category Description: Events that result in minor releases of toxic vapors and radioactive aerosols with no damage to the basic tank structure.

General Controls: Institutional controls for working in an area where aerosols and vapors could be present. These may include protective clothing, greenhouses, drapes, radiation monitoring and respiratory protection.

4. Category Description: Events that result in a criticality occurring in the tank waste.

General Controls: Controls to prevent criticalities in the tank are provided in HNF-2012 (1997), except as modified by the recently completed analysis on addition of rinse solution to the tank (Ref 4.2-5). The proposed controls from this reference as amended by (Ref 4.2-5) are:

- Fissile material should not be added to the tank,
- Sluicing and mechanical processing, other than activities needed to characterize the tank, should be prohibited,
- No more than 5 liters of chemical or organic solvents should be added to the tank,
- No more than 1000 gallons of aqueous solutions (e.g., Lithium Bromide drill rinse solution) should be added to the tank.

5. Category Description: Events postulated to result in an ignition of nitrate compounds in the tank with subsequent release of toxic vapors and radioactive aerosols.

General Controls: Control of vehicle access to the tank to prevent vehicle impacts into risers that could dump burning fuel into the tank. Control to stop operations on the tank when lightning is detected within a 50 mile radius of the tank.

Preventing flame cutting/welding in the tank.

6. Category Description: Events involving normal industrial hazards or small quantities of radioactive contamination.

General Controls: No special controls beyond what are imposed by the normal institutional requirements for this type of work.

7. Category Description: Leaks to the soil column due to general tank degradation. Also, events that result in localized flooding above the tank and intrusion of water into the tank, exacerbating a tank leakage condition.

General Controls: Only hand digging or excavation using the "guzzler" machine should be allowed near the tank to minimize the possibility of breaking water lines. Ground penetrating radar will be used to identify the location of water lines near the tank. The concrete cap poured on top of the tank limits potential intrusion. Should a water tank be used to load test the tank a limited water source will be used to fill the tank to limit the volume of water potentially spilled on the tank.

Installation of the helical piers with appropriate torque limits so that the tank walls are not damaged by the helical piers.

8. Category Description: Events that result in pressurized releases from the tank.

General Controls: (Note as a result of Phase I activities the tank is passively and continuously vented. As such, this general type of hazard is no longer present. This section is being retained for reference purposes.) A glovebag will be installed around the first riser to be opened to confine and mitigate any potential release of radioactive particulate when the riser is opened. The riser should be opened in a manner that controls the blow down rate of the tank without allowing ejection of the blind flange. The glovebag HEPA filter(s) should be sized large enough to accommodate the controlled blowdown flow without significant pressurization to protect the glovebag and HEPA filter integrity. Moreover, the flow rate needs to be sufficiently low that the glovebag is not damaged by the flow through the glovebag. If purging is used, controls on purge flow are needed to ensure glovebag or breather filter integrity. A control is also needed to ensure installed breather filters are not valved out during purging to prevent over pressurization of the tank or

unfiltered releases through HEPA filter assembly seal loops. Ignition and spark source controls need to be established for glovebag activities to ensure hydrogen released from the tank into the glovebag is not ignited.

9. Category Description: Events that result in radioactive releases within, or from, the OTC weather enclosure.

General Controls: Ensure weather enclosure is passively ventilated to reduce likelihood that the hydrogen can build up or airborne radioactive concentrations will be significant. Apply ignition controls during venting. Conduct airborne radioactive particulate sampling before entry. Post warning signs identifying the presence of flammable gas.

B.5.0 REFERENCES

DOE 76-45/19, SSDC-19, 1979, *Job Safety Analysis*, U.S. Department of Energy, Washington D.C.

HNF-SD-CP-CN-003, 1997, *Hazard Analysis of 241-Z-361 Tank*, Rev. 0, Fluor Daniel Northwest Inc., Richland, Washington.

HNF-2012, 1997, *Engineering Study of the Criticality Issues Associated with Hanford Tank 241-Z-361*, Rev. 0, Duke Engineering and Services Hanford, Inc., Richland, Washington.

TF-97-0236, *Evaluation Of Push Mode Core Sampling Against The Authorization Basis*, Rev. 2, Lockheed Martin Hanford Corporation, May 7, 1998, Richland, Washington.

Letter, Fluor Daniel Northwest, D.P. Hughes to A.L. Ramble, *Addition of Core Drill Rinse Solution to Tank 241-Z-361, Contract 915, Release 3*, March 30, 1999, Richland, Washington.

Table B-1. PHA Table

Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequences	Engineered Features	Administrative Controls	Cons Rank	Freq Rank	Remarks
Activities									
Passive Tank--Prior to Phase I Activities									
Passive Tank--After Phase I (Breather Filters Installed)									
Natural Phenomena Hazards									
External Events									

Table B-2. Phase I Tank 241-Z-361 Operations/Conditions

1.	Civil Survey and load test - Check to determine ground level and soil depth and verify capability of tank to support personnel and equipment for riser opening
2.	Ground Penetrating Radar (Optional) - determine outline of tank top and location of buried lines near tank
3.	Excavate small area next to tank to permit ultrasound wall and roof check (Optional)
4.	Perform Ultrasound Check - attempt to verify tank wall and top integrity (Optional)
5.	Install People Bridge (Optional depending on tank load test results)
6.	Radiological Survey of Risers (activity preliminary to any further actions to enter tank)
6.A	External Gamma and Neutron Scans (Optional) - attempt to determine if criticality event has occurred
7.	Inspect Riser [Procedure Item - Riser Prep] (It is assumed that a people bridge is in place or it has been determined that one is not required for access on the tank roof)
8.	Open Riser - replace bolts, install glovebag, relieve pressure, remove flange
9.	Install Breather Filter On Open Riser
9.A	Purge Tank [This is a contingency and the only way tank can be accessed if atmosphere is determined to be flammable]
10.	Take Pictures/Video Inside Tank (requires entry through 8-inch riser)
11.	Perform Vapor Sampling (this data is for characterization)
12.	Take Hard Gamma/Test for Mixed Fission Products (Optional) - further testing to determine if criticality has occurred
13.	Take Waste Grab Sample (Optional)

Table B-3 Phase II Tank 241-Z-361 Operations/Conditions

1.	Shortening risers and replacing flanges.
2.	Moving fence lines, associated security systems, and power lines.
3.	Installing truck sampling foundation piers.
4.	Truck sampling bridge construction.
5.	Preparing risers for push mode sampling.

6.	Opening risers for video monitoring (Optional).
7.	Establishing grounding/bonding termination point.
8.	Establishing contamination control area.
9.	Install <i>push-mode</i> core sampling riser equipment.
10.	Position push mode sampling truck on the bridge.
11.	Stage push-mode core sampling equipment.
12.	Ground/bond equipment.
13.	Raise and level sampling truck and assemble drill string.
14.	<i>Collect push-mode</i> core segment.
15.	Seal core segment into On-site Transfer Cask.
16.	Package waste and clean-up area.
17.	Store Onsite Transfer Cask.
18.	Natural phenomena hazards.

Table B-4. PIIA Results.

Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
<p>I. Civil Survey - Check to Determine Ground Level and Soil Depth; and Tank Roof Load Test - Verify Capability of Tank to Support Personnel and Equipment for Riser Opening</p> <p>Significant Steps:</p> <ul style="list-style-type: none"> • Place Transit Benchmark • Position Crane Outside Tank Exclusion Zone • Certify Rigging at Tank Site • Pick Up Load • Swing Load Over Tank • Apply Load Incrementally - hold for 20 minutes at each increment • Take Transit Readings to Verify Tank Ability to Support Load at each load increment • Lift Load and Swing Away From Tank 									
I.a	Set up transit and sight on risers -- set benchmark on tank (Requires manned access to tank lid)	Hydrogen deflagration in the ex-tank region	Electro-static spark ignites hydrogen	Worker injury. Potential for backflash into the tank causing deflagration in tank and release of radioactive aerosols through damaged tank confinement system.	Cumulative gas monitor (CGM)	Atmosphere around the riser will be sampled for combustibles prior to setting the benchmark on a riser	S1* S3	F2 F1	S1*/F2 for deflagration that doesn't flashback into tank S3/F1 for event where deflagration occurs in tank Tank is believed to be sealed. Any gap for communication with the atmosphere would be very small, accordingly backflash is extremely unlikely. Moreover, if a gap is present, the hydrogen concentration in the tank would be much less.
I.b	Setup transit and sight on risers -- set benchmark on tank (Requires manned access to tank lid)	Overload tank causing tank collapse with subsequent spark generation and flammable gas ignition	Additional weight of person walking on the tank to set benchmark causes tank failure	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration Worker injury	None	Exclusion zone Weight test (~600 lbs) prior to allowing manned access to the tank lid	S3	F1	The weight of a person walking on the tank to set the benchmark is not expected to cause catastrophic tank failure. The weight test will confirm a safety factor of two for personnel monitoring for combustibles gases and setting benchmarks.
I.c	Benchmark Transit	No significant hazards if access to the tank top does not occur. If tank access is required to reset the benchmark, then the hazards would be the same as in Step I.a and I.b.					N/A	N/A	

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
1 d	Position Crane Near Tank	Overload tank wall causing tank failure (yield in lower wall, wall buckles; soil slumps; tank has no load bearing capacity)	Human error Mechanical failure (brakes, steering, etc)	Potential release to soil Potential programmatic impact due to loss of tank integrity requiring subsequent recovery actions	None	Exclusion zone Crane positioning procedures Vehicle spotter Personnel training Critical lift procedures	S0	F3	Could consider placing "Jersey" barriers to prevent placement of crane too close to tank
1 e	Position Crane Near Tank	Overload tank wall causing tank collapse with subsequent spark generation and flammable gas ignition	Human error Mechanical failure (brakes, steering, etc)	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	None	Exclusion zone Crane positioning procedures Vehicle spotter Personnel training Critical lift procedures	S3	F3	Could consider placing "Jersey" barriers to prevent placement of crane too close to tank
1 f	Position Crane Near Tank	Overload tank wall causing tank collapse and aerosol release	Human error Mechanical failure (brakes, steering, etc)	Worker exposure to radioactive and toxic vapors released from tank atmosphere and entrainment of tank sludge	None	Exclusion zone Crane positioning procedures Vehicle spotter Personnel training Critical lift procedures	S3	F3	Could consider placing "Jersey" barriers to prevent placement of crane too close to tank
1 g	Pick Up Load	Load dropped when certifying rigging or when lifting for actual test (not swung to tank)	Rigging failure Human error Crane mechanical failures Two blocking	Potential worker injury	None	Critical lift procedures Site wide hoisting and rigging procedures	S1	F3	It is the opinion of the PIA team that use of a plastic tank that can be filled after it is placed onto the tank top will reduce the likelihood of this type of accident as compared to a solid block
1 h	Move Load Over Tank	Load impacts riser causing collapse and spark igniting flammable gas	Human error	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	None	Critical lift controls for height of lift, lift path, use of spotters Site wide hoisting and rigging procedures	S3	F3	It is the opinion of the PIA team that use of a plastic tank that can be filled after it is placed onto the tank top will reduce the likelihood of this type of accident as compared to a solid block
1 i	Move Load Over Tank	Load impacts riser shearing it off and allowing airborne release	Human error	Worker exposure to radioactive and toxic vapors released from tank atmosphere	None	Critical lift controls for height of lift, lift path, use of spotters Site wide hoisting and rigging procedures	S3	F3	It is the opinion of the PIA team that use of a plastic tank that can be filled after it is placed onto the tank top will reduce the likelihood of this type of accident as compared to a solid block

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
1.j	Move Load Over Tank	Dropped load over tank fails roof or tank walls causing mechanical spark and flammable gas ignition	Human error Mechanical failure Boom failure Crane tipped over	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	None	Critical lift controls for height of lift, lift path, use of spotters Site wide hoisting and rigging procedures	S3	F3	It is the opinion of the PHIA team that use of a plastic tank that can be filled after it is placed onto the tank top will reduce the likelihood of this type of accident as compared to a solid block
1.k	Move Load Over Tank	Dropped load over tank fails roof or tank walls causing release to environment	Human error Mechanical failure Boom failure Crane tipped over	Worker exposure to radioactive and toxic vapors released from tank atmosphere and entrainment of tank sludge	None	Critical lift controls for height of lift, lift path, use of spotters Site wide hoisting and rigging procedures	S3	F3	It is the opinion of the PHIA team that use of a plastic tank that can be filled after it is placed onto the tank top will reduce the likelihood of this type of accident as compared to a solid block
1.l	Move Load Over Tank	Crane boom contacts energized overhead power lines	Human error	Potential severe worker injury	None	Critical lift controls for height of lift, lift path, use of spotters Site wide hoisting and rigging procedures Take cover procedures	S1*	F3	
1.m	Move Load Over Tank	Dropped load over tank fails roof or tank walls causing mechanical spark and flammable gas ignition	Natural phenomena effects such as high wind, earthquake	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	None	Take cover procedures	S3	F2	
1.n	Move Load Over Tank	Dropped load over tank fails roof or tank walls causing release to environment	Natural phenomena effects such as high wind, earthquake	Worker exposure to radioactive and toxic vapors released from tank atmosphere and entrainment of tank sludge	None	Take cover procedures	S3	F2	
1.o	Move Load Over Tank	Lightning strike on crane results in arc inside riser that ignites flammable gas	Natural phenomena - lightning strike	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	None	Administrative controls for tank farm activities when lightning storms are within 50 miles of site	S3	F1	Low likelihood due to limited area for lightning strike
1.p	Incremental Application of Test Load	Load applied to tank suddenly in one large increment causing tank yielding, slumping roof, walls, base slab with leak to soil	Inability to control load application due to crane operator error, boom flex, lack of fine control High wind causes boom to flex	Potential for worker exposure to radioactive and toxic vapors released from tank atmosphere and entrainment of tank sludge Damage to tank allowing leaks to soil Programmatic impact due to required recovery actions	Crane dynamometer Transit readings	Critical lift procedures Operator training No slack in crane rigging for load application limits Amount of degradation that could occur if tank cannot take test load Engineered test plan	S3 S0 S0	F3 F3 F3	It is the opinion of the PHIA team that fine control of load application will be difficult to achieve using the controls on the crane It is the opinion of the PHIA team that use of a plastic tank that can be filled with water (by hose) after it is placed onto the tank top will reduce the likelihood of this type of accident as compared to a solid block It is possible that a spring suspended load could offer better fine control of load application

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
1.q	Incremental Application of Test Load	Tank loaded to failure when overload condition not detected	Human error - surveyor failure to observe riser height change Survey equipment failure causes zero point to shift so that movement not detected	Subsequent tank failure with possible collapse of tank and release of radioactive and toxic vapors from tank atmosphere	None	Redundant surveyors Engineered test plan	S3	F3	
1.r	Incremental Application of Test Load	Tank loaded to failure when overload condition not detected	Human error - surveyor failure to observe riser height change Survey equipment failure causes zero point to shift so that movement not detected	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	None	Redundant surveyors Engineered test plan	S3	F3	
1.s	Incremental Application of Test Load	Tank loaded to failure when overload condition not detected	Human error - surveyor failure to observe riser height change Survey equipment failure causes zero point to shift so that movement not detected	Subsequent tank failure with possible collapse of tank and release to soil	None	Redundant surveyors Engineered test plan	S0	F3	
1.t	Incremental Application of Test Load	Tank loaded to failure when overload condition not detected	Human error - surveyor failure to observe riser height change Survey equipment failure causes zero point to shift so that movement not detected	Subsequent tank failure with exposure of worker to radioactive sludge	None	Redundant surveyors Engineered test plan	S1*	F3	
1.u	Tank Load Test	Concrete cracks igniting flammable gases in tank	Load test causes crack in concrete due to overstress creating a energy source that ignites hydrogen in the tank.	Deflagration in the tank releasing radioactive aerosols through damaged tank top.	None	Engineered Load Test Plan that maintains concrete in the elastic region Incremental load test application using water tank versus load blocks to prevent dropped loads	S3	F1	Environmental loads (snow) have applied large tank loads similar to that the load test will apply Current overburden on the tank is about 200,000 lbs. As such, the load test adds a small marginal load not expected to create significant cracks Micro cracks will not produce sufficient heat to ignite potential hydrogen in cracks
1.v	Remove Load From Tank	Same hazards as for placement					N/A	N/A	
1.w	Use Water Filled Tank for Load Application Instead of Solid Object	Tank top flooded with water	Human error when filling or emptying the tank allows water to flow onto tank top	Potential spread of contamination Possible overloading of tank from soil saturation	Limitations on water supply - flow rate and maximum quantity of water available Quantity and Rate instrumentation	Procedures for use of water filling to apply load Personnel training	S3	F3	The amount of water required to provide a 4000 lb load is approximately 500 gallons

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
2.	<p>Ground Penetrating Radar (Optional)</p> <ul style="list-style-type: none"> Significant steps: <ul style="list-style-type: none"> Set up equipment outside tank area Move scanning unit to tank Drag scanning unit across tank in multiple passes 								
2 a	Set up equipment outside tank area Move scanning unit to tank Drag scanning unit across tank in multiple passes	Partial collapse of tank roof causing mechanical spark and flammable gas ignition	Too many people and heavy equipment on tank roof	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	Tank roof is estimated to have at least 225 lbs/sq ft live load capacity based on design information	Access controls for tank roof Administrative controls for maximum number of people on tank roof Currently, there is a 25 foot exclusion zone with rope and post demarcation	S3	F1	Radar unit weighs about 150 pounds Scan path is approximately 2 feet wide Some load calculations are being performed Tank is not being opened in this activity (ev-tank activity) Sparks from ground penetrating radar unit not postulated to be able to ignite flammable gas in tank when no entry has been made No critical decisions envisioned that are based solely on the information gathered by this technique
2 b	Set up equipment outside tank area Move scanning unit to tank Drag scanning unit across tank in multiple passes	Partial collapse of tank roof	Too many people and heavy equipment on tank roof	Worker exposure to radioactive and toxic vapors released from tank atmosphere and entrainment of tank sludge	Tank roof is estimated to have at least 225 lbs/sq ft live load capacity based on design information	Access controls for tank roof Administrative controls for maximum number of people on tank roof	S1	F2	Radar unit weighs about 150 pounds Scan path is approximately 2 feet wide Tank is not being opened in this activity (ev-tank activity) Sparks from ground penetrating radar unit not postulated to be able to ignite flammable gas in tank when no entry has been made No critical decisions envisioned that are based solely on the information gathered by this technique

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
2.c	Set up equipment outside tank area Move scanning unit to tank Drag scanning unit across tank in multiple passes	Partial collapse of tank roof allows worker to fall into tank	Too many people and heavy equipment on tank roof	Worker exposure to tank sludge	Tank roof is estimated to have at least 225 lbs/sq ft live load capacity based on design information	Access controls for tank roof Administrative controls for maximum number of persons on tank roof	S1*	F2	Radar unit weighs about 150 pounds Scan path is approximately 2 foot wide Tank is not being opened in this activity (see tank acth (b)) Sparks from ground penetrating radar unit are postulated to be able to ignite flammable gas in tank when no entry has been made No critical decisions envisioned that are based solely on the information gathered by this technique
3.	Excavate Small Area Next To Tank to Permit Ultrasound Wall and Roof Check (Optional)								
	Significant steps:								
	• Dig a 4 to 6 foot diameter hole less than 4 feet deep on each side of tank								
	• Put soil back								
3.a	Dig a 4 to 6 foot diameter hole less than 4 feet deep on each side of tank Put soil back	Contaminated soil is disturbed	Contamination expected to be found due to many years of contaminated material being handled in the area	Possible contamination of workers	None	Institutional controls for radiation protection Surveys of soil to determine contamination level and contamination makeup Limits on depth of excavation to reduce chance of reaching contaminated soil caused by tank leaks	S0	F3	Not intended to dig from off the people bridge or perform ultrasound checks Digging will be performed by hand above or with a vacuum "guzler" It is assumed that consistent surveys will be occurring during excavation Excavation work is considered ex-tank
3.b	Dig a 4 to 6 foot diameter hole less than 4 feet deep on each side of tank	Worker buried when hole collapses	Error in slope of hole	Possible severe injury	None	The depth of the hole will be limited to less than 4 feet Institutional controls for the control of excavation activities	S1*	F3	Digging may be performed using a vacuum "guzler"
3.c	Dig a 4 to 6 foot diameter hole less than 4 feet deep on each side of tank	Roof of tank collapses when personnel stand on it during excavation	Human error results in too many people standing on top of the tank	Roof collapse causes release of contamination to atmosphere - splatter release from waste surface due to falling concrete	Tank roof is estimated to have at least 225 lbs/sq ft live load capacity based on design information	Access controls for tank roof Administrative controls for maximum number of people on tank roof Worker training	S1	F2	Not intended to dig from off the people bridge

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
3 d	Dig a 4 to 6 foot diameter hole less than 4 feet deep on each side of tank	Roof of tank collapses when personnel stand on it during excavation, consequent flammable gas ignition from mechanical spark	Human error results in too many people standing on top of the tank	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	Tank roof is estimated to have at least 225 lb/sq ft live load capacity based on design information	Access controls for tank roof Administrative controls for maximum number of people on tank roof Worker training	S3	F2	Not intended to dig from off the person bridge
3 c	Dig a 4 to 6 foot diameter hole less than 4 feet deep on each side of tank	"Guzzler" vehicle falls into tank when roof collapses	Human error allows moving vehicle onto tank roof	Roof collapse causes release of contamination to atmosphere - splatter release from waste surface due to falling concrete	Tank roof is estimated to have at least 225 lb/sq ft live load capacity based on design information	Access controls for tank roof Administrative controls for maximum number of people on tank roof Worker training	S3	F2	
3 f	Dig a 4 to 6 foot diameter hole less than 4 feet deep on each side of tank	"Guzzler" vehicle falls into tank when roof collapses with subsequent flammable gas ignition from mechanical or electrical spark	Human error allows moving vehicle onto tank roof	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	None	Access controls for tank roof Administrative controls for maximum number of people on tank roof Worker training	S3	F2	
3 B	Dig a 4 to 6 foot diameter hole less than 4 feet deep on each side of tank	"Guzzler" suction hose lifting arm contacts power line resulting in severe injury to worker	Human error	Worker injury	None	Institutional controls for worker safety when around power lines with equipment Worker training	S1*	F3	
3 h	Dig a 4 to 6 foot diameter hole less than 4 feet deep on each side of tank	Water floods onto tank roof when water line is breached during excavation	Human error	Possible spread of contamination or water intrusion into tank causing contamination spread	None	Institutional controls for excavation activities Ground penetrating radar scan for lines before excavation begins	S0	F2	This is an environmental problem, not a personnel exposure problem
3 i	Put soil back into holes	Tank wall falls into tank	Excess force placed on wall due to use of power tampers	Aerosol release	None	Backfill will be done by hand No power tampers permitted	S1	F2	
4.	Perform Ultrasonic Check (Optional)								

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cone Rank	Freq Rank	Remarks
4 a	Ultrasound check	No hazardous events identified for ultrasound check itself					N/A	N/A	All equipment is hand carried to the area Work is non-intrusive and places no pressure on tank walls Intent of check is to identify if walls intact Flammable gas advisory board should verify that this can be done early in the work sequence Ultrasound check is an ex-tank activity
4 b	Ultrasound check	Personnel contaminated when installing transducers	Contamination present on tank exterior wall	Personnel contamination with chance for uptake	None	Institutional controls for performance of work on potentially contaminated items	S1	F3	
4 c	Ultrasound check	Personnel receive unexpected whole body dose	Void or crack in wall of tank with high radiation from waste sludge	Personnel over exposed	None	Institutional controls for performance of work where radiation fields may be present	S1*	F1	Tank sludge is not expected to create high radiation fields
<p>5. Install People Bridge (Optional depending on tank load test results)</p> <p>Significant steps:</p> <ul style="list-style-type: none"> Put aluminum planks on ground surface over tank roof Construct enclosures on top of people bridge as required 									
5 a	Put aluminum planks on ground surface over tank roof Construct enclosures on top of people bridge as required	Partial collapse of tank roof causing mechanical spark and flammable gas ignition	Too many people and heavy equipment on tank roof - roof structure significantly degraded	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas degradation	Tank roof is estimated to have at least 225 lbs/sq ft live load capacity based on design information	Access controls for tank roof Administrative controls for maximum number of people on tank roof Worker training for bridge installation If bridge required, the entire tank top will be covered	S3	F1	

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
5 b	Put aluminum planks on ground surface over tank roof Construct enclosures on top of people bridge as required	Partial collapse of tank roof	Too many people and heavy equipment on tank roof - roof structure significantly degraded	Worker exposure to radioactive and toxic vapors released from tank atmosphere and entrainment of tank sludge	Tank roof is estimated to have at least 225 lbs/sq ft live load capacity based on design information	Access controls for tank roof Administrative controls for maximum number of people on tank roof Worker training for bridge installation If bridge required, the entire tank top will be covered	S3	F1	
5 c	Put aluminum planks on ground surface over tank roof Construct enclosures on top of people bridge as required	Partial collapse of tank roof allows worker to fall into tank	Too many people and heavy equipment on tank roof - roof structure significantly degraded	Worker exposed to tank sludge	Tank roof is estimated to have at least 225 lbs/sq ft live load capacity based on design information	Access controls for tank roof Administrative controls for maximum number of people on tank roof Worker training for bridge installation If bridge required, the entire tank top will be covered	S1*	F1	People bridge may be constructed of something other than aluminum planks - planks were used as an example of a viable solution No crane work assumed Evaluation of the structural capacity of the tank will determine whether a bridge is required or if safe loading is declared
5 d	Put aluminum planks on ground surface over tank roof Construct enclosures on top of people bridge as required	Riser collapse due to running planks or other equipment into riser with resulting mechanically generated spark	Human error coupled with collapse of riser from impact with equipment causing spark in tank	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration causing damage to tank including partial roof collapse	None	Worker training	S3	F1	People bridge may be constructed of something other than aluminum planks - planks were used as an example of a viable solution No crane work assumed
5 e	Put aluminum planks on ground surface over tank roof Construct enclosures on top of people bridge as required	Riser collapse due to running planks or other equipment into riser	Human error coupled with collapse of riser - no flammable gas ignition	Worker exposure to radioactive and toxic vapors released from tank atmosphere and entrainment of tank sludge	None	Worker training	S1	F1	The people bridge may be constructed of something other than aluminum planks - planks were used as an example of a viable solution No crane work assumed
5 f	Put aluminum planks on ground surface over tank roof Construct enclosures on top of people bridge as required	Operator injury occurs during bridge installation (such as falls, trips, cuts)	Human error	Industrial accidents resulting in injury	None	Institutional controls for worker safety	N/A	N/A	This is a normal industrial hazards item

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
6.	Radiological Survey of Risers (Activity preliminary to any further actions to enter tank)								
	Significant steps								
	Survey risers with CP meter (CP), geiger-mueller (GM), portable alpha meter (PAM) on tank roof								
	Take tech smears from risers								
	Sniff area around riser for flammable gas								
6 a	Survey risers with CP, GM, and PAM on tank roof Take tech smears from risers Sniff area around riser for flammable gas	Partial collapse of tank roof causing mechanical spark and flammable gas ignition	Too many people and heavy equipment on tank roof - roof structure significantly degraded	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas explosion	Tank roof is estimated to have at least 225 lbs/sq ft live load information People bridge if installed	Access controls for tank roof Administrative controls for maximum number of people on tank roof	S3	F1	Reader unit weighs about 150 pounds Tank is not being opened in this activity. (ex-tank activity) Work is being performed to survey for anomalous readings and alpha contamination 1 after surveys (such as ultra-sound) will provide information about roof/tank wall integrity Bonding not required for low voltage sources
6.b	Survey risers with CP, GM, and PAM on tank roof Take tech smears from risers	Skin contamination occurs while performing survey	Human error	Personnel contamination	None	Institutional controls for radiological safety	S1	F3	Several surveys will be performed to reduce the likelihood of having undiscovered contamination
6.c	Survey risers with CP, GM, and PAM on tank roof Take tech smears from risers	Skin contamination later in step sequence from undiscovered contamination	Human error in performing survey or in failing to perform any survey	Personnel contamination	None	Institutional controls for radiological safety Subsequent steps also require surveys	S1	F3	Several surveys will be performed to reduce the likelihood of having undiscovered contamination
6.A	External Gamma and Neutron Scans (Optional)								
6.A.a	Detector placed outside riser cap with weather enclosure	High voltage spark inside riser ignites flammable gas	Voltage leakage from defective insulation on wiring or in detector coupled with poor connection between riser cap and riser allows arc from cap to riser (inside riser) where flammable gas is present	Deflagration of flammable gas inside tank See item 7.a	Riser flange cover and riser flange connected with bolts essentially bonding unit together	Requirements for bonding equipment (ensures that riser and cap cannot be at different potentials)	S3	F2	This is a low current, high voltage device - the concern is that the riser cap may not be electrically tied to the riser The hard gamma scan can be taken on undisturbed riser - time may be in the hour to days frame

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
6.A.b	Detector placed outside riser cap with weather enclosure	Riser collapses when detector unit secured to flange with possible generation of mechanical spark and flammable gas ignition	Riser is corroded from neutral/acidic atmosphere in tank or external corrosion from soil moisture that reduces riser strength where attached to tank roof	See item 7.b	None	Administrative requirements for riser loading	S1	F1	The consequence for this event is the same as other riser collapses where the tank has not been opened
7.	<p>Inspect Riser [referred to as riser prep] (It is assumed that a people bridge is in place or it has been determined that one is not required for access on the tank roof)</p> <p>Significant steps:</p> <ul style="list-style-type: none"> Smear riser for contamination Take dose rate readings Sniff riser for flammable gas Check bolt size Check flange configuration Bond flanges 								
7 a	Smear riser for contamination Take dose rate readings Sniff riser for flammable gas Check bolt size Check flange configuration Bond flanges	Drop equipment on riser generating spark causing ignition of flammable gas in tank	Human error coupled with movement of riser from equipment impact causing spark in tank	Release of airborne radioactive material through manhole covers and damage to tank roof due to flammable gas deflagration	None	No heavy equipment allowed Riser is capped preventing flammable gas being present in significant quantities Use of spark proof tools Use of intrinsically safe measuring equipment	S3	F1	Sniffing riser is control that is prudent Amount of flammable gas is considered to be insufficient for ex-tank deflagration Tank atmosphere is assumed to have sufficient concentration of gas to be flammable Practice I/O-020-006 not currently released may have controls that are pertinent to this hazardous event
7 b	Smear riser for contamination Take dose rate readings Sniff riser for flammable gas Check bolt size Check flange configuration Bond flanges	Load on riser during inspection causes riser to buckle/collapse or fall into tank Same as above with spark generation	Corrosion of riser from acidic vapor in tank or external water intrusion weakens riser so that small additional load causes failure	Worker exposure to release of radioactive and toxic vapors Release of airborne radioactive material through manhole covers and damage to tank roof due to flammable gas deflagration	Potential use of riser clamp to prevent significant downward movement	Administrative limits on placing load or side pressure on riser Administrative limits on placing load or side pressure on riser	S1* S3	F1 F1	If flammable gas is found from closed riser, further evaluations will be necessary before subsequent steps can be performed

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
7 c	Smear riser for contamination Take dose rate readings Sniff riser for flammable gas Check bolt size Check flange configuration Bond flanges	Static spark ignites flammable gas in tank when opening riser flange (opening flange is actually item 8.)	Incorrect bonding or failure to bond	Release of airborne radioactive material through manhole covers and damage to tank roof due to flammable gas deflagration	None	Procedure requires bonding	S3	F2	Procedure (O-020-086 (not currently released) may have pertinent controls Event has a chance of occurrence only for the first opening of a riser on the tank, subsequent risers will be opened with the tank vented of flammable gas
7 d	Smear riser for contamination Take dose rate readings Sniff riser for flammable gas Check bolt size Check flange configuration Bond flanges	Worker contaminated	Riser contaminated and contamination not detected before work started (Human error)	Skin contamination and potential uptake of radioactive material	None	Institutional controls for radiological hazards -Rad manual -Training	S1	F3	
7 e	Smear riser for contamination Take dose rate readings Sniff riser for flammable gas Check bolt size Check flange configuration Bond flanges	Worker bridge collapses causing tank roof overload and collapse (possible flammable gas ignition)	Bridge design error Material flaw Overload	Tank roof damage or collapse - flammable gas deflagration from collapse generated spark	Tank roof is estimated to have at least 225 lbs/sq ft live load capacity based on design information	Procedures will indicate maximum load that bridge can accept Training Design requirements for people bridge	S3	F2	Frequency of inspection determined when the tank roof structural analysis complete Waste is assumed to contain significant liquid People have been walking over tank recently with no adverse consequences
7 f	Smear riser for contamination Take dose rate readings Sniff riser for flammable gas Check bolt size Check flange configuration Bond flanges	Worker bridge collapses causing tank roof overload and collapse (possible flammable gas ignition)	Bridge design error Material flaw Overload	Tank roof collapse with airborne release of radioactive material	Tank roof is estimated to have at least 225 lbs/sq ft live load capacity based on design information	Administrative controls for people bridge bonding Verification of bridge design before design implemented	S3	F1	There is uncertainty about difference between consequence of deflagration event versus roof collapse without deflagration -- Tank Waste Remediation System analysis indicates that collapse without deflagration is a S3 event for large waste storage tanks

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
8.0	<p>Open Riser (vent tank pressure and remove flange)</p> <p>Significant steps:</p> <ul style="list-style-type: none"> Replace bolts and nuts one at a time Install glovebag Relieve tank pressure (by opening crack in riser flange) Remove blind flange from vented tank Take gas sample from riser 								
<p>NOTE: Hazardous events associated with tank roof loading are addressed in prior items and are not included in item 8</p>									
8 a	Replace bolts and nuts	Spark transmitted to the tank during bolt replacement	Failed gasket on full-faced flange allows mechanical or static spark to enter tank atmosphere.	Flammable gas deflagration with release of radioactive aerosols to the environment through manhole covers and damage to tank structure. See item 7 a.	None	Use a riser with a raised face flange for initial opening. Sniff for hydrogen before loosening bolts to verify no significant leak path.	S3	F1	
8 b	Replace bolts and nuts	Flange flies off when bolts replaced	Human error: Bolts not removed one at a time.	Worker injury from impact with flange. Worker exposure to radioactive particulates and toxic gases	None	Work procedure specifies removing and replacing one bolt at a time.	S1	F3	Tank may be under positive pressure due to radiologically generated gases since tank risers and transfer lines were sealed. Weather covers on manholes may provide an existing relief path limiting any potential pressure buildup. Without relief path, pressure may be on the order of 15.5 psig in the tank, with about 34% hydrogen
8 c	Replace bolts and nuts	Spark caused in tank because riser rotates while bolts are loosened causing flammable gas ignition	Bolt is frozen requiring excessive torque, mechanical spark generated as riser surface abrades concrete Riser is corroded from neutral/acidic atmosphere in tank, reducing riser strength where attached to tank roof	Flammable gas deflagration in tank with release of radioactive aerosols See item 7 a	Use of riser clamp if needed to prevent significant downward movement.	Personnel experienced on torque required to loosen bolt. Torque limit for risers	S3	F1	Risers to be opened were set in concrete roof with welded disk encircling riser, phase 1 activities will only open this type of riser
8 d	Prepare riser	Riser collapses when attempt is made to loosen bolts	Riser is corroded from neutral/acidic atmosphere in tank, reducing riser strength where attached to tank roof See item 7.b	See item 7 b	Use of riser clamp if needed to prevent significant downward movement.	Stake load and vertical load limits for the riser	S3	F1	

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cona Rank	Freq Rank	Remarks
8 c	Install glovebag	Glovebag and breather filter assembly dropped on riser during installation resulting in failure of riser.	Human error: Rigging manual requirements not followed. Mechanical failure of the rigging equipment	Riser collapse with open hole in top of tank Potential hydrogen deflagration in the tank. See item 7 b.	Riser design uses welded flange embedded in concrete tank roof	Riser could be banded at the soil level or attached to bridge to support it against drop Critical lift procedures	S1 S3	F2 F2	S1/F2 for release without ignition of flammable gases S3/F2 for event resulting in ignition of flammable gas in the tank
8 f	Relieve Tank Pressure	Release of radioactive material and toxic gases (e.g., NOx, NH3) to environment when flange is loosened	Tank under pressure causing expulsion of contaminated tank atmosphere Low atmospheric pressure at time tank is vented	Worker exposure to radioactive particulates	Glove bag around flange during removal ensures release to environment is filtered Glovebag HEPA filter sized to handle relieving air flow without significant pressurization of the bag	Institutional controls for use of protective equipment when opening a tank riser Institutional controls for radiation monitoring when opening tank riser Nuts will be loosened in \leq half turn increments while relieving pressure to ensure flange is not ejected	S1	F3	Tank may be under positive pressure due to radiolytically generated gases since tank risers and transfer lines were sealed Weather covers on manholes may provide an existing relief path limiting any potential pressure buildup Without relief path, pressure may be on the order of 1.5 psig in the tank, with about 34% hydrogen
8 g	Relieve Tank Pressure	Hydrogen deflagration in glovebag during loosening of flange	Hydrogen released from tank accumulates in glovebag to flammable level and is ignited by mechanical or electro-static spark resulting from: Improper tools used that create spark, i.e. spark-free tools not used Non-intrinsically safe instruments used that ignite hydrogen Incorrect or inadequate banding causes electro-static spark Glovebag design builds up static charge and creates spark	Failure of glovebag with release of contamination to the environment Worker injury Potential for backflash into the tank causing deflagration in tank and release of radioactive aerosols through damaged tank confinement system	Glovebag purge system Combustible gas monitor (CGM) Electrostatically dissipative glovebag design	Non-sparking tools will be used to loosen flange Flange and riser will be banded together. CGM will be on continuously to warn workers of potentially flammable gas levels in the glovebag. The purge system will be started on detection of potentially flammable gas in the glovebag. Work inside the glovebag will be halted until flammable gas concentration drops below 25% of the LFL. Sweep will be used to allow visual detection of off-gassing through riser flange Flange gap will be controlled to $< 1/16"$ making backflash unlikely.	S1* S3	F2 F1	S1*/F2 for deflagration that doesn't flashback into tank S3/F1 for event where deflagration occurs in tank

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cone Rank	Freq Rank	Remarks
8 h	Relieve Tank Pressure	Rupture of the glovebag due to over-pressure	<p>Tank vented to fast</p> <p>Flow from the riser and purge combined exceed the HEPA filter design flow rate</p> <p>Purge applied at a rate exceeding the vent capacity</p> <p>Purge is applied or the tank is sealed while the vent path is isolated</p>	<p>Rupture of the glovebag</p> <p>Worker exposure to airborne contamination</p> <p>Potential hydrogen deflagration in glovebag and tank</p> <p>(See item 8 g)</p>	<p>Vent path sized to accommodate the sum of the purge rate and pressure relief flow rate</p>	<p>Nuts will be loosened in 1/2 turn increments to allow blind flange to be separated from riser flange in a controlled manner</p> <p>Requirement that purge be applied at a rate less than that which will damage the HEPA filter or cause damage to the confinement, i.e., glovebag</p> <p>Requirement that the vent path be out service when the tank is vented or purge applied</p> <p>The flange gap will be controlled to 1/16-inch making backflash unlikely</p>	<p>S1*</p> <p>S3</p>	<p>F2</p> <p>F1</p>	<p>Tank may be under positive pressure due to radiolytically generated gases since tank risers and transfer lines were sealed</p> <p>Weather covers on manholes may provide an existing relief path limiting any potential pressure buildup</p> <p>Without relief path, pressure may be on the order of 1.5 psig in the tank, with about 34% hydrogen S3/F1 for event that ignites hydrogen in tank</p>
8 i	Relieve Tank Pressure	Glovebag torn by excessive flow rate of gases through the glovebag	<p>Tank under pressure</p> <p>Flow not restricted to a rate acceptable for the confinement design</p> <p>Human error: Flow restricting band is not properly installed and falls off</p> <p>Flow restricting band is not adequately designed to receive the pressure associated with relieving the tank pressure and it fails</p> <p>Excessively large orifice in the flow restricting band</p> <p>Glovebag HEPA filters not sized to accept the maximum flow rate associated with the flow restricting band orifice</p> <p>Excessively large diameter conduit inserted through the gasket into the tank</p>	<p>See item 8 h</p>	<p>Flow restricting devices limit maximum achievable flow</p>	<p>Flow rate restricted to a value that will not over-pressurize or damage the glovebag due to high flow rates</p> <p>Application of flow restricting devices</p> <p>The flange gap will be controlled to 1/16 inch making backflash unlikely</p>	<p>S1*</p> <p>S3</p>	<p>F2</p> <p>F1</p>	<p>Tank may be under positive pressure due to radiolytically generated gases since tank risers and transfer lines were sealed</p> <p>Weather covers on manholes may provide an existing relief path limiting any potential pressure buildup</p> <p>Without relief path, pressure may be on the order of 1.5 psig in the tank, with about 34% hydrogen S1*/F2 for the deflagration that doesn't backflash into the tank</p>

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Conc Rank	Freq Rank	Remarks
8.j	Relieve Tank Pressure	Spark ignites flammable gas in the glove bag while relieving tank pressure through a flow restricting band	Hydrogen released from tank accumulates in glovebag to flammable level and is ignited by mechanical or electrostatic spark. Incorrect bonding or failure to bond the flow restricting band	See item 8.g	None	Bond the flow restricting band Use non-sparking tools Replace bolts with those made of non-sparking material	S1* S3	F2 F1	S1*/F2 for deflagration that doesn't flashback into tank S3/F1 for event where deflagration occurs in tank
8.k	Relieve Tank Pressure	Glovebag punctured by flying object propelled by pressurized gas being relieved from the tank	Tank under pressure Human error: Flow restricting band is not properly installed Flow restricting band is not adequately designed to receive the pressure associated with relieving the tank pressure Human error: Excessive flow rate propels tools and debris and punctures glovebag	Rupture of glovebag Worker exposure to airborne contamination Worker injury from flying debris if glovebag torn Potential hydrogen deflagration in glovebag and tank (See item 8.h)	Small effective surface area of the penetrating tools limits propulsive force that could be applied	Flow rate restricted to a small value in order to protect glovebag (See Item 8.1). This small flow rate is not capable of lifting or propelling flying debris or tools of significance Glovebag and gloves constructed of robust material Use of non-sparking tools	S1* S3	F1 F1	S1*/F1 for the glovebag being ruptured by flying tools or debris S3/F1 for event where deflagration occurs in tank The maximum tank pressure of 15.5 psig and the small effective surface area of the tools makes it extremely unlikely that tools or debris could be driven through the confinement
8.l	Relieve Tank Pressure	Glove in the glovebag or glovebag punctured by a sharp object being used to penetrate riser flange gasket to verify tank vented	Human error: Worker punches hole in glovebag with the needle/conduit being used to penetrate the riser flange gasket Human error: Needle/conduit breaks off while penetrating the gasket due to use of excessive force Material flaw in the needle/conduit used Pressure ejects needle/conduit used to penetrate the gasket	Failure of the glovebag with release of contamination to the environment Potential worker injury from the needle/puncture wound or laceration Worker exposure to radioactive particulates, potentially including a contaminated wound	None	Work procedure requirements and precautions for handling needle/conduit while verifying relief path Sizing glovebag to provide ample room for the venting procedure Limitations on the force to be applied that are consistent with the design capability of the needle/conduit Glovebag and gloves constructed of robust materials.	S1	F3	The gasket between the riser and flange was 1/16-inch thick prior to compression. Small diameter needles or conduits of less than 1/16-inch external diameter may be required. Even at 13.5 psig, the very small effective surface area of the needle or conduit makes it unlikely the pressure could cause it to be ejected from the riser with significant effect S1 because the amount of contamination spread would be expected to be small from a puncture

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
8 m	Relieve Tank Pressure	Glove in the glovebag or glovebag sliced by the flow restricting band	Human error flow restricting band mishandled, cutting glove Pressure causes rapid movement of the flow restricting band	Failure of the glovebag with release of contamination to the environment Potential worker injury cut from the flow restricting band Worker exposure to radioactive particulates, potentially including a contaminated wound	None	Work procedure requirements and precautions for handling flow restricting band Sizing glovebag to provide ample room for the manipulating the flow restricting band Glovebag and gloves constructed of robust materials.	S1	F2	Even at 15.5 psig, the very small effective surface area of the flow restricting band makes it unlikely it could be propelled with sufficient energy to slice the glovebag. S1 because the amount of contamination spread would be expected to be small from a puncture
8 n	Relieve Tank Pressure	Spark ignites flammable gas in the tank and in the glovebag when needle/conduit inserted through the riser flange gasket to verify vent path	Non-sparking needle/conduit used Incorrect bonding or failure to bond the needle/conduit leads to electrostatic spark Needle/conduit inserted with sufficient force that friction heating or friction spark is created	Flammable gas delamination in the ex-tank region Flammable gas delamination in the tank Worker injury See item 7.c	None	Needles/conduits constructed on non-sparking materials to minimize likelihood of metal sparks Work precautions and limitations that limit force being applied to the conduit to avoid to minimize likelihood of a friction spark or heating igniting hydrogen Bonding equipment to reduce likelihood of an electro-static spark	S3	F2	
8 o	Relieve Tank Pressure	Flange ejected from riser	Tank pressurized Vent path not actually verified because the conduit/needle plugged upon insertion into the gasket Gasket blocks relief vent path through the flow restricting band orifice Human error bolts loosened too far or completely removed.	Worker injury from impact with flange Glovebag damaged resulting in spread of contamination Worker exposure to radioactive particulates Potential hydrogen delamination due to mechanically generated spark (see 7.c)	None	Institutional controls for use of protective equipment when opening a tank riser Nuts will be loosened in 1/2 half turn increments while relieving pressure to ensure flange is not ejected Work procedure requirements and precautions for ensuring the tank pressure is relieved prior to removing flange	S1 S3	F3 F2	Tank may be under positive pressure due to radiolytically generated gases since tank risers and transfer lines were sealed Weather covers on manholes may provide an existing relief path limiting any potential pressure buildup Without relief path, pressure may be on the order of 15.5 psig in the tank, with about 34% hydrogen S3/F2 for event that ignites hydrogen in tank
8 p	Remove blind flange	Electrostatic discharge occurs when blind flange is lifted - flammable gas ignition See item 7.c	See item 7.c	Flammable gas delamination in tank See item 7.c	None	Administrative requirements for bonding	S3	F1	

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
8 q	Remove blind flange	Thermite or mechanical spark ignites flammable gas in tank when flange is removed	Metal oxides or metal friction cause spark due to blind flange being rotated while being lifted off	Flammable gas delagration in tank See item 7 c	None	Flange will be lifted straight off riser (not rotated) Use of h-hits made of non-sparking material Use of non-sparking tools	S3	F1	"Thermite" type reactions considered extremely unlikely
8 r	Remove blind flange	Exposure of worker to ionizing radiation	Beta radiation streaming through flange hole due to unexpected presence of beta emitting radionuclides Failure to perform correct radiation monitoring	Worker exposure above guidelines	None	Institutional controls for radiation protection CP meter Step 7 requires radiation monitoring	S1 S0	F1 F3	Only significant source of penetrating radiation would be as a result of a low yield criticality in the tank sludge and the initial radiation survey incorrectly performed
8 s	Remove blind flange	Electrical spark from combustible gas monitoring instrument ignites flammable gas in glovebag and tank	Use of wrong equipment (not intrinsically safe) Use of defective equipment Human error	Flammable gas delagration in tank See item 7 c & 8 f	Use of intrinsically safe instruments will be required	Requirements for the use of intrinsically safe equipment in areas where flammable gas may be present	S3	F3	
8 t	Remove blind flange	Electrostatic spark causes flammable gas ignition when swirling tube is dropped and falls on waste surface	Human error Equipment failure	Flammable gas delagration in tank See item 7 c	None	Procedures require intrinsically safe instruments and bonding	S3	F1	
8 u	Remove blind flange	Electrostatic spark from worker causes flammable gas ignition in glovebag	Worker not properly bonded human error	Flammable gas delagration in tank See item 7 c	None	Procedures require use of bonding techniques Glove bag material is required to be electrostatic dissipative	S3	F3	If operator working in glove bag, the bag is assumed to dissipate electrostatic charge and isolates worker Appropriate flammable gas controls will have to be determined
8 v	Remove blind flange	Mechanical spark causes ignition of flammable gas	Riser blind flange stuck to riser due to sealant presence requiring chiseling or prying to remove	Flammable gas delagration in tank See item 7 c	None	Non-sparking wedges used to pry open flange	S3	F2	F2 based on fact that most generated sparks will be outside the tank atmosphere
8 w	Remove blind flange	Airborne release of contamination	Flange cover dropped during removal, shaking contamination loose	Worker exposure Potential for radioactive material uptake	Glove bag if used	Institutional controls for use of protective equipment when opening a tank riser Procedures for handling the flange cover to prevent drops	S1	F3	Protective equipment could be a glove bag or the use of fresh air supplied respirators and anti-contamination clothing

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cone Rank	Freq Rank	Remarks
8.x	Remove blind flange	Blind flange inadvertently dropped onto riser generates mechanical spark that ignites flammable gas in the tank	Human error	Flammable gas deflagration in tank See item 7.c	None	Non-sparking plate or sheets could be slid between the bolts and between two flanges before hitting off the blind flange. This will reduce the likelihood of mechanical sparks if the blind flange is dropped on the riser.	S3	F3	Removal of the blind flange could be performed while flammable gas concentration is above lower flammability limit
<p>9. Install Breather Filter/Adaptor Assembly</p> <p>Significant steps:</p> <ul style="list-style-type: none"> • • • 									
9.a	Install breather filter	Release of asbestos to environment as a result of abatement activities	Human error while removing the asbestos gasket material from the riser flanges	Worker exposure to asbestos	Glovebag mitigates release of asbestos to environment	Site wide asbestos control procedures Procedures for opening riser specify asbestos controls required	S1	F3	The amount of asbestos on the riser flanges is small but site requirements for asbestos require safe handling practices
9.b	Install breather filter	Mechanical spark produced during asbestos abatement activities causes flammable gas ignition	Use of wrong tool Presence of sparking materials on surface of cover flange	Flammable gas deflagration in tank See item 7.c Glove bag blown off riser allowing asbestos release	Glovebag purge system to keep glovebag below LFL. Continuous combustible gas monitoring in glovebag	Spark resistant tools will be used to remove asbestos.	S3	F3	
9.c	Assembly lowered with winch from tripod	Riser failure from weight of filter and adaptor causes riser to fall into tank allowing radioactive material to escape through hole	Corroded, degraded riser	Riser collapse with resulting open hole in top of tank See item 7.b	Potential use of riser clamp to prevent movement	Vertical load limits for risers Filter could be suspended by tripod until bolts tightened Riser could be "banded" at the soft level or attached to bridge to prevent movement	S1	F2	May want to just bolt up the filter and let riser sink to ground level Adaptor could be made much smaller, reducing weight and eliminating the need for a crane

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cone Rank	Freq Rank	Remarks
9 d	Assembly lowered with winch from tripod	Riser failure from weight of filter and adaptor causes riser to fall into tank producing mechanical sparks and flammable gas ignition	Corroded, degraded riser - sparks occur from mechanical interaction between riser and tank top concrete	Flammable gas deflagration in tank See item 7 a (includes worker exposure to toxic vapor and radioactive material)	Riser design uses welded flange embedded in concrete tank roof Potential use of riser clamp to prevent significant movement	Vertical load limits for risers Riser could be "banded" at the soil level or attached to bridge to prevent movement If the tank is above lower flammability limits it could be allowed to breathe or could be purged through the glovebag until the tank drops below 25% of the LFL, before attaching filter Filter could be suspended by tripod unit bolts tightened to "test" riser integrity	S3	F1	May want to just bolt up the filter and let riser sink to ground level Adaptor could be made much smaller, reducing weight Adaptor could be eliminated and filter direct coupled to the riser significantly reducing the weight on the riser.
9 e	Assembly lowered with winch from tripod	Riser failure due to drop of breather filter/adaptor assembly	Equipment failure Human error	Riser collapse with resulting open hole in top of tank See item 7 b	None	Filter could be suspended by unit bolts tightened Riser could be "banded" at the soil level or attached to bridge to prevent movement Adaptor could be eliminated and filter direct coupled to the riser significantly reducing the weight on the riser	S1	F2	Adaptor could be made much smaller, reducing weight
9 f	Assembly lowered with winch from tripod	Riser failure due to drop of breather filter/adaptor assembly with resulting mechanical spark and ignition of flammable gas	Equipment failure (boom, cable, brake, clutch) Human error (such as double blocking)	Flammable gas deflagration in tank See item 7 a (includes worker exposure to toxic vapor and radioactive material)	Riser design uses welded flange embedded in concrete tank roof	Riser could be "banded" at the soil level or attached to bridge to prevent movement If the tank is above lower flammability limits it will be allowed to breathe until below LFL, before attaching filter Crane not permitted to be used if tank above 25% LFL. Adaptor could be made of non-sparking stainless steel No Y adaptor could be used and filter direct coupled to riser eliminating the need for a crane	S3	F2	If the tank atmosphere is below the 25% lower flammability limits then Y adaptor could be used with crane Control for minor bump could be using a stainless steel coupling Adaptor could be made much smaller, reducing weight and eliminating the need for a crane

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
9 g	Assembly lowered with winch from tripod	Riser failure due to winch (or crane, if used instead of tripod and winch) pulling the riser out of the tank top resulting in open hole	Human error Equipment failure	Open hole in top of tank with possible tank roof damage and partial roof failure See item 7 b	None	Site wide hoisting and rigging procedures - treat as critical lift Personnel training	S1	F2	This propagates to many different release problems as well as recovery difficulties Crane use not planned for installing filter
9 h	Assembly lowered with winch from tripod	Riser failure due to winch (or crane, if used instead of tripod and winch) pulling the riser out of the tank top resulting in mechanical spark and flammable gas ignition	Human error Equipment failure	Flammable gas deflagration in tank See item 7 a (includes worker exposure to toxic vapor and radioactive material)	Riser design uses welded flange embedded in concrete tank roof	Site wide hoisting and rigging procedures - treat as critical lift Personnel training	S3	F1	This propagates to many different release problems as well as recovery difficulties Crane use not planned for installing filter
9 i	Assembly lowered with winch from tripod	Crane boom placed or dropped on tank roof causing roof failure (applies only if crane used to install filter instead of tripod and winch)	Human error High wind Mechanical failure of boom Procedural error	If boom hits riser the riser will be pushed into tank roof causing roof damage and release of radioactive materials and toxic vapor See item 7 b	Tank roof is estimated to have at least 225 lb/94 ft live load capacity based on design information	Site wide hoisting and lifting procedures and controls (critical lift) Crane location chosen to minimize amount of boom that is over tank	S1*	F3	Boom could strike workers or riser Crane use not currently planned for installing breather filter
9 j	Assembly lowered with winch from tripod	Crane boom placed or dropped on tank roof causing roof failure and subsequent mechanical spark with flammable gas ignition (applies only if crane used to install filter instead of tripod and winch)	Human error High wind Mechanical failure of boom Procedural error	Flammable gas deflagration in tank See item 7 a	Tank roof is estimated to have at least 225 lb/94 ft live load capacity based on design information	Site wide hoisting and lifting procedures and controls (critical lift) No crane use until tank is below 25% lower flammability limits Crane location chosen to minimize amount of boom that is over tank	S3	F1	Crane use not currently planned for installing breather filter
9 k	Assembly lowered with winch from tripod	Crane boom contacts power and phone lines during the installation of breather filter (applies only if crane used to install filter instead of tripod and winch)	Human error	Severe operator injury	None	Site wide hoisting and rigging procedures - treat as critical lift Operator training	S1*	F3	Lighting power could be de-energized during activity Other lines are present besides lighting power Could the lines be rerouted? Crane use not currently planned for installing breather filter

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
9 l	Assembly lowered with winch from tripod	Crane boom contacts power and phone lines during the installation of breather filter (applies only if crane used to install filter instead of tripod and winch)	Human error	Sparking lines fall onto riser and ignite flammable gas Hot embers from sparking lines fall into tank through open riser and ignite flammable gas See item 7 a	None	Crane used only when tank readings below 25% LFL. Site work: hoisting and rigging procedures - treat as critical lift Operator training	S3	F3	Lighting power could be de-energize during activity Other lines are present besides lighting power Could the lines be rerouted? If work could be accomplished without crane there would be less risk Crane use not currently planned for installing breather filter
9 m	Assembly lowered with winch from tripod	Tank roof collapse due to crane being driven too close to tank (applies only if crane used to install filter instead of tripod and winch)	Human error	Tank roof collapse with resulting significant release of tank waste particulates	None	Limit placed on how close crane can come to tank Vehicle exclusion zone established	S3	F3	Consequence high because of waste splashing and aerosol creation Crane use not currently planned for installing breather filter
9 n	Assembly lowered with winch from tripod	Tank roof collapse due to crane being driven too close to tank and resulting mechanical spark igniting flammable gas (applies only if crane used to install filter instead of tripod and winch)	Human error	Flammable gas deflagration inside tank See item 7 a	None	Limit placed on how close crane can come to tank Vehicle exclusion zone established	S3	F2	Crane use not currently planned for installing breather filter
9 o	RID Camera Check	No significant hazards identified							
9 p	ZIP cord tank level reading	Electrical spark ignites flammable gas when cord contacts waste	Conductivity instrument produces sufficient electrical potential to produce spark at sludge surface	Flammable gas deflagration in tank See items 7 a and 7 b	None	Conductivity instrument required to be of low power to prevent spark Tank will be allowed to breathe until flammable gas concentration drops below LFL or will be purged before level readings will be taken	S3 S1	F3 F3	
9 q	ZIP cord tank level reading	Electrostatic spark from nonconductive insulation of ZIP cord ignites flammable gas	ZIP cord is nonconductive and not bonded on outer surface allowing static charge buildup	Flammable gas deflagration in tank See items 7 a and 7 b	None	Tank will be allowed to breathe until flammable gas concentration drops below the LFL or will be purged before level reading is taken Flammable gas sample can be drawn from port on Y-adaptor to verify that tank is below 25% LFL before ZIP cord is placed in tank	S3 S1	F3 F3	A decision is required to determine what flammable gas controls will be used FCI/AB-97-008 indicates that sniffing for flammable gas is sufficient for ensuring that static sparks from ZIP cord insulation are not a risk

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Frag Rank	Remarks
9.A.c	Purge through tube lowered into riser via glovebag port or Y-adapter port	Flammable gas ignition in tank due to failure to purge tank	Flow bypasses tank because tube never lowered into riser or tube leak develops upstream of tank. Subsequent work ignites gas. Wrong gas bottle (e.g. containing fuel such as hydrogen or containing pure oxygen instead of air) used for purging	Damage to tank, and release of radioactive particles to environment. (See 7.c)	Flow meter on purge supply	Samples will be drawn of vapor space gases before performing activities that might generate a spark in the tank. Labeling of compressed gas bottles ensures wrong bottle not connected to purge line. Different threads on combustible gases than inert gases. Vendor certifications on gas bottle contents	S3	F2	
9.A.d	Purge through tube lowered into riser through Y-adapter port or purge tank using camera purge system (if flammable gas built up or present after installing camera)	Pressurize tank releasing contamination to environment	Loss of flow control on purge supply (see 9.A.b) (supply exceeds capacity of exhaust paths). or HEPA filter isolation valve closed during purge	Flow out of HEPA filter with release of tank contamination to environment (if pressurization not caused by closed isolation valve) Release of contamination from tank to environment through seal loop on breather assembly	Seal loop on breather assembly provides vent path	Isolation valve on breather filter assembly required to be open during purging	S1*	F3	
10.	Take Pictures/Video Inside Tank (Requires entry through 8 inch riser)								
	Significant steps:								
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	•								
	•								
	•								
	•								
	•								
	•								
10.a	Open riser	Hazards and hazardous events for opening riser addressed in item 8	See item 8	See item 8	See item 8	See item 8			Risk is not as great as with opening of initial vent path. Breather filter previously installed would ensure tank atmosphere is non-flammable when camera installed. Tank will be verified to be below 25% of the LFL before the camera will be installed.

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Conc Rank	Freq Rank	Remarks
10 b	Monitor for flammable gas	Hazards and hazardous events for monitoring for flammable gas covered in section 8.	See item 8	See item 8	See item 8	See item 8			
10 c	Check out system before use	No hazards identified					N/A	N/A	
10 d	Erect and install greenhouse	Greenhouse dropped on tank striking riser and driving into tank	Equipment failure (boom, cable, brake, clutch) Human error (such as double blocking)	Compromise structural integrity of top of tank with resulting airborne release of toxic vapors and radioactive material	None	Site wide hoisting and rigging procedures Riser could be clamped or otherwise supported Tank lower flammability limits verified to be below 25% before greenhouse installed If no waste disturbing activity identified, camera may not need to be purged	S1* S3	F2 F1	Greenhouse (8 X 8 X 10) installed before riser opened. Probably use third riser for camera entry The consequence for this event does not include gas deflagration because it is assumed that open risers with HEPA filters will create sufficient ventilation to keep tank flammable gas concentration below 25% LFL once that level has been obtained. This event is assumed to not cause a gas release event It is assumed there will be a verification that this tank does not experience spontaneous episodic releases
10 e	Erect and install greenhouse	Crane accident while moving greenhouse (see item 9)	See item 9	See item 9					
10 f	Install, use, and remove camera	Small radioactive material and toxic vapor release when camera lowered into tank	Riser open and barometric breathing occurs	Localized movement of contamination Possible worker contamination and uptake	None	Institutional controls for radiation worker protection (fresh air and anti-contamination equipment) Camera is plastic sleeved	S1	F3	Worker most likely will be on fresh air
10 g	Install, use, and remove camera	Camera dropped onto waste surface causing small gas release event and local ignition	Human error Allen bolts slip or air missing Cable fails	Deflagration of pocket of flammable gas released during gas release event causes airborne release of radioactive material out open riser	None	Institutional controls for radiation worker protection Procedures for installing restraint collar Vapor space sampling to verify that flammable gas concentration less than 25% lower flammability level	S1	F3	Not a significant pressure causing event FI assumes that ignition of small GFR occurs The tank vapor space sampling will indicate presence of organics and allow decisions to be made regarding precautions to be taken for organics The consequence for this event does not include global flammable gas ignition because it is assumed that open risers with HEPA filters will create sufficient ventilation to keep global tank flammable gas concentration below 25% LFL once that level has been obtained

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
10 h	Install, use, and remove camera	Camera dropped onto waste surface igniting organic waste layer	See item 10 g	Release of radioactive material Programmatic delay if no deflagration occurs (examination of camera and delay in retrieval)	None	Procedures for use of lanyard to prevent drop	S2	F0	Organic layers do not ignite easily if not highly volatile. Highly volatile organic no expected Only mechanisms for igniting organic are lightning, vehicle fuel fire (see HNF-SD-WM-CN-032)
10 i	Install, use, and remove camera	Camera dropped onto waste surface igniting organic nitrate salts	See item 10 g	Release of radioactive aerosols and toxic vapors from the tank. Potential tank failure	None	Procedures for use of lanyard to prevent drop	S3	F0	Based on information about this tank it is not expected that this tank is a candidate to have organic nitrate present Consequence not anticipated because organic nitrate is not expected to be present, tank waste is expected to be wet A paragraph should be included in the justification for continued operation chemical characterization section to address organic nitrates
10 j	Install, use, and remove camera	Loss of camera purge permits leakage of flammable gas with subsequent ignition	Camera installed in tank with significant quantities of flammable gas present (human error) ANI Compressor failure Generator failure Equipment failure	If no deflagration of flammable gas then failure of camera purge is only a programmatic problem If deflagration of gas occurs then consequences would be similar to item 7 a	Auto power shutdown on indication of purge failure	No activities permitted in tank if flammable gas concentration greater than 25% of LFL. Tank sampled for flammable gas concentration before entry Tank is vented	S1 S3	F1 F0	No episodic flammable gas releases expected in this tank Vapor sampler ok for IC Set II conditions It is assumed that open risers with HEPA filters will create sufficient ventilation to keep global tank flammable gas concentration below 25% LFL, once that level has been obtained
10 k	Install, use, and remove camera	Vehicle drives onto tank and roof collapses	This event is addressed under the evaluation for the passive case				N/A	N/A	
11.	Perform Vapor Sampling [This data is for characterization]								
	Significant steps:								
	<ul style="list-style-type: none"> Open riser Put in vapor sampler tubes 								
11 a	This sampling will be performed in the third riser that is opened (an 8 inch riser)	All steps and hazards for opening a riser apply - See item 8 on riser opening	See item 8	See item 8					Do we need this if SUMA canister sampling used? Is it required for data quality objective? This is an 8 inch riser

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
11 b	Put in vapor sampler tubes	Flammable gas ignition	Electrostatic/electrical/mechanical spark	Flammable gas deflagration inside tank See item 7 a	None	The sampler will not be put into the tank until the flammable gas concentration is less than 25% lower flammability limits The sampler is bonded	S3	F3	The vapor sampler has a sealing flange to mate up with the riser
11 c	Put in vapor sampler tubes	Tube bundle lowered into waste and waste sucked up	Human error in placing sampler Had ZIP cord reading	Contaminated pump	Pump exhaust is HI/PA filtered	Intent is to place the bottom of the bundle quite a distance above the waste to prevent aerosol trapping	S0	F3	As low as reasonably achievable issue only
11 d	Put in vapor sampler tubes	Tube bundle dropped into tank	Human error	Contaminated equipment needing eventual retrieval	None	Requirement for having lanyard on equipment being put into tank	S0	F3	The vapor sampler has a sealing flange to mate up with the riser that will prevent dropping
12. Take Hard Gamma/Test for Multiple Fission Products (Optional)									
12 a	Put detector within a few feet of waste using center riser	Detector dropped into waste See items 10 g, 10 h, and 10 i	Human error Equipment failure	Small gas release event with subsequent deflagration and puff release of radioactive material	None	Flammable gas monitoring and requirement for less than 25% of lower flammability limits to allow entry Tank is vented Drop protection such as fixed collar on support lanyard Equipment to be shutdown if drop occurs	S1	F1	This activity is not allowed on the tank unless risers have been opened and vent filters installed It is assumed that the open risers on the tank will continue to maintain a low concentration of flammable gas in the tank once a low concentration has been measured The detector is supported on a cable and which arrangement The hazards and controls are essentially the same as for in tank camera activities
12 b	Remove detector	Release of radioactive material when detector removed from riser	Human error	Personnel contamination	None	Procedures for installing and removing detector Institutional controls for radiation protection	S1	F3	Standard radiological control item

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cone Rank	Freq Rank	Remarks
13. Take Waste Grab Sample (OPTIONAL OPERATION)									
Significant steps:									
					Open riser on vented tank				
					Install sampler including glove bag and hoist assembly				
					Put sampler into waste				
					Pull sampler out of tank				
					Put sample in PIG				
13 a	Open riser on vented tank	See item 8.	See item 8	See item 8					
13 b	Install glove bag	See item 8.	See item 8.	See item 8					See install glove bag hazards in item 8
13 c	Put sampler into waste	Drop sample string	Human error Equipment failure	Programmatic impact	None	Procedures requiring use of safeguard restraints	S0	F1	The sampler requires only a 3 inch riser for entry This is a waste intrusive activity
13 d	Put sampler into waste	Ignition of flammable gas due to electrostatic or mechanical spark when string enters waste (gas release event occurs)	Incorrect bonding - human error	Small airborne release from gas pocket deflagration	None	Bonding requirements for all equipment Operator training	S1	F1	It is assumed that the effect of a small gas pocket being ignited is minor
13 e	Pull sampler up and put sample in PIG	Radioactive material released when sampler dropped on ground	Human error	Personal contamination	None	Institutional controls for radiation work	S1	F1	
13 f	Pull sampler up and put sample in PIG	Sampler hangs up on debris in tank and cannot be removed	Pre-existing structures and debris in tank hook onto sampler	Programmatic impact	None	Verify that area appears free of debris	S0	F3	This event has occurred in other tanks; if the sampler cannot be retrieved, the cable is cut and the sample string is abandoned
14. Passive Tank - Before Tank Is Opened									
14 a	No specific activities are included in this section - these hazards are the result of potential flammable gas in the tank	Flammable gas deflagration in tank results in release of toxic vapours and radioactive aerosols	Internal ignition source (such as static discharge, or mechanical spark)	Release of airborne, radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	No voltage sources are connected to the tank Pumps, neutron monitors, thermocouples, and level probes have been removed from the tank Tank inlets were capped off in the 1970s; transfers no longer made to/from the tank, minimizing potential for static discharges	Tank isolated in the 1970s Intrusive activities are prohibited while tank is in passive state	S3	F1	F1 based on potential ignition sources being only probable due to phenomena Spurious ignition in the absence of an external event is extremely unlikely; mechanical sparks could only be caused by movement of items in the tank Condition of the concrete and rebar is unknown but estimates are that the tank structure is probably sound

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
14 b		Criticality occurs in tank	Plutonium migration or selective precipitation due to chemical changes in the tank	Release of radioactive aerosols, ionizing radiation, and radioactive gases through tank riser seals to the atmosphere	Inlet lines were capped in the 1970s preventing further addition of plutonium and disturbance of the waste	Intrusive activities are prohibited while tank is in passive state Criticality prevention specification (CPS) posted in the contamination area above the tank notifies individuals to not disturb the tank	S1	F1	S1 consequence ranking is for criticality that does not compromise the integrity of the tank No mechanism has been identified that results in selective precipitation or agglomeration of plutonium, the criticality safety evaluation report for the tank evaluated the chemical and physical phenomena to determine possible causes; intrusive activities are the only possibility Sample results indicate the tank waste is over moderated and its poison content too high for a criticality to occur
14 c		Criticality occurs in tank	Pu migration or selective precipitation due to chemical changes in the tank	Potential failure of tank top due to over pressure from steam explosion caused by the energy released in the criticality event; subsequent condensation of steam could fall tank due to excessive vacuum if initial over pressurization is insufficient to fall tank	None	None	S3	F0	S3 ranking is for the less likely scenario where steam explosion causes tank top to collapse
14 d		Criticality occurs in tank	Pu migration or selective precipitation due to chemical changes in the tank	Criticality could also ignite buildup of hydrogen in the tank	None	None	S3	F0	
14 e		Exothermic chemical reaction (such as organic/nitrate reaction) occurs in tank	Tank waste dries out due to evaporation and heat load Reduced heat transfer from solids allows heat of reaction between organics and nitrates in the tank to raise temperature to autocatalytic level	Release of airborne radioactive material through manhole covers and damage to tank roof due to exothermic chemical reaction	None	None	S3	F0	S3 consequence applies to tank roof collapse F0 frequency estimate based on low heat load and low organic content of the waste in the tank Plutonium Finishing Plant waste contains no cesium or strontium Organics are hydrolyzed in caustic solution and destroyed. However, the acidity of the tank was measured at 4 when majority of liquid was pumped out in 1970s Liquid phase runaway reactions (that is red oil explosions) not considered because waste is not acidic enough Temperature measurements of the tank waste in the past have shown no significant increase

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cone Rank	Freq Rank	Remarks
14.f		Exothermic chemical reaction (such as organo/nitrate reaction) occurs in tank	Tank waste dries out due to evaporation and heat load. Reduced heat transfer from solids allows heat of reaction between organics and nitrates in the tank to raise temperature to autocatalytic level	Release of radioactive and toxic vapors from tank atmosphere (tank remains intact)	None	None	S1	F0	S1 consequence applies to events that do not cause roof collapse F0 frequency estimate based on low heat load and low organic content of the waste in the tank. Plutonium Finishing Plant waste contains no cesium or strontium. Organics are hydrolyzed in caustic solution and destroyed. However, the pH of the tank was measured at 4 when majority of liquid was pumped out in 1970s. Liquid phase runaway reactions (that is red oil explosions) not considered because waste is not acidic enough. Temperature measurements of the tank waste in the past have shown no significant increase.
14.g		Collapse of tank top under dead load releases vapors and aerosols	Degradation of tank structure due to aging Corrosion of rebar in concrete Corrosion of tank liner and chemical attack of concrete	Release of radioactive aerosols and toxic vapors from tank	None	Administrative requirements preventing access to tank roof Exclusion zone	S3	F2	S3 consequence based on significant entrainment of sludge in air due to splashing from collapse Condition of concrete and rebar is unknown
14.h		Tank leak to soil	Corrosion of liner coupled with degradation of concrete	Environmental release	None	Tank isolated to minimize intrusion of water	S0	F3	S0 based on no airborne release Photos taken before tank was isolated show that liner is corroded
14.i		Tank collapse with ignition of flammable gas due to mechanical spark	Vacuum in tank created due to liquid leak below sludge level exceeds tank load capacity	Release of airborne radioactive material through manhole covers and damage to tank roof due to flammable gas deflagration	None	None	S3	F1	F1 frequency based on the fact that it is extremely unlikely that the tank is sufficiently airtight to permit a significant vacuum to exist
14.j		Tank collapse	Vacuum in tank due to liquid leak below sludge level exceeds tank load capacity	Radioactive and toxic vapors released from tank atmosphere and entrainment of tank sludge in atmosphere	None	None	S1	F1	F1 frequency based on the fact that it is extremely unlikely that the tank is sufficiently airtight to permit a significant vacuum to exist
14.k		Tank failure due to hydrostatic load	Intrusion of large quantity of water into tank	Radioactive and toxic vapors released from tank atmosphere and entrainment of tank sludge in atmosphere	None	Tank isolated to minimize intrusion of water	S3	F1	
15.	Passive Tank With Filters Installed								

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
1.5 a	No specific activities are included in this section - these hazards are the result of steady state conditions	Flammable gas deflagration in tank results in release of toxic vapors and radioactive aerosols	Internal ignition source (such as static discharge, or mechanical spark)	Release of airborne radioactive material through manhole covers and damage to tank roof due to flammable gas deflagration	No voltage sources are connected to the tank Pumps, neutron monitors, thermocouples, and level probes have been removed from the tank Tank inlets were capped off in the 1970s; transfers no longer made to/from the tank minimizing potential for static discharges Tank is constructed of reinforced concrete 10 inches thick	Tank isolated in the 1970s Intrusive activities are prohibited while tank is in passive state	S3	F1	F1 based on potential ignition sources being only probable due to external events or natural phenomena, this is also only possible in the highly unlikely chance that natural breathing is insufficient to keep up with hydrogen production in the tank. Spurious ignition in the absence of an external event is extremely unlikely, mechanical sparks could only be caused by movement of items in the tank. Condition of the concrete and rebar is unknown but estimates are that the tank structure is sound
1.5 b		Criticality occurs in tank	Plutonium migration or selective precipitation due to chemical changes in the tank	Release of radioactive aerosols, ionizing radiation, and radioactive gases through tank riser seals to the atmosphere.	Inlet lines were capped in the 1970s preventing further addition of plutonium and disturbance of the waste	Intrusive activities are prohibited while tank is in passive state Fissile material not permitted to be added to tank Slurcing and mechanical processing prohibited No moderators other than water in excess of 5 Liters allowed to be added to tank No more than 5 Liters of chemical or organic solvents allowed to be added to tank Neutron monitoring required during access to tank	S1	F1	No mechanism has been identified that results in selective precipitation or agglomeration of plutonium, the criticality safety evaluation report for the tank evaluated the chemical and physical phenomena to determine possible causes, intrusive activities are the only possibility Sample results indicate the tank waste is over moderated and its poison content too high for a criticality to occur
1.5 c		Criticality occurs in tank	Plutonium migration or selective precipitation due to chemical changes in the tank	Potential failure of tank top due to over pressure from steam explosion caused by the energy released in the criticality event; subsequent condensation of steam could fail tank due to excessive vacuum if initial over pressurization is insufficient to fail tank	None	Fissile material not permitted to be added to tank Slurcing and mechanical processing prohibited No moderators other than water in excess of 5 Liters allowed to be added to tank No more than 5 Liters of chemical or organic solvents allowed to be added to tank	S3	F1	S3 ranking is for the less likely scenario where steam explosion causes tank top to collapse

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
15.d		Criticality occurs in tank	Plutonium migration or selective precipitation due to chemical changes in the tank	Criticality could also ignite buildup of hydrogen in the tank	None	Fissile material not permitted to be added to tank Sluicing and mechanical processing prohibited No moderators other than water in excess of 5 Liters allowed to be added to tank No more than 5 Liters of chemical or organic solvents allowed to be added to tank	S3	F1	
15.c		Exothermic chemical reaction (such as organic/nitrate reaction) occurs in tank	Tank waste dries out due to evaporation and heat load Reduced heat transfer from solids allows heat of reaction between organics and nitrates in the tank to raise temperature to autocatalytic level	Release of airborne radioactive material through manhole covers and damage to tank roof due to flammable gas deflagration	None	None	S3	F0	S3 consequence applies to tank roof collapse F0 frequency estimate based on low heat load and low organic content of the waste in the tank. Plutonium Finishing Plant waste contains no cesium or strontium Organics are hydrolyzed in caustic solution and destroyed. However, the acidity of the tank was measured at 4 when majority of liquid was pumped out in 1970s Liquid phase runaway reactions (that is red oil explosions) not considered because waste is not acidic enough Temperature measurements of the tank waste in the past have shown no significant increase

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
15.f		Exothermic chemical reaction (such as organic/nitrate reaction) occurs in tank	Tank waste dries out due to evaporation and heat load Reduced heat transfer from solids allows heat of reaction between organics and nitrates in the tank to raise temperature to autocatalytic level	Release of radioactive and toxic vapors from tank atmosphere (tank remains intact)	None	None	S1	F0	S1 consequence applies to events that do not cause roof collapse F0 frequency estimate based on low heat load and low organic content of the waste in the tank. Plutonium Finishing Plant waste contains no cesium or strontium Organics are hydrolyzed in caustic solution and destroyed. However, the acidity of the tank was measured at 4 when majority of liquid was pumped out in 1970s Liquid phase runaway reactions (that is red oil explosions) not considered because waste is not acidic enough Temperature measurements of the tank waste in the past have shown no significant increase
15.g		Collapse of tank top under dead load releases vapors and aerosols	Degradation of tank structure due to aging Corrosion of rebar in concrete Corrosion of tank liner and chemical attack of concrete	Release of radioactive aerosols and toxic vapors from tank	None	Administrative controls prohibiting uncontrolled access to top of tank Load test to verify minimum load capability	S3	F2	S3 consequence based on significant entrainment of sludge in air due to splashing from collapse Condition of concrete and rebar is unknown
15.h		Tank leak to soil	Corrosion of liner coupled with degradation of concrete	Environmental release	None	Tank isolated to minimize intrusion of water	S0	F3	S0 based on no airborne release Photos taken before tank was isolated show that liner is corroded
16. Natural Phenomena									
16.a	Natural phenomena hazards are present for all activities	High wind causes release from tank risers	Airflow across risers creates negative pressure permitting release of tank atmosphere	Release of toxic tank vapors and radioactive particulates to the atmosphere when riser open	None	Work prohibited when high winds are forecast or present	S1	F3	Minor contamination release from tank High wind results in increased atmospheric dispersion which reduces exposures to a given individual
16.b		High wind causes overhead 2,200 volt electrical line to fall and drop onto open or closed tank riser causing an ignition of flammable gas	Power line causes electrical spark in tank riser	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	Venting of tank to prevent flammable mixture buildup	None	S3	F2	Only possible when flammable conditions exist in tank

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
16.c		High wind creates missile that damages riser and causes mechanical spark in tank	Severe storm with objects that can become missiles located in vicinity of tank	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	None	Administrative requirements for area housekeeping	S3	F1	Area of risers is small presenting a limited target Many items are available in the tank vicinity that could become missiles
16.d		Ash fall adds load to tank roof resulting in roof collapse and generation of mechanical spark igniting flammable gas	Roof overload from ash fall	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	Roof capacity estimated to be 225 lbs/sq ft (live load)	Administrative controls on roof load	S3	F0	The ash fall loading is not expected to add more than 20 lbs/sq ft
16.e		Lightning ignites flammable gas in vapor space of the tank	Lightning strikes riser or underground pipe connected to tank and causes arcing across flammable tank vapor space	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	None	Intrusive activities halted when lightning detected within 50 miles of site	S3	F1	This accident assumes flammable gas is present
16.f		Lightning initiates organic/nitrate reaction in the tank waste	Lightning strikes riser or underground pipe connected to tank and arcs into waste causing localized heating above autocatalytic temperature	Release of airborne radioactive material from over pressure causing tank roof damage due to nitrate/organic reaction	None	Intrusive activities halted when lightning detected within 50 miles of site	S3	F1	Moisture content of the tank waste makes large reaction unlikely in a lightning strike event Significant quantities of organic nitrate are not expected Lightning strike likelihood is small due to the small area that the tank occupies
16.g		Seismic event causes mechanical spark that ignites flammable gas in tank	Mechanically generated spark from contact of metal parts in the tank due to shaking ignites hydrogen in tank Overhead 2,200 volt electrical line falls and drops onto riser of tank	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	None	Institutional controls for emergency response to earthquakes - reduces number of individuals exposed to radioactive material	S3	F2	Seismic event may weaken tank structure making it more vulnerable to failure in a subsequent hydrogen deflagration
16.h		Seismic event causes structural failure of tank creating mechanical spark that ignites flammable gas in tank	Mechanically generated spark caused by failure of tank structure	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	None	Institutional controls for emergency response to earthquakes - reduces number of individuals exposed to radioactive material	S3	F2	Tank has not been analyzed for seismic loads; integrity of tank structure may be compromised due to long term exposure of sidewalls to acidic waste
16.i		Seismic event causes structural failure of tank (roof or sidewalls)	Seismic event forces exceed strength of concrete tank (may be degraded from age and chemical attack)	Radioactive and toxic vapors released from tank atmosphere and entrainment of tank sludge in atmosphere	None	Institutional controls for emergency response to earthquakes - reduces number of individuals exposed to radioactive material	S3	F2	Tank has not been analyzed for seismic loads; integrity of tank structure may be compromised due to long term exposure of sidewalls to acidic waste

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cone Rank	Freq Rank	Remarks
16.j		Localized flooding on top of tank intrudes into tank	Large rainfall or rapid snow melt	Water intrusion into tank results in further leakage into soil column (liner appears to be failed)	4 inch concrete cap on top of tank roof and central plug limits water intrusion (manhole covers not covered by cap) Coating/insulation applied to risers to help prevent corrosion of risers which might allow in leakage Gravel layer on top of tank roof to promote drainage	None	S0	F3	S0 and F3 ranking for flooding with intrusion into tank - no airborne release
16.k		Localized flooding on top of tank due to snowmelt or rain causes roof collapse	Degraded roof structure	Radioactive and toxic vapors released from tank atmosphere and entrainment of tank sludge in atmosphere	Snow and rain water load is expected to be below the capacity of the roof	Administrative requirements for adding loads to roof Load testing roof assures minimum capacity	S3	F1	S3 and F1 ranking based on splashing of waste by collapse - assumes no flammable gas present Flooding from the Columbia River will not reach the 200 areas and so is not considered
16.l		Localized flooding on top of tank due to snowmelt or rain causes roof collapse with mechanical spark causing ignition of flammable gas	Degraded roof structure	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	Snow and rain water load is expected to be below the capacity of the roof	Administrative requirements for adding loads to roof Load testing roof assures minimum capacity	S3	F1	Assumes flammable gas present Flooding from the Columbia River will not reach the 200 areas and so is not considered
17. External Events									
17.a	External event hazards are present for all activities	Vehicle inadvertently driven on top of tank causes roof collapse and mechanical spark that ignites flammable gas in tank	Human error	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	None	Access controls for tank roof Administrative controls for maximum loading of tank roof	S3	F1	There is no reason for a vehicle to be intentionally driven on top of tank Tank is located near traveled routes within the Plutonium Finishing Plant fence
17.b		Vehicle inadvertently driven on top of tank causes roof collapse	Human error	Radioactive and toxic vapors released from tank atmosphere and entrainment of tank sludge in atmosphere	None	Access controls for tank roof Administrative controls for maximum loading of tank roof	S3	F3	S1 for small contaminated release through riser
17.c		Vehicle inadvertently driven on top of tank strikes riser causing mechanical spark that ignites flammable gas in tank	Human error	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	None	Access controls for tank roof Administrative controls for maximum loading of tank roof	S3	F1	
17.d		Vehicle inadvertently driven on top of tank strikes riser causing release of radioactive material	Human error	Radioactive and toxic vapors released from tank atmosphere	None	Access controls for tank roof Administrative controls for maximum loading of tank roof	S1	F3	

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
17.e		Vehicle fire on top of tank causes ignition of hydrogen or ignition of organic/nitrites	Vehicle inadvertently driven on top of tank; gas tank strikes riser and is ruptured; spark ignites fuel; burning fuel ignites flammable gas in riser or spills into tank and ignites organic/nitrites	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	None	Operator training Speed limit inside Plutonium Finishing Plant fence Administrative controls for limiting tank access Gas tank protection on all vehicles that travel in areas where tanks are present	S3	F1	There is no reason for vehicle to be intentionally driven on top of the tank
17.f		Vehicle fire on top of tank causes ignition of hydrogen or ignition of organic/nitrites	Vehicle inadvertently driven on top of tank; gas tank strikes riser and is ruptured; spark ignites fuel; burning fuel spills into tank and ignites organic/nitrites	Radioactive and toxic vapors released from tank atmosphere	None	Operator training Speed limit inside Plutonium Finishing Plant fence Administrative controls for limiting tank access Gas tank protection on all vehicles that travel in areas where tanks are present	S3	F1	There is no reason for vehicle to be intentionally driven on top of the tank
17.g		Crane load drop onto tank roof from activities not associated with tank	Crane being used at nearby facility drops load on tank due to mechanical failure, or human error; collapse causes mechanical spark and ignites flammable gas	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	None	Site wide hoisting and rigging procedures Operator training	S3	F1	Highly unlikely heavy loads will be lifted in vicinity of tank Planned lifts over tank are covered in internal events sections
17.h		Crane load drop onto tank roof causing partial collapse from activities not associated with tank	Crane being used at nearby facility drops load on tank due to mechanical failure or human error	Release of radioactive and toxic vapors released from tank atmosphere	None	Site wide hoisting and rigging procedures Operator training	S1	F1	Highly unlikely heavy loads will be lifted in vicinity of tank Planned lifts over tank are covered in internal events sections
17.i		Range fire ignites flammable gases in tank	Range fires can be caused from a variety of sources - lightning, power line failures, human activity	Release of airborne radioactive material from lifting of manhole covers and tank roof damage due to flammable gas deflagration	Large gravelled area on top and around tank precludes fire presence near risers	Brush and combustible material controls to prevent any brush closer than 25 feet from tank	S3	F0	Range fires are an anticipated event; potential for a range fire to cause ignition of flammable gases in the tank is considered to be beyond extremely unlikely
Phase II Activities									

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
1.	Shorten Risers And Replace Flanges And Perform Logging								
	Significant steps:								
	• Open riser on vented tank								
	• Perform asbestos abatement								
	• Cut riser at desired height and replace flange								
	• Seal riser								
	• Dry-well logging								
1.a	Open riser	Pressurized release from flange	HEPA filter isolated	Worker injured by flange cover displacement Worker exposure to airborne contamination	HEPA filter installed and in service	Verify HEPA filter in service before beginning activity	S1*	F2	S1* because the flange could strike the worker with sufficient energy to kill or seriously injure the worker.
1.b	Open riser	Hydrogen deflagration	HEPA filter isolated and Tank not verified less than 25% of LFL before beginning work	Release of airborne radioactive materials and chemicals through open riser. Tank roof damage from deflagration Worker injury or death.	HEPA filter installed and in service	Verify tank less than 25% of LFL before beginning activity Verify HEPA filter in service before beginning activity	S3	F2	
1.c	Open riser	Spread of radioactive contamination	Interior of flange surfaces contaminated and then exposed when cover removed	Worker contamination	None	Radiological protection program — requirement to survey potentially contaminated work areas	S1	F3	
1.d	Open riser	Tank collapse	Excessive weight applied to the tank top during activity	Worker contamination Worker injury or death Onsite worker contaminated from potential tank splash	None	Dome loading controls Access restriction control	S1* S2	F3 F2	Although overstress of the tank may not cause tank collapse, to be conservative it is assumed that this occurs. S2 consequence could result from tank contents splashing out of the tank, potentially causing onsite workers to be contaminated. The S1* consequence could result from falling into the tank and the large exposure to radioactive material that may occur as a result of a tank collapse. S3 consequences are not anticipated because the tank is continuously vented as a result of Phase 1 activities.

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
1.c	Dry-well logging	Tank collapse	Excessive weight applied to tank top during activity	Worker contamination Worker injury or death Onsite worker contaminated from potential tank splash	None	Dome loading controls Access restriction control	S1*	F3	Although overstress of the tank may not cause tank collapse, to be conservative it is assumed that this occurs. S2 consequences could result from tank contents splashing out of the tank, potentially causing onsite workers to be contaminated. The S1* consequence could result from falling into the tank and the large exposure to radioactive material that may occur as a result of a tank collapse. S3 consequences are not anticipated because the tank is continuously vented as a result of Phase I activities.
1.f	Dry-well logging	Criticality	Neutron source (Ca) initiates criticality	Worker exposure and potential death	None	Criticality safety program	S1*	F1	The tank is substantially subcritical. PFP criticality safety program requires evaluation of this activity before it is performed.
1.g	Perform asbestos abatement	Spread of asbestos contamination	Asbestos control not applied for garlock gaskets	Worker exposure to asbestos in excess of limits	None	Industrial Hygiene Program — requirement to take actions to control spread of asbestos contamination	S1	F3	
1.h	Cut riser	Organic-nitrate deflagration	Flame cutting used to cut riser, hot slag drops into tank.	Release of airborne radioactive materials and chemicals through open riser. Tank roof damage from deflagration Worker injury or death.	None	Prevent use of flame cutting equipment or other equipment that can produce hot slag when cutting the risers without catch. The tank has been evaluated as FG3. Accordingly, GRE during this activity are unlikely. As such, H ₂ deflagration is not expected.	S3	F1	The likelihood of significant organic/organic nitrate compounds in the tank is considered remote, but the possibility cannot yet be excluded. Lower energy sparks are not considered to have sufficient energy to heat organic-nitrate material to ignition point.
1.i	Move/Remove dry well	Organic nitrate deflagration	Flame cutting used to cut riser, hot slag drops into tank	Release of airborne radioactive materials and chemicals through open riser. Tank roof damage from deflagration. Worker injury or death	None	Prevent use of flame cutting equipment or other equipment that can produce hot slag when cutting risers without catch.	S3	F1	The likelihood of significant organic/organic nitrate compounds in the tank is considered remote, but the possibility cannot yet be excluded. Lower energy sparks are not considered to have sufficient energy to heat organic-nitrate material to ignition point.

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
1.j	Move/Remove dry well	Hydrogen deflagration	Gas release event during waste disturbing activity. Spark ignites gas released.	Worker contamination Onsite worker potentially contaminated	None	Flammable gas controls for waste disturbing activities	S2	F3	Tank has been classified FG3. Accordingly, only gas from the disturbed area would be released. Small volume of gas would not likely lead to offsite releases.
1.k	Replace Flange	Organic-nitrate deflagration	Welding slag from reinstallation of flange drops into tank	Release of airborne radioactive materials and chemicals through open riser. Tank roof damage from deflagration Worker injury or death.	None	Reinstall flange without the use of equipment that can produce a hot slag. The tank has been evaluated as FG3. Accordingly, GKE during this activity are unlikely. As such, H ₂ deflagration is not expected.	S3	F1	The likelihood of significant organic/nitrate compounds in the tank is considered remote, but the possibility cannot yet be excluded. Lower energy sparks are not considered to have sufficient energy to heat organic-nitrate material to ignition point.
1.l	Seal riser	No significant hazards identified that have not been previously analyzed							
2.	Moving Fence Lines, Associated Security Systems, And Power Lines								
	Significant steps:								
	• Move power lines								
	• Move security systems to support new fence line								
	• Move fence line								
2.a	Move power lines	Tank collapse	Excessive weight near tank due to power line cherry picker or other activities	Worker contamination. Worker injury or death Onsite worker contaminated from potential tank splash	None	None loading controls Access restriction control	S1* S2	F3 F2	Although overstress of the tank may not cause tank collapse, to be conservative it is assumed that this occurs. S2 consequences could result from tank contents splashing out of the tank, potentially causing onsite workers to be contaminated. The S1* consequence could result from falling into the tank and the large exposure to radioactive material that may occur as a result of a tank collapse. S3 consequences are not anticipated because the tank is continuously vented as a result of Phase 1 activities.
2.b	Move power lines	Electrical shock	Cherry picker or other equipment contacts energized electrical lines	Worker injury or death	None	Industrial Safety Program	S1*	F3	

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
2.c	Move security systems to support new fence line	No significant hazards identified that have not been previously analyzed.							
2.d	Move fence lines	No significant hazards identified that have not been previously analyzed							
<p>3. Installing Truck Sampling Bridge Foundation Piers</p> <p>Significant steps:</p> <ul style="list-style-type: none"> • Install vertical helical piers • Install angled helical anchors • Cut helical piers and anchors for height • Install concrete caps on vertical piers 									
3.a	Install vertical helical piers/install angled helical anchors	Tank collapse	Excessive weight near tank due to equipment used to install helical piers	Worker contamination. Worker injury or death Onsite worker contaminated from potential tank splash	None	Dome loading controls Access restriction control	S1* S2	F3 F2	Although oversress of the tank may not cause tank collapse, to be conservative it is assumed that this occurs. S2 consequence could result from tank contents splashing out of the tank, potentially causing onsite workers to be contaminated. The S1* consequence could result from falling into the tank and the large exposure to radioactive material that may occur as a result of a tank collapse. S3 consequences are not anticipated because the tank is continuously vented as a result of Phase I activities.
3.b	Install vertical helical piers	Tank damaged (gouged, cracked, etc.)	Helical piers strike tank during insertion and cause hole/crack in tank	Potential contamination released to soil column Potential programmatic impact due to loss of tank integrity requiring subsequent recovery actions.	None	Torque limit on installation of piers	S0	F3	The small amount of liquid observed indicates leak, if created would be of a small volume.

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
3.c	Install vertical piers	Tank collapse	Helical piers installed too shallow. Tank sampling loads applied to tank walls instead of beneath tank.	Worker contamination. Worker injury or death Onsite worker contaminated from potential tank splash	None	Work instruction requirement to install vertical helical piers to a minimum depth Work instruction requirement to install vertical helical piers to at least a minimum torque value Quality assurance program	S2	F3	Although overstress of the tank may not cause tank collapse, to be conservative it is assumed that this occurs. S2 consequence could result from tank contents spilling out of the tank, potentially causing onsite workers to be contaminated. The S1* consequence could result from falling into the tank and the large exposure to radioactive material that may occur as a result of a tank collapse. S3 consequences are not anticipated because the tank is continuously vented as a result of Phase I activities.
3.d	Install vertical helical piers	Worker injury	Worker places hands or feet near rotating helical pier or drive equipment	Worker pinch injury, potential loss of extremity	None	Industrial safety program	S1	F3	
3.e	Install vertical helical piers	Worker injury	Worker trips and falls on exposed end of helical pier	Worker impaled	None	Industrial safety program	S1	F3	
3.f	Install vertical helical piers	Shocks/Release of hazardous material	Helical pier strikes buried power line/hazardous material line during installation	Worker injury or death	None	Industrial safety program controlling excavation activities	S1*	F3	
3.g	Install helical angled anchors	Tank Collapse	Angled helical anchors installed too shallow. Angled helical anchors fail or not installed with sufficient torque to ensure they will hold. Angled helical anchor does not control lateral loads leading to failure of the tank walls and bridge.	Bridge collapse Worker contamination. Worker injury or death Onsite worker contaminated from potential tank splash	None	Work instruction requirement to install angled helical anchors to a minimum insertion length Work instruction requirement to install angled helical anchors to at least a minimum torque value Quality assurance program	S1* S2	F3 F2	Although overstress of the tank may not cause tank collapse, to be conservative it is assumed that this occurs. S2 consequence could result from tank contents spilling out of the tank, potentially causing onsite workers to be contaminated. The S1* consequence could result from falling into the tank and the large exposure to radioactive material that may occur as a result of a tank collapse. S3 consequences are not anticipated because the tank is continuously vented as a result of Phase I activities.
3.h	Cut helical piers and anchors	No significant hazards identified that have not been previously analyzed							

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
3.i	Install concrete caps	No significant hazards identified that have not been previously analyzed							
4. Truck Sampling Bridge Construction Significant steps: <ul style="list-style-type: none"> • Install cross beams • Install support I-beams • Install bridge deck 									
4.a	Install cross beams/Install support I-beams/Install bridge deck	Tank collapse	Excessive weight near tank due to equipment used to install bridge	Worker contamination Worker injury or death Onsite worker contaminated from potential tank splash	None	Dome loading controls Access restriction controls	S1* S2	F3 F2	Although overstress of the tank may not cause tank collapse, to be conservative it is assumed that this occurs. S2 consequence could result from tank contents splashing out of the tank, potentially causing onsite workers to be contaminated. The S1* consequence could result from falling into the tank and the large exposure to radioactive material that may occur as a result of a tank collapse. S3 consequences are not anticipated because the tank is continuously vented as a result of Phase 1 activities.
4.b	Install cross beams/Install support I-beams/Install bridge deck	Loss control of load on crane	Wind, earthquake, etc. Mal-operation of crane Incorrect spotter direction Crane failure	Worker crush injury or death	None	Hanford rigging procedures	S1*	F3	

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
4.c	Install cross beams/Install support I-beams/Install bridge deck	Load drop from crane	Wind, earthquake, etc. Mal-operation of crane Crane failure	Tank collapse Worker contamination Worker injury or death Onsite worker contaminated from potential tank splash	None	Hanford rigging procedures Dome loading controls (Load lift height restrictions)	S1* S2	F3 F2	Although overstress of the tank may not cause tank collapse, to be conservative it is assumed that this occurs. S2 consequence could result from tank contents splashing out of the tank, potentially causing onsite workers to be contaminated. The S1* consequence could result from falling into the tank and the large exposure to radioactive material that may occur as a result of a tank collapse. S3 consequences are not anticipated because the tank is continuously vented as a result of Phase I activities.
4.d	Install cross beams/Install support I-beams/Install bridge deck	Bridge collapse	Bridge not constructed in accordance with design requirements	Tank collapse Worker contamination Worker injury or death Onsite worker contaminated from potential tank splash	None	Quality assurance program	S1* S2	F3 F2	Although overstress of the tank may not cause tank collapse, to be conservative it is assumed that this occurs. S2 consequence could result from tank contents splashing out of the tank, potentially causing onsite workers to be contaminated. The S1* consequence could result from falling into the tank and the large exposure to radioactive material that may occur as a result of a tank collapse. S3 consequences are not anticipated because the tank is continuously vented as a result of Phase I activities.
4.e	Install cross beams/Install support I-beams/Install bridge deck	Riser failure	Load on crane strikes riser	Worker contamination	None	Hanford rigging procedures	S1	F3	S2/S3 consequences are not anticipated because the tank is continuously vented as a result of Phase I activities.
5.	<p>Preparing Risers For Push Mode Sampling</p> <p>Significant steps:</p> <ul style="list-style-type: none"> • Removing riser covers • Perform asbestos abatement • Replace bolts on riser covers 								

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
These steps were analyzed as part of the development of the TWRS authorization and safety basis. This analysis is not repeated here.									
6	Preparing risers To Insert Video Monitoring Equipment/Conduct Video Monitoring (Optional) Significant steps: <ul style="list-style-type: none"> • Removing riser covers • Perform asbestos abatement • Stage video support equipment • Perform video monitoring of the drill string 								
These steps were analyzed as part of the development of the TWRS authorization and safety basis. This analysis is not repeated here.									
7	Establishing Grounding/Bonding Termination Point Significant steps: <ul style="list-style-type: none"> • Establish electrical connection point 								
These steps were analyzed as part of the development of the TWRS authorization and safety basis. This analysis is not repeated here.									
8	Establishing Contamination Control Area Significant steps: <ul style="list-style-type: none"> • Establish contamination control area 								
8.a	Establish contamination control area	No significant hazards identified that have not been previously analyzed							Note: it was assumed that the contamination area construction would not entail large structures. If large structures are required, then dome loading and bridge loading constraints will apply.
9	Install Push-Mode Core Sampling Riser Equipment Significant steps: <ul style="list-style-type: none"> • Install riser sleeve • Install riser adapter • Install spray wash assembly • Install foot clamp • Install frisbee and frisbee plug 								
These steps were analyzed as part of the development of the TWRS authorization and safety basis. This analysis is not repeated here.									

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
10. Position Push Mode Sampling Truck On Bridge Significant steps: <ul style="list-style-type: none"> • Drive or lift truck onto platform • Maneuver truck into sampling position 									
10.a	Drive or lift truck onto platform	Tank collapse	Excessive load applied to tank walls Bridge platform not extended sufficiently far from tank. Sampling truck drives across area next to tank	Worker contamination Worker injury or death Onsite worker contaminated from potential tank splash	Bridge platform extends past 22 feet from the tank wall	Dome loading controls Access control restrictions	S1* S2	F3 F2	<p>Although overstress of the tank may not cause tank collapse, to be conservative it is assumed that this occurs.</p> <p>S2 consequence could result from tank contents splashing out of the tank, potentially causing onsite workers to be contaminated.</p> <p>The S1* consequence could result from falling into the tank and the large exposure to radioactive material that may occur as a result of a tank collapse.</p> <p>S3 consequences are not anticipated because the tank is continuously vented as a result of Phase I activities.</p>
10.b	Drive or lift truck onto platform	Load drop	Wind, earthquake, etc. Mal-operation of crane Crane failure	Tank collapse Worker contamination Worker injury or death Onsite worker contaminated from potential tank splash	Crane design	Hanford rigging procedures Dome loading controls (Load lift height restriction)	S1* S2	F3 F2	<p>Although overstress of the tank may not cause tank collapse, to be conservative it is assumed that this occurs.</p> <p>S2 consequence could result from tank contents splashing out of the tank, potentially causing onsite workers to be contaminated.</p> <p>The S1* consequence could result from falling into the tank and the large exposure to radioactive material that may occur as a result of a tank collapse.</p> <p>S3 consequences are not anticipated because the tank is continuously vented as a result of Phase I activities.</p>

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
10.c	Maneuver truck into sampling position	Truck falls from bridge	Brake or other truck system failure Operator error Wind Earthquake	Tank collapse Worker contamination Worker injury or death Onsite worker contaminated from potential tank splash	Edge and end guards (bumpers) on the truck sampling bridge	Low operational speeds specified while on bridge	S1* S2	F3 F2	Although overstress of the tank may not cause tank collapse, to be conservative it is assumed that this occurs. S2 consequence could result from tank contents splashing out of the tank, potentially causing onsite workers to be contaminated. The S1* consequence could result from falling into the tank and the large exposure to radioactive material that may occur as a result of a tank collapse. S3 consequences are not anticipated because the tank is continuously vented as a result of Phase I activities.
10.d	Maneuver truck into sampling position	Bridge collapse	Dynamic and static loads exceed bridge design limits	Tank collapse Worker contamination Worker injury or death Onsite worker contaminated from potential tank splash	None	Bridge load limit established and controlled	S1* S2	F3 F2	Although overstress of the tank may not cause tank collapse, to be conservative it is assumed that this occurs. S2 consequence could result from tank contents splashing out of the tank, potentially causing onsite workers to be contaminated. The S1* consequence could result from falling into the tank and the large exposure to radioactive material that may occur as a result of a tank collapse. S3 consequences are not anticipated because the tank is continuously vented as a result of Phase I activities.
10.e	Maneuver truck into sampling position	Riser failure	Truck strikes riser due to operator error or truck system failure	Worker contamination	None	Hanford rigging procedures	S1	F3	S2/S3 consequences are not anticipated because the tank is continuously vented as a result of Phase I activities.
10.f	Maneuver truck into sampling position	Worker injury	Worker struck/pinched by moving vehicle	Worker crushed or pinched by truck and equipment	None	Industrial safety program	S1	F3	Because of the very low speeds more serious injury seems unlikely.

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Core Rank	Freq Rank	Remarks
11.	Stage Push-Mode Core Sampling Equipment				Storage crane Stage distribution trailer Stage inert gas trailer Stage diesel generator Stage support truck Stage cask stands Stage on-site transfer casks Install glovebag				
	Significant steps:								
11.a	Stage equipment	Tank Collapse	Excessive weight near tank due to equipment being staged	Worker contamination. Worker injury or death Onsite worker contaminated from potential tank splash	None	Dome loading controls Access restriction control	S1* S2	F3 F2	Although overstress of the tank may not cause tank collapse, to be conservative it is assumed that this occurs. S2 consequence could result from tank contents spilling out of the tank, potentially causing onsite workers to be contaminated. The S1* consequence could result from filling into the tank and the large exposure to radioactive material that may occur as a result of a tank collapse. S3 consequences are not anticipated because the tank is continuously vented as a result of Phase 1 activities.

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
11.b	Stage equipment	Bridge collapse	Dynamic and static loads exceed bridge design limits	Tank collapse Worker contamination Worker injury or death Onsite worker contaminated from potential tank splash	None	Bridge load limit established and controlled	S1* S2	F3 F2	Although overstress of the tank may not cause tank collapse, to be conservative it is assumed that this occurs. S2 consequence could result from tank contents splashing out of the tank, potentially causing onsite workers to be contaminated. The S1* consequence could result from falling into the tank and the large exposure to radioactive material that may occur as a result of a tank collapse. S3 consequences are not anticipated because the tank is continuously vented as a result of Phase 1 activities.
The remainder of the hazards associated with these steps were analyzed as part of the development of the TWRS authorization and safety basis. This analysis is not repeated here.									
12.	Ground/Bond Equipment								
	Significant steps:								
	• Ground/Bond Equipment								
These steps were analyzed as part of the development of the TWRS authorization and safety basis. This analysis is not repeated here.									
13.	Raise And Level Sampling Truck								
	Significant steps:								
	• Rise and level sampling truck								
	• Take drill string measurements								
These steps were analyzed as part of the development of the TWRS authorization and safety basis. This analysis is not repeated here.									
14.	Collect Push-Mode Core Segment								
	Significant steps:								
	• Install sampler into core barrel								
	• Lower drill string to the waste surface								
	• Push sampler 19-inches into waste (core segment)								
	• Remove drill string from tank								

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
14a.	Take push-mode core sample	Puncture hole in tank	Excessive down force applied	Potential contamination release to soil column Potential programmatic impact due to loss of tank integrity requiring subsequent recovery actions	None	PMCS down force limit	SO	F3	The small amount of liquid observed indicates leak, if created, would be of small volume.
These steps were analyzed as part of the development of the TVRS authorization and safety basis. This analysis is not repeated here.									
15. Seal Core Segment Into On-site Transfer Cask									
Significant steps:									
• Place sampler into OTC and seal									
These steps were analyzed as part of the development of the TVRS authorization and safety basis. This analysis is not repeated here.									
16. Package Waste And Cleanup Area									
Significant steps:									
• Wash drill string with Li Br solution									
• Remove sampling equipment									
• Radiologically survey areas and release									
These steps were analyzed as part of the development of the TVRS authorization and safety basis. This analysis is not repeated here.									
17. Store OTC									
Significant steps:									
• Place and store OTC in weather enclosure									
• Vent OTC while in weather enclosure									
These steps were analyzed as part of the development of the TVRS authorization and safety basis. This analysis is not repeated here.									
17 a	Store OTC in weather enclosure	Contaminated weather enclosure	OTC not properly sealed	Worker contamination	Passively vent weather enclosure	Sample air space before entry Radiological surveys of weather enclosure	S1	F3	
17 b	Store OTC	Hydrogen deflagration in weather enclosure	OTC not properly sealed, releases hydrogen to weather enclosure	Worker contamination Potential onsite worker exposure Worker injury or death	Passively vent weather enclosure	Post warning signs	S2	F1	Significant hydrogen buildup is unlikely. The hydrogen would not likely be contained by the weather enclosure.

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
17.c	Vent OTC in weather enclosure	Hydrogen deflagration in weather enclosure	Spark while venting hydrogen into weather enclosure	Worker contamination Potential onsite worker exposure Worker injury or death	Passively vent weather enclosure	Ignition controls (Grounding/bonding during venting)	S2	F2	
<p>18. Natural Phenomena Hazards (NPH)</p> <p>Significant steps:</p> <ul style="list-style-type: none"> • Earthquake • Wind • Excessive precipitation 									
18.a	NPH	Earthquake during sampling	NPH	Tank collapse Worker contamination Worker injury or death Onsite worker contaminated from potential tank splash	None	Emergency Preparedness Program	S2	F1	It was judged that the likelihood of the earthquake occurring during sampling was remote due to the short duration of the activity and because it is a one time effort. Because of these features no recommended engineering design features are recommended to address seismic events.
18.b	NPH	High wind during sampling truck movement	NPH	Bridge collapse leading to tank collapse Worker contamination Worker injury or death Onsite worker contaminated from potential tank splash	Bridge designed to accommodate dynamic loads from truck movement and that applied by wind in addition to static loads.	Bridge load limits	S1* S2	F3 F2	Although overstress of the tank may not cause tank collapse, to be conservative it is assumed that this occurs. S2 consequence could result from tank contents splashing out of the tank, potentially causing onsite workers to be contaminated. The S1* consequence could result from falling into the tank and the large exposure to radioactive material that may occur as a result of a tank collapse. S3 consequences are not anticipated because the tank is continuously vented as a result of Phase 1 activities.

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Item Number	Operating Steps/Procedures	Hazardous Event	Cause	Consequence	Candidate Engineered Features	Candidate Administrative Controls	Cons Rank	Freq Rank	Remarks
18.c	NPI1	Excessive precipitation during Phase II activities	NPI1	Tank collapse Worker contamination Worker injury or death Onsite worker contaminated from potential tank splash	None	Done loading controls Access restriction controls	S1* S2	F3 F2	Although overpress of the tank may not cause tank collapse, to be conservative it is assumed that this occurs. S2 consequences could result from tank contents spilling out of the tank, potentially causing onsite workers to be contaminated. The S1* consequence could result from falling into the tank and the large exposure to radioactive material that may occur as a result of a tank collapse. S3 consequences are not anticipated because the tank is continuously vented as a result of Phase I activities.

APPENDIX: C

FLAMMABLE GAS

This appendix summarizes the understanding regarding flammable gases generated by Hanford tank wastes including hazard phenomenology and control strategies. This understanding and control strategy has been developed based on extensive study of the flammable gas hazards present in the TWRS Tank Farms and is adapted for the hazards present in Tank 241-Z-361.

C.1 FLAMMABLE GAS GENERATION AND COMPOSITION

Radioactive waste generates hydrogen through the radiolysis of water, thermolytic decomposition of organic components, and corrosion of a tank's carbon steel walls. Radiolysis and thermolytic decomposition also generate ammonia. Non-flammable gases such as nitrogen, which act as diluents, are also produced. Additional flammable gases, such as methane and an oxidizer, nitrous oxide, are generated by chemical reactions between various degradation products of organic chemicals originally present in the tanks. Volatile or semi-volatile organic chemicals in some tanks also produce organic vapors.

Hydrogen. Hydrogen gas has been identified as a major component of flammable gas in tanks. A primary source of hydrogen gas is the thermolysis of organic components which is a function of total organic carbon, the liquid volume of waste, and waste temperature. Radiolytic decomposition of water is another primary source of hydrogen gas, and it is proportional to the radionuclide content of the tank. Corrosion of waste tank walls also produces hydrogen gas, but it is an insignificant portion of the overall generation rate.

Although hydrogen is a major component of gas samples, and hydrogen generation mechanisms are known, uncertainties still exist in the parameters of the equation used to estimate generation rates. Conservative calculations have been performed to estimate the hydrogen generation rate in Tank 241-Z-361. This calculation, contained in Appendix D, indicates a hydrogen generation rate of 14 L/day with a bounding value of 27 L/day.

Other Gases. Other flammable gases and oxidizers have been identified in waste tanks. Nonmethane organic compounds from past chemical processing operations have been found at very low concentrations (less than 0.1% of the LFL) in the head spaces of TWRS tanks.

Nitrous oxide is not a flammable gas, but is an oxidizer. Its presence in trapped waste gases can cause the trapped gas mixture to be flammable without needing to mix with air. When gases are released from the waste and diluted with the air in the tank vapor space, the effect of nitrous oxide on the LFL is significantly reduced.

Nitrogen is also a significant component of waste gas. It is not a flammable gas or oxidizer. Its presence will dilute flammable gases in the waste gas mixture.

C.2 FLAMMABLE GAS HAZARDS CONDITIONS

The gases generated by the waste have the potential to accumulate in flammable concentrations in the tank vapor spaces or within the waste. This potential is evaluated below.

Vapor Space Flammable Gas Concentration Because of Steady State Releases. Flammable gases are generated by all radioactive wastes, and although a fraction of the gas may be retained in tanks containing waste solids, a portion of the generated gas is continuously released at a very low rate. These steady state releases are different from the acute, episodic releases of retained gas. Steady state releases are generally managed by diluting and removing the gases from the tank headspace through active or passive ventilation. This prevents a steady accumulation of gas from reaching flammable concentrations. Concentrations have been maintained very low with the existing ventilation configurations in TWRS high level waste storage tanks.

For tanks having small waste volumes, low radionuclide content, small concentrations of organic chemicals, and relatively large head spaces, steady state gas releases can be maintained at low concentrations with passive ventilation. Passive ventilation consists of atmospheric breathing combined with a convective flow through tank openings caused by the buoyancy effects from gas temperature differences, and bernoulli flow caused by wind blowing past the tank exhausts. Currently, passive ventilation rates have not been measured for Tank 241-Z-361. Under the pre-Phase I configuration of capped risers and no passive "breather filters," passive ventilation maybe limited to barometric breathing, which would not, by itself be adequate to reduce concentration to below 25% of the LFL. Diffusion of hydrogen through the porous concrete wall and top, however, is also an important mechanism for diluting the hydrogen released from the waste.

Prior to installation of the breather filter, the head space concentration that resulted from a conservative gas generation rate and diffusion through the tank walls and top are calculated in Appendix D. The best estimate calculations indicate the hydrogen concentration is about 30% of the LFL (1.2% hydrogen) assuming a 31 kg plutonium source term. Using more conservative assumptions about the diffusion performance of the tank's mastic liner the calculated value is on the order of 5.44%. The amount of hydrogen would also increase proportionately with the plutonium source term.

Gas Retained Within the Waste. Some generated gas is retained in the waste. Because retained gases can include fuel (for example, hydrogen, ammonia, methane) and an oxidizer (for example, nitrous oxide), the gases can be in flammable concentrations. Retained gas presents a flammability hazard in the following ways:

- It is theorized that the retained gas could burn below the waste surface if ignited; and the amount of gas, bubble type, size, and distribution could enable flame propagation.
- Gases can be released from the waste and burn in tank domes, connected vapor spaces such as ventilation systems, and outside of tank openings such as ventilation inlet paths or open risers if the released gas remains above 100% of the LFL.
- The retained gases can be released and ignited inside equipment inserted into the waste, such as core sample drill strings.

Deflagrations Below the Waste Surface. The original USQ declaration for the TWRS Tank Farm flammable gas hazard (Lawrence 1990) acknowledged that a flammable mixture of gases may exist in the waste thereby creating the possibility of a combustion event below the waste surface. Further study of this potential has indicated that such a scenario is at best very unlikely. For a deflagration to propagate through a porous media, the gas voids must be contiguous and the mean void size must be larger than the maximum experimental safe gap (MESG) for the mixture. For stoichiometric mixtures of hydrogen in air, the MESG is 0.076 mm (0.003 inch) (Underwriter's Laboratories 1970). However, hydrogen diffuses from a porous media. Calculations show that diffusion will readily occur in media with a mean pore diameter less than 1/100th the minimum diameter needed to support flame propagation (HNF-SD-WM-ES-410, Rev. 0). This issue, however, has not been completely resolved and therefore this JCO specifies controls to be used with waste intruding equipment in Tank 241-Z-361. Data regarding the amount of gas that may have accumulated in the waste in this tank has not yet been obtained, and therefore it is prudent to address the potential for subsurface combustion.

Gas Release Events (GREs). Gases that are released from the waste in a nearly continuous manner can be managed quite effectively by ventilation. Less straight forward, however, is the situation where a significant amount of the gas is retained within the waste and released relatively rapidly in a GRE.

TWRS Experience and Basis - The large GREs that occurred in Tank 241-SY-101 before the mixer pump was installed were unique in size and frequency (130 to 200 m³ of gas, or 35 to 70% of its 300- to 500-m³ retained-gas inventory every 100 to 150 days). In contrast, the next highest mean release fraction is 16% in Tanks 241-AW-101 and 241-AN-105. None of the gas releases in the other double-shell tanks (DSTs) have been large enough to have created flammable mixtures after mixing in the tank head space. The mechanism for large gas releases in these DSTs is thought to be a buoyant displacement instability (sometimes referred to as a rollover). This occurs when a waste sludge is stored with a large supernate liquid layer above it. Gas is retained in the sludge and the gas void builds until the sludge becomes less dense than the supernate and a glob of waste breaks free from the sludge layer and rises to the waste surface. The expansion of the gas bubbles as the waste rises breaks apart the sludge/bubble matrix and releases some of the gas to the tank head space.

The TWRS single-shell tanks (SSTs), like Tank 241-Z-361, do not have large supernate liquids and therefore buoyant displacement GREs are not possible in these tanks. The ongoing study of gas retention behavior of SST waste forms has narrowed the number of plausible spontaneous release mechanisms to only a few possibilities that are capable of only small releases. Observation of a number of the most notable flammable-gas-retaining SSTs indicates that no large GREs are occurring and only a few SSTs experience small spontaneous GREs. The typical spontaneous GRE in a SST has a small release volume of tens of cubic feet of hydrogen.

Gas releases can be induced by waste disturbing operations, but local disturbances do not trigger a general, large-scale gas release. Rather, gas is released only from the volume of waste actually disturbed.

For the purpose of applying controls, each facility in TWRS has been placed in one of four facility

groups depending on whether the waste is postulated to present a hazard from large or small GREs and whether the GREs may be spontaneous or only induced during waste disturbing operations or no GREs are postulated at all. Ignition source controls and monitoring requirements are applied at times when and in locations where flammable conditions resulting from GREs can be present, as appropriate to this grouping scheme. Facilities that have had significant GREs are conservatively postulated to have the potential for large spontaneous and large induced GREs. These tanks have been assigned to Facility Group 1. Five TWRS DSTs have been placed in this category.

If a facility is postulated to have the potential for a large induced GRE but only a small spontaneous GRE, it is assigned to Facility Group 2. The remainder of the 28 DSTs have been placed in this category along with a number of SSTs that indicated a significant amount of gas retention.

Facilities which show no propensity for spontaneous GREs but may produce a small induced GRE, are assigned to Facility Group 3. The majority of TWRS SSTs have been placed in this category. Facilities with little or no waste solids capable of retaining gases are categorized as non-GRE. All facility groups assume that the subject tanks undergo steady state gas generation at all times.

The grouping of facilities reflects a conservative approach even in light of uncertainties in the underlying methodology. It also enables a graded application of controls based on perceived hazards and frees less hazardous tanks from unnecessarily restrictive or burdensome controls. This method also enables a degree of simplicity in applying control sets to specific tanks.

Because many of the TWRS IMUSTs contain waste similar in composition to SST waste, it is postulated that flammable gas behavior (gas generation, retention, and release) is analogous to that in SSTs, but on a much smaller scale because of the small amount of waste present.

The facility group control sets for TWRS IMUSTs were assigned based on the amount of waste solids and overlying supernate known or suspected to be contained in the tank. The IMUSTs with significant solids but little supernate (less than 378.5 L (100 gal) or less than 1% of the tank capacity) were assigned to Facility Group 3. Conversely, IMUSTs with significant solids and a large supernate layer were assigned to Facility Group 2. If the waste solid and liquid volumes of an IMUST were unknown, the tank was assigned to Facility Group 2 as a prudent measure until better knowledge of the waste contents is obtained. Finally, those IMUSTs containing mostly liquids with only a small amount of solids (less than 378.5 L [100 gal]) were classified as non-GRE tanks.

Flammable Gas Facility Group for 241-Z-361 - Based on a comparison of Tank 241-Z-361's configuration and contained waste (a large amount of sludge with little or no supernate liquid) controls used for FG3 facilities are appropriate. But, Appendix D postulates the possibility of flammable hydrogen concentrations in the tank. Moreover, there are uncertainties in the actual tank conditions upon which this facility group determination was made. Accordingly, until conditions were shown to be safe (i.e., less than 25% of the LFL) and consistent with FG 3, more restrictive controls were applied. Now, when the tank is known to be less than 25% of the LFL, controls typical of a FG 3 tank will be applied.

C.3 FLAMMABLE GAS ACCIDENT PHENOMENA

Flammable gas accidents require gases to accumulate in flammable concentrations (i.e., the concentrations of fuel and oxidizers must be such that the mixture is above the lower flammability limit [LFL]) and an ignition source must be present to initiate the combustion event.

Combustion Limits. Combustion limits for waste gas fuels have been developed to account for nitrous oxide as a possible oxidizer rather than just air. Experiments have determined that below 20% hydrogen, there is no significant difference in the flammability data for hydrogen-air or 1:1 or 3:2 hydrogen-to-nitrous oxide ratios in air. The lower flammability limit (LFL) has been measured and reported in (WHC-SD-WM-ES-219, *Laboratory Flammability Studies of Mixtures of Hydrogen, Nitrous Oxide, and Air*):

Quiescent conditions, upward propagation	5% H ₂
Quiescent conditions, downward propagation	8% H ₂
Turbulent conditions, upward propagation	4% H ₂
Turbulent conditions, downward propagation	6% H ₂

Studies at the California Institute of Technology (Ross and Shepherd 1996) indicate that the combustion limits for waste gas mixtures can be reasonably estimated by use of Le Chatelier's Rule.

Ignition. Hydrogen, a major constituent of the flammable gases, ignites with a very small energy source; only 0.017 mJ to 0.1 mJ electrical spark energy is required (Fischer 1986; Dufresne and Karwat 1988). Other ignition sources include mechanical sparks, electrostatic sparks and contact with a hot object (i.e., hotter than the autoignition temperature). Installed equipment in the tank or ventilation system, activities being conducted in the tank, human errors, or natural phenomena (such as an earthquake or lightning) provide potential ignition sources.

Combustion pressure. Global burns represent events when the gas concentration in the entire vessel is above the LFL. For these deflagrations, the pressure in the vessel (e.g., tank) will be nearly uniform and bounded by the adiabatic isochoric (constant volume) complete combustion pressure (adiabatic isochoric complete combustion [AICC] pressure).

Under lean combustion conditions, developed pressures will be less than the AICC pressure because of incomplete combustion. Combustion pressures are well below AICC until fuel concentrations are well above the LFL. AICC pressures are approached when the mixtures are above the limit for downward propagation (Ross and Shepherd 1996). Once concentrations exceed the lower limit for downward propagation, combustion pressures exceed about 4 atmospheres gauge.

If insufficient gas is available to create flammable concentrations in the well mixed head space, but a GRE creates a local plume of flammable gases, combustion of the plume will result in pressures less than the AICC pressures shown above, as the combustion energy is dissipated into the rest of the inert dome space volume. Tank pressures created by plume burns can range from very low and inconsequential to pressures high enough to challenge the structure of Tank 241-Z-361.

C.4 FLAMMABLE GAS CONTROL STRATEGY

The flammable gas control strategy for TWRS facilities, and its application to Tank 241-Z-361 is designed to prevent a flammable gas accident by (1) maintaining the head space concentration below 25% of the LFL for gases that are released in a steady manner, and (2) preventing ignition sources when and where flammable gases may be present due to gas retention within the waste and GREs or accumulation within waste intruding equipment. When and where ignition controls are required are determined by three factors affecting the nature and extent of postulated flammable gas hazards: (1) waste behavior postulated as defined by the facility group assignment, (2) the type of operational activity that may be performed (i.e., waste disturbing or non-waste disturbing), and (3) the region or location within the tank. More specifically, the factors are as follows:

1. Type of waste behavior known or postulated to be possible for a given facility:

- Steady-state gas release
- "Large" GRE
- "Small" GRE
- Spontaneous GRE
- Induced GRE.

A "large" GRE is defined to be capable of pressurizing the dome space above atmospheric such that flammable gases may occupy pits and flow out of open risers and other spaces external to the dome space. For 241-Z-361, the Facility Group 3 assignment reflects the conclusion that small GREs are not postulated except when induced when the waste is disturbed (locally), and a large GRE in this tank is not postulated unless induced when a large portion of the waste were to be disturbed (i.e., globally).

2. The impact of operational activities on the waste contained in a facility or structure:

- Nonwaste-disturbing
- Locally waste-disturbing
- Globally waste-disturbing.

Locally waste-disturbing activities include such work as grab sampling and core sampling and are not considered to be capable of affecting significant portions of the waste. Globally waste-disturbing activities, such as salt well pumping or waste retrieval, more aggressively affect a larger fraction of the waste. No globally waste disturbing activities are postulated until after Phase II. Phase I of the work in Tank 241-Z-361 is non-waste disturbing, or in the case of grab sampling, minimally waste intrusive. Phase II includes waste sampling activities that are locally waste disturbing (e.g., grab sampling and core sampling).

3. The location or region within a waste receptacle where work activities are being performed:
- Waste intrusive
 - Dome intrusive
 - Ex-tank intrusive
 - Nonintrusive.

Waste-intrusive locations are those below the waste surface and within the vapor spaces of waste-intruding equipment where undiluted waste gas may accumulate. Dome-intrusive locations are those between the top of the risers and the waste surface, including ventilation systems up to the first mixing point. Ex-tank-intrusive locations are those outside tank openings directly connected to the dome space; this region also includes boundaries of greenhouses, as defined in Section 5.0 of this JCO.

These factors are used to specify the aspects of the three-pronged approach to flammable gas risk management (i.e., ventilation, monitoring, and ignition control) required across the range of TWRS facilities and operational activities and to Tank 241-Z-361 in this JCO. Controls differ from activity to activity in a given facility depending upon each of these factors.

Prevention of ignition sources involves the use of two sets of ignition source controls that are each invoked depending on the type of activity performed and where the activity may create sparks. The ignition source controls address electrical equipment requirements, non-electrical equipment and materials requirements, and work practices. Set 1 primarily applies to activities and locations that involve direct contact with waste and undiluted waste gases. Set 2 primarily applies to circumstances where flammable gas conditions may be postulated to occur in the dome space or ex-tank locations. To ensure consistent application and interpretation of industry standards used by these control sets, the TWRS Flammable Gas Advisory Board (FGEAB) has been formed to oversee the implementation of the ignition source controls.

Monitoring is used to (1) verify that ventilation is adequately diluting gases that are being released in a steady manner and (2) prior to work activities to prevent work when gas concentrations resulting from a GRE are in excess of 25% of the LFL.

This three-pronged control strategy (ventilation, monitoring, and ignition source control) has been judged to be a practical means for preventing the accumulation of flammable gases where ignition sources may be present or to eliminate ignition sources where flammable gases may be present.

To effectively manage the risk associated with steady state accumulation, this JCO requires passive or active ventilation to ensure that steady state flammable gas concentrations are well below the LFL. To manage the risks associated with retained gases and GREs, specific ignition source controls and continuous monitoring requirements are applied on a graded basis depending on the work performed.

Table C-1 summarizes the application of the control strategies to address each flammable gas hazard discussed above. Each strategy is discussed in the following section.

Table C-1. Summary of Flammable Gas Controls Strategy for Tank 241-Z-361 (FG 3).
(1 sheet)

Flammable Gas Hazard	Control Strategy
Steady state accumulation in head spaces	<ol style="list-style-type: none"> 1. Dilution by ventilation, and 2. Gas monitoring (characterization sampling and work activity entry gas monitoring) 3. If adequate ventilation has not been verified, apply ignition source controls (Set 1) or de-energize
Accumulation in sealed risers	<ol style="list-style-type: none"> 1. Ignition source controls (Set 1) for installed equipment until low concentrations are verified. 2. Work activity entry gas monitoring to verify low concentrations when opening riser
Ignition of flammable gas retained within the waste	<ol style="list-style-type: none"> 1. Ignition source controls (Set 1) at all times
Large spontaneous GREs	Not postulated for 241-Z-361 as a FG 3 tank.
Small spontaneous GREs	Not postulated for 241-Z-361 as a FG 3 tank.
Large induced GREs. (Only postulated in 241-Z-361 during globally waste disturbing operations.) [Post Phase II]	<ol style="list-style-type: none"> 1. Ignition source controls (Set 2) in ex-tank and dome intrusive locations during waste disturbing operations and activities and 2. Continuous gas monitoring during manned waste disturbing activities
Small induced GREs (Only postulated in 241-Z-361 during locally waste disturbing operations.)	<ol style="list-style-type: none"> 1. Ignition source controls (Set 2) for dome intrusive locations during waste disturbing operations and activities and 2. Continuous gas monitoring during manned waste disturbing activities
Accumulation in waste intruding equipment (e.g., inside core sampler drill string) [Phase II]	<ol style="list-style-type: none"> 1. Purge or flush before energizing equipment and during use of equipment or 2. Ignition controls (Set 1) at all times

Tank Regions.

Nonintrusive. Nonintrusive includes all equipment located in parts of the tank or ventilation system isolated from the tank head space by a seal barrier (i.e., compressive mechanical barriers, adhesive barrier, ventilation system seal loops, drain line seal loops, welded enclosures). There are no JCO related flammable gas controls for nonintrusive equipment or work, except for assurance that isolation exists, where applicable.

Conversely, equipment and work meeting the definition of intrusive (ex-tank intrusive, dome intrusive, or waste intrusive) shall be subject to the control strategy specified in this JCO.

Waste Intrusive. Waste intrusive refers to the region below the waste surface. Waste intruding equipment includes open ended and breached objects that are inserted below the waste surface that may create an unvented vapor space where flammable gases retained in the waste may accumulate with little dilution. Waste intruding equipment includes core sample drill pipes.

This region is defined so that gas retained within the waste is considered as a possible flammable environment. Significant gas retention is not postulated unless waste solids such as sludge or salt cake are present. Equipment that comes in contact with gas bubbles retained within the waste are therefore considered to be in a waste intrusive location.

Equipment, such as thermocouple trees, inserted below the waste surface and properly sealed is not considered waste intruding equipment.

Dome Intrusive Dome intrusive includes any location within the tank between the top of a riser and the surface of the waste. Gases released to this region mix with the air already present and are diluted. However, local high concentrations may exist for a short period of time until mixing occurs through natural convection and diffusion. Because breather filter housings and connecting ducting extends the riser, the dome-intrusive region extends to the open-air inlet/outlet of breather filters or active ventilation system inlet filters or bags/sleeving around an open riser.

Ignition source controls are applied to equipment installed in the region at the top of sealed risers. Higher concentrations may result in this region because of buoyancy effects and the reduced ventilation provided to these potentially stagnant areas. Based on anecdotal evidence from entry monitoring and the expected effects of diffusion, accumulation of gas concentrations above the LFL in this region is judged to be unlikely. Ignition source controls that are consistent with this judgement are applied. Once the riser is opened and entry monitoring has confirmed that gas concentrations are less than 25% of the LFL, normal GRE controls are applicable.

Ex-Tank Intrusive. Ex-tank intrusive includes locations that are not within the tank vapor space but could receive flammable gases above the LFL if the tank head space were to be pressurized as by a large GRE. The gases from the tank head space are diluted with air already present in these ex-tank regions and are therefore less likely to remain above the LFL than in dome intrusive regions. The definition of this region for Tank 241-Z-361 is contained in Section 5.0.

C.5 FLAMMABLE GAS CONTROLS FOR TANK 241-Z-361

Adequate ventilation is the primary means for preventing a deflagration. In addition, this JCO stipulates specific equipment and work controls (ignition source controls and monitoring) for Tank 241-Z-361, until additional data is gathered. New data may justify relaxing the controls for future activities. These controls shall apply to all equipment and activities unless the equipment or work meets the definition of nonintrusive.

Ventilation Controls. Ventilation is the most fundamental control for flammable gas hazards in waste containing tanks. Ventilation's main purpose is to dilute the gases that are released in a steady state manner. If ventilation were inadequate, the tank vapor spaces could exceed the LFL as an ongoing condition, posing an ignition risk from difficult to control, but unlikely, ignition sources such as lightning and seismic events. With the steady state releases control by ventilation, deflagration risk is reduced to that posed by the unlikely and short lived conditions created by GREs and the unlikely risk that the gases retained within the waste being combustible.

Prior to Phase I activities, Tank 241-Z-361 did not have a dedicated ventilation system, either passive or active. However, headspace gases are diluted by diffusion through the tank wall and top, and barometric breathing through cracks in the tank manhole covers. Subsequent to Phase I activities the tank now has a continuous, passive ventilation path through the installed HEPA filters. Monitoring has shown that the tank can be maintained less than 25% of the LFL.

Ignition Source Controls. Ignition source controls are applied to equipment installed or used during work activities in tank intrusive locations on a graded basis as determined by Tank 241-Z-361's FG 3 assignment. Field implementation, however, accounts for the specific details of the facility and activity/operation under consideration. This detailed implementation of the JCO is accomplished through work packages and operating procedures. The ignition source controls described in the JCO are the baseline in meeting the intent of industry standards. Work packages ensure that these controls are met across the planned operations and activities.

A process is followed to specify the allowed safe conditions and control requirements to address the flammable gas hazards as described in this JCO. Ignition source control requirements and work activity compliance with the requirements is documented by this process. In cases where direct compliance with the ignition source controls cannot be accomplished, the equipment and activity can be evaluated to determine if equivalent safety can be established. The TWRS FGEAB has been formed to determine when specific work level control implementation provides equivalent safety to the baseline controls in this JCO. The development of equivalencies shall involve analysis, evaluation, or testing and will include appropriate documentation, review, and approval. The FGEAB, consisting of TWRS Engineering, representatives from the Hanford Electrical Codes Board, and the contractor NFPA Interpretative Authority, will review the design based on equivalent safety, and approve the equipment and its installation.

Ignition Source Control Set 1 - All equipment installed or used during work activities is evaluated and Set 1 is used for that portion of the equipment that can make contact with the gases retained in the waste (in waste intrusive locations) or undiluted gases which may be present in the vapor space of waste intruding equipment. The basis is that flammable conditions may be present in these locations; therefore the highest level of control consistent with NFPA 70 (1996) Class I,

Division 1 is appropriate. IC Set 1 includes controls for ignition that might occur from mechanical sparks, electrostatic sparks, electrical sparks, and contact by hot objects. In addition, IC Set 1 specifies requirements for use of purged and pressurized equipment if such are used to prevent ignition of flammable gases. The application of this control set for Tank 241-Z-361 is as indicated in Table C-1. Specific requirements are specified in Section 5.0 of this JCO.

Ignition Source Control Set 2 - Set 2 is applied to vapor space locations (ex-tank intrusive and dome-intrusive) when a GRE is postulated to create flammable conditions. Set 2 is similar to Set 1 except that requirements (5), (6), and (7) are modified to allow the use of more readily available equipment. The basis is that the flammable conditions are unlikely or of only a short duration. Therefore, the use of equipment that meets the intent of NFPA 70 (1996) Class I, Division 2 or equivalent is adequate. The applicability for Tank 241-Z-361 is summarized in Table C-1. Specific requirements are specified in Section 5.0 of this JCO.

Exceptions to Ignition Source Control Requirements

Table C-2 covers equipment and materials that do not meet the Ignition Source Control Requirements and do not have safety equivalency with ignition source controls (Set 1 or Set 2) established by the FGEAB. Most of these items are used throughout TWRS field activities and are needed to perform important characterization activities in Tank 241-Z-361. Therefore, the exceptions in Table C-2 are required to perform the activities that are or will be covered in this JCO (Phase I and Phase II) for Tank 241-Z-361, although not each of these exceptions may be needed during Phase I activities.

A number of items in Table C-2 are considered to be "de minimus" exceptions because they are judged to pose a negligible risk as ignition sources. These de minimus items are judged to represent uncontrolled, but negligible spark sources. Most are associated with manned work. In these cases, the work location monitoring requirements, as called for in this JCO, are in force.

Additional items in Table C-2 are equipment, materials, and activities that do not meet the JCO Ignition Source Control Requirements and do not have safety equivalency established by the TWRS FGEAB. These items do not meet the definition of "de minimus." Flammable gas risk management, therefore, depends on flammable gas monitoring (standard monitoring or augmented monitoring as indicated in Table C-2), ventilation, and/or work practices that minimize the potential for a spark (for example, slow insertion of non-spark-resistant equipment). These practices provide confidence that a spark source would not be present when a flammable gas environment exists. This second category contains items that are evaluated to have an associated small, incremental increase in risk, but the benefits associated with their use justify their continued application in the field. It is judged that the risk posed by these items is acceptable for ongoing operations. This decision is based on a qualitative assessment of the importance of the waste management and safety-related activities and operations that must use these items. The TWRS Flammable Gas JCO (HNF-SD-WM-BIO-001, Appendix E) describes the justification for these exceptions.

Table C-2. Exceptions to Ignition Source Control Requirements. (2 Sheets)

Item #	Authorized Activities
1	Personal Protection Equipment (i.e., raingear, airline respirator hoses, rubber/plastic and canvas gloves, respirator masks, rubber/plastic boots, masking tape, Tyvek® coveralls) are authorized for use in ex-tank locations, but may be used in a minimally dome intrusive location (e.g., at the plane of a riser).
2	Wearing of plastic badges, badge holders, and dosimeters.
3	Installation of, removal of, working on, or extended presence of nonconductive lead blankets in ex-tank regions. Lead blankets shall not be used in a vapor trapping configuration.
4	Installation, removal, or extended presence of nonconductive adhesive tape (e.g., green tape, white tape) in ex-tank regions, Dome Intrusive regions, and in Waste Intruding Equipment.
5	Use of Portable Alpha Monitor (PAM) in ex-tank regions, Dome Intrusive regions, and in Waste Intruding Equipment.
6	Use of nonconductive poly bottles in ex-tank and Dome Intrusive regions.
7	Use of zip cords in ex-tank regions and Dome Intrusive regions.
8	Use of nonconductive plastic ropes in ex-tank regions.
9	Use of nonconductive plastic tubing in ex-tank regions and Dome Intrusive regions (e.g., aerosol testing). Nonconductive plastic tubing shall not be used below the plane of a riser.
10	Installation and removal of Garlock gaskets in ex-tank regions.
11	Use of nonconductive plastic garden type sprayer (approximately 5 gallons, hand pump pressurizer and brass spray wand) in ex-tank regions.
12	Use of grab sample cap, sampling and sludge weight retrieval device and coated steel cable in ex-tank and Dome Intrusive regions.
13	Installation and removal of PVC riser liners in Dome Intrusive regions.
18	Installation of, removal of, working with, or extended presence of the pipe wiper (Frisbee) during push mode core sampling (PMCS) with Truck 1, 2, and 3, in ex-tank and Dome Intrusive regions.

Table C-2. Exceptions to Ignition Source Control Requirements. (2 Sheets)

Item #	Authorized Activities
18	Installation of, removal of, or extended presence of plastic Kamlock caps during push mode core sampling with Trucks 1, 2, or 3 in ex-tank and Dome Intrusive regions.
19	The presence of extension cords in ex-tank regions. Power strips (and outlet strips) are not allowed in these regions. Energized lines shall not be connected or disconnected in an ex-tank region.
21	Electrical bonding is not required for removal or installation of fittings on openings less than or equal to 2.54 cm (1 in.) inside diameter during intrusive location entry.
22	Use of Type 4 vapor sampling head in ex-tank and Dome Intrusive regions. Conductive plastic sleeving shall be used during Type 4 vapor sampling.
24	Use of Type 4 vapor cart in ex-tank and Dome Intrusive regions.
25	Open riser work related equipment (e.g. Pike Poles, T-Bars, Sockets, Chokers, Shackles, and Bull Hooks) in ex-tank regions. Installation and removal of vapor seal in ex-tank regions. Continuous monitoring in the tank dome and the ex-tank region required during use of this exception.
27	Installation, removal, presence of, or movement of cover blocks, riser flanges, shield plugs, tank installed waste and non waste intrusive equipment items (e.g. heated vapor probes, corrosion probes, water lances, void fraction meter, core sampling drill string, cameras/lights, viscometer, auger, sampler) each as used in ex-tank or dome intrusive or waste intrusive regions. Work packages and procedures will include practical measures to reduce the likelihood of a mechanical spark when equipment movement performed as part of an operation or activity can create mechanical sparks. Such measures may include: limiting insertion speeds, water bathing of equipment, prevention of contact with other non-spark resistant materials by use of collars or bumpers, use of critical lift procedures where appropriate. This exception does not cover the operation of large mixer pumps that might cause significant motion of installed equipment. Any other ignition source hazards (other than mechanical spark source potential) must comply with this JCO's requirements for ignition source controls.
31	Use of Continuous Air Samplers in ex-tank regions. CAS shall be shutdown if 10% of the LFL is exceeded in the ex-tank area. Motor shall be placed outside the ex-tank region. Continuous monitoring in the tank dome and the pit is required during use of this exception.

Gas Monitoring Requirements. Flammable gas monitoring is used as part of the flammable gas

hazard management strategy for the following reasons:

- To prevent the introduction of an uncontrolled or errant spark source into a location when and where flammable gas concentrations are above a level of concern for fire, deflagration, or detonation. This includes entry monitoring for all manned work to be performed in intrusive locations for the facilities within the scope of this JCO. This function also is used if required ventilation is not operable so that equipment that does not meet ignition source controls can be shut down before concentrations of concern develop.
- To prevent the continued use of equipment and materials that may present uncontrolled spark sources or errant spark sources if flammable gas concentrations of concern develop during manned work activities. This includes manned activities in facilities when and where the effects of GREs must be considered. Continuous monitoring is required to satisfy this function.

These functions and requirements are discussed in the following paragraphs.

Entry Monitoring (and associated ignition source controls) - Flammable gas concentrations in intrusive work locations must be verified to be below the flammable gas work control limits before beginning manned work. This requirement shall be applied to all manned work activities in waste containing vessels when the manned work activity is near an opening in the vessel containment. Meeting this requirement will ensure that flammable conditions in the work space are not present as a result of steady state accumulation and/or recent GREs. Manned work shall not begin or proceed if flammable gas concentrations are greater than 25% of the LFL except for gas sampling and necessary actions to reduce gas concentrations, de-energize ignition sources, etc. Installed qualified equipment may continue to operate (not be de-energize) if flammable gas concentrations are greater than 25% of the LFL. Specific requirements are included in Section 5.0 of this JCO.

Until gas concentrations of less than 25% of the LFL are verified, the equipment used to perform this verification shall meet the requirements of ignition source controls (Set 1).

Manned Activities (Continuous Monitoring) - Because of the possibility of flammable conditions developing during work as a result of a GRE depending on the flammable gas facility group and activity type, work space (ex-tank intrusive or dome intrusive) monitoring is continued. This means using a continuous monitor, such as a portable CGM that monitor continuously and alarm at $\leq 25\%$ LFL. Ignition source controls are also imposed in these locations to prevent ignition in the unlikely event that flammable conditions develop. The potential for an errant (uncontrolled) spark is judged to be higher during manned work activities even though all equipment must meet ignition source controls for manned activities and unmanned operations. The chance of an errant spark is judged to be higher during manned activities because equipment is being manipulated, and the chance for human error is present. Therefore, a distinction is made between manned and unmanned activities. Manned activities require continuous monitoring and work stoppage if the concentrations exceed 25% of LFL; unmanned operations generally do not require monitoring. Monitoring thus provides an additional safety measure to the ignition source controls during these activities. Therefore, all manned work activities must immediately halt if flammable gas

concentrations exceed 25% of the LFL with an exception for gas sampling and necessary actions to reduce gas concentrations, de-energizing ignition sources, etc. These manned work activity monitoring controls are specified in Section 5.0 of this JCO.

C.6 REFERENCES

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APPENDIX D

**AN ESTIMATE OF POTENTIAL HYDROGEN CONCENTRATION
IN THE AIRSPACE OF TANK 241-Z-361**

D.1 INTRODUCTION

This appendix estimates the potential hydrogen concentration in the air space of Tank 241-Z-361.

Tank 241-Z-361 is a settling tank that had been used in the effluent circuit of the Plutonium Finishing Plant (PFP). The tank has been inactive since 1973. In the mid 1970s the majority of supernatant liquid was pumped out, and inlet and outlet pipes were capped and sealed. The tank has been in this "sealed" configuration for the past 20+ years.

Airborne hydrogen is a safety concern because radiolysis of water in residual waste is expected to generate hydrogen at a slow rate. Since the tank is neither actively ventilated nor equipped with a "breather" filter, hydrogen gas would build to a steady state level in which escape rate is balanced by generation rate. Of key interest herein is the rate at which hydrogen would escape from the tank by diffusion and leakage through tank walls.

D.2 OBJECTIVE AND SCOPE

The objective of this effort is to estimate the potential hydrogen concentration in the air space of Tank 241-Z-361. The scope of this effort is quite limited in that it is based on readily available information regarding the tank and its contents and on simple engineering mass transfer models. It is difficult to estimate the diffusional admittance of the sealant layer applied to the top surface of the tank and the diffusional admittance of an elastomeric liner originally applied to the inner walls of the tank. A range of hydrogen concentration values is therefore estimated, varying the diffusional admittance values assumed for the sealant layer and wall liner.

D.3 DESCRIPTION OF TANK AND CONTENTS

Tank 241-Z-361 is a rectangular concrete tank 26 feet long by 13 feet wide. Its depth is 17 feet at one end and 18 feet at the other end, i.e. it has a sloped floor. The top of the tank is 2 feet below grade.

The top slab of the tank is 10-inches thick and was originally cast with two man holes (3 feet diameter) and one concrete plug (4 feet diameter). The side walls and floor consisted initially of 3/8 inch thick steel plate backed up by 1 foot of reinforced concrete. This information is taken from drawing No. H-2-16024.

A note on drawing H-2-16024 indicates that a 4 inch thick concrete slab was poured over the top of the tank. The 4 inch top slab was removed in the vicinity of the two man holes, and a 6 inch hole was core drilled through the centrally located concrete plug. A riser, covered by a blind flange is currently installed in this central hole.

Note A on drawing H-2-16024 indicates that a sealant film (0.25 inch thick when wet) was applied to the top (outside surface) of the 10 inch thick concrete ceiling of the tank. At present the top of the tank would consist of a sandwich of two concrete slabs separated by the sealant layer. The exceptions are the two 3 foot diameter man holes covered by steel plates. A number of steel risers covered by blind flanges are installed in the ceiling of the tank.

Photographs of the inside of the tank show that significant portions of the steel lining covering the walls have corroded away, exposing the concrete wall and a water proofing liner installed between the steel liner and the wall (Franz 1997).

Approximately 94" of sludge remains in the tank, estimated at 75 m³ (Bogen 1997), assuming the sludge hasn't subsided due to dry out or leakage of liquid from the tank since the supernate was pumped out in 1975.

D.4 ESTIMATE OF HYDROGEN CONCENTRATION

This section details how the hydrogen concentration is estimated.

D.4.1 METHODOLOGY

Hydrogen concentration is predicted by making a hydrogen mass balance on the gas phase in Tank 241-Z-361, accounting for hydrogen generation by radiolysis and depletion by diffusion and leakage:

$$\text{accumulation rate} = \text{input rate} - \text{output rate} \quad (1)$$

$$\text{accumulation rate} = V \frac{dc}{dt} \quad (1a)$$

$$\text{input rate} = G \quad (1b)$$

$$\text{output rate} = QC + DC \quad (1c)$$

Inserting equations 1a, 1b, and 1c, into Equation (1), the differential equation that describes the buildup of concentration with time is:

$$V \frac{dc}{dt} = G - QC - DC \quad (2)$$

where,

V = volume of gas space, cm³,
 C = hydrogen concentration, moles/cm³,
 G = hydrogen generation rate, moles/s,
 Q = headspace ventilation rate, cm³/s,
 D = diffusional admittance, cm³/s,
 t = time, seconds.

The solution to Eq.(2), under conditions where G, Q, D, and V are constants, is:

$$C = \frac{G[1 - \exp(-(Q+D)t/V)]}{Q+D} \quad (3)$$

The maximum in C occurs when t is large, causing the exponential term to go to zero. The maximum, or equilibrium concentration, is

$$C = \frac{G}{Q+D}. \quad (4)$$

The terms in Equations (3) and (4) are numerically evaluated in the following section, allowing an estimate of C, as well as defining how long it would take to approach equilibrium conditions.

D.4.2 QUANTIFICATION OF RELEVANT PARAMETERS

G-Hydrogen Generation Rate

The sludge in Tank 241-Z-361 contains various Pu isotopes and Am-241. Radiolysis in the tank is due primarily to alpha radiation. The hydrogen production rate due to radiolysis is given by the following equation:

$$m'(H_2) = \sum_{i=1}^{i=n} I_i E_i F G(H_2) A_i d \quad (4a)$$

where,

- $m'(H_2)$ = the hydrogen production rate, in molecules/s
- I_i = total inventory of the i_{th} Pu isotope in the tank, in g
- E_i = the average alpha particle energy for the i_{th} isotope, in eV/disintegration
- F = fraction of ionizing radiation absorbed by the target molecules
- $G(H_2)$ = radiolysis constant, molecules H_2 produced/eV of ionizing radiation absorbed
- A_i = average Pu alpha activity, in Ci/g of Pu
- d = conversion from Ci to Bq, $3.7E10$ Bq/Ci = $3.7E10$ disintegrations/s/Ci

The tank is believed to contain between 26 and 75 kg of Pu (Freeman and Pollard 1994). Plutonium material accountability records at PFP indicate that approximately 31 kg of Pu is contained in the tank. The "best estimate" 31 kg inventory estimate from the Pu material accountability records is used in this analysis to determine the potential hydrogen generation rate in the tank. The isotopic distribution of the plutonium in the Tank 241-Z-361 is assumed to be the same as is used in estimating accident consequences in the PFP Facility. The PFP FSAR (WHC-SD-CP-SAR-021), Table 9-44 gives the mass weighted isotopic concentrations for two categories of Pu material stored in the PFP--for material containing less than 10% Pu-240, and for material containing > 10% Pu-240. The bulk of the plutonium processed at PFP was weapons grade with an isotopic composition of approximately 93% Pu-239, 6% Pu-240, and 0.6% Pu-241 (Emery and Garland 1974). In the late 1960's limited processing of fuel elements from power reactors occurred. The plutonium recovered from this fuel had a different isotopic composition estimated at 55% Pu-239, 25% Pu-240, and 15% Pu-240. Because the bulk of the material processed through PFP was weapons grade, the <10% Pu-240 isotopic distribution reported in the PFP FSAR is assumed to be representative of the Tank 241-Z-361 contents. Multiplying the isotopic distribution values from the PFP FSAR by the best estimate total Pu value of 31 kg gives the I_i values needed to solve Equation 4a.

The radiolysis constant $G(H_2)$ needed to solve Equation 4 cannot be accurately determined until the waste is characterized. $G(H_2)$ is a function of pH, NO_3 ion content, temperature and other variables. $G(H_2)$ is significantly higher for organic molecules than for water. The organic content of the waste is unknown. For this analysis the $G(H_2)$ for pure water is used. This is believed to provide a conservative (but not necessarily bounding estimate if the tank unexpectedly contained large amounts of organic) estimate of hydrogen generation as $G(H_2)$ tends to go down with increasing salt content and decreasing pH (the pH of the liquid in the tank has been measured at 4). The $G(H_2)$ for water exposed to alphas with an energy of 5.3 MeV is $1.6E-02$ molecules H_2 /eV (WHC-SD-TP-RPT-014).

"F" is also difficult to determine. For sludges, the solids portion of the sludge can absorb a fraction of the alphas and make them unavailable for cleaving hydrogen from water molecules. For this analysis F is assumed to be 0.5. The basis for estimating 50% of alpha energy to be absorbed by water is as follows.

- For a solid/aqueous material, the fraction of energy absorbed by water is a number that falls between 0 and 1. The average of the extremes is 0.5.
- If half of the waste mass is water (a reasonable guess for drained sludge) and if the alpha range is long compared to particle size, roughly half of the energy would be absorbed by water, i.e., $F \approx 0.5$.
- If the mean size of sludge particles was comparable to or larger than the alpha range, geometric factors would cause a preferential absorption by the solids: This is because a significant fraction of alpha particles originating from the solid phase (Pu expected to be mainly present in solids) would be captured within the solid phase. Thus, the estimated F of 0.5 is probably conservative. At present there is insufficient waste characterization data available to justify an expanded analysis of F, so $F = 0.5$ is proposed as a best-estimate value.

The spreadsheet shown in Table D-1 was used to solve Equation 4a, to determine the potential hydrogen production rate in the tank. The values for the variables I_i , E_i , F , $G(H_2)$, A_i , and d are provided, respectively, in columns D through I of the spreadsheet. The hydrogen production rate from each isotope is calculated in column J as the product of the respective values in columns D through I. Cells B2 through B6 in the spreadsheet identify the alpha generating radioisotopes of concern in the analysis. Cells C2 through C6 give the weight fraction of each alpha emitting isotope, taken from the <10% Pu-240 distribution from Table 9-44 of the PFP FSAR. Cells D2 through D6 calculate the inventories of each isotope, values for the variable I_i in Equation 4a, by multiplying the respective values in columns C and D together. The next column in the spreadsheet (Cells E2 through E6) give the average alpha particle energies for each isotope, values for the variable E_i , in Equation 4a. The average alpha particle energies for each isotope were determined using the RadDecay computer program (Grove 1990). Cells F2 through F6 give the fraction of alpha particles assumed to be absorbed by water in the waste, or F . Cells G2 through G6 give the alpha radiolysis constant $G(H_2)$ used (basis discussed above). Cells H2 through H6 provide the specific activities for each isotope, to convert from a weight basis to a curie basis for each isotope inventory. Column I gives the conversion constant ($3.7E+10$ Bq/Ci) for converting the activities from units of Ci to units of Bq, or disintegrations per second.

The sum of the values in column J of the spreadsheet gives a total estimated hydrogen production rate for the tank, $M'_i(H_2)$, of $3.74E+18$ molecules/s. Dividing by Avogadro's number gives a molar flow rate of $(3.74E+18 \text{ molecules/s}) / (6.0235E+23 \text{ molecules/mole}) = 6.21E-6$ moles/s. Hence,

$$G = 6.21E-6 \text{ moles } H_2/s$$

The ideal gas law is used to estimate the volumetric flow rate, assuming a tank temperature of 289 K and a tank vapor space pressure of 1 atm:

$$Q'(H_2) = (6.21E-6 \text{ moles/s})(0.08205 \text{ atm.L/mol.K})(289 \text{ K})/(1 \text{ atm})$$

$$= 1.47E-4 \text{ L/s, or } 0.147 \text{ cm}^3/\text{s}$$

V - Volume of Gas Phase

Based on the tank dimensions discussed in Section 3.0, the volume of the tank is (13 ft)(26 ft)(17.5 ft avg depth) = 5915 ft³, or 167.5 m³. As discussed earlier, the volume of the sludge in the tank has been estimated at 75 m³. The vapor space volume of the tank, V, is thus 167.5 - 75 = 92.5 m³, or 9.25E07 cm³.

Q - Ventilation Rate

Ventilation would occur by atmospheric pressure fluctuations and by the outflow of gases generated by chemical reactions in the waste. While known penetrations have been sealed, leak paths would exist between manhole covers and their seats in the tank ceiling. The flow admittance of leak paths is uncertain but is likely that the tank inhales and exhales in response to atmospheric pressure fluctuations. If flow resistance in the leak path is neglected, then an average ventilation rate of 0.45% of the tank volume per day is predicted (Crippen 1993). An average breathing rate for Tank 241-Z-361, based on its vapor space volume, is (9.25E7 cm³)(0.0045/day) = 4.16E5 cm³/day, or 4.82 cm³/s. A best-estimate breathing rate of half this value, 2.41 cm³/s, is used herein to account for flow resistance in leak paths.

In addition to atmospheric "breathing," gases generated in the tank will also cause ventilation as they escape from the tank. Gases generated would include H₂, O₂ and possibly N₂O, NH₃, and N₂. A best estimate of gas generation rate is twice the H₂ generation rate. Doubling the hydrogen generation rate calculated earlier gives a gas displacement ventilation rate of 0.147 x 2 = 0.294 cm³/s.

The total ventilation rate is calculated by adding gas generation rate to ventilation rate induced by atmospheric pressure fluctuations:

$$Q = 2.41 + 0.294 = 2.70 \text{ cm}^3/\text{s}.$$

D - Diffusional Admittance

Hydrogen has a high molecular diffusivity and can diffuse through porous boundaries at an appreciable rate. For the current exercise, a best estimate of diffusion rate will be made for exposed side wall concrete and the ceiling concrete lid. First, a simple version of Fick's law is assumed to apply for the diffusional transport of hydrogen within concrete pores:

$$N_A = D_H \frac{\Delta C}{\Delta X} \quad (5)$$

where,

N_A = diffusion flux of H_2 , moles/cm²s,
 D_H = molecular diffusivity of H_2 in air, cm²/s,
 ΔC = concentration difference across the concrete walls, moles H_2 / cm³s,
 ΔX = thickness of concrete, cm.

Two additional factors are now applied to Eq.(5) to make it applicable on a macroscopic basis, i.e., so that it applies to bulk concrete as opposed to just the pores. The factors are porosity and tortuosity, ϵ and τ Equation (5) is reformulated as follows.

$$N_{AC} = \frac{\epsilon}{\tau} D_H \frac{\Delta C}{\Delta X} \quad (6)$$

where,

N_{AC} = diffusion flux in concrete, moles/cm²s,
 ϵ = porosity of concrete, dimensionless,
 τ = tortuosity factor in concrete, dimensionless.

The total transport rate of hydrogen through concrete walls is the flux multiplied by the cross-sectional area for transport:

$$W_{AC} = AN_A = A \frac{\epsilon}{\tau} D_H \frac{\Delta C}{\Delta X} \quad (7)$$

By definition the diffusional admittance factor, D , in Equations (1-4) is the transport rate divided by the hydrogen concentration inside the tank:

$$D = \frac{W_{AC}}{C} = \frac{A\epsilon}{C\tau} D_H \frac{\Delta C}{\Delta X} \quad (8)$$

A numerical estimate of D for Tank 241-Z-361 is evaluated as follows.

A-Area of Exposed Concrete Ceiling and Wall

The plan cross-section of the tank is 13 feet by 26 feet. The total area is $13 \times 26 = 338 \text{ ft}^2$. Diffusion would be greatly impeded by the steel manhole cover plates. The diameter of the manhole seats is 4 feet. There are two manhole covers. Therefore, the surface area blocked by steel is: $2\pi(2)^2 = 25.1 \text{ ft}^2$. The net area of concrete in the ceiling is:

$$\text{ceiling area} = (338 - 25.1) * (30.5)^2 = 2.91E5 \text{ cm}^2.$$

Concrete walls above waste level are likely to be exposed to the tank headspace air because the steel liner originally present has suffered corrosion. The exposed area is calculated for walls extending from the ceiling down 8 feet. The area is:

$$2(8)(26 + 13)(30.5)^2 = 5.80E5 \text{ cm}^2$$

ΔX - Diffusion Path Length

For the tank walls, the diffusion path length is estimated as the concrete wall thickness. The wall concrete is 12 inches thick so ΔX for the walls is 30.5 cm. This estimate of diffusion barrier thickness neglects the possible diffusional resistance of a sealant film originally applied to the outside of the steel liner. It is the authors judgment, based on photographic evidence of large scale corrosion of the steel liner (Franz 1997) that the sealant layer would be ineffective in preventing head space air from communicating with concrete sidewalls. Cracking and corrosion of sidewall concrete as a result of aging (~50 yr.) and exposure to acidic waste liquids would probably enhance diffusional loss, but current information does not provide a basis for quantifying such an enhancement. Therefore such effects are not accounted for in this analysis. Any increase in concrete admittance due to corrosion and cracking would offset decreases in concrete admittance attributable to sealant that is still in an effective configuration. Our estimate of side wall diffusional admittance is thus based on the assumption that potential factors which could cause an increase in diffusional resistance are balanced by factors which could cause the diffusional resistance to decrease as compared to the bare concrete wall picture.

A bounding assumption with respect sidewall diffusion path length is that the sealant layer forms an impermeable barrier, and totally prevents hydrogen loss by diffusion. For this hypothetical case the effective diffusion length is infinite.

The concrete ceiling thickness in the ceiling is estimated as the sum of the two slabs, 10 inches and 4 inches, or 14 inches (35.6 cm). The layer of sealant that is thought to exist between the two concrete ceiling layers would probably represent a diffusion barrier with less admittance than concrete. In the absence of more information on the diffusional properties of the sealant layer, it is assumed herein that the admittance of this layer is 10% of that of the same thickness of concrete. Therefore, the equivalent concrete thickness is calculated as $10(0.25 \text{ in.}) = 2.5 \text{ in.}$ or

5.04 cm. The total estimated equivalent thickness of concrete in the ceiling is 14 in. + 2.5 in. or 41.9 cm. The assumed diffusional resistance of the sealant layer can be considered only a first guess. A technical reviewer (Marusich 1997) has suggested that the sealant diffusional admittance could be an order of magnitude (or more) lower than estimated above. The potential impact of a lower diffusional admittance of the sealant layer is quantified by comparing results for three cases: (1) the effective concrete ceiling thickness is 16.5 in. (41.9 cm) (the best estimate), (2) the effective concrete ceiling thickness is 14 in. + 25 in. or 39 in. (99.06 cm), (10x lower admittance), and (3) the effective thickness of the concrete ceiling is infinite, i.e. the ceiling has zero permeability to hydrogen.

Diffusional Impedance of Soil Overburden

Diffusional impedance of soil overburden is neglected herein on the basis that diffusion is rapid in soil as compared to diffusion in concrete. For soil, porosity is in the neighborhood of 0.3 and tortuosity is expected to be a relatively small number, three or less. Using these values, the ratio of ϵ over τ is ~ 0.1 for soil. This value is $0.1/4.97E-4$ or ~ 200 times higher than estimated for concrete (see discussion following Eq.(6a)). Since the effective diffusivity in soil overburden is estimated to be several orders of magnitude higher than estimated for concrete, diffusional resistance of soil overburden is expected to be negligible.

C. ΔC - Hydrogen Concentration and Difference in Concentration Across Concrete Wall

The driving force for diffusion is the concentration difference across the concrete boundary, ΔC . Numerically, ΔC is inside concentration minus outside concentration. Since diffusion in soil overburden is expected to be fast as compared to diffusion through concrete, hydrogen concentration outside the tank is assumed to be negligibly small. Therefore, the ratio $\Delta C/C$ expressed in Eq.(8) is evaluated as unity:

$$\frac{\Delta C}{C} = 1.$$

D_H - Hydrogen Diffusivity

The molecular diffusivity of hydrogen was estimated by correcting an experimental value for H_2 in N_2 at 298°K (Sherwood 1975) to the assumed tank temperature of 289°K:

$$D_H = 0.78 \text{ cm}^2/\text{s} * \left[\frac{289}{298} \right]^{1.75} = 0.74 \text{ cm}^2/\text{s}.$$

ϵ, τ - Porosity, Tortuosity

The ratio ϵ/τ can be interpreted as a correction factor to apply to gas phase diffusivity to account for the diffusional resistance of a porous solid. This can be illustrated by factoring Eq.(6):

$$N_{AC} = \frac{\epsilon}{\tau} D_H \frac{\Delta c}{\Delta X} = D_C \frac{\Delta C}{\Delta X} \quad (6a)$$

where,

$$D_C = \frac{\epsilon}{\tau} D_H = \text{effective diffusivity of H}_2 \text{ in concrete, cm}^2/\text{s}.$$

Experimental measurements on the effective diffusivity of hydrogen through a concrete slab (Atkinson et al. 1988) can be used to estimate a numerical value of ϵ/τ for concrete. Atkinson's 1988 report a measured value of D_C of $3.83E-4$ cm^2/s for a hydrogen-argon binary gas mixture at a pressure of 1 atmosphere. The diffusivity of hydrogen in argon gas is estimated from molecular theory (Bird et al. 1960) to be 0.77 cm^2/s . Therefore, based on the measured value of D_C and the predicted value of D_H , the ϵ/τ ratio is calculated as:

$$\frac{\epsilon}{\tau} = \frac{D_C}{D_H} = \frac{3.83E-4}{0.77} = 4.97E-4$$

This value of ϵ/τ is used herein to obtain a best-estimate of the diffusional admittance factor D .

D - Diffusional Admittance Factor

The diffusional admittance factor, D , as defined in Eq.(8), is quantified using the numerical values of individual parameters described in the foregoing paragraphs. Inserting values of parameters for the tank ceiling concrete slab,

$$D_c = \frac{A \epsilon D_H \Delta C}{\tau \Delta x C} = \frac{(2.91E5 \text{ cm}^2)(4.97E-4)(0.74 \text{ cm}^2/\text{s})(1)}{(41.9 \text{ cm})} = 2.55 \text{ cm}^3/\text{s}.$$

The sensitivity of this analysis to assumed sealant diffusional resistance as evaluated by varying the effective concrete thickness of the roof slab. The diffusional admittance of the tank

ceiling for an effective concrete thickness of 99.06 cm is $2.55 \times 41.9/99.06 = 1.08 \text{ cm}^3/\text{s}$. This effective thickness is calculated for a 0.25 in thick sealant layer that offers diffusional resistance of 100 times that of dry concrete. For the infinite thickness case (assumed impermeable sealant layer) the diffusional admittance of the tank ceiling is zero.

For the exposed side wall, D_w is:

$$D_w = \frac{A \epsilon D_H \Delta C}{\tau \Delta X C} = \frac{(5.80E5 \text{ cm}^2)(4.97E-4)(0.74 \text{ cm}^2/\text{s})(1)}{(30.5 \text{ cm})} = 6.99 \text{ cm}^3/\text{s}.$$

The total diffusional admittance is the sum of that of the ceiling and exposed walls:

$$D = D_c + D_w = 2.55 + 6.99 = 9.55 \text{ cm}^3/\text{s}.$$

Comparing D ($9.55 \text{ cm}^3/\text{s}$) with Q ($2.70 \text{ cm}^3/\text{s}$), indicates that the diffusional loss rate of hydrogen from Tank 241-Z-361 is predicted to be faster than the ventilation loss rate.

D.4.3 PREDICTED HYDROGEN CONCENTRATION

Equation (4) expresses the equilibrium hydrogen concentration as the ratio of generation rate to loss admittance factors. Inserting numerical values of parameters quantified in the foregoing paragraphs,

$$C = \frac{G}{Q + D} = \frac{6.21E-6 \text{ moles } H_2/\text{s}}{2.70 \text{ cm}^3/\text{s} + 9.55 \text{ cm}^3/\text{s}} = 5.07E-7 \text{ moles } H_2/\text{cm}^3.$$

This concentration can be converted to a volumetric basis using the standard molar volume of 22,400 cm^3/mole . Correcting for a temperature of 289°K (60°F) at tank conditions

$$5.07E-7 \frac{\text{moles } H_2}{\text{cm}^3} * 22,400 \frac{\text{cm}^3 H_2}{\text{mole } H_2} * \frac{289}{273} = 1.20E-2 \frac{\text{cm}^3 H_2}{\text{cm}^3}$$

Thus the volume percent of H_2 at equilibrium is predicted to be $100(1.20E-2) = 1.20\%$. This value is approximately 30% of the LFL for hydrogen in air.

The impact of lower diffusional admittances assumed for the ceiling is illustrated as follows. For a sealant layer having one-tenth the best-estimate diffusional admittance, the equilibrium hydrogen

concentration is:

$$1.20\% * \frac{2.70 \text{ cm}^3/\text{s} + 9.55 \text{ cm}^3/\text{s}}{2.70 \text{ cm}^3/\text{s} + 6.99 \text{ cm}^3/\text{s} + 1.08 \text{ cm}^3/\text{s}} = 1.36\%.$$

For the hypothetical impermeable ceiling case the equilibrium hydrogen concentration is:

$$1.20\% * \frac{2.70 \text{ cm}^3/\text{s} + 9.55 \text{ cm}^3/\text{s}}{2.70 \text{ cm}^3/\text{s} + 6.99 \text{ cm}^3/\text{s} + 0 \text{ cm}^3/\text{s}} = 1.52\%$$

These calculations show that the diffusional properties of the tank ceiling are relatively unimportant because the diffusional admittance of the ceiling is small compared to the sum of admittances estimated for the sidewalls and head space ventilation.

A bounding case with respect to diffusion is to assume both sidewalls and ceiling are impermeable to hydrogen. For this hypothetical case the equilibrium hydrogen concentration is:

$$1.20\% * \frac{2.70 \text{ cm}^3/\text{s} + 9.55 \text{ cm}^3/\text{s}}{2.70 \text{ cm}^3/\text{s} + 0 \text{ cm}^3/\text{s} + 0 \text{ cm}^3/\text{s}} = 5.44\%$$

Predicted hydrogen concentrations for the several cases of diffusional properties assumed above are summarized in Table D-2.

If the high end Pu estimate of 75 kg is used instead of the best estimate value of 31 kg for estimating the hydrogen production rate due to alpha radiolysis, the equilibrium H₂ concentrations in the tank would be approximately a factor of 75/31 = 2.4 times higher than shown in Table D-2.

The temporal approach to equilibrium may be quantified from Equations (3) and (4). Dividing Eq.(3) by Eq.(4), the ratio of concentration at time, t, to the equilibrium concentration (t_∞) is:

$$\frac{C_t}{C_\infty} = 1 - \exp -[(Q + D)t/v] \quad (9)$$

The time required to reach 99% of the equilibrium concentration may be quantified by setting C/C_∞ = 0.99 in Eq.(9):

$$0.99 = 1 - \exp -[(Q + D)t/V]$$

From algebraic manipulation of this expression, time can be solved for. Assuming the best estimate diffusional admittance for the tank sealant, the time to reach 99% of the equilibrium value is:

$$t_{0.99} = \frac{\ln(0.01)V}{Q + D} = \frac{4.61(9.25E7 \text{ cm}^3)}{(2.70 \text{ cm}^3/\text{s} + 9.55 \text{ cm}^3/\text{s})} = 3.48E7 \text{ s.}$$

The time required to reach 99% of the equilibrium concentration is 3.48E7 s, which is 403 days. This time is short compared to the storage time of decades, so it is concluded that equilibrium concentrations prevail in Tank 241-Z-361.

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Table D-1. Determination of Hydrogen Production Rate in Tank 241-Z-361

A	B	C	D	E	F	G	H	I	J
1	Isotope	Isotope Weight Fraction (unitless)	I ₀ Isotope Inventory # (g)	E _α Average Alpha Particle Energy (eV/disintegration)	F, Fraction Of Alphas Absorbed By Water (unitless)	G(H ₂), Alpha Radiolysis Constant (molecules H ₂ /eV)	A _α Isotope Alpha Activity (Ci/g)	d, Conversion Constant, Ci to Bq (Bq/Ci)	m'(H ₂), hydrogen production rate (molecules/s)
2	Pu-238	1.00E-04	3.1	5.49E+06	0.5	1.60E-02	17.1	3.70E+10	8.61434E+16
3	Pu-239	9.37E-01	29047	5.15E+06	0.5	1.60E-02	6.20E-02	3.70E+10	2.74531E+18
4	Pu-240	6.05E-02	1875.5	5.15E+06	0.5	1.60E-02	2.27E-01	3.70E+10	6.48996E+17
5	Pu-242	3.00E-04	9.3	4.91E+06	0.5	1.60E-02	3.88E-03	3.70E+10	5.2443E+13
6	Am-241	1.50E-03	46.5	5.47E+06	0.5	1.60E-02	3.43	3.70E+10	2.58242E+17
Total m'(H ₂) =									3.73875E+18

* from Table 9-44 of the PFP FSAR (WHC-SD-CP-SAR-021), for material containing < 10% Pu-240

based on 31 Kg of total Pu

Table D-2. Summary of Predicted Hydrogen Concentrations

Case Description	Predicted Equilibrium H ₂ Volume Percent
Best Estimate Diffusional Admittance for Ceiling and Walls	1.20
Ceiling Sealant Film with 0.1 of Best Estimate Admittance	1.36
Ceiling Sealant Film with Zero Diffusional Admittance	1.52
Ceiling and Walls with Zero Diffusional Admittance	5.44

Note: If a tank Pu inventory of 75 kg is assumed instead of the "best estimate" value of 31 kg, the H₂ equilibrium values would be predicted to be a factor of 2.4 times higher than in the above table.

APPENDIX: E

**CALCULATION OF POTENTIAL FLAMMABLE GAS FLOW RATE FROM
THE RISER THROUGH 1/16" CIRCULAR GAP, CONDUITS, NEEDLES,
OR ORIFICES**

E.1.0 BACKGROUND

Tank 241-Z-361 may be significantly pressurized due to sealing the tank in the mid 1980's and the subsequent production of H₂ and O₂ in the tank from radiolysis. The 3 in. diameter riser on the tank will be opened in a filtered glovebag to prevent spread of radioactive contamination to the environment. The riser must be opened in a manner that controls the gas flow rate into the glovebag to prevent the glovebag or its HEPA filter from being ruptured due to over-pressure or tearing the glovebag from an excessively high flow rate. The flow rate can be controlled by limiting the gap that can occur between the riser and flange. To further control the rate of pressure relief from the tank, small conduits or needles can be inserted through the gasket (See Figure E-1), or a band could be applied around the riser/flange joint with a properly sized orifice.

E.2.0 PURPOSE

The purpose of this calculation is to determine the potential blow down rate from the tank assuming a 1/16" gap is opened on the 3" diameter raised face flange on the tank; and to determine the size of the HEPA filter needed on the glovebag to accommodate such blow down flow from the riser.

High flow rates that might potentially be achieved if such a gap were opened are believed to necessitate the construction of specialized enclosures owing to the significant hydrodynamic forces such flow will create. This Appendix therefore also provides calculation of the potential flow rates through small conduits (needles) inserted through the flange gasket into the tank air space and the flow rates through an orifice in a band around the riser/flange joint. Additional calculations are provided to address the cases where an orifice in a circumferential band is used to control the flammable gas release rate. Flow rates were limited to 6 scfm because this is believed to be acceptable for typical glovebag construction. Confirmatory testing will be conducted to ensure these values of flow do not create unforeseen performance issues.

The potential pressure and the H₂ concentration in the tank is calculated first to provide a bases for estimating the blow down rate. To examine the sensitivity of the blow down and HEPA filter sizing calculations to assumed flange gap size, an 1/8" controlled gap is evaluated in addition to the 1/16" base case (see Section E.6).

E.3.0 INPUT DATA AND ASSUMPTIONS

1. All gases are assumed to be ideal at 298 °K (60°F)
2. Initial tank atmosphere is assumed to be air at a pressure of 14.7 psi when the tank was sealed up in 1985.

3. The 3" diameter riser is assumed to be schedule 40. The riser flanges are assumed to be raised face, class 150 RF weld neck. (Diagram of riser is provided in Figure E-1.)
4. The flow through the flange is assumed to occur through a 1/16" gap, controlled by turning nuts on riser bolts in \leq half turn increments.
5. The H₂ generation rate in the tank due to radiolysis is 6.21E-6 moles/s, the oxygen generation rate is 3.1E-6 moles/s (see Appendix D, pg. D-6). The gas generation rate is assumed to be constant.
6. The tank is assumed to have remained perfectly sealed and airtight for 14 years (since the tank was sealed in 1985).
7. The vapor space volume of the tank is 92.5 m³ (Appendix D, pg. D-6).
8. The pressure outside the tank at the time the riser is opened is assumed to be 14.7 psi. Due to atmospheric pressure fluctuations, actual ambient pressure might be slightly higher or lower than this value, but assuming 14.7 psi introduces little error.
9. The differential pressure across the glovebag HEPA filter(s) is not to exceed 10 in. w.g.
10. The glovebag is assumed to handle pressure at least as well as the HEPA filter (e.g., the glovebag is assumed to not rupture until glovebag pressure exceeds 10 in. w.g.).

E.4.0 SUMMARY OF KEY FINDINGS

- The potential current H₂ concentration in the tank was calculated to be 34 vol%.
- The potential current tank pressure was calculated to be 15.5 psig.
- The maximum instantaneous flow rate if the tank is vented with a 1/16 in. gap between the two flanges on a 3 in. diameter riser was calculated to be 385 scfm.
- For the controlled 1/16 in. vent path, the following nuclear separator-type HEPA filters were found to be adequate to accommodate maximum vent flow while maintaining a pressure drop across the glovebag HEPAs less than 10 in. w.g.
 - one 12" x 12" x 11 1/2" HEPA filter
 - two 12" x 12" x 5 7/8" HEPA filter

- Preliminary testing indicated the glovebag may not be able to accommodate as much pressure drop as a separator type HEPA filters, and flow rates through the glovebag may have to be kept below 6 scfm to ensure satisfactory glovebag performance. If the flow rate is to be limited to 6 scfm, then a single orifice with a cross-sectional area equivalent to an 1/8-inch diameter circular opening can be made in a band around the riser/flange joint. Alternatively, a single, rectangular conduit with a cross-sectional area equivalent to a 1/8-inch inner diameter circular conduit can be inserted through the gasket, or up to 6 "hypodermic" needles with an outside diameter of 1/16" may be inserted to relieve the tank pressure.

E.5.0 CALCULATIONS

E.5.1 MOLES OF GAS INITIALLY IN TANK

The number of moles of air in the tank at the time of closure in 1985 can be calculated from the ideal gas law.

$$n_{air} = \frac{PV}{RT}$$

where,

n_{air} = moles of air initially in tank

P = initial pressure in tank, 14.7 psi (E.3, item 2)

V = volume of vapor space in tank, 92.5 m³ (E.3, item 7)

R = ideal gas constant, 0.08205 $\frac{\text{atm} \cdot \text{L}}{\text{mol} \cdot \text{K}}$

T = tank temperature, 289°K (E.3, item 1)

$$n_{air} = \frac{(1 \text{ atm})(92.5 \text{ m}^3)\left(\frac{1000 \text{ L}}{\text{m}^3}\right)}{\left(0.082 \frac{\text{atm} \cdot \text{L}}{\text{mol} \cdot \text{K}}\right)(289 \text{ }^\circ\text{K})} = 3.90\text{E}3 \text{ moles}$$

E.5.2 POTENTIAL HYDROGEN CONCENTRATION IN THE TANK

The estimated H₂ gas production in the tank due to radiolysis is 6.2E-6 moles/s; the estimated production rate of oxygen due to radiolysis is half this value, or 3.1E-6 moles/s (E.3, item 5).

Assuming the tank has been sealed for 14 years, the number of moles of each gas generated due to radiolysis in the tank is:

$$\begin{aligned} n_{hydrogen} &= (6.2E-6 \text{ moles/s}) \left(\frac{3600s}{h} \right) \left(\frac{24h}{day} \right) \left(\frac{365day}{yr} \right) (14yr) \\ &= 2.74E3 \text{ moles} \end{aligned}$$

$$\begin{aligned} n_{oxygen} &= (3.1E-6)(3600)(24)(365)(14) \\ &= 1.37E3 \text{ moles} \end{aligned}$$

The volume percent hydrogen in the tank atmosphere is given by:

$$C_{hydrogen} = \frac{n_{hydrogen}}{n_{air} + n_{hydrogen} + n_{oxygen}}$$

From the previous section, $n_{air} = 3.90E3$ moles. Therefore,

$$C_{hydrogen} = \frac{2.74E3}{3.90E3 + 2.74E3 + 1.37E3} = 0.34 \text{ mol fraction} \\ \text{(or vol fraction)}$$

E.5.3 POTENTIAL PRESSURE IN THE TANK

The potential pressure in the tank can be estimated using the ideal gas law:

$$\frac{P_1 V_1}{P_2 V_2} = \frac{n_1 R T_1}{n_2 R T_2}$$

where,

P = pressure
 V = volume
 n = number of moles of gas in the tank, total
 R = ideal gas constant
 T = tank air temperature
 1 = initial condition
 2 = final condition

Since the tank vapor space volume and temperature are constant,

$$P_2 = P_1(n_2/n_1)$$

$$\begin{aligned} n_2 &= n_{air} + n_{hydrogen} + n_{oxygen} \\ &= 3.90E3 + 2.74E3 + 1.37E3 = 8.01E3 \end{aligned}$$

$$n_1 = n_{air} = 3.90E3 \text{ moles}$$

Therefore,

$$P_2 = (14.7 \text{ psi})(8.01E3/3.90E3) = 30.2 \text{ psia (15.5 psig)}$$

The above calculation assumes all of the oxygen generated due to radiolysis is evolved into the tank vapor space. Oxygen is quite soluble in water, compared to hydrogen, and would also tend to be scrubbed by nitrate waste in the tank, so it is conservative to assume all the oxygen contributes to tank pressurization.

E.5.4 MAXIMUM INSTANTANEOUS FLOW RATE UPON VENTING

The maximum instantaneous flow rate upon opening of the riser can be calculated from Eq'n 3-20

from the Crane Handbook (Ref. 1).

$$q_m = 412Yd^2/S_g \sqrt{\frac{\Delta P \rho_1}{K}} \quad (\text{Eqn.1})$$

where,

q'_m = flow rate, in scfm (@14.7 psia and 60°F)

ΔP = differential pressure, in psi

K = sum of resistance coefficient or velocity head losses through the flow path

d = diameter of equivalent circular cross-sectional area to flow path, in inches

S_g = specific gravity of gas relative to air, unitless

ρ_1 = density of gas, in lb/ft³

Y = net expansion factor for compressive flow

E.5.4.1 Determination of K Value

A diagram of the raised-face flange joint is provided in Figure E-1. For this analysis, the riser flange and blind flange are assumed to be separated to a controlled gap of 1/16 in.

The following frictional losses occur as the gas flows through the gap between the two flanges into the glovebag.

1. Contraction losses as the gas in the vapor space enters the riser
2. Frictional losses due to flow through the riser, which is approximately 5 ft long
3. Contraction losses as the gases passes into the 1/16 in. slot between the riser flanges
4. Frictional losses as the gas passes through the 1/16 in. slot between the riser flanges
5. Expansion losses as the gas expands into the wider slot associated with the bolted portion of the flanges
6. Frictional losses as the gas flows through the slot associated with the bolted portion of the flanges
7. Expansion loss as the gas escapes from the flanges into the glovebag.

All losses will be calculated relative to the first 1/16 in gap, using the following eq'n (Crane, pg. 3-5):

$$\left(\frac{L}{D}\right)_a = \left(\frac{L}{D}\right)_b (d_a/d_b)^4 \quad (\text{Eqn.2})$$

Where 'a' is the reference, and 'b' is the known value.

Frictional Losses 1 and 2

Frictional losses associated with flow through the riser will be negligible compared to the frictional losses associated with flow through the gap between the riser flanges. Frictional losses 1 and 2 are thus ignored.

Frictional Loss 3

For sudden contraction into a sharp edged entrance, $K = 0.50$ (Crane, pg. A-26).

$$K_3 = 0.50$$

Frictional Loss 4

In order to calculate the loss due to sudden contraction, the equivalent slot diameter must be known. The equivalent slot diameter is the diameter of a circular shaped conduit giving the same frictional loss per unit length as the non-circular conduit.

$$D_{\text{equiv}} = 4R_H \quad (\text{Crane, Eqn. 3-35})$$

where,

R_H = hydraulic radius

The hydraulic radius is given by the cross-sectional area divided by the wetted perimeter of the conduit. For the slot between the flanges, this gives

where,

$$R_H = \frac{2\pi r w}{4\pi r + 2w}$$

r = radius of riser, inches

w = width of gap, inches

For a slot with a very small width to length ratio $R_H \approx w/2$ and hence

$$d_{\text{equiv}} = 2w$$

For the 1/16 in. slot, d_{equiv} therefore = 1/8 in.

The frictional loss coefficient, K for the slot is given by:

$$K_4 = fL/d_{\text{equiv}}$$

where,

L = length of slot associated with raised-face portion of the flange, in inches

f = friction coefficient for flow through pipe

It is assumed the surfaces of each flange have a roughness equivalent to that of wrought iron pipe. This is conservative as the surface roughness of the gasket would be expected to be rougher than iron. Assuming fully turbulent flow through the slot, the friction factor, f , can be estimated from a Moody Diagram. Extrapolating from the figure on Pg A-25 of Crane's Handbook, for $D = 0.125$ in., $f \approx 0.05$.

Therefore,

$$K_4 = \frac{0.05(1 \text{ in.})}{(1/8 \text{ in.})} = 0.4$$

The assumption of full turbulence will be verified later.

Frictional Loss 5

For expansion from sharp-edged exit K is given by (Crane, Pg. A-26) to be:

$$K_5 = \left[1 - \frac{d_1^2}{d_2^2}\right]^2 \quad (\text{Eqn. 3})$$

where,

d_1 = characteristic diameter of slot between the two raised-faces of the flanges

d_2 = characteristic diameter of slot between the bolted portions of the flanges

$d_1 = 1/8$ in (derived for Frictional Loss 4).

$d_2 = 2$ in. (see calculations for Frictional Loss 6)

Hence,

$$K_5 = \left[1 - \frac{(1/8)^2}{(2)^2} \right]^2 = 0.992$$

Frictional Loss 6

This is similar to frictional loss 4. The width of the slot in this region is 4/16 in., accounting for the two raised faces, the 1/16 in. gasket, and a 1/16 in. gap.

$$R_H = 2w = 1/2 \text{ in.}$$

and

$$d_{equiv} = 4R_H = 2 \text{ in.}$$

Assuming turbulent flow, f for a 2 in. wrought iron pipe is about 0.019 from pg. A-25 of Crane's. L for this portion of the flange is about 1.25 in. based on Figure E-1.

Therefore,

$$K_6 = \frac{0.019(1.25 \text{ in.})}{(2 \text{ in.})} = 1.19E-2$$

This frictional loss is small compared to K_3 , K_4 , and K_5 and hence is considered no further. The number becomes even smaller when corrected back to the 1/16 slot basis.

Frictional Loss 7

The K of expansion on the gas leaving the riser is 1 (see Crane, pg. A-26). This K must be corrected back to the 1/16 in slot basis.

This is done by first converting K to equivalent pipe diameters.

$$\text{pipe diameters} = \frac{L}{D} = \frac{K_7}{f}$$

The f for the 2 in. equivalent pipe representing the gap between the bolted portions of the flange was estimated before to be about 0.019. Hence,

$$\frac{L}{D} = \frac{1}{0.019} = 52.6$$

This L/D is now converted to a L/D for the equivalent pipe representing the gap between the raised-face portions of the two flanges, using Eqn. 2.

$$\left(\frac{L}{D}\right)_a = \left(\frac{L}{D}\right)_b \left(\frac{d_a}{d_b}\right)^4$$

$$\left(\frac{L}{D}\right)_a = (52.6) \left(\frac{1/8 \text{ in.}}{2 \text{ in.}}\right)^4 = 8.0E-4$$

Now K_7 can be converted to the proper basis, using the friction factor for the raised face portion of the flange.

$$K_7 = f \left(\frac{L}{D}\right)_a$$

$$K_7 = (0.05)(8.0E-4) = 4.0E-5$$

This frictional loss is negligible and is ignored in subsequent calculations.

Total K

$$\begin{aligned} K_{\text{tot}} &= K_3 + K_4 + K_5 \\ &= 0.5 + 0.4 + 0.99 \\ &= 1.9 \end{aligned}$$

E.5.4.2 Calculation of Flow rate

Flow through the flanges is calculated from Eqn. 1:

$$q'_m = 412Yd^2/S_g \sqrt{\frac{\Delta P \rho_1}{K}}$$

Y can be determined from the graph on pg. A-22 of Crane's. Y is a function of $\Delta P/P_1$; the specific heat ratio for the gases of concern, k; and K. ΔP was calculated previously to be 15.5 psig.

$$\frac{\Delta P}{P_1} = \frac{15.5 \text{ psi}}{14.7 + 15.5 \text{ psi}} = 0.51$$

For the gases of concern in this analysis $k = 1.4$. K from the previous section is 1.9. From the graph on pg. A-22 of Crane's:

$$Y \approx 0.69$$

The specific gravity of the gas in the tank is estimated based on the molecular weight of the gas compared to air. From Section E.5.2, the number of moles of air, H_2 and O_2 in the pressurized tank are $3.90E3$, $2.74E3$, and $1.37E3$, respectively. The molecular weight (MW) of air is 29, the MW of H_2 is 2, and the MW of $O_2 = 32$. The specific gravity of the gas in the tank is thus:

$$\begin{aligned} S_g &= \frac{(3.9E3)(29) + (2.74E3)(2) + (1.37E3)(32)}{(3.9E3 + 2.74E3 + 1.37E3)(29)} \\ &= 0.70 \end{aligned}$$

The density of the pressurized gas in the tank is calculated from the mass of each gas in the tank and the vapor space volume of the tank.

$$\rho_1 = \frac{(3.9E3 \text{ mol})(\frac{29g}{\text{mol}}) + (2.74E3 \text{ mol})(\frac{2g}{\text{mol}}) + (1.37E3 \text{ mol})(\frac{32g}{\text{mol}})}{(92.5 \text{ m}^3)}$$

$$= \frac{1.76E3 \text{ g}}{\text{m}^3}$$

The units for this parameter have to be converted to lb/ft₃ to be used in the flow rate equation.

$$\rho_1 = (\frac{1.76E3g}{\text{m}^3})(\frac{\text{lb}}{454g})(\frac{\text{m}}{3.28\text{ft}})^3 = 0.11 \text{ lb/ft}^3$$

The diameter, *d*, used in the flow rate equation is the diameter of a circular shaped conduit having the same cross-sectional area as the flow path through the gap between the raised-faces of the flanges. The cross-sectional area of the flow path is

$$A_{fp} = 2\pi r_f w$$

where,

r_f = radius of flange, middle of raised face ≈ 2 in.

w = width of gap between two raised faces of flanges, 1/16 in.

Therefore,

$$A_{fp} = 2\pi(2)(1/16) = 0.785 \text{ in}^2$$

The diameter of an equivalent circle with the same area is given by

$$d = \sqrt{\frac{4A_{fp}}{\pi}} = \sqrt{\frac{(4)(0.785)}{\pi}} = 1.0 \text{ in.}$$

Solving Eqn. 1 for maximum flow rate through the riser gives

$$q'm = \frac{(412)(0.69)(1.0)^2}{(0.70)} \sqrt{\frac{(15.5)(0.11)}{1.9}}$$

$$= 385 \text{ ft}^3/\text{min}$$

Verify that flow through gap in riser is turbulent.

$$Re = 123.9 d_{\text{equiv}} v \rho / \mu \quad (\text{Crane, pg. 3-2})$$

where,

$$d_{\text{equiv}} = \text{characteristic diameter of flow path, } 1/8 \text{ in. (calculated previously)}$$

$$v = \text{velocity, ft/s}$$

$$\rho = \text{density of gas, } 0.11 \text{ lb/ft}^3$$

$$\mu = \text{dynamic viscosity, in Cp.}$$

μ for the gas mixture can be estimated from the table on pg. A-5 of Crane's. At 60°F, the approximate viscosities of the three gases in the tank are 0.017 Cp for air, 0.0085 for H₂, and 0.02 Cp for O₂. Calculating the mole-weighted viscosity for the mixture gives:

$$\mu_{\text{mix}} = \frac{(3.9E3)(0.017) + (2.74E3)(0.0085) + (1.37E3)(0.020)}{3.9E3 + 2.74E3 + 1.37E3}$$

$$= 0.0146 \text{ Cp}$$

Flow velocity through the gap in the flanges is given by:

$$v = \frac{q'_m}{A_{fp}} = \frac{(385 \text{ ft}^3/\text{min})\left(\frac{\text{min}}{60\text{s}}\right)}{(0.785 \text{ in}^2)\left(\frac{\text{ft}}{12\text{in.}}\right)^2} = \frac{1,180 \text{ ft}}{\text{s}}$$

$$Re = \frac{123.9(1/8)(1180)(0.11)}{0.0146} = 1.38E5$$

The high Reynolds Number is well into the flat portion of the curve on pg. A-25 of Crane's. Further iteration of the flow calculations therefore is not necessary.

Verify flow is not sonic.

From Crane, Eqn. 1-10, sonic velocity is given by:

$$v = \sqrt{kg \ 144P' \ V_s}$$

where,

v = mean velocity of flow, ft/s

k = ratio of specific heat at constant pressure to specific heat at constant volume = 1.4

P' = pressure at the point of interest = 14.7 psia

V_s = specific volume of fluid, ft³/lb, at the point of interest

= $1/\rho_{\text{outlet}}$ = 18.9 ft³/lb where

$\rho_{\text{outlet}} = \rho_l (14.7/30.2) = 0.11 (14.7/30.2) = 0.053$

g = acceleration of gravity, 32.2 ft/s²

Solving gives:

$$v = \sqrt{(1.4) \left(\frac{32.2 \text{ ft}}{s^2} \right) \left(\frac{144 \text{ in.}^2}{\text{ft}^2} \right) \left(\frac{14.7 \text{ lb}}{\text{in.}^2} \right) \left(\frac{18.9 \text{ ft}^3}{\text{lb}} \right)}$$

$$v = 1,343 \text{ ft/s}$$

Since the predicted velocity is below the sonic velocity, gas flow is subsonic.

E.5.5 SIZE OF FILTERS REQUIRED FOR GLOVEBAG

For comparison purposes, nuclear grade separator-type HEPA filters will be used as the basis to determine the sizes of the filters required for the glovebag. 11-1/2" deep filters are typically used where there is a need for a minimum amount of space relative to a maximum amount of flow.

Some of the 5-7/8" deep filters will be assessed due to potential size limitations in the glovebag. Flow capacity for the various filter sizes are shown in Table E-1. Generally, rated flow corresponds to approximately 1 in. w.g. pressure drop. Typically, 10 in. w.g. is the maximum ΔP a filter can maintain. Pressure drop across a filter is proportional to the square of flow velocity and the square of flow rate.

$$\Delta P \propto \text{velocity}^2 \propto \text{flowrate}^2$$

The assessment of various filter sizes follows:

12" x 12" x 11 1/2": $\Delta P = 1$ in. w.g. for 200 cfm

Pressure drop at the estimated maximum flow through the riser flanges of 385 cfm.

$$\Delta P = \frac{1 \text{ in.} (385 \text{ cfm})^2}{(200 \text{ cfm})^2} = 3.71 \text{ in. w.g.}$$

One 12" x 12" x 11 1/2" HEPA filter is adequate for use.

8" x 8" x 5 7/8": $\Delta P = 1.3$ in. w.g. for 50 cfm

$$\Delta P = \frac{(1.3 \text{ in.}) (385 \text{ cfm})^2}{(50 \text{ cfm})^2} = 77.0 \text{ in. w.g.}$$

One 8" x 8" x 5 7/8" filter is unacceptable as ΔP is well above 10 in. w.g.

12" x 12" x 5 7/8": $\Delta P = 1.3$ in. w.g. for 125 cfm

$$\Delta P = \frac{(1.3 \text{ in.}) (385 \text{ cfm})^2}{(125 \text{ cfm})^2} = 12.3 \text{ in. w.g.}$$

One 12" x 12" x 5 7/8" filter would be inadequate as the ΔP is above 10 in. w.g. However, two of these filters would be adequate with each handling half the flow at a ΔP of 3.1 in. w.g.

E.6 CALCULATION OF MAXIMUM FLOW AND GLOVEBAG

HEPA FILTER SIZE FOR CONTROLLED 1/8 IN GAP

This section is provided to provide a basis to evaluate the sensitivity of calculations performed for the 1/16-inch circular gap calculated in the previous section.

E.6.1 DETERMINATION OF K VALUE

Frictional Loss 3

Frictional loss 3 is the same as in the base case.

$$K_3 = 0.5$$

Frictional Loss 4

$$d_{\text{equiv}} = 2w = 2(1/8 \text{ in.}) = 1/4 \text{ in.}$$

From graph on pg. A-25 of Crane's, $f = 0.034$

$$K_4 = \frac{(0.034)(1 \text{ in.})}{\left(\frac{1}{4} \text{ in.}\right)} = 0.136$$

Frictional Loss 5

$$K_5 = \left[1 - \frac{\left(\frac{1}{4}\right)^2}{(2)^2}\right]^2 = 0.97$$

Total K

$$\begin{aligned} K_{\text{tot}} &= K_3 + K_4 + K_5 \\ &= 0.5 + 0.14 + 0.97 \end{aligned}$$

$$K_{\text{tot}} = 1.61$$

E.6.2 CALCULATION OF FLOW RATE

$$q'_m = \frac{412Yd^2}{S_g} \sqrt{\frac{\Delta P \rho_1}{K_{tot}}}$$

From the graph on Pg. A-22 of Crane's, for $\Delta P/P_1 = 0.51$, $k = 1.4$, and $K_{tot} = 1.61$:

$$Y = 0.675$$

d is calculated as in the base case:

$$A_{fp} = (2)(\pi)(2)(1/8) = 1.57 \text{ in.}^2$$

$$d = \sqrt{\frac{4(1.57)}{\pi}} = 1.41 \text{ in.}$$

From the base case $S_g = 0.70$, $\Delta P = 15.5$ psi, and $P_1 = 0.11$.

Therefore:

$$\begin{aligned} q'_m &= \frac{(412)(0.675)(1.41)^2}{(0.70)} \sqrt{\frac{(15.5)(0.11)}{1.61}} \\ &= 813 \text{ scfm} \end{aligned}$$

Flow was confirmed to be subsonic and turbulent for this case.

E.6.3 SIZE OF FILTERS REQUIRED FOR GLOVEBAG

12" x 12" x 11 1/2": $\Delta P = 1$ in. w.g. for 200 cfm

$$\Delta P = \frac{1 \text{ in.}(813 \text{ cfm})^2}{(200 \text{ cfm})^2} = 16.5 \text{ in. w.g.}$$

One 12" x 12" x 11 1/2" HEPA would be inadequate. Two 12" x 12" x 11 1/2" HEPA filters would be acceptable.

12" x 12" x 5 7/8": $\Delta P = 1.3 \text{ in. w.g.}$ for 125 cfm

$$\Delta P = \frac{(1.3 \text{ in.})(813 \text{ cfm})^2}{(125 \text{ cfm})^2} = 55.0 \text{ in. w.g.}$$

The ΔP is well above 10 in. w.g., and even two filters would not be acceptable.

E.7.0 FLOW THROUGH SMALL CONDUITS AND NEEDLES

High flow rates described in the previous section are believed to necessitate the construction of specialized enclosures owing to the significant hydrodynamic forces such flow will create. This section provides calculation of the flow rates through small conduits (needles) that are inserted through the gasket into the tank air space. Flow rates were limited to 6 scfm because this is believed to be acceptable for typical glovebag construction. Confirmatory testing will be conducted to ensure these values of flow do not create unforeseen performance issues.

E.7.1 CALCULATION OF FLOW RATE

Flow through the flanges is calculated from Eqn. 1:

$$q'_m = \frac{412 Y d^2}{S_g} \sqrt{\frac{\Delta P \rho_1}{K_{tot}}}$$

E.7.1.1 Determination Of K_{tot}

The following frictional losses occur as the gas flows out of the riser into the glovebag:

1. Contraction losses as the gas enters the conduit.

2. Frictional losses as the gas flows through the conduit.
3. Expansion losses as the gas flows out of the conduit and expands into the glovebag.

Frictional Loss 1

For sudden contraction into an inward projecting pipe entrance, $K=0.78$ (Crane, pg. A-26)

$$K_1 = 0.78$$

Frictional Loss 2

The frictional loss flow through the conduit is given by:

$$K_2 = \frac{fL}{d}$$

where,

f = friction coefficient for flow through conduit

L = length of the conduit, in inches

d = diameter of circular conduit, in inches.

It is assumed the conduit is made of smooth metal, such as drawn tubing. This provides the lowest value for f , which in turn provides a conservative (high) estimate of flow rate. The value of f is determined from a Moody diagram. [See fluid dynamics textbooks such as Bober and Kenyon (1980).] The value of f is a function of the relative roughness of the conduit, e/d , and the Reynolds Number, where e is the surface roughness of the conduit in inches. The Reynold's Number is given by (Crane, pg 3-2):

$$Re = 123.9dv \frac{\rho_1}{\mu}$$

where,

d = the diameter of the conduit

v = the velocity of the gas through the conduit, in ft/s

μ = the viscosity of the gas, in Cp (Section E.5.4.2)

ρ_1 = density of the gas, in lb/ft³ (Section E.5.4.2).

To accurately determine the flow rate, an iterative solution is required. First, a diameter for the circular conduit is assumed. Using this, and assuming turbulent flow, determine an f value from a Moody diagram. After calculating the flow rate using Eqn. 1, verify on the Moody Diagram that the Reynold's Number and the e/d value correspond to the assumed value for f . This process is iterated until convergence is obtained.

Frictional Loss 3

For expansion from sharp-edged exit, K is given by (Crane, Pg. A-26):

$$K_3 = \left[1 - \frac{d_1^2}{d_2^2}\right]^2$$

where,

d_1 = diameter of the conduit

d_2 = diameter of the conduit the gas expands into

For this analysis, it is assumed the gas expands directly from the conduit into the glovebag. Therefore, $d_2 \gg d_1$ and thus:

$$K_3 = 1$$

E.7.1.2 Flow Rate Calculation For A 1/16-Inch Circular Conduit

For drawn tubing, $e = 6 \times 10^{-5}$ inches (Bober and Kenyon, Figure 6-4). With $d = 1/16$ inch,

$$\frac{e}{d} = 9.6 \times 10^{-4}$$

Assuming turbulent flow, from the Moody diagram (Bober and Kenyon, Figure 6-4), f is about 0.02. Assume a conduit length of 2.2 inches. This is the minimum distance from the outside the flange to the air space inside the riser (See Figure E-1).

$$K_2 = 0.02 \left[\frac{2.2 \text{ inches}}{1/16 \text{ inches}} \right] = 0.7$$

Hence,

$$K_{tot} = K_1 + K_2 + K_3 = 0.78 + 0.7 + 1 = 2.48.$$

The value of Y is a function of K_{tot} , $\Delta P/P$, and the specific heat ratio for gases of concern, k . The differential pressure (ΔP) was determined to be 15.5 psig in Section E.5.3. The absolute pressure in the tank (P) is therefore 30.2 psia. Therefore,

$$\frac{\Delta P}{P} = 0.51$$

For the gases of concern in this analysis, $k=1.4$. From the graph on pg. A-22 of Cranes:

$$Y=0.71$$

From Section E.5.4.2, $S_g = 0.70$ and $\rho_l = 0.11 \text{ lb/ft}^3$. Accordingly, the estimated flow rate through the conduit is:

$$q'_m = \frac{(412)(0.71)(1/16)^2}{0.70} \sqrt{\frac{(15.5)(0.11)}{2.48}} = 1.35 \text{ scfm}$$

The value for f is then checked.

The Reynolds Number is given by:

$$Re = 123.9dv \frac{\rho_l}{\mu}$$

where,

d = the diameter of the conduit

v = the velocity of the gas through the conduit, in ft/s

μ = the viscosity of the gas, in Cp (Section E.5.4.2)

ρ_l = density of the gas, in lb/ft³ (Section E.5.4.2).

The flow velocity (v) is calculated by dividing the volumetric flow rate by the cross-sectional area of the conduit (given by $\pi d^2/4$). Accordingly, the flow velocity is:

$$v = \frac{(1.35 \text{ ft}^3/\text{min})(1 \text{ min}/60 \text{ secs})}{\frac{[(3.14)(1/16 \text{ inches})^2 (\text{ft}^2/144 \text{ inches}^2)]}{4}} = 1060 \text{ ft/s}$$

Verify the predicted flow is subsonic as in Section E.5.4.2.

From Crane, Eqn 1-10, sonic velocity is given by:

$$v = \sqrt{kg \ 144 P^* V_s}$$

where,

v = mean velocity of flow, ft/s

k = ratio of specific heat at constant pressure to specific heat at constant volume = 1.4

g = acceleration of gravity, 32.2 ft/s²

P^* = maximum tank pressure at the point of interest = 14.7 psia

V_s = specific volume of fluid, ft³/lb, at the point of interest

= 18.9 ft³/lb

Solving gives:

$$v = \sqrt{(1.4) \left(\frac{32.2 \text{ ft}}{\text{s}^2} \right) \left(\frac{144 \text{ in.}^2}{\text{ft}^2} \right) \left(\frac{14.7 \text{ lb}}{\text{in.}^2} \right) \left(\frac{18.9 \text{ ft}^3}{\text{lb}} \right)}$$

$$v = 1,343 \text{ ft/s}$$

Since the predicted velocity of 1060 ft/s is below the sonic velocity of 1,343 ft/s, gas flow is subsonic.

The Reynolds Number is thus:

$$Re = \frac{(123.9)(1/16 \text{ inches})(1060 \text{ ft/sec})(0.11 \text{ lb/ft}^3)}{(0.0146 \text{ Cp})} = 6.2 \times 10^4$$

From the Moody diagram (Bober and Kenyon, Figure 6-4), flow is in the transition zone between turbulent and laminar. The value for f at this Reynolds Number and an e/d of 9.6×10^{-4} is 0.023 versus the assumed turbulent f value of 0.020. Accordingly, an iteration will be performed.

Iteration 2

Assume $f = 0.023$,

$$K_2 = \frac{(0.023)(2.2)}{1/16} = 0.81 \Rightarrow K_{tot} = 2.59$$

From the graph on pg. A-22 of Cranes:

$$Y = 0.72$$

The flow rate for this new assumed f value can then be determined:

$$q'm = \frac{(412)(0.72)(1/16)^2}{0.70} \sqrt{\frac{(15.5)(0.11)}{2.59}} = 1.34 \text{ scfm}$$

This is essentially the same flow rate as estimated before and will therefore give the same Reynolds Number and value of f . Convergence has occurred and no further iterations are required. This 1.34 scfm flow rate is well below the maximum desired 6 scfm, and would therefore be acceptable.

E.7.1.3 Flow Rate Calculation For A 1/8-inch Circular Conduit

With $d = 1/8$ inch,

$$\frac{e}{d} = \frac{6 \times 10^{-5}}{1/8} = 4.8 \times 10^{-4}$$

Assuming turbulent flow, from the Moody diagram, f is about 0.018 (Bober and Kenyon, Figure

6-4). Assume a conduit length of 2.2 inches. This is the minimum distance from the outside the flange to the air space inside the riser (See Figure E-1).

$$K_2 = 0.018 \left[\frac{2.2 \text{ inches}}{1/8 \text{ inches}} \right] = 0.32$$

Hence,

$$K_{tot} = K_1 + K_2 + K_3 = 0.78 + 0.32 + 1 = 2.10.$$

The value of Y is a function of K_{tot} , $\Delta P/P$, and the specific heat ratio for gases of concern, k . The differential pressure (ΔP) was determined to be 15.5 psig in Section E.5.3. The absolute pressure in the tank (P) is therefore 30.2 psia. Therefore,

$$\frac{\Delta P}{P} = 0.51$$

For the gases of concern in this analysis, $k=1.4$. From the graph on pg. A-22 of Cranes:

$$Y=0.68$$

From Section E.5.4.2, $S_g = 0.70$ and $\rho_l = 0.11 \text{ lb/ft}^3$. Accordingly, the estimated flow rate through the conduit is:

$$q'_m = \frac{(412)(0.68)(1/8)^2}{0.70} \sqrt{\frac{(15.5)(0.11)}{2.10}} = 5.6 \text{ scfm}$$

The value for f is then checked.

The flow velocity is:

$$v = \frac{(5.6 \text{ ft}^3/\text{min})(1 \text{ min}/60 \text{ secs})}{\frac{[(3.14)(1/8 \text{ inches})^2 (\text{ft}^2/144 \text{ inches}^2)]}{4}} = 1096 \text{ ft/s}$$

The predicted velocity is subsonic. (Section E.7.1.2)

The Reynolds Number can then be determined:

$$Re = \frac{(123.9)(1/8\text{inches})(1096\text{ft/sec})(0.11\text{lb/ft}^3)}{(0.0146Cp)} = 1.28 \times 10^5$$

From the Moody diagram (Bober and Kenyon, Figure 6-4), flow is in the transition zone between turbulent and laminar. The value for f at this Reynolds Number and an e/d of 4.8×10^{-4} is 0.019 versus the assumed turbulent f value of 0.018. Accordingly, an iteration will be performed.

Iteration 2

Assume $f = 0.019$,

$$K_2 = \frac{(0.019)(2.2)}{1/8} = 0.33 \Rightarrow K_{tot} = 2.11$$

From the graph on pg. A-22 of Cranes:

$$Y = 0.68$$

The flow rate for this new assumed f value can then be determined:

$$q'm = \frac{(412)(0.68)(1/8)^2}{0.70} \sqrt{\frac{(15.5)(0.11)}{2.11}} = 5.6 \text{ scfm}$$

This is the same flow rate as estimated before and will therefore give the same Reynolds Number and value of f . Convergence has occurred and no further iterations are required. The 1/8-inch diameter conduit gives an acceptable flow rate.

E.7.1.4 Flow Through A Hypodermic Needle

The gasket installed between the flange and riser was 1/16-inch thick before compression. It may only be possible to insert a "hypodermic" needle through the gasket between the flange and riser. The wall thickness of a typical hypodermic needle is about 0.14mm. Assuming a maximum needle outer diameter of 1/16-inch, the maximum inner diameter of a needle that can penetrate the gasket is:

$$(1/16\text{inch}) - [(2)(0.14\text{mm})(1\text{cm}/10\text{mm})(1\text{inch}/2.54\text{cm})] = 5.15 \times 10^{-02} \text{ inches}$$

With $d = 5.15 \times 10^{-02}$,

$$\frac{e}{d} = \frac{6 \times 10^{-5}}{5.15 \times 10^{-02}} = 1.17 \times 10^{-3}$$

Assuming turbulent flow, from the Moody diagram, f is about 0.020 (Bober and Kenyon, Figure 6-4). Assume a needle length of 2.2 inches. This is the minimum distance from the outside of the flange to the air space inside the riser (See Figure E-1).

$$K_2 = 0.020 \left[\frac{2.2 \text{ inches}}{5.15 \times 10^{-02} \text{ inches}} \right] = 0.85$$

Hence,

$$K_{tot} = K_1 + K_2 + K_3 = 0.78 + 0.85 + 1 = 2.63.$$

The value of Y is a function of K_{tot} , $\Delta P/P$, and the specific heat ratio for gases of concern, k . The differential pressure (ΔP) was determined to be 15.5 psig in Section E.5.3. The absolute pressure in the tank (P) is therefore 30.2 psia. Therefore,

$$\frac{\Delta P}{P} = 0.51$$

For the gases of concern in this analysis, $k=1.4$. From the graph on pg. A-22 of Cranes:

$$Y=0.72$$

From Section E.5.4.2, $S_g = 0.70$ and $\rho_1 = 0.11 \text{ lb/ft}^3$. Accordingly, the estimated flow rate through the conduit is:

$$q'_{m} = \frac{(412)(0.72)(5.15 \times 10^{-02})^2}{0.70} \sqrt{\frac{(15.5)(0.11)}{2.63}} = 0.90 \text{ scfm}$$

The value for f is then checked.

The flow velocity is:

$$v = \frac{(0.90 \text{ ft}^3/\text{min})(1 \text{ min}/60 \text{ secs})}{\frac{[(3.14)(5.15 \times 10^{-02} \text{ inches})^2 (\text{ft}^2/144 \text{ inches}^2)]}{4}} = 1038 \text{ ft/s}$$

The predicted velocity is subsonic. (Section E.7.1.2)

The Reynolds Number can then be determined:

$$Re = \frac{(123.9)(5.15 \times 10^{-02})(1038 \text{ ft/sec})(0.11 \text{ lb/ft}^3)}{(0.0146 \text{ Cp})} = 4.99 \times 10^4$$

From the Moody diagram (Bober and Kenyon, Figure 6-4), flow is in the transition zone between turbulent and laminar. The value for f at this Reynolds Number and an e/d of 1.17×10^{-3} is 0.025 versus the assumed turbulent f value of 0.020. Accordingly, an iteration will be performed.

Iteration 2

Assume $f = 0.025$,

$$K_2 = \frac{(0.025)(2.2)}{5.15 \times 10^{-02}} = 1.07 \Rightarrow K_{tot} = 2.85$$

From the graph on pg. A-22 of Cranes:

$$Y = 0.72$$

The flow rate for this new assumed f value can then be determined:

$$q'_{m} = \frac{(412)(0.72)(5.15 \times 10^{-02})^2}{0.70} \sqrt{\frac{(15.5)(0.11)}{2.85}} = 0.87 \text{ scfm}$$

The value for f is then checked.

The flow velocity is:

$$v = \frac{(0.87 \text{ ft}^3/\text{min})(1 \text{ min}/60 \text{ secs})}{\frac{[(3.14)(5.15 \times 10^{-02} \text{ inches})^2 (\text{ft}^2/144 \text{ inches}^2)]}{4}} = 1003 \text{ ft/s}$$

This predicted velocity is subsonic. (Section E.7.1.2)

The Reynolds Number can then be determined:

$$Re = \frac{(123.9)(5.15 \times 10^{-02})(1003 \text{ ft/sec})(0.11 \text{ lb/ft}^3)}{(0.0146 \text{ Cp})} = 4.8 \times 10^4$$

From the Moody diagram (Bober and Kenyon, Figure 6-4), flow is in the transition zone between turbulent and laminar. The value for f at this Reynolds Number and an e/d of 1.17×10^{-3} is 0.025, and convergence has occurred. The flow rate through the needle would be an estimated 0.87 scfm. Up to six needles could be inserted and the flow rate would be under 6 scfm.

E.7.1.5 Flow Through A Circular Orifice In A Band Around The Riser Flange

A band around the circumference of the riser and flange that overlaps both provides a seal as the flange bolts are loosened. A circular orifice in the band will allow a controlled flow release.

The maximum instantaneous flow rate upon opening of the riser and venting it through a circular orifice can be calculated from Eq'n 3-22 of Crane's, and is given by:

$$q'm = \frac{412 Y d_o^2 C}{S_g} \sqrt{\Delta P \rho_1}$$

where,

$q'm$ = flow rate, in scfm

Y = net expansion factor for compressible flow

d_o = diameter of orifice, in inches

C = flow coefficient for square edged orifice

S_g = specific gravity of gas relative to air, 0.7 in this case.

ΔP = differential pressure, in psi

ρ_1 = density of gas, in lbs/ft^3

The value of Y is a function of the orifice size d_0/d_1 (where d_0 = diameter of orifice and d_1 = diameter of pipe), $\Delta P/P$, and the specific heat ratio for the gases of concern, k . The differential pressure (ΔP) was determined to be 15.5 psig in Section E.5.3. The absolute pressure in the tank (P) is therefore 30.2 psia, and:

$$\Delta P/P = 0.51.$$

For the gases of concern in this analysis $k = 1.4$. For the orifice size in this analysis d_0/d_1 is very small and falls in the range of 0 to 0.2. From the graph on pg. A-20 of Crane's:

$$Y = 0.85$$

The value of C is a function of the square edge orifice size (d_0/d_1), and the Reynolds Number of the flow. For the orifice size of concern in this analysis d_0/d_1 is very small and falls in the range of 0 to 0.2. From Section E.7.1.2, $Re = 6.2 \times 10^4$ for the flow through a 1/16-inch conduit, and from Section E.7.1.3, $Re = 1.28 \times 10^5$ for the flow through a 1/8-inch conduit. In the graph for determination of C on pg. A-19 of Crane's, the value of C (when $d_0/d_1 = 0$ to 0.2) is a constant value for Re numbers in the range from 10^4 to 10^6 .

From the graph on pg. A-19 of Crane's then:

$$C = 0.595$$

From Section E.5.4.2, $S_g = 0.70$, $\rho_1 = 0.11 \text{ lb/ft}^3$. Accordingly, the estimated flow rate through the orifice with a 1/8-inch diameter is:

$$\begin{aligned} q'_{m} &= \frac{(412)(0.85)(1/8)^2(0.595)}{0.70} \sqrt{(15.5)(0.11)} \\ &= 6.07 \text{ scfm.} \end{aligned}$$

This is desired flow rate to insure that the glove bag does not incur damage.

As long as flow is turbulent, the total flow rate is proportional to the square of the diameter of the orifice. A 1/16 diameter orifice would have a flow rate of:

$$(6.07 \text{ scfm}) \frac{(1/16)^2}{(1/8)^2} = 1.51 \text{ scfm}$$

A 1/4-inch diameter orifice would have a flow rate of:

$$(6.07 \text{ scfm}) \frac{(1/4)^2}{(1/8)^2} = 24 \text{ scfm}$$

E.7.1.6 Summary Of Conduit, Needle And Orifice Flow Calculations

These calculations show that a 2.2-inch long tube with a 1/16-inch inner diameter would produce a flow rate into the glovebag of about 1.4 scfm. A tube with a 1/8-inch inner diameter would produce a flow rate of about 6 scfm. Because of the limited space available between the riser and flange, "hypodermic" needles may be the only objects that would fit. A hypodermic needle with an outer diameter of 1/16-inch would produce a flow rate of 0.87 scfm. Up to six needles can be used and maintain the maximum flow rate under 6 scfm. A 1/8-inch orifice in a band constricted around the riser/flange joint gives a maximum flow rate of 6 scfm.

E.8.0 REFERENCES

1. Carne Technical Paper 410, 1965, *Flow of Fluids Through Valves, Fittings, and Pipe*, Technical Paper No. 410, CRANE CO., Chicago, Illinois.
2. *Flanders Filtration Products*, Bulletin 936, Flanders Filters Inc.
3. *Tube-Turn Welding Fittings and Flanges*, Catalog 311, Tube Turns, Division of Chemetron Corporation, Louisville, Kentucky.
4. Bober, W. and R.A. Kenyon, 1980, *Fluid Mechanics*, John Wiley and Sons, Inc., New York, New York.

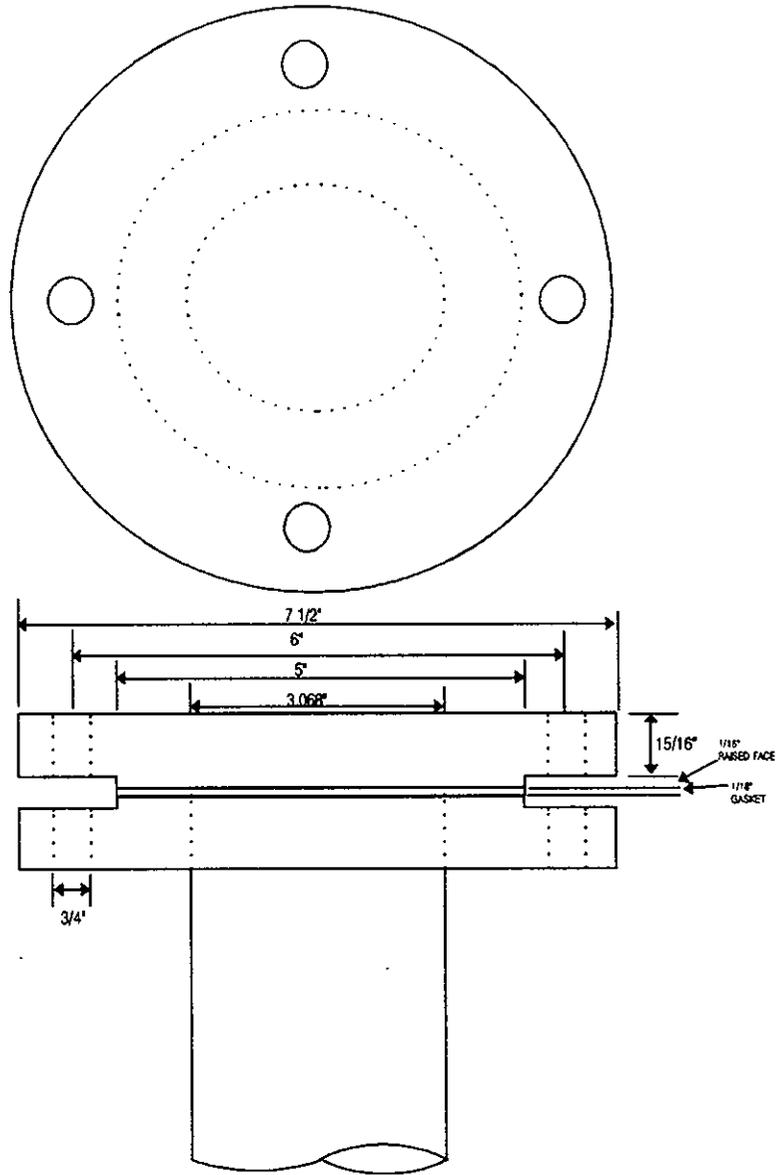
Table E-1. Filter Sizes and Capacities

Filter Size Designator	Dimensions			Capacity (cfm)
	H	W	D	
CC-F	12"	12"	11 ½"	200
GC-F	24"	12"	11 ½"	455
GE-F	24"	18"	11 ½"	725
GG-F	24"	24"	11 ½"	1000
BB-D*	8"	8"	5 7/8"	50
CC-D*	12"	12"	5 7/8"	125
GC-D	24"	12"	5 7/8"	250
GE-D	24"	18"	5 7/8"	375
GG-D	24"	24"	5 7/8"	500

* 1.3" w.g. maximum initial resistance. Otherwise 1.0" w.g.

Reference: Flanders Filters Inc., Bulletin 936

Figure E-1. 3" Riser Raised Flange
 (Dimensions per Tube-Turn Welding Fitting and Flanges, Catalog 311)



APPENDIX F

**EVALUATION OF 3-INCH AND 8-INCH RISERS FOR
BREATHING FILTER MOUNTING ON TANK**

F1.0 INTRODUCTION

This report provides the results of the structural analysis performed on the 3-inch (nozzle H) and 8-inch (nozzle A or B) pipe risers of Tank 241-Z-361 where breather filters will be installed (See Appendix A for sketches of the Tank). Tank 241-Z-361 has been out of service for several years and Babcock & Wilcox Hanford Company (BWHC) is in process of characterizing the waste left in the tank. Before the waste can be sampled breather filters must be mounted on the one or two of the pipe risers to mitigate the build up of dangerous gases in the tank. A sketch of the breather filter is included in Appendix F.A.

Tank 241-Z-361 is a rectangular underground tank built out of reinforced concrete with a carbon steel liner on the sides and bottom. The tank has eight carbon steel pipe risers ranging from 2-inch to 8-inch diameter on its top slab. Previously, Fluor Daniel Northwest, Inc. (FDNW), evaluated all of the pipe risers (Ref 1) to determine the riser capacity and validate the load limits of 100 lbs horizontal and vertical and a 50 ft-lb torque established in the "Draft Justification for Continuing Operation of Tank 241-Z-361".

This re-evaluation of 3-inch and 8-inch pipe risers for breather filter mounting was performed by FDNW at the request of BWHC by Task Order Release for Task Order No. PF820.

F2.0 SUMMARY AND CONCLUSION

The 3-inch (nozzle H) and 8-inch (nozzle A or B) pipe risers were analyzed to determine if they would support the installation of breather filters. The analysis assumes a 50% reduction in the wall thickness of the riser due to corrosion over the 50 years of service. Two load cases were evaluated; load case 1 included loads which would occur during installation of the filter. Load case 2 included the loads expected to occur during operation of the filter. The analysis demonstrates that nozzles A, B, and H are adequate to withstand the loads from both load cases.

F3.0 APPROACH/EVALUATION

The 3-inch and 8-inch pipe risers were evaluated using hand calculations. First, the pipe riser was analyzed as a cantilever column with the length of the column being from the middle of the breather filter to the top of the embedded plate (see Appendix F.A). Since the properties for the weld of the embedded plate to the pipe riser and the pipe riser are approximately the same, this one analysis covered both of them. Second, the embedded plate and concrete was analyzed by evaluating the punching shear of the embedded plate on the concrete.

The following two load cases were identified for the analysis:

Load Case 1: Loads encountered during installation of the breather assembly.

- 500 lbs vertical (weight of the filter plus the live load)
- 250 lbs horizontal (applied at the top of the riser)
- 100 ft-lbs torque (applied at the top of the riser)

Load Case 2: Loads encountered during operation of the filter.

250 lbs vertical (weight of the filter)

Horizontal seismic load based on performance category 2 (Ref. 4)

The analysis of the 3-inch and 8-inch pipe risers is located in Appendix F.B.

F4.0 RECOMMENDATIONS

Based on the analysis performed, the 3-inch and 8-inch pipe risers are structurally adequate to receive the breather filter. In the first evaluation performed on the risers (Ref. 1), it was recommended that the interaction of stresses for the pipe risers be limited to 0.5 (the normal interaction is 1.0). This was done to account for unknown factors. However, for the 3-inch riser during the installation of the breather filter (load case 1), the interaction of stresses was 0.75. This interaction stress is above the 0.5 recommend by the first evaluation (Ref. 1). This is acceptable for the following reasons: the loads will be applied for a short period of time during installation of the breather assembly and the wall thickness of the pipe has been assumed to be only 50% of its original thickness in analysis.

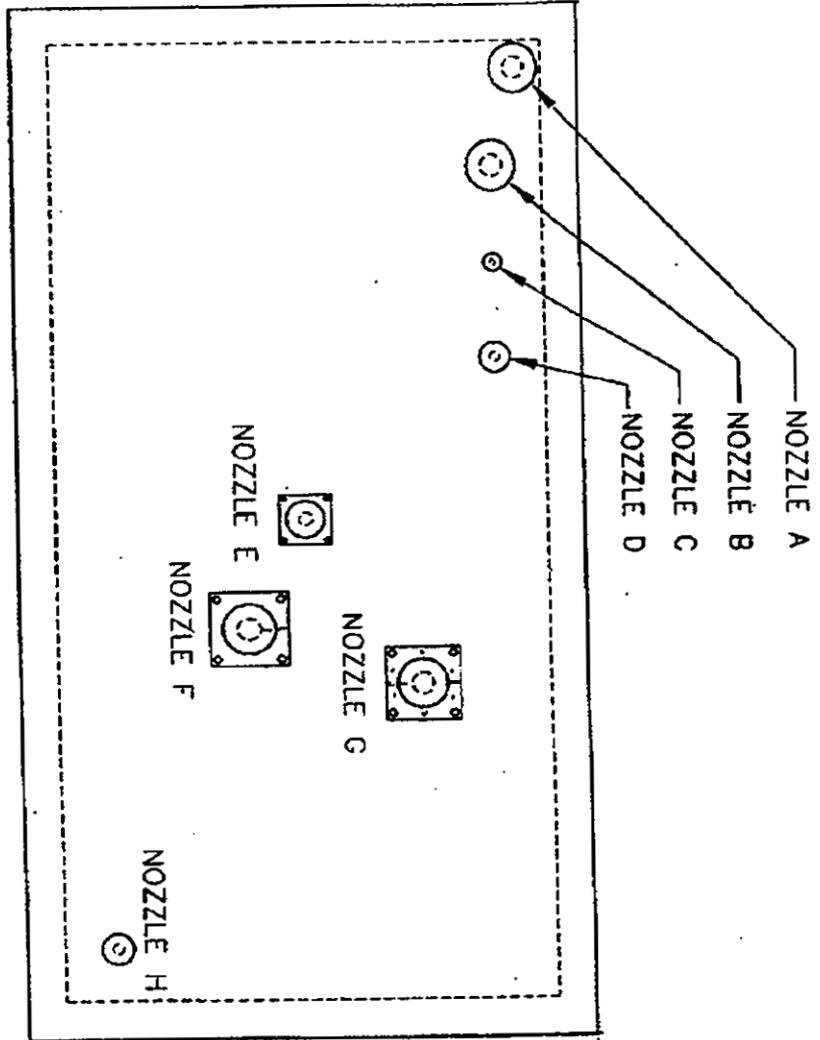
F5.0 REFERENCES

1. Letter report, "Engineering Load Evaluation of the Riser on Tank 241-Z-361," dated January 1998, Task Order PF820, by Fluor Daniel Northwest, Inc., Richland, Washington.
2. Letter, D. P. Hughes, Area Manager, Fluor Daniel Northwest, Inc., to A. L. Ramble, B&W Hanford Company, "Engineering Load Evaluation of the Riser on Tank 241-Z-361," dated 2/10/98 (CO-98-037).
2. cc:Mail, D. M. Bogen, B&W Hanford Company, to D. P. Hughes, Fluor Daniel Northwest, Inc., "Statement of Work for Fluor Daniel Northwest Riser Evaluation," dated May 18, 1998 (CI-98-115).
4. HNF-PRO-097, Rev. 0, Project Hanford Procedures, Engineering Design and Evaluation, dated 10/15/97.

**APPENDIX F.A
TANK SKETCHES**

APPENDIX A - TANK SKETCH

SHEET A2 OF 4

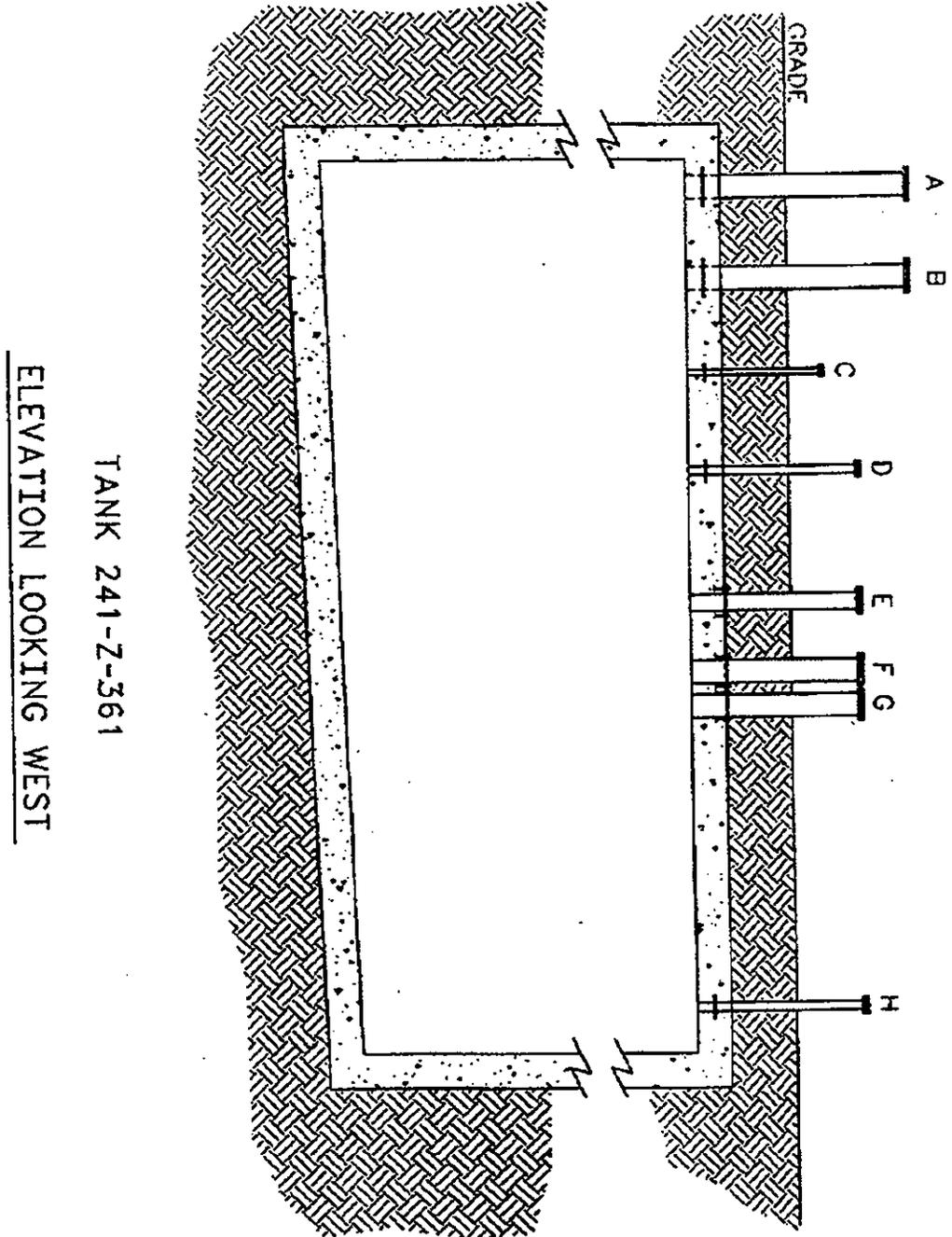


TANK 241-Z-361

PLAN VIEW

APPENDIX A - TANK SKETCH

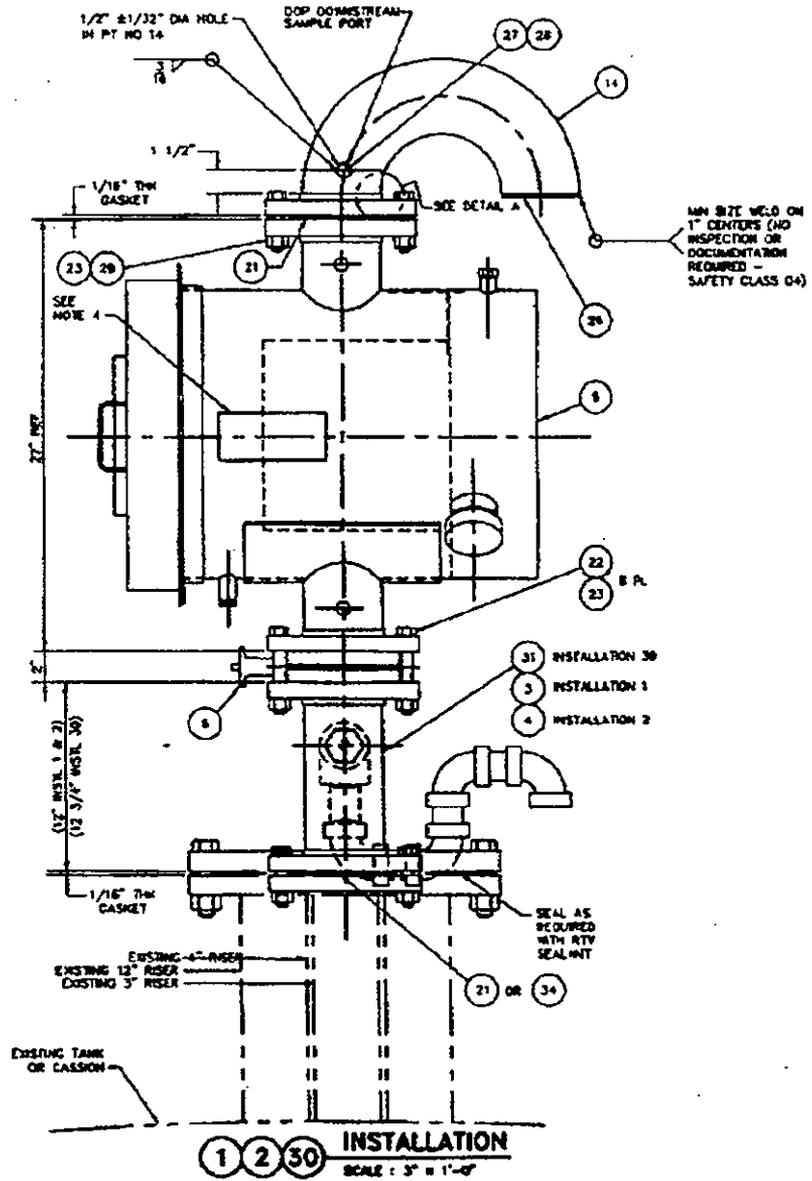
SHEET A3 OF 4



TANK 241-Z-361
ELEVATION LOOKING WEST

APPENDIX A - BREATHER FILTER ASSEM.

SHEET A4 OF 4



BREATHER FILTER
ASSEMBLY

**APPENDIX F.B
CALCULATIONS**

CALCULATIONS AND SKETCHES SHEET

FLUOR DANIEL NORTHWEST

CLIENT: BWHC	CALC No.: PP012-03	REV.: 0
DEPARTMENT: CIVIL	ORIGINATED BY: <i>David M. Shea</i>	DATE: <i>6/05/98</i>
CONTRACT/TASK ORDER No.: 65100201-PP012	CHECKED BY: <i>George J. Ryan</i>	DATE: <i>6/05/98</i>
LOCATION: 200 West PFP	REVISED BY:	DATE:
SUBJECT: Riser Analysis for PFP Tank 241-Z-361 Nozzles A or B and H for the loading of the breather filter		

OBJECTIVE

This calculation will analyze nozzles A or B and H of tank 241-Z-361 as shown on pages 3 and 4 of this calculation.

METHODS

Hand methods using standard engineering practices.

REFERENCES

1. AISC, Manual of Steel Construction, Allowable Stress Design, Ninth Edition
2. ACI 318R Building Code Requirements for Reinforced Concrete
3. Design of Welded Structures, Blodgett
4. Crane, Flow of Fluids Through Valves, Fittings, and Pipe, Technical Paper No. 410
5. Drawings H-2-16024, H-2-16640, and H-2-90718 Sht 3
6. FCN 25603
7. Uniform Building Code, 1997
8. Statement of Work (Attachment A)
9. HNF-PRO-097, Project Hanford Procedures, Engineering Design and Evaluation.

CONCLUSION

Risers A or B, and H were analyzed for the two load cases described in the statement of work (Attachment A). All of the nozzles were determined to be structurally adequate to withstand the applied loads.

CALCULATION

Nozzle Configuration

Tank 241-Z-361 has eight nozzles. A sketch of the nozzle location is shown on page 3 and 4. This sketch provides an identification letter for each nozzle. Details of how the nozzles are secured to the concrete are shown on Page 5.

Nozzles A, B, C, D, and H

These risers were installed with the original construction using the embedded nozzle detail shown on Page 5. Pictures of the interior of the tank taken in 1975 show that all metal below the water line has corroded away. Metal above the water line is badly rusted but is still there. The underside of the concrete top appears to be discolored but the ties from the forms boards are still visible.

CALCULATIONS AND SKETCHES SHEET

FLUOR DANIEL NORTHWEST

CLIENT: BWHC

CALC No.: PP012-03

REV.: 0

DEPARTMENT: CIVIL

ORIGINATED BY: *David McInerney* DATE: 6-4-98

CONTRACT/TASK ORDER No.: 65100201-PP012

CHECKED BY: *Gloria J. Lopez* DATE: 6/05/98

LOCATION: 200 West PFP

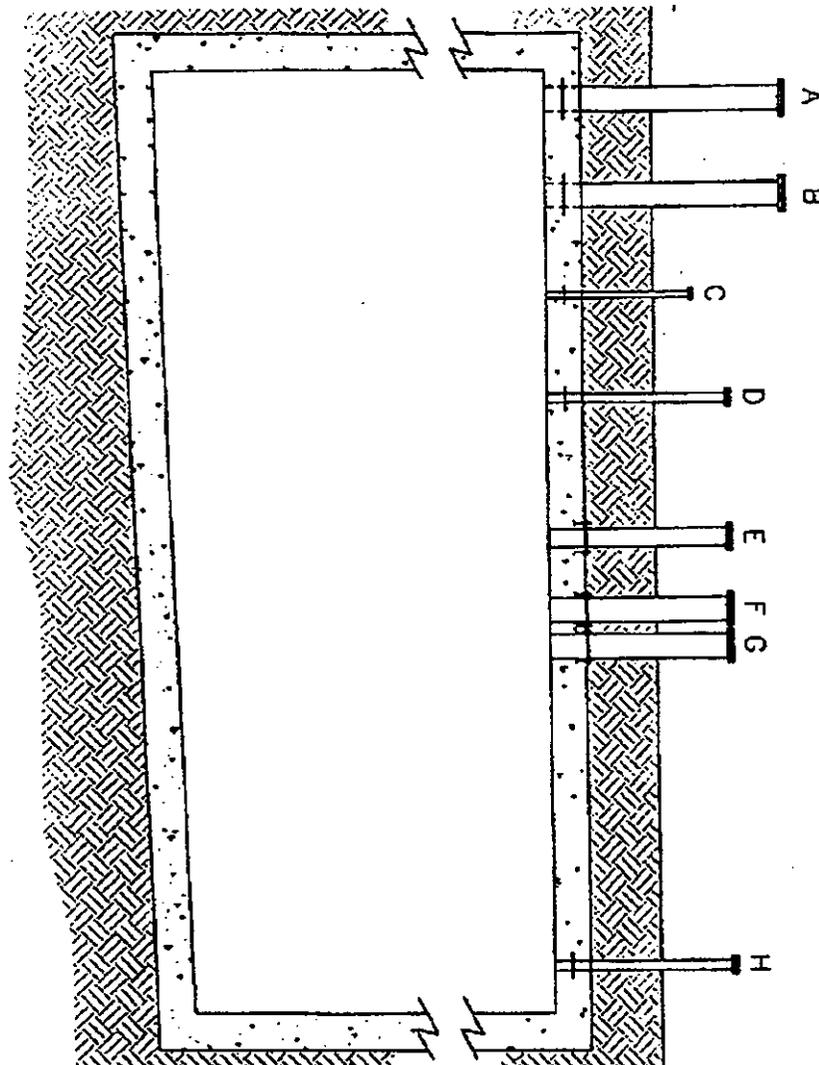
REVISED BY:

DATE:

SUBJECT: Riser Analysis for PFP Tank 241-Z-361 Nozzles A or B and H for the loading of the breather filter

ELEVATION LOOKING WEST

TANK 241-Z-361



CALCULATIONS AND SKETCHES SHEET

FLUOR DANIEL NORTHWEST

CLIENT: BWHC

CALC No.: PP012-03

REV.: 0

DEPARTMENT: CIVIL

ORIGINATED BY: *David H. [unclear]*

DATE: 6-4-98

CONTRACT/TASK ORDER No.: 65100201- PP012

CHECKED BY: *George J. [unclear]*

DATE: 6/02/98

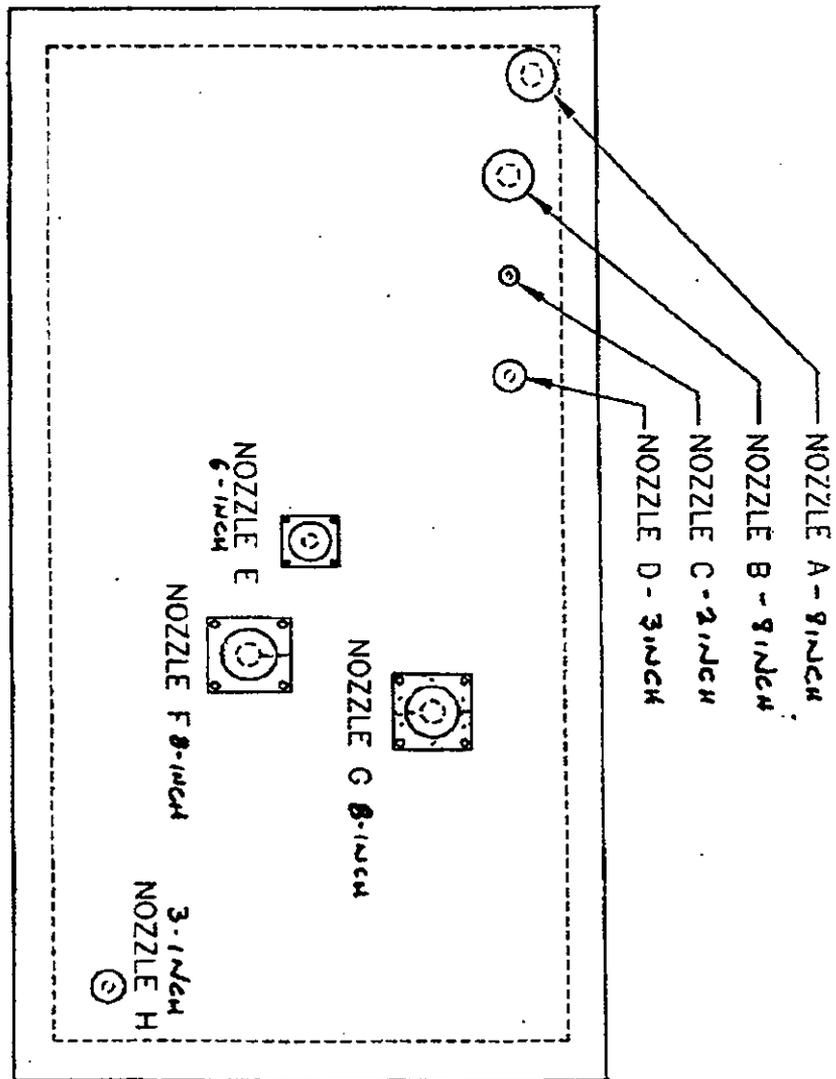
LOCATION: 200 West PFP

REVISED BY:

DATE:

SUBJECT: Riser Analysis for PFP Tank 241-Z-361 Nozzles A or B and H for the loading of the breather filter

TANK 241-Z-361
PLAN VIEW



CALCULATIONS AND SKETCHES SHEET

FLUOR DANIEL NORTHWEST

CLIENT: BWHC

CALC No.: PP012-03

REV.: 0

DEPARTMENT: CIVIL

ORIGINATED BY: *David McNamee*

DATE: 6-4-98

CONTRACT/TASK ORDER No.: 65100201- PP012

CHECKED BY: *George J. Zupic*

DATE: 6/05/98

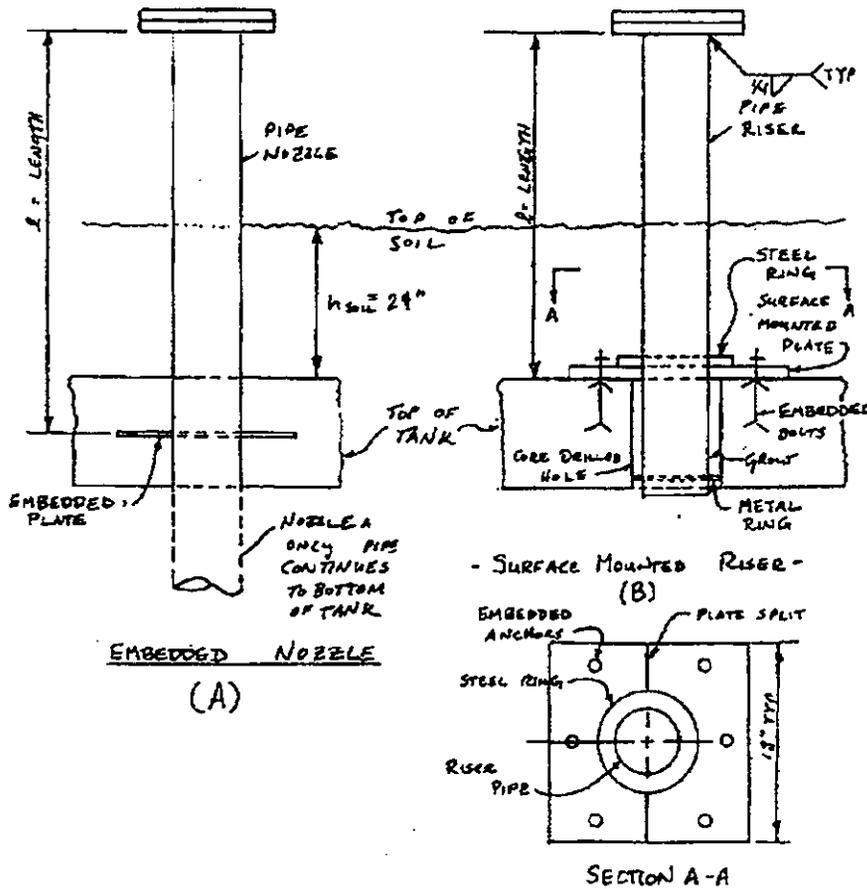
LOCATION: 200 West PFP

REVISED BY:

DATE:

SUBJECT: Riser Analysis for PFP Tank 241-Z-361 Nozzles A or B and H for the loading of the breather filter

RISER INSTALLATION DETAILS



CALCULATIONS AND SKETCHES SHEET

FLUOR DANIEL NORTHWEST

CLIENT: BWHC	CALC No.: PP012-03	REV.: 0
DEPARTMENT: CIVIL	ORIGINATED BY: <i>David McJannet</i>	DATE: 6/4/99
CONTRACT/TASK ORDER No.: 65100201-PP012	CHECKED BY: <i>Gregory J. Ryan</i>	DATE: 6/08/99
LOCATION: 200 West PFP	REVISED BY:	DATE:
SUBJECT: Riser Analysis for PFP Tank 241-Z-361 Nozzles A or B and H for the loading of the breather filter		

Nozzles E, F, and G

These risers were installed in the mid 1970's using a base plate with embedded bolts (see page 5). Riser E was installed at a different time and there is insufficient data (ie base plate thickness, and size of embedded bolts) is available to analyze this nozzle. Risers F and G were install after the use of steam in the tank was discontinued. Therefore, the rise will have minimal degradation due to corrosion.

APPLIED LOADS

As directed in the statement of work two loads cases will be applied to the nozzles

Load Case 1: Loads encountered during installation of the filter.
 500 lbs vertical (weight of the filter plus the live load)
 250 lbs horizontal (applied at the top of the riser)
 100 ft-lb torque (applied at the top of the riser)

Load Case 2: Loads encountered during operation of the filter
 250 lbs vertical (weight of the filter)
 60 lbs horizontal (seismic load as calculated below)

Calculation of seismic load (Ref 8)

Pipe riser for filter assembly is to be analysed as Performance Category 2 (Ref. 8).
 UBC Seismic Zone 2B (Ref. 9 Sec. 5.1.5.1) will be used to comply with this criteria.
 Therefore per UBC requirement (Ref. 7, Sec. 1634.5):

$$V = 0.56 * C_a * I * w$$

$$V = 0.56 * 0.34 * 1.25 * 290 = 60 \text{ lbs}$$

ASSUMPTIONS

1. The thickness of the base metal of the risers A, B, and H will be decreased by one half to account for corrosion. For these risers this reduction due to corrosion amounts to more that 1.5 mils per year. This is greater than what is assumed for the double shelled tanks and therefore is conservative.
2. The outside of the pipe was not affected by corrosion.
3. The weld of the riser to the embedded plate will be assumed to be an all around fillet weld of the same thickness as the embedded plate.
4. The outside of the pipe embedded in the concrete is not affected by corrosion.

CALCULATIONS AND SKETCHES SHEET

FLUOR DANIEL NORTHWEST

CLIENT: BWHC	CALC No.: PP012-03	REV.: 0
DEPARTMENT: CIVIL	ORIGINATED BY: <i>David McNamee</i>	DATE: 6/4/98
CONTRACT/TASK ORDER No.: 65100201-PP012	CHECKED BY: <i>George J. Zyr</i>	DATE: 6/05/98
LOCATION: 200 West PFP	REVISED BY:	DATE:
SUBJECT: Riser Analysis for PFP Tank 241-Z-361 Nozzles A or B and H for the loading of the breather filter		

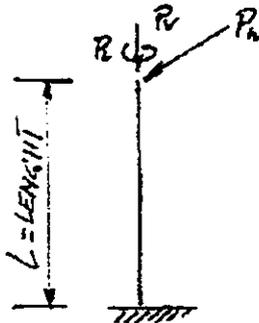
5. The embedded plate will be assumed to be placed at the middle of the concrete top.
6. Four inches will be used for the distance from the embedded plate to the reinforcing steel.
Assumptions (con't)
7. When analyzing the concrete for the punching shear the strength of the reinforcing steel will be neglected.
8. The Yield Stress for carbon Steel will be 36 ksi.
9. The positive effect of the soil depth on the unbraced length will be conservatively neglected.
10. The brace on riser H will be conservatively neglected.

NOZZLE ANALYSIS

Nozzles A, B, and H will all be analyzed the same way. First, the pipe will be analyzed as cantilever column with the length of the column being from the top of the flange to the top of the embedded plate for Load Case 1. For Load Case 2 the length will be from the center of the filter to the top of the embedded plate. Since the properties for the weld of the embedded plate to the pipe and the pipe riser are approximately the same, this one analysis will cover both. Second the embedded plate and concrete will be analyzed evaluating the punching shear on the concrete.

Column Analysis

LOAD DIAGRAM



Physical properties are tabulated on page 9.

Stresses at the Support

Axial $f_a = P_v/a$
 Shear $f_v = (P_h/a) + (P_t^*c/J)$
 Bending $f_b = (P_h^*l^*c)/I$

Allowable Stresses (AISC)

$F_a = 36 \text{ ksi} * C_a$ (table 3 AISC, pg 5-119)
 $F_v = .4 * 36 \text{ ksi}$
 $F_b = .6 * 36 \text{ ksi}$

Interaction Equation

$(f_a/F_a) + (f_v/F_v) + (f_b/F_b) \leq 1$

Tabulated Results are shown on Page 10.

CALCULATIONS AND SKETCHES SHEET

FLUOR DANIEL NORTHWEST

CLIENT: BWHC

CALC No.: PP012-03

REV.: 0

DEPARTMENT: CIVIL

ORIGINATED BY: *David McGinnis*

DATE: 6-4-98

CONTRACT/TASK ORDER No.: 65100201- PP012

CHECKED BY: *George J. Lynn*

DATE: 6/02/98

LOCATION: 200 West PFF

REVISED BY:

DATE:

SUBJECT: Riser Analysis for PFF Tank 241-2-361 Nozzles A or B and H for the loading of the breather filter

Nozzle Data for design purposes

Riser Identification (see page 5)	Insulation Detail (see page 5)	Nominal Riser Pipe Size (in)	Embedded Pipe Dia (in)	Length l (ft)	Nominal Wall Thickness (in)	Nominal Area A_n (in ²)	Reduced Wall Thickness (in)	Reduced Area A_r (in ²)	Moment of inertia I (in ⁴)	Torsional moment of inertia J (in ⁴)
A/B LC1	A	8	13.5	72	0.32	8.4	0.18	4.28	39.35	78.7
A/B LC2	A	8	13.5	87	0.32	8.4	0.18	4.28	39.35	78.7
H LC1	A	3	7.5	54	0.22	2.228	0.11	1.18	1.86	3.318
H LC2	A	3	7.5	81	0.22	2.228	0.108	1.15	1.86	3.314

Riser Identification (see page 5)	Insulation Detail (see page 5)	Radius of CG c (in)	Radius of Gyration r (in)	k/r	k/r/c ²	Ca ²	Allowable Stresses		
							Compression F _{ax} F _y /Ca (psi)	Bending F _{bx} F _y (psi)	Shear F _{vx} F _y (psi)
A/B LC1	A	4.31	2.89	50.52	0.40	0.51	18324	21600	14400
A/B LC2	A	4.31	2.89	68.88	0.54	0.51	18324	21600	14400
H LC1	A	1.75	1.20	94.50	0.75	0.38	13644	21600	14400
H LC2	A	1.75	1.20	141.78	1.12	0.38	7431	21600	14400

- a. $r = (I/A)^{0.5}$ (ref Blodget page 2-2-7)
- b. $J = 2 \cdot I$ (ref Blodget 2.10-1)
- c. Ca is from table 3 of the AISC Page 8-118
- d. Cc = 126.1 (ref AISC Page 5-120)
- e. AISC Table C-C2.1 page 5-135, Fixed-free end restraints
- f. For Load Case 2 add 27 inches (Ref drawing H-2-90718 sheet 3)

CALCULATIONS AND SKETCHES SHEET

FLUOR DANIEL NORTHWEST

CLIENT: BWHC	CALC No.: PP012-03	REV.: 0
DEPARTMENT: CIVIL	ORIGINATED BY: <i>David McLean</i>	DATE: 6/4/98
CONTRACT/TASK ORDER No.: 65100201-PP012	CHECKED BY: <i>George J. Lopez</i>	DATE: 6/05/98
LOCATION: 200 West PFP	REVISED BY:	DATE:

SUBJECT: Riser Analysis for PFP Tank 241-Z-361 Nozzles A or B and H for the loading of the breather filter

AISC Code Based
PIPE COLUMN LOAD EVALUATION

Load Case	Riser Identification	Applied Load				Calculated Stresses			Combined Stresses	
		Vertical Pv (lbs)	Horizontal Ph (lbs)	Moment		Axial fa (psi)	Shear fv (psi)	Bending fb (psi)	fa + fb + fv	
				Torsion Pt (ft-lbs)	Bending Pb = Ph * l (in-lb)				Value	Acceptable Value < 1
1	A & B	500	250	100	18000	118.82	126.84	2024.12	0.11	Yes
2	A & B	250	60	0	5820	58.41	14.02	654.47	0.03	Yes
1	D & H	500	250	100	13500	434.78	851.07	14231.93	0.75	Yes
2	D & H	250	60	0	4860	217.39	52.17	5123.49	0.27	Yes

ATTACHMENT A CALCULATION PPO12-03

Author: Dennis P Hughes at HANFORD03E
 Date: 5/19/98 11:13 AM
 Priority: Normal
 TO: Mian A Haq at HANFORD07E
 TO: David S McShane at HANFORD10A
 Subject: FW: Statement of Work for FDNW Riser Evaluation

----- Message Contents -----

> -----Original Message-----
 > From: Keith V Scott@apexc.rl.gov (SMTP:Keith_V_Scott@apexc.rl.gov)
 > Sent: Monday, May 18, 1998 5:03 PM
 > To: Duane M Bogen@aplmc01.rl.gov
 > Subject: Statement of Work for FDNW Riser Evaluation
 >
 > Ref. Letter, D. P. Hughes to A. L. Ramble, "Structural Integrity
 > Assessment for PFP Tank 241-2-361", dated February 10, 1998.
 >
 > Statement of Work
 > For the first phase of the characterization of tank 2-361,
 > breather filters will be mounted as needed (on one or two risers)
 >
 > to ensure the tank stays below 25% of the LFL. The breather
 > filters will be mounted directly on a 3-inch riser (nozzle H in
 > the reference letter) and, if necessary, another filter will be
 > mounted on an 8-inch riser (either nozzle A or B in the reference
 > letter). The configuration of the filter housing assembly is
 > shown on drawing H-2-90718 Sh. 1, 2, and 3. The installation of
 > a filter housing on the 8-inch riser will require the addition of
 > an adapter (part 3 in drawing H-2-85349 Sh. 1).
 >
 > FDNW is requested to evaluate if the risers selected have
 > sufficient load capacity to carry the filters.
 >
 > Riser Loads:
 > 1. Assumed Filter assembly weight - 250 lbs.
 > 2. Natural Phenomenon Hazards - Performance Category 2.
 > 3. Live load - 250 lbs. vertical and 250 lbs. lateral and 100
 > ft-lbs torque (These live loads may be encountered during
 > filter installation).
 >
 >

ATTN-1

APPENDIX G

**BASIS FOR ACCEPTANCE OF TANK LOADING DURING PHASE-I
INSPECTION ACTIVITIES OF TANK 241-Z-361**

BASIS FOR ACCEPTANCE OF TANK LOADING DURING PHASE I INSPECTION ACTIVITIES OF TANK 241-Z-361

INTRODUCTION

This report provides an engineering basis for the acceptance of the resulting tank loads associated with the proposed Phase I inspection activities of Tank 241-Z-361 in support of the Justification for Continued Operation (JCO) for Tank 241-Z-361 (Ref. 1). Tank 241-Z-361 is an inactive, underground storage tank located within the protected area of the Plutonium Finishing Plant (PFP) in the 200 West Area of the Hanford Site. The tank is a reinforced-concrete, rectangular underground structure used as a settling tank to receive low-salt, liquid effluent from PFP processes from 1949 to May 1973. After 1973, the liquid from the tank was pumped leaving about 75 cubic meters of sludge in the tank. The tank was last monitored internally and photographed in 1975, and then sealed, including sources of ventilation.

Because of the uncertainties regarding the present structural condition of the tank, Fluor Daniel Northwest, Inc. (FDNW) had recommended the performance of a load test prior to allowing any significant direct access to the tank (Ref. 2). The testing consisted of two work packages: one for performing a perimeter load test to allow personnel and equipment of up to 300 lbs to safely approach the tank with a safety factor of two; and the second for performing the dome load test to allow a working load directly over the tank of up to 2,000 lbs with a safety factor of two. The perimeter load test was successfully completed (Ref. 3) by moving a remote controlled robot weighing 600 lbs over the adjacent soil perimeter access area (2 to 10 feet outboard of the tank perimeter) surrounding the tank. The dome load test was successfully completed (Ref. 4) by placing a water tank near the center of the 241-Z-361 tank and incrementally filling the water tank to a total test weight of 4,000 lbs.

The proposed Phase I inspection activities require the placement of a containment tent (800 lbs), breather filter (250 lbs), tripod/chain fall (200 lbs), tools/monitoring equipment (100 lbs), and up to ten support people (2,000 lbs) on or near the 241-Z-361 Tank. The total weight directly above the tank is estimated to be approximately 1,616 lbs which is within the 2,000-lb working load limit established through the dome load test. The total weight within the access area of the north wall is estimated to be approximately 1,732 lbs. This exceeds the 300-lb access area limit established through the soil perimeter load test and hence requires additional justification for the specific proposed loading configuration.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The layout of equipment and support personnel (see Figure 1 of Appendix A) for the proposed Phase I inspection activity of Tank 241-Z-361 is acceptable. The 1,616-lb total load directly above the tank is acceptable since it is less than the 2,000 lb working load limit established through the dome load test. The remaining 1,732 lb load within the access area to the tank is acceptable on the basis of a comparative assessment that showed that the resulting moments induced in the tank side wall are less, by at least a factor of 2 in the region of interest, than the resulting maximum moments induced by either the 1992 record 21-inch snow fall or the tank wall moments induced by the past practice of parking of a 12,000-lb armored car near the tank. In addition to the loads resulting from the Figure 1 configuration (see Appendix A), two other load configurations were evaluated: the movement of the NEVS cart within the containment tent (includes cart, support equipment, and three support personnel for a total weight of 732 lbs) and the placement of waste drums (total weight of 1,500 lbs) approximately 15 feet outboard of the tank's east or west wall. Both of these load conditions are acceptable.

The region of primary interest for the tank is the lower half of the wall because of the uncertain potential degradation of the wall from exposure to the waste content. In addition, the lower portion of the wall is expected to be subject to greater lateral wall pressures from the existing in-place soil loading. The lateral wall pressure and resulting wall moments from the proposed activity is shown to be greatest in the upper half of the wall which is less challenged by the in-place soil loading and is less likely to be degraded in strength. The lateral wall pressure from the armored car has a greater effect on the lower portion of the tank wall. However, in the case of the uniform snow load, the resulting lateral wall pressure is uniform over the wall.

For added flexibility in operations, the allowable concentrated load within the tank access area was also determined as a function of the perpendicular distance of the load to the tank while maintaining a factor of safety of 2 relative to the 1992 record snow load experienced by the tank. Multiple concentrated loads within the access area to the tank can be easily evaluated for acceptance by requiring that the sum of the ratios of each individual applied load to allowable load at the distance of the applied load to the tank be less than or equal to one. This evaluation method can be applied to each of the walls separately. However, for loads within 2 feet outboard of the wall, 50 percent of this load shall be considered as acting on the tank dome (roof) when evaluating the acceptability of loads directly over the tank. Loads beyond 20 feet from the tank walls can be considered as unrestricted.

APPROACH / EVALUATION

The accurate prediction of the resulting lateral wall pressure distribution on an adjacent below grade wall from a concentrated surcharge load at soil grade on backfill is a difficult task.

Empirical relations have been developed (see Figure 14-5 of Ref. 5) as well as theoretical solutions (Ref. 6). Even in the case of earth pressure loading, the actual distribution of the lateral wall pressure from the in-place soil is dependent on the compaction of the backfill soil during construction and the flexibility of the tank walls. Compaction of the soil can lead to a more uniform lateral wall pressure with soil depth than the usually assumed linearly increasing pressure with depth. Actual earth pressure distributions are not typically linear.

The Boussinesq theoretical solution for the lateral wall pressure from a concentrated surcharge load is recommended in Ref. 6 as the preferred approach. It is based on the Boussinesq solution for the radial pressure (resolved in the perpendicular direction to the wall) in an elastic semi-infinite half space (see Appendix A for equation). This equation is dependent on Poisson's ratio for the assumed elastic medium and can have a significant effect on the results depending on the compaction of the soil. The resulting lateral pressure distribution predicted from this solution method is more concentrated and gives smaller lateral pressures as the load approaches the wall than predicted by applying the lateral pressure coefficient (K) to the vertical pressure distribution given by Boussinesq (see Appendix A for this alternate method). In an attempt to bound the actual lateral pressure from the concentrated loads both approaches were considered. A Poisson's ratio (ν) typical of Hanford Site soil of 0.27 (Ref. 7) was assumed and for consistency K was taken equal to $\nu / (1 - \nu) = 0.37$ assuming an elastic isotropic medium.

In the case of the uniform snow load the lateral increase in pressure on the wall is given by KQ_s , where Q_s is the vertical pressure applied to the ground by the accumulated snow. For the December 1992 record snow fall of 21 inches the total precipitation at the Hanford weather station was reported as 1.82 inches (Ref. 8, pages 4.2 and 4.8) corresponding to a uniform ground pressure load of 9.46 lb/ft² or a lateral uniform wall pressure of 3.5 lb/ft².

The tank wall moments induced by the past practice of parking of a 12,000-lb armored car near the tank were also considered. Typically an armored car was parked at an approximate 45-degree angle, approximately 6 feet from the north-west corner of the 241-Z-361 Tank. In addition to the loads resulting from the Figure 1 configuration (see Appendix A), two other load configurations were evaluated: the movement of the NEVS cart (92 lbs) within the tent with support equipment (40 lbs) and three support personnel (600 lbs) for a total weight of 732 lbs and the placement of waste drums (total weight of 1,500 lbs) approximately 15 feet outboard of the tank's east or west wall.

Details of the load configurations considered are shown in Appendix A. The results of the evaluation are summarized in Table 1. The acceptance of the proposed load configurations is based on maintaining a factor of safety of 2 in the lower portion of the tank wall relative to the maximum moment induced in the wall from either the snow load or armored car load. This has been demonstrated for all load cases considered, as shown in Table 1, for either of the methods used to predict the lateral wall load induced from the concentrated surcharge loads considered.

The moments induced in the wall from the lateral pressure distributions are conservatively calculated based on assumed one-way action of the wall which is assumed fixed at its outer boundaries.

In addition to the above proposed load configurations evaluated, the allowable concentrated load within the tank access area was also determined as a function of the perpendicular distance of the load to the tank while maintaining a factor of safety of two relative to the 1992 record snow load experienced by the tank. The allowable concentrated load, $Q_{\text{allowable}}$ (lbs), as a function of perpendicular distance, D (ft), from the tank wall is given by the second order regression equation:

$$Q_{\text{allowable}}(D) = 957 + 163.6 D + 8.14 D^2 .$$

Multiple concentrated loads within the access area of the tank can be easily evaluated for acceptance by requiring that the sum of the ratios of each individual applied load, Q_i , to allowable load at the distance, D_i , of the applied load to the tank be less than or equal to one, i.e.

$$\sum_{i=0}^N \frac{Q_i}{957 + 163.6 D_i + 8.14 D_i^2} \leq 1$$

This evaluation method can be applied to each of the walls separately depending on the location of the load relative to the nearest wall and is valid for either the end or side walls.

However, for loads within two feet outboard of any of the walls, 50 percent of this load shall be considered as acting on the tank dome (roof) when evaluating the acceptability of loads directly over the tank. Loads beyond 20 feet from the tank walls can be considered as unrestricted.

UNCERTAINTIES

Although there are uncertainties in determining the actual lateral pressure transmitted to the tank walls, the bounding engineering approach applied herein is considered conservative. Loadings which differ from the proposed activity can be evaluated as discussed above. The application of these results does not address the true capacity of the tank but the capacity of the tank relative to loads that the tank has already experienced. Hence, the true safety factor for the proposed loading is at least two and may be much greater pending verification of the actual structural integrity of the tank. However, the apparent safety factor of loads present during periods of significant snow or rain fall will be reduced in direct proportion relative to the 1992 record snow fall accumulation. The apparent safety factor of the loads with snow or rain fall present is equal to the safety factor without snow or rain fall times the quantity 1 minus the ratio of the current accumulated moisture to the moisture accumulated (1.82 inches) in the 1992 record snow fall.

REFERENCES

1. Report, *Justification for Continued Operation for Tank 241-Z-361*, HNF-2024, Rev. 0, dated January 1998, Richland, Washington.
2. Letter report, "Structural Integrity Assessment for PFP Tank 241-Z-361," dated December 1997, Task Order PF820, by Fluor Daniel Northwest, Inc., Richland, Washington.
3. Letter report, "Result of the Load Test Perimeter of Underground Tank 241-Z-361 Roof," TRP-98-003, dated October 1998, Task Order TM22, Fluor Daniel Northwest, Inc., Richland, Washington.
4. Letter report, "Tank 241-Z-361 Dome Load Test Results Summary," dated October 1998, Task Order TM22, Fluor Daniel Northwest, Inc., Richland, Washington.
5. Report, *Soils and Geology Procedures for Foundation Design of Buildings and Other Structures (Except Hydraulic Structures)*, ARMY TM 5-818-1/AFM 88-3, Chap. 7, dated October 1983, Department of the Army and Air Force, Washington, DC.
6. Bowles, J. E., 1988, *Foundation Analysis and Design*, 4th edition, McGraw-Hill, Inc., New York, New York.
7. Report, *Soil Structure Analysis Tool and Properties for Hanford Site Waste Tank Evaluation*, WHC-SD-WM-DA-208, Rev. 0, dated September 1995, by ICF Kaiser Hanford Company for Westinghouse Hanford Company, Richland, Washington.

8. Report, *Climatological Data Summary 1993 with Historical Data*, PNL-9809, dated June 1994, by Pacific Northwest Laboratory for U.S. Department of Energy, Washington, DC.

Table 1. Resulting Side Wall Loading on Tank 241-Z-361 for Proposed Phase-I Inspection Activity Compared to 1992 Record Snow Fall and Parking of Armored Car Near

Load Case	Description	Total Surcharge Load	Maximum Lateral Pressure (lb/ft ²)	Resulting Wall Induced Moment (ft-lb/ft)		Ratio of Maximum Moment from Snow or Armored Car Load to Moment from Proposed Activity						Depth (ft) from Top of Wall where Ratio First Exceeds 2		
						Armored Car			Snow			Armored Car		Snow
						(Case 5)		(Case 6)	(Case 7)		(Case 5)	(Case 6)	(Case 7)	
						Max	Min	Max	Min	Max	Min	Max	Min	
Lateral pressure coefficient ¹ * vertical pressure from Boussinesq solution at wall for concentrated load on semi-infinite elastic medium														
1	North Wall (15 x 20 ft) Tent (5 supports) + 600 lb at Pad 1 (4 ft out from wall) + 800 lb at Pad 2	1,800 lbs	1.6	24.3	-12.2	> 10	1.4	> 10	1.1	> 10	2.7	10	14	0
2	Tent + 732 lb at Pad 1 (4 ft out from wall)	1,132 lbs	1.8	24.7	-12.9	> 10	1.4	> 10	1	> 10	2.5	8.5	11	0
3	Tent + 732 lb at Pad 1 (5 ft out from wall)	1,132 lbs	1.2	18.7	-9.7									
4	Tent + 200 lb at Pad 1 (4 ft out from wall) + 732 lb at Pad 2	1,332 lbs	0.8	13.7	-6.7									
5	12,000 lb Armored Car 6 feet from corner	12,000 lbs	4.0	40.0	-17.7									
6	12,000 lb Armored Car 10.6 feet from corner	12,000 lbs	1.6	27.5	-13.4									
7	1992 21-in. Snow Fall Accumulation	9.46 lb/ft ²	3.5	65.3	-32.7									
East or West Wall (28 x 20 ft)														
8	Waste Drums at Center of Tank 15 ft from Wall	1,500 lbs	0.2	6.0	-2.8					(Case 9) > 20	19.4			(Case 9) 0
9	1992 21-in. Snow Fall Accumulation	9.46 lb/ft ²	3.5	116.3	-58.6									
Direct solution for lateral pressure at wall from Boussinesq solution for concentrated load on semi-infinite elastic medium (v = 0.27)														
1	North Wall (15 x 20 ft) Tent (5 supports) + 600 lb at Pad 1 (4 ft out from wall) + 800 lb at Pad 2	1,800 lbs	4.5	61.4	-31.0	> 10	1.1	> 10	1.18	> 10	1.06	3.7	3.5	4
2	Tent + 732 lb at Pad 1 (4 ft out from wall)	1,132 lbs	5.0	60.9	-33.2	> 10	1.04	> 10	1.1	> 10	0.98	3	3	3.5
3	Tent + 732 lb at Pad 1 (5 ft out from wall)	1,132 lbs	3.5	48.2	-25.3									
4	Tent + 200 lb at Pad 1 (4 ft out from wall) + 732 lb at Pad 2	1,332 lbs	2.2	33.6	-16.6									
5	12,000 lb Armored Car 6 feet from corner	12,000 lbs	9.1	80.9	-34.4									
6	12,000 lb Armored Car 10.6 feet from corner	12,000 lbs	4.7	76.7	-36.6									
7	1992 21-in. Snow Fall Accumulation	9.46 lb/ft ²	3.5	65.3	-32.7									
East or West Wall (28 x 20 ft)														
8	Waste Drums at Center of Tank 15 ft from Wall	1,500 lbs	0.6	17.5	-8.8					(Case 9) > 10	6.6			(Case 9) 0
9	1992 21-in. Snow Fall Accumulation	9.46 lb/ft ²	3.5	116.3	-58.6									

¹ Lateral pressure coefficient, $K = v / (1 - v) = 0.37$ for Poisson's ratio (Hanford Site backfill soil) $v = 0.27$

Total weight of containment tent = 800 lbs with total of 10 supports or 80 lbs / support

Corner of Tank.

APPENDIX G,A
SUPPORTING CALCULATIONS

Page 1 of 90
ENGINEERING CALCULATION COVER SHEET

FLUOR DANIEL NORTHWEST

DATE: 17 Nov. 1998

REV.: 0

DEPARTMENT: CIVIL / STRUCTURAL ORIGINATED BY: David S. Messinger, PE DATE: 17 Nov. 1998

ENG COMM. NO.: CHECKED BY: L.J. Julyk DATE: 17 Nov. 1998

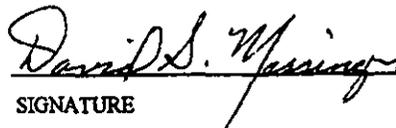
AREA: REVISED BY: DATE:

SUBJECT: INDUCED PRESSURE ON TANK 241-Z-361 SIDEWALL FROM CONCENTRATED SURFACE LOAD

CLIENT: BABCOCK AND WILCOX HANFORD COMPANY

CONTRACT NUMBER: TASK ORDER TM22

CALCULATION IDENTIFICATION TM22-C-01


SIGNATURE

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01Revision: 0Page No. 1 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: FFP 249 W Area - Hanford Site, Richland, Washington

WC/No. TM22
 Date: 11/17/88
 Checked: 1/24/92
 Revised:

By: DAVID S. MESSINGER, PE
 By: L. J. JULYK

- OBJECTIVE:** Determine the Factor of Safety of anticipated operational loads versus previously applied vehicle and precipitation loads from the armored car parked adjacent to the tank and the 1992 snow load as described in reference 2. See Fig. 1 for the operational load patterns considered.
- CRITERIA:** Task Order PF820
- ASSUMPTIONS:** Soil is in an "at rest" condition; i.e. (elastic response - high relative density). Soil conditions are as described in reference 5, Table 4; i.e. having a Poisson's ratio of 0.27. The factor of safety will be based on the ratio of incremental moment induced in the tank walls from the applied load cases assuming one-way action across the horizontal tank dimension. Based on photographs taken in the late 1970's the wall area below the eight foot level, as measured from the tank top, was not visible and must therefore be considered possibly of lower structural capacity than the visible portion of wall above the eight foot tank level. The wall stress's or moments are therefore of more concern in this area than the area above the eight foot level.
- METHOD USED:** Hand calculation using "Mathcad 6+" solver software. Two methods of analysis were used: The first was using Bossinesq technique to determine the vertical pressure along the tank face and multiplying this by a "K" factor (at rest coefficient) to determine the wall pressure. "K" was determined from measured Poisson's ratio (Ref.5, table 4 and Ref.3, E.Q. 10-13). This method will be referred to as the classical method.
- The second method was to use Bossinesq equations to determine soil stresses in the horizontal direction as recommended in references 1 and 2. This method will be referred to as the elastic method.
- LIMITATIONS:** The actual condition of the tank side walls are unknown and must be ascertained on the basis of loads from vehicles operating near the tank, load tests applied to the tank top and the effect of environmental loading from precipitation.
- REFERENCES:**
1. *Foundation Analysis and Design*, Fourth Edition, 1988, Joseph E. Bowles, P.E., S.E., McGraw-Hill, New York, New York.
 2. *Advanced Soil Mechanics*, Braja M. Das, McGraw-Hill, New York, New York.
 3. *Foundations, Retaining and Earth Structures*, by Gregory P. Tschebotarioff, Second Edition, McGraw-Hill New York, New York.

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-81

Revision: 8

Page No. 2 of 90

Client: Babcock & Wilcox Hanford Company

Subject: 241-Z-361 Underground Tank

Location: Lateral Load on Tank Wall from Concentrated Load at Grade

Location: FFP 229 W Area - Hanford Site, Richland, Washington

WONo. TM22

Date: 11/17/98

Checked: 8/24/98

Revised:

By: DAVID S. MESSINGER, PE

By: L. J. BLYK

By:

4. Letter Report, "Engineering Basis for Critical Lift and Load Test Plan for Tank 241-Z-361," FDNW, by D. S. Messinger and M. A. Haq, dated March 1998.
5. Report, *Final Report for Task Order ICF KH-8008-3, Project W-580, Replacement of the Cross-Site Transfer System, Hanford Site, Richland Washington*, by Shannon and Wilson, Inc. March 1995.

CONCLUSION:

The stresses induced in the tank walls from the December 1992 precipitation (Ref. 4, pg.3) loading exceeded the loading on the tank from the vehicle traffic (armored car). The anticipated wall stresses from the proposed load cases are well below stresses believed to have been induced in the wall from the precipitation load.

The factor of safety relative to the precipitation loading is well in excess of 2:1 in the portion of the wall where concern for the structural integrity of the wall was in question (i.e. eight feet or more below the tank top). This can be seen in the FS (Factor of Safety) plots for each of the load cases investigated.

Several other load cases were investigated that would determine the maximum allowable concentrated load placed normal to the long wall of the tank at the wall centerline. Points investigated were at the following offset distances: 0 ft., 5 ft., 10 ft., 15 ft. and 20 ft..

It was determined that the allowable load at the wall face was 950 lbs.; at 5 ft., the allowable load was found to be 1,800 lbs.; at 10 ft., 3,415 lbs.; at 15 ft., 5,000 lbs; and at 20 ft., 7,850 lbs.

Since practical operations will require some loading at various locations simultaneously, a regression analysis was performed on the calculation results. An expression was then developed that will allow for any loading pattern within 20 feet of the wall to be evaluated. Q_i is the discrete load and D_i is the associated distance from the tank wall. If the loading combination satisfies the following expression, then the load pattern is acceptable.

$$\sum_{i=0}^N \frac{Q_i}{957 + 163.6D_i + 8.14D_i^2} \leq 1$$

The classical method of analysis as well as experience has shown that at distances beyond the depth of the tank, the loading has little if any effect. Therefore loads beyond 20 feet can be considered unrestricted.

Loads placed within 2 feet of the tank edge will also effect the tank top. One-half of any load, placed within 2 feet of the tank edge should be considered to be tank top load.

Calculations follow:

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision 0

Page No. 4 of 92

Client: Babcock & Wilcox Hartford Company

WC No. TM22

Subject: 241-Z-361 Underground Tank

Date: 11/17/88

By: DAVID S. MESSINGER, PE.

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 1/24/92

By: I. J. JULYK

Location: PEP 200 W.Ams - Hartford Site, Richland, Washington

Revised: _____

By: _____

PROPOSED EQUIPMENT LOCATION

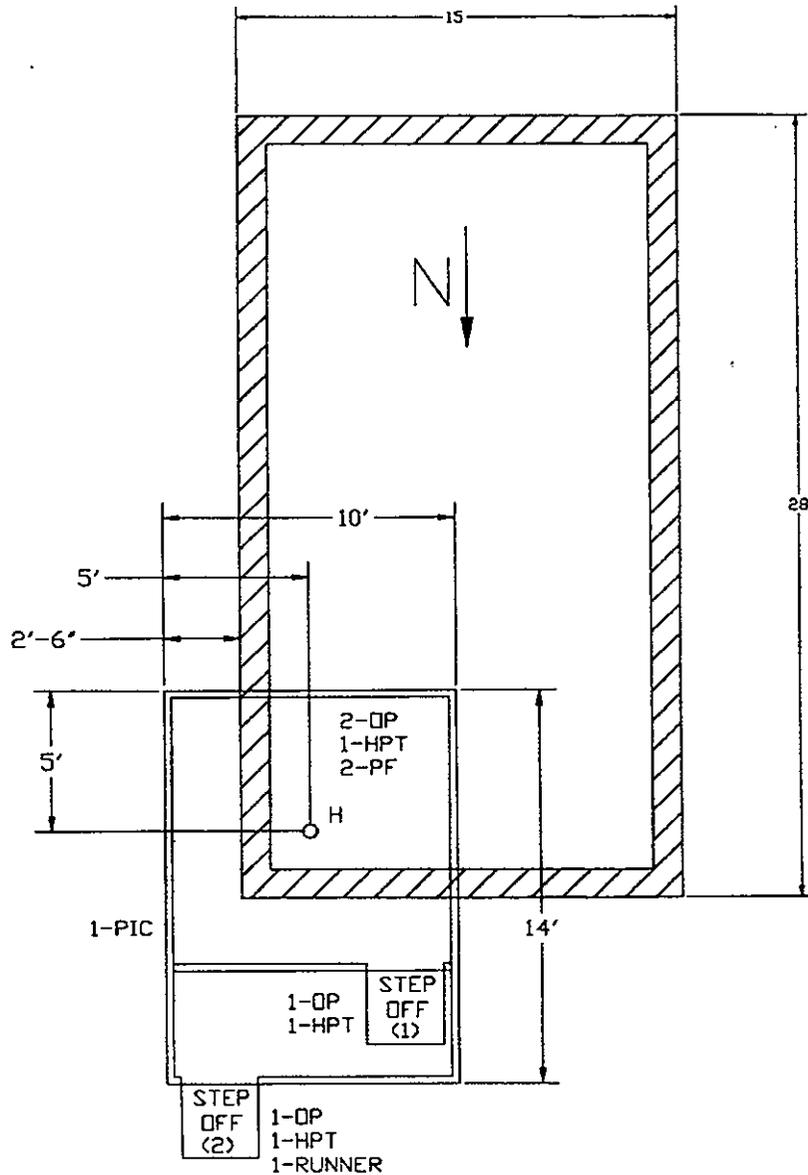


Fig. 1

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 0

Page No. 5 of 90

Client: Rohcock & Wilcox Hanford Company

WONo. TM22

Subject: 241-Z-361 Underground Tank

Date: 11/17/08

By: DAVIDS MESSINGER PE

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 11/24/08

By: L.J. JULYK

Location: PEP 200 W Area - Hanford Site, Richland, Washington

Revised: _____

By: _____

80 lb. LOAD POINTS FOR TENT FRAME LOADS

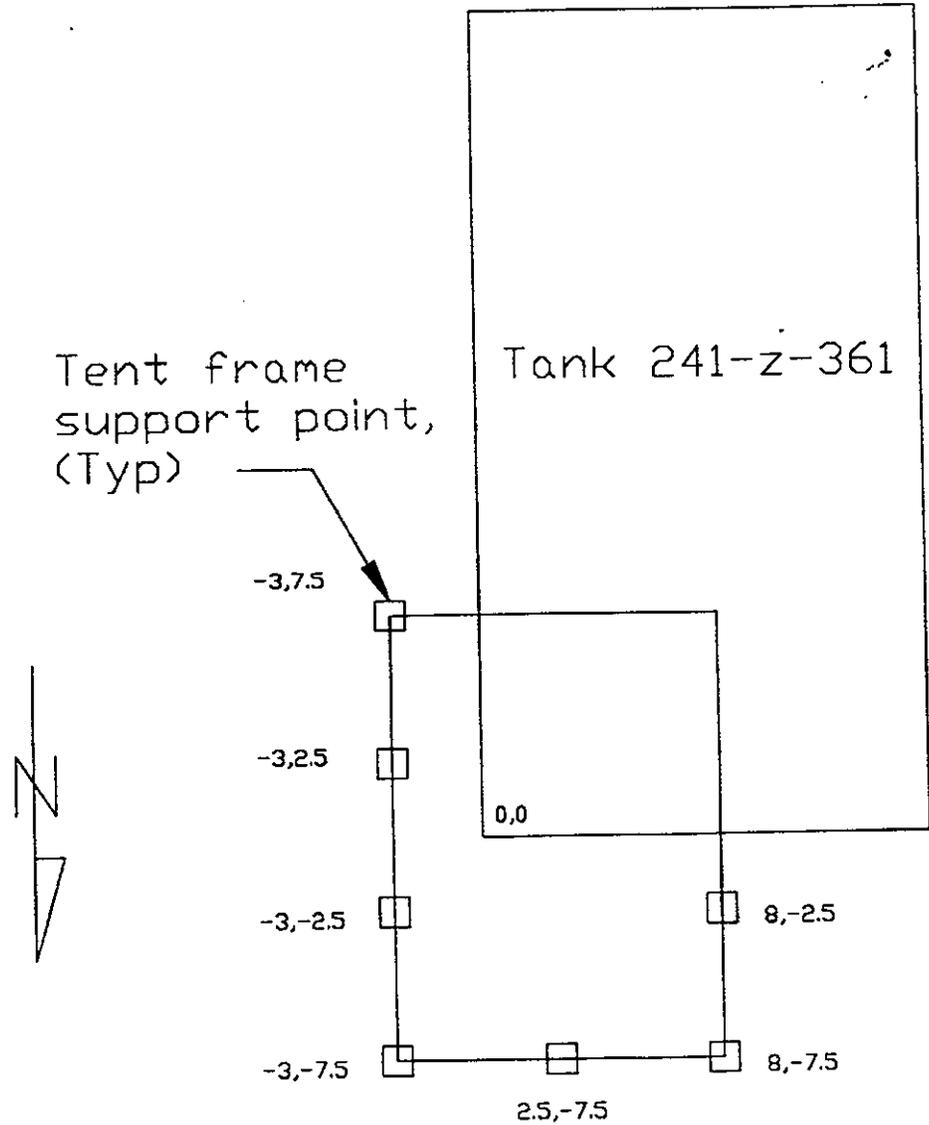


Fig. 2

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 0

Page No. 6 of 90

Client: Babcock & Wilcox Hanford Company

WONo. TM22

Subject: 241-z-361 Underground Tank

Date: 11/17/88

By: DAVIDS MESSINGER PE

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 1/21/90

By: L.J. JULYK

Location: PEP 200 W Area - Hanford Site, Richland, Washington

Revised: _____

By: _____

12,000 lb ARMORED CAR POSITIONS

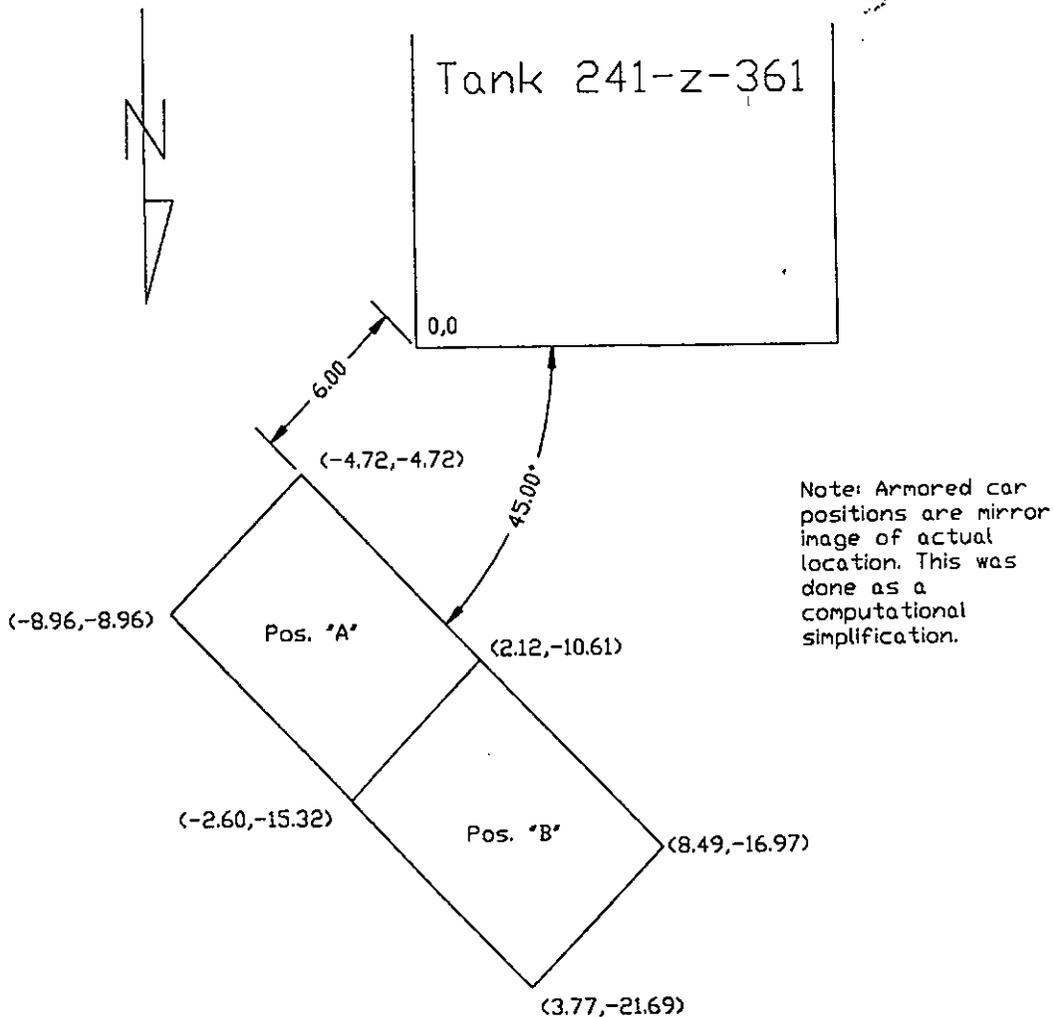


Fig. 3

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 0

Page No. 7 of 90

Client: Babcock & Wilcox Hanford Company

WO No. TM22

Subject: 241-Z-381 Underground Tank

Date: 11/17/98

By: DAVID S. MESSINGER, PE

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 4/24/99

By: L.J. JULYK

Location: FFP 200 W Area - Hanford Site, Richland, Washington

Revised: _____

By: _____

EVALUATE CONCENTRATED LOADS BASED ON "BOUSSINESQ" EQUATION TO DETERMINE STRESS ON A VERTICAL PLANE "P" AT A POINT (r,y,z) along the wall face using "Poisson's ratio".

GENERAL LATERAL PRESSURE FUNCTION

$$F := 0 \quad z := 0, 1..20 \quad y := 0, 1..15 \quad L := 15 \quad \nu := 0.27 \quad Q_s := 9.46 \quad K := \frac{\nu}{1-\nu}$$

$$p(Q,r,z,y) := \frac{Q}{2\pi} \left[\frac{3 \cdot (r^2 + y^2) \cdot z}{(r^2 + y^2 + z^2)^{\frac{5}{2}}} - \frac{1 - 2 \cdot \nu}{\sqrt{r^2 + y^2 + z^2} \cdot (\sqrt{r^2 + y^2 + z^2} + z)} \right] \frac{r}{\sqrt{r^2 + y^2}} \quad \text{Ref 1, eq. 11-17a, fig. 11-16}$$

DISCRETE LEFT END REACTION FUNCTION

$$R(y,z,F) := F_{y,z} \frac{(L-y)^2}{L^3} (3y + (L-y))$$

LOAD CASE 1: TENT FRAME LOAD PLUS 600 LB AT STEPOFF PAD (1) AND 800 LB AT STEPOFF PAD (2)

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := \left(\begin{array}{l} p(80, 2.5, 22 - z, y - 3) + p(80, 2.5, 22 - z, y - 8) + p(80, 7.5, 22 - z, y - 3) \dots \\ + p(80, 7.5, 22 - z, y - 2.5) + p(80, 7.5, 22 - z, y - 8) + p(600, 4.0, 22 - z, y - 5.5) \dots \\ + p(200, 8.0, 22 - z, y - 7.5) + p(600, 8.0, 22 - z, y - 1) \end{array} \right) \quad \text{FILLING POINT LOAD ARRAY}$$

P1 := F

LEFT END REACTION VECTOR

LEFT END FIXED MOMENT VECTOR

GENERAL SHEAR ARRAY

$$RL_z := \sum_{y=0}^L R(y,z,P1)$$

$$ML_z := \sum_{y=0}^L P1_{y,z} \cdot y \cdot \frac{(L-y)^2}{L^2}$$

$$V_{y,z} := RL_z - \sum_{y=0}^y P1_{y,z}$$

GENERAL MOMENT ARRAY

SPECIFIC MOMENT ARRAY

SPECIFIC SHEAR ARRAY

$$M_{y,z} := ML_z - \sum_{y=0}^y P1_{y,z} \cdot y - V_{y,z} \cdot y$$

$$MI := M$$

$$VI := V$$

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-G-01

Revision: 0

Page No. 8 of 90

Client: Babcock & Wilcox Hanford Company

WO/No. TM22

Subject: 241-Z-361 Underground Tank

Date: 11/17/98

By: DAVID S. MESSINGER, PE

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 4/24/99

By: L.J. JULYK

Location: PFP 200 W Area - Hanford Site, Richland, Washington

Revised:

By:

LOAD CASE 2: Pressure and total force exerted on tank endwall due to 5 point loads of 80 lb from tent frame and one 732 lb concentrated load from cart at pad (1) and no load at pad (2). Load center for pad (1) is 4 ft. from tank end wall.

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := \left(\begin{array}{l} p(80, 2.5, 22 - z, y - 3) + p(80, 2.5, 22 - z, y - 8) + p(80, 7.5, 22 - z, y - 3) \dots \\ + p(80, 7.5, 22 - z, y - 2.5) + p(80, 7.5, 22 - z, y - 8) + p(732, 4.0, 22 - z, y - 5.5) \end{array} \right) \quad \text{FILLING POINT LOAD ARRAY}$$

$P2 := F$

LEFT END REACTION VECTOR

$$RL_z := \sum_{y=0}^L R(y, z, P2)$$

LEFT END FIXED MOMENT VECTOR

$$ML_z := \sum_{y=0}^L P2_{y,z} \cdot y \cdot \frac{(L-y)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_z - \sum_{y=0}^y P2_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} := ML_z - \sum_{y=0}^y P2_{y,z} \cdot y - V_{y,z} \cdot y$$

SPECIFIC MOMENT ARRAY

$$M2 := M$$

SPECIFIC SHEAR ARRAY

$$V2 := V$$

LOAD CASE 3: Pressure and total force exerted on tank endwall due to 5 point loads of 80 lb from tent frame and one 732 lb concentrated load from cart at pad (1) and no load at pad (2). Load center for pad (1) is 5 ft. from tank end wall.

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := \left(\begin{array}{l} p(80, 2.5, 22 - z, y - 3) + p(80, 2.5, 22 - z, y - 8) + p(80, 7.5, 22 - z, y - 3) \dots \\ + p(80, 7.5, 22 - z, y - 2.5) + p(80, 7.5, 22 - z, y - 8) + p(732, 5.0, 22 - z, y - 5.5) \end{array} \right) \quad \text{FILLING POINT LOAD ARRAY}$$

$P3 := F$

LEFT END REACTION VECTOR

$$RL_z := \sum_{y=0}^L R(y, z, P3)$$

LEFT END FIXED MOMENT VECTOR

$$ML_z := \sum_{y=0}^L P3_{y,z} \cdot y \cdot \frac{(L-y)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_z - \sum_{y=0}^y P3_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} := ML_z - \sum_{y=0}^y P3_{y,z} \cdot y - V_{y,z} \cdot y$$

SPECIFIC MOMENT ARRAY

$$M3 := M$$

SPECIFIC SHEAR ARRAY

$$V3 = V$$

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 0

Page No. 9 of 90

Client: Babcock & Wilcox Hanford Company

WCN No. TM22

Subject: 241-Z-381 Underground Tank

Date: 11/17/98

By: DAVID S. MESSINGER, PE

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: [Signature]

By: L.J. JURYK

Location: PPF 200 W Area - Hanford Site, Richland, Washington

Revised: _____

By: _____

LOAD CASE 4: Pressure and total force exerted on tank endwall due to 5 point loads of 80 lb from tent frame and one 200 lb concentrated load from HPT at pad (1) and cart load of 732 lb at pad (2). Load center for pad (1) is 4 ft. from tank end wall.

SPECIFIC PRESSURE ARRAY FOR WALL FACE

FILLING POINT LOAD ARRAY

$$F_{y,z} := \begin{pmatrix} p(80, 2.5, 22 - z, y - 3) + p(80, 2.5, 22 - z, y - 8) + p(80, 7.5, 22 - z, y - 3) \dots \\ + p(80, 7.5, 22 - z, y - 2.5) + p(80, 7.5, 22 - z, y - 8) + p(200, 4, 22 - z, y - 5.5) \dots \\ + p(732, 8.0, 22 - z, y - 1) \end{pmatrix}$$

P4 := F

LEFT END REACTION VECTOR

LEFT END FIXED MOMENT VECTOR

GENERAL SHEAR ARRAY

$$RL_z := \sum_{y=0}^L R(y, z, P4)$$

$$ML_z := \sum_{y=0}^L P4_{y,z} \cdot y \cdot \frac{(L-y)^2}{L^2}$$

$$V_{y,z} := RL_z - \sum_{y=0}^y P4_{y,z}$$

GENERAL MOMENT ARRAY

SPECIFIC MOMENT ARRAY

SPECIFIC SHEAR ARRAY

$$M_{y,z} := ML_z - \sum_{y=0}^y P4_{y,z} \cdot y - V_{y,z} \cdot y$$

M4 := M

V4 := V

LOAD CASE 5: A 12,000 lb armored car located as shown in fig. 3 at position "A".

SPECIFIC PRESSURE ARRAY FOR WALL FACE

FILLING POINT LOAD ARRAY

$$F_{y,z} := \begin{pmatrix} p(3000, 8.96, 22 - z, y - 8.96) + p(3000, 4.24, 22 - z, y - (-4.24)) \dots \\ + p(3000, 10.6, 22 - z, y - 2.12) + p(3000, 15.32, 22 - z, y - -2.60) \end{pmatrix}$$

P5 := F

LEFT END REACTION VECTOR

LEFT END FIXED MOMENT VECTOR

GENERAL SHEAR ARRAY

$$RL_z := \sum_{y=0}^L R(y, z, P5)$$

$$ML_z := \sum_{y=0}^L P5_{y,z} \cdot y \cdot \frac{(L-y)^2}{L^2}$$

$$V_{y,z} := RL_z - \sum_{y=0}^y P5_{y,z}$$

GENERAL MOMENT ARRAY

SPECIFIC MOMENT ARRAY

SPECIFIC SHEAR ARRAY

$$M_{y,z} = ML_z - \sum_{y=0}^y P5_{y,z} \cdot y - V_{y,z} \cdot y$$

M5 := M

V5 := V

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-G-01

Revision: 0

Page No. 10 of 92

Client: Babcock & Wilcox Hanford Company

WORNo. TM22

Subject: 241-Z-341 Underground Tank

Date: 11/17/88

By: DAVID S. MESSINGER, PE

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: [Signature]

By: L.J. JULYK

Location: PPF 209 W Area - Hanford Site, Richland, Washington

Revised: _____

By: _____

LOAD CASE 6: A 12,000 lb armored car located as shown in fig. 3 at position "B".

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := \left[\begin{array}{l} p(3000, 15.32, 22 - z, y - - 2.60) + p(3000, 10.60, 22 - z, y - (2.12)) \dots \\ + p(3000, 16.96, 22 - z, y - 8.48) + p(3000, 21.68, 22 - z, y - 3.76) \end{array} \right]$$

FILLING POINT LOAD ARRAY

$$P6 := F$$

LEFT END REACTION VECTOR

$$RL_z := \sum_{y=0}^L R(y, z, P6)$$

LEFT END FIXED MOMENT VECTOR

$$ML_z := \sum_{y=0}^L P6_{y,z} \cdot y \cdot \frac{(L-y)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_z - \sum_{y=0}^y P6_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} := ML_z - \sum_{y=0}^y P6_{y,z} \cdot y - V_{y,z} \cdot y$$

SPECIFIC MOMENT ARRAY

$$M6 := M$$

SPECIFIC SHEAR ARRAY

$$V6 := V$$

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-G-01

Revision: 0

Page No. 11 of 90

Client: Babcock & Wilcox Hanford Company

WQNo. TM22

Subject: 241-Z-381 Underground Tank

Date: 11/17/98

By: DAVID S. MESSINGER, PE

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 1/29/99

By: L.J. JULYK

Location: PPF 200 W Area - Hanford Site, Richland, Washington

Revised: _____

By: _____

LOAD CASE 7: December 1992 precipitation load primarily made up of 21 inches of snow fall accumulation. Water equivalent precipitation was 1.82 inches of water with negligible evaporation loss. Equivalent ground load is 9.46 psf. Use a lower at rest soil factor of 0.70 for an estimated uniform wall load of 6.62 psf.

SPECIFIC PRESSURE ARRAY FOR WALL FACE

FILLING POINT LOAD ARRAY

$$F_{y,z} := K \cdot Q_s$$

$$P7 := F$$

LEFT END REACTION VECTOR

$$RL_z := \sum_{y=0}^L R(y,z,P7)$$

LEFT END FIXED MOMENT VECTOR

$$ML_z := \sum_{y=0}^L P7_{y,z} \cdot y \cdot \frac{(L-y)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_z - \sum_{y=0}^y P7_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} := ML_z - \sum_{y=0}^y P7_{y,z} \cdot y - V_{y,z} \cdot y$$

SPECIFIC MOMENT ARRAY

$$M7 := M$$

SPECIFIC SHEAR ARRAY

$$V7 := V$$

MAXIMUM PRESSURES, SHEARS AND MOMENTS FOR LOAD CASES 1 THROUGH 4

max(P1) = 1.63	max(P2) = 1.78	max(P3) = 1.25	max(P4) = 0.85
min(P1) = 0.01	min(P2) = 0.01	min(P3) = 0.01	min(P4) = 0.01
max(V1) = 9.13	max(V2) = 8.95	max(V3) = 6.89	max(V4) = 5.33
min(V1) = -6.03	min(V2) = -6.14	min(V3) = -5.08	min(V1) = -6.03
max(M1) = 24.25	max(M2) = 24.66	max(M3) = 18.73	max(M4) = 13.68
min(M1) = -12.23	min(M2) = -12.92	min(M3) = -9.67	min(M4) = -6.67

Fluor Daniel Northwest, inc.

EVALUATION ANALYSIS

Calc No. TM22-G-01

Revision: 0

Page No. 12 of 30

Client: Babcock & Wilcox Hanford Company

WO/No. TM22

Subject: 241-Z-381 Underground Tank

Date: 11/17/88

By: DAVID S. MESSINGER, PE

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 8/29/98

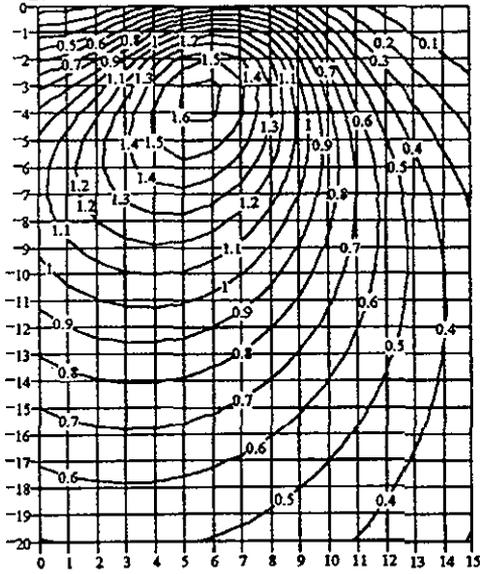
By: L. J. JULYK

Location: PPF 200 W Area - Hanford Site, Richland, Washington

Revised: _____

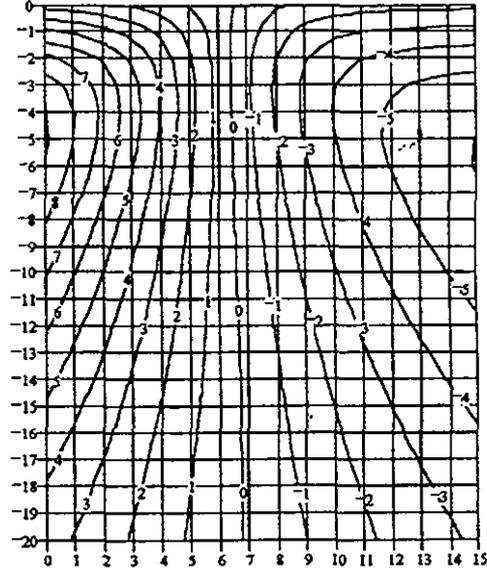
By: _____

ENDWALL PRESSURE FROM LOAD CASE 1 - PSF



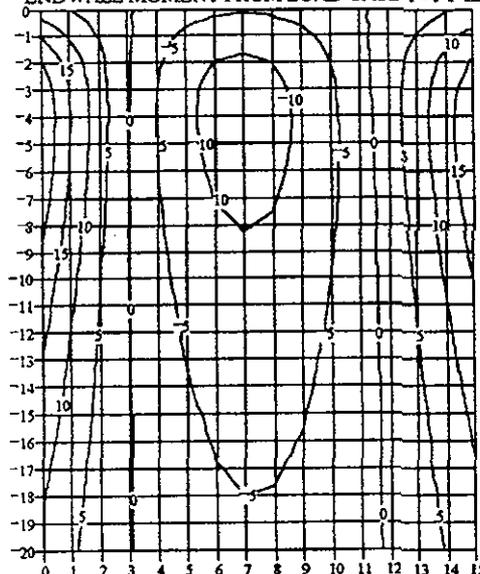
P1

ENDWALL SHEAR FROM LOAD CASE 1 - PSF



V1

ENDWALL MOMENT FROM LOAD CASE 1 - FT-LB



M1

max(P1) = 1.63

min(P1) = 0.01

max(V1) = 9.13

min(V1) = -6.03

max(M1) = 24.25

min(M1) = -12.23

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 0

Page No. 14 of 70

Client: Babcock & Wilcox Hanford Company

WONo. TM22

Subject: 241-Z-341 Underground Tank

Date: 11/17/98

By: DAVID S. MESSINGER, PE

Lateral Load on Tank Wall from Concentrated Load at Grade

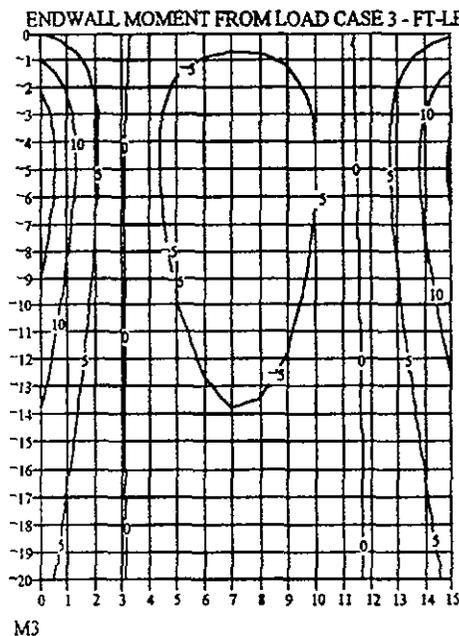
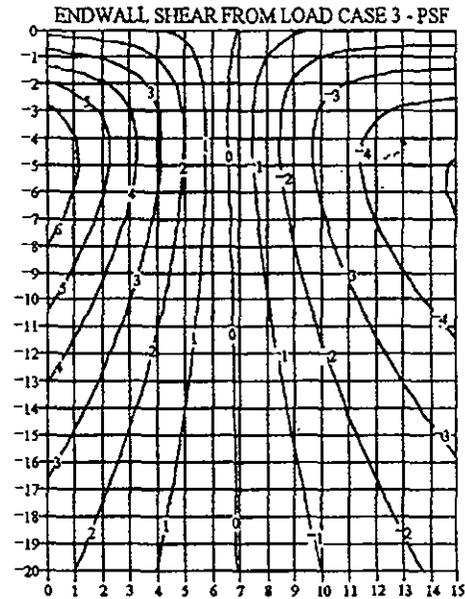
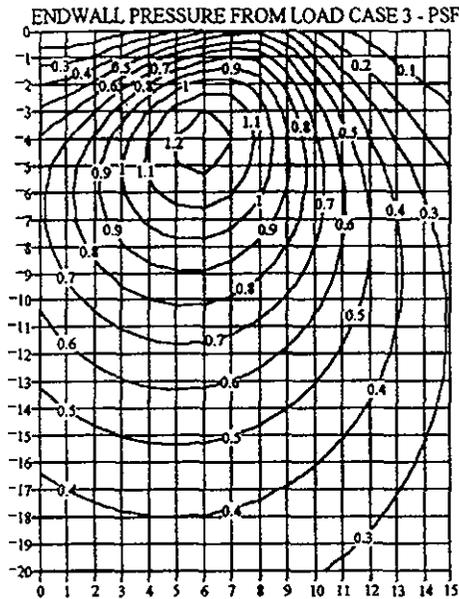
Checked: 11/22/98

By: L.J. JULYK

Location: PFP 200 W Area - Hanford Site, Richland, Washington

Revised: _____

By: _____



max(P3) = 1.25

min(P3) = 0.01

max(V3) = 6.89

min(V3) = -5.08

max(M3) = 18.73

min(M3) = -9.67

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revisions: 0

Page No. 16 of 70

Client: Babcock & Wilcox Hartford Company

Subject: 241-Z-381 Underground Tank

Lateral Load on Tank Wall from Concentrated Load at Grade

Location: PPF 200 W Area - Hanford SRA, Richland, Washington

W/No. TM22

Date: 11/17/99

Checked: [Signature]

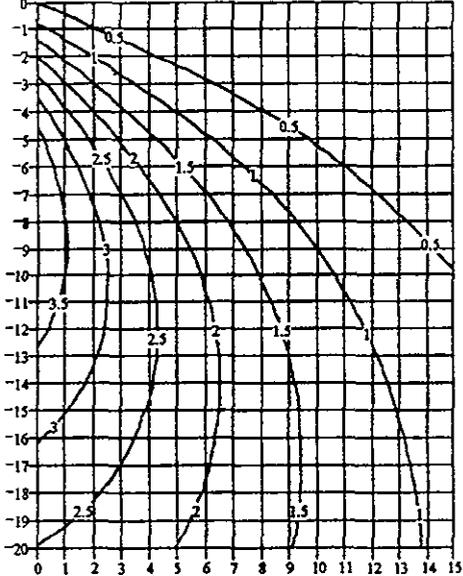
Revised: _____

By: DAVID S. MESSINGER, PE [Signature]

By: L.J. JULYK [Signature]

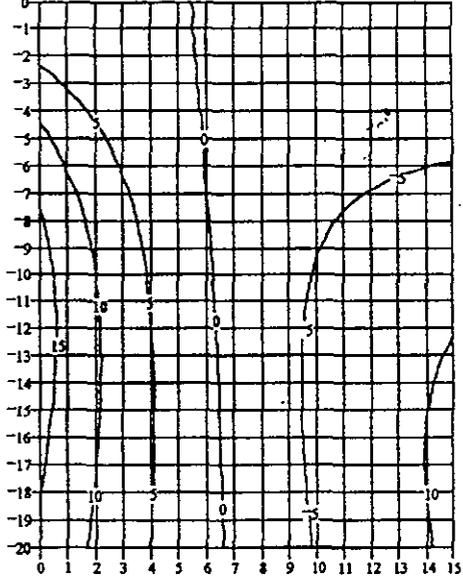
By: _____

ENDWALL PRESSURE FROM LOAD CASE 5 - PSF



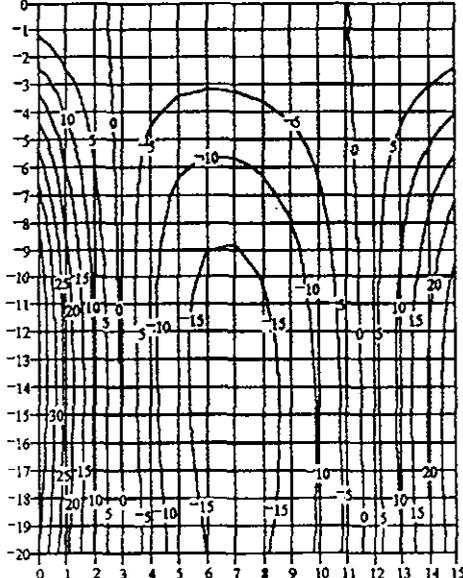
P5

ENDWALL SHEAR FROM LOAD CASE 5 - PSF



V5

ENDWALL MOMENT FROM LOAD CASE 5 - FT-LB



M5

max(P5) = 3.95
min(P5) = 0.01

max(M5) = 40.04
min(M5) = -17.7

max(V5) = 16.96
min(V5) = -10.86

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-0-01

Revision: 0

Page No. 17 of 20

Client: Babcock & Wilcox Hanford Company

WO/No. TM22

Subject: 241-2-361 Underground Tank

Date: 11/17/98

Lateral Load on Tank Wall from Concentrated Load at Grade

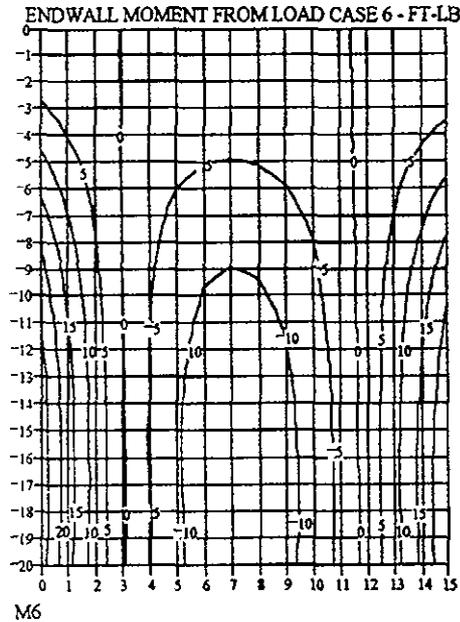
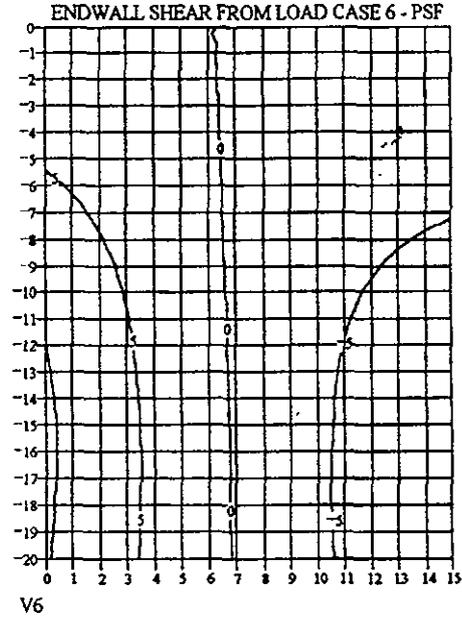
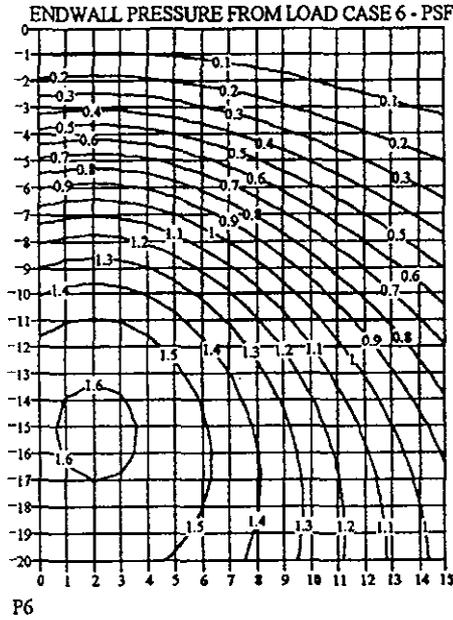
Checked: 11/24/98

By: DAVID S. MESSINGER, PE

Location: PPF 200 W Area - Hanford Site, Richland, Washington

Revised: _____

By: L.J. JULYK



max(P6) = 1.62
 min(P6) = 0.01
 max(M6) = 27.54
 min(M6) = -13.38
 max(V6) = 10.64
 min(V6) = -9.71

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 0

Page No. 13 of 20

Client: Babcock & Wilcox Hartford Company

WO/No. TM22

Subject: 241-Z-381 Underground Tank

Date: 11/17/98

By: DAVID S. MESSINGER, PE

Lateral Load on Tank Wall from Concentrated Load at Grade

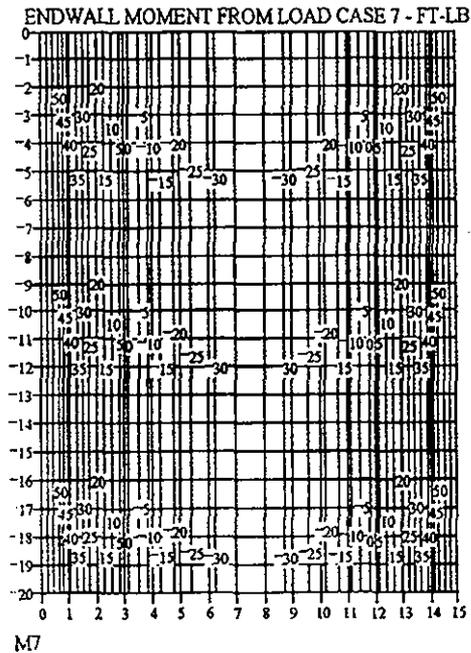
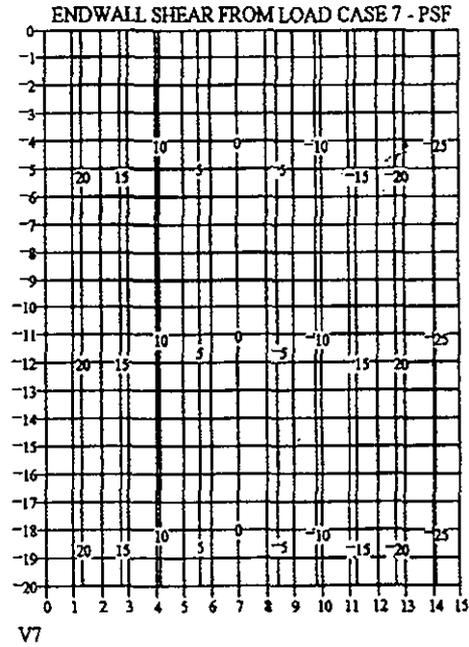
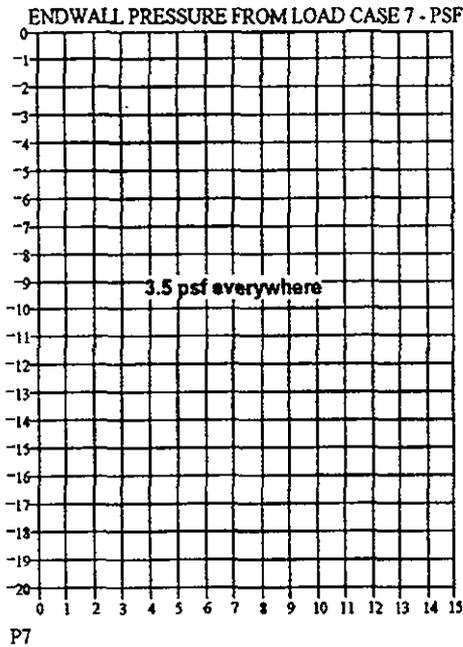
Checked: 4/24/99

By: L.J. JULYK

Location: PFP 200 W Area - Hanford Site, Richland, Washington

Revised: _____

By: _____



max(P7) = 3.5
 min(P7) = 3.5
 max(M7) = 65.31
 min(M7) = -32.66
 max(V7) = 24.49
 min(V7) = -27.99

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-G-01

Revision: 0

Page No. 17 of 22

Client: Babcock & Wilcox Hanford Company

Subject: 241-Z-381 Underground Tank

Lateral Load on Tank Wall from Concentrated Load at Grade

Location: PPF 200 W Area - Hanford Site, Richland, Washington

WONo. TM22

Date: 11/17/98

Checked: 1/24/02

Revised: _____

By: DAVID S. MESSINGER, PE

By: L.J. JULYK

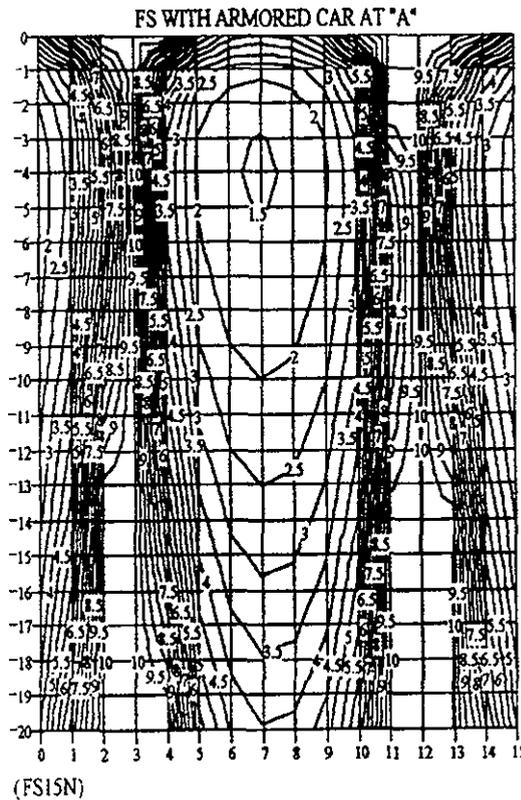
By: _____

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 1 VS MAXIMUM MOMENTS PRODUCED BY THE ARMORED CAR LOADING IN POSITION "A". FACTORS OF SAFETY > 10 HAVE BEEN NORMALIZED TO 10 TO REDUCE PLOT CONGESTION.

$$FS15_{y,z} := \frac{\text{if}(M1_{y,z} > 0, \max(M5), \min(M5))}{M1_{y,z}}$$

$$FS15N_{y,z} := \text{if}(FS15_{y,z} < 10, FS15_{y,z}, 10)$$

$$\min(FS15) = 1.45 \max(FS15) = 264.11$$

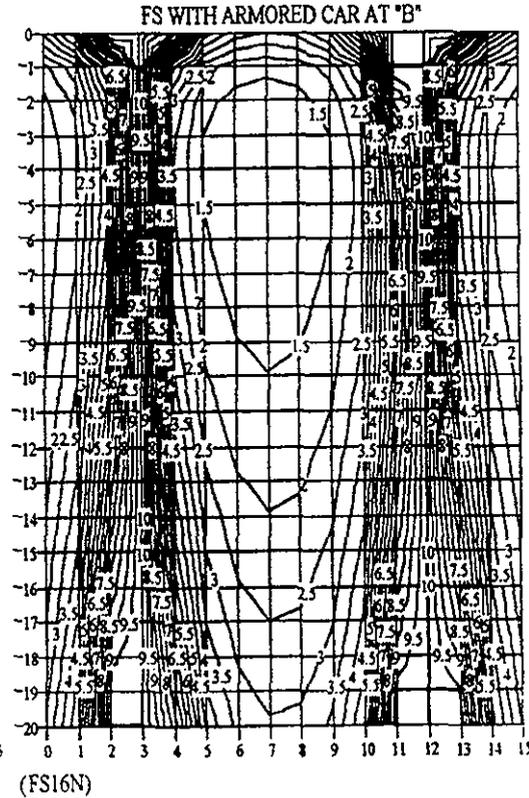


CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 1 VS MAXIMUM MOMENTS PRODUCED BY THE ARMORED CAR LOADING IN POSITION "B". FACTORS OF SAFETY > 10 HAVE BEEN NORMALIZED TO 10 TO REDUCE PLOT CONGESTION.

$$FS16_{y,z} := \frac{\text{if}(M1_{y,z} > 0, \max(M6), \min(M6))}{M1_{y,z}}$$

$$FS16N_{y,z} := \text{if}(FS16_{y,z} < 10, FS16_{y,z}, 10)$$

$$\min(FS16) = 1.09 \max(FS16) = 181.65$$



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-91

Revision: 0

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Client: Babcock & Wilcox Hanford Company

WONo. TM22

Subject: 241-Z-381 Underground Tank

Date: 11/17/88

By: DAVID S. MESSINGER, PE

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 11/24/88

By: L.J. JULYK

Location: PPF 200 W Area - Hanford Site, Richland, Washington

Revised: _____

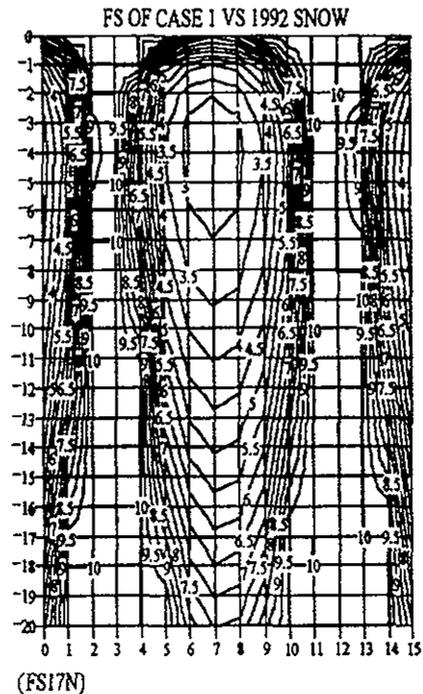
By: _____

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 1 VS MAXIMUM MOMENTS PRODUCED BY THE 1992 SNOW LOADING OF 6.62 PSF ON THE WALL FACE. FACTORS OF SAFETY > 10 HAVE BEEN NORMALIZED TO 10 TO REDUCE PLOT CONGESTION.

$$FS17_{y,z} := \frac{\text{if}(M1_{y,z} > 0, \max(M7), \min(M7))}{M1_{y,z}}$$

$$FS17N_{y,z} := \text{if}(FS17_{y,z} < 10, FS17_{y,z}, 10)$$

$$\min(FS17) = 2.67 \quad \max(FS17) = 430.79$$



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-G-01

Revision: 0

Page No. 21 of 90

Client: Babcock & Wilcox Hanford Company

WO/No. TM22

Subject: 241-Z-341 Underground Tank

Date: 11/17/99

By: DAVID S. MESSINGER, PE

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: [Signature]

By: L.J. JULYK

Location: PEP 200 W Area - Hanford Site, Richland, Washington

Revised: _____

By: _____

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 2 VS MAXIMUM MOMENTS PRODUCED BY THE ARMORED CAR LOADING IN POSITION "A". FACTORS OF SAFETY > 10 HAVE BEEN NORMALIZED TO 10 TO REDUCE PLOT CONGESTION.

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 2 VS MAXIMUM MOMENTS PRODUCED BY THE ARMORED CAR LOADING IN POSITION "B". FACTORS OF SAFETY > 10 HAVE BEEN NORMALIZED TO 10 TO REDUCE PLOT CONGESTION.

$$FS25_{y,z} := \frac{\text{if}(M2_{y,z} > 0, \max(M5), \min(M5))}{M2_{y,z}}$$

$$FS26_{y,z} := \frac{\text{if}(M2_{y,z} > 0, \max(M6), \min(M6))}{M2_{y,z}}$$

$$FS25N_{y,z} := \text{if}(FS25_{y,z} < 10, FS25_{y,z}, 10)$$

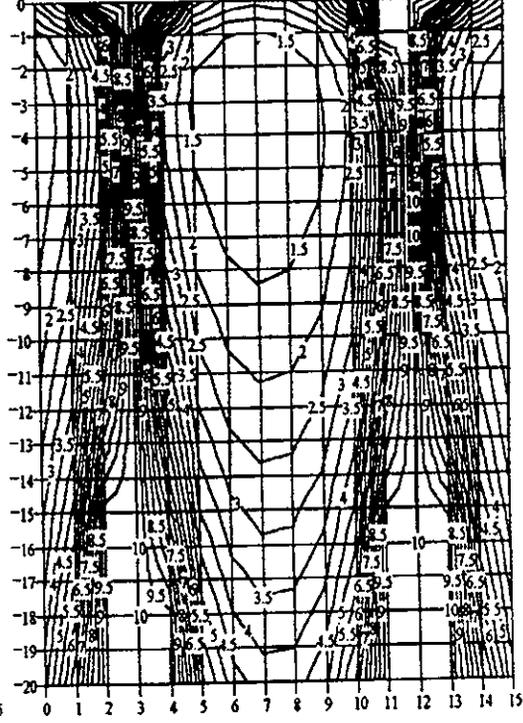
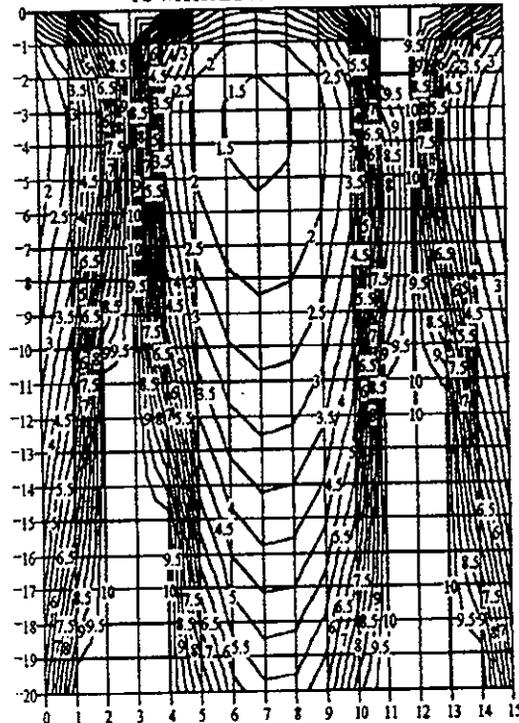
$$FS26N_{y,z} := \text{if}(FS26_{y,z} < 10, FS26_{y,z}, 10)$$

$$\min(FS25) = 1.37 \quad \max(FS25) = 224$$

$$\min(FS26) = 1.04 \quad \max(FS26) = 154.06$$

FS WITH ARMORED CAR AT "A"

FS WITH ARMORED CAR AT "B"



(FS25N)

(FS26N)

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-G-01

Revision: 0

Page No. 22 of 90

Client: Babcock & Wilcox Hanford Company

WONo. TM22

Subject: 241-Z-361 Underground Tank

Date: 11/17/88

By: DAVID S. MESSINGER, PE

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: [Signature]

By: J. JULYK

Location: PPF 200 W Area - Hanford Site, Richland, Washington

Revised: _____

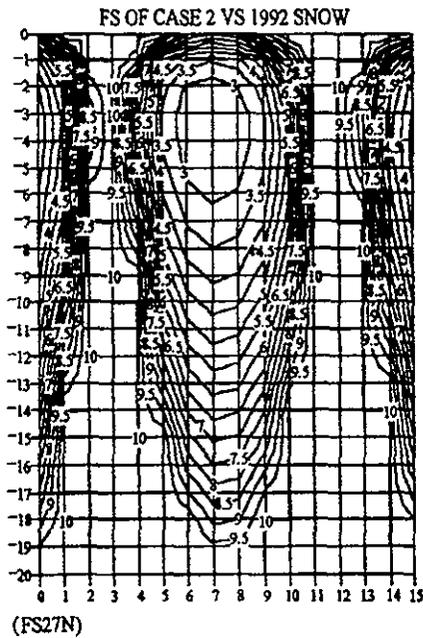
By: _____

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 2 VS MAXIMUM MOMENTS PRODUCED BY THE 1992 SNOW LOADING OF 6.62 PSF (LOAD CASE 7) ON THE WALL FACE. FACTORS OF SAFETY > 10 HAVE BEEN NORMALIZED TO 10 TO REDUCE PLOT CONGESTION.

$$FS27_{y,z} := \frac{\text{if}(M2_{y,z} > 0, \max(M7), \min(M7))}{M2_{y,z}}$$

$$FS27N_{y,z} := \text{if}(FS27_{y,z} < 10, FS27_{y,z}, 10)$$

$$\min(FS27) = 2.53 \quad \max(FS27) = 365.37$$



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 23 of 90

Client: Balboock & Wilcox Hanford Corrosion
 Subject: 241-Z-381 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WONo. TM22
 Date: 11/17/98
 Checked: U.S./JY
 Revised:

By: DAVID S. MESSINGER, PE
 By: J.J. YK
 By:

LOAD CASE 8: A 1,500 lb concentrated load located normal to the long tank wall at centerline and offset 15 feet to represent a temporary storage location.

Reset variables for new tank orientation: F:=0 z:=0,1..20 y:=0,1..28 L:=20

DISCRETE LEFT END REACTION FUNCTION

$$R(y,z,F) := F \frac{(L-z)^2}{L^3} (3z + (L-z))$$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := (p(1500, 15, 22 - z, y - 14))$$

FILLING POINT LOAD ARRAY

$$P8 := F$$

LEFT END REACTION VECTOR

$$RL_y := \sum_{z=0}^L R(y,z,P8)$$

LEFT END FIXED MOMENT VECTOR

$$ML_y := \sum_{z=0}^L P8_{y,z} z \frac{(L-z)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_y - \sum_{z=0}^z P8_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} := ML_y - \sum_{z=0}^z P8_{y,z} z - V_{y,z} z$$

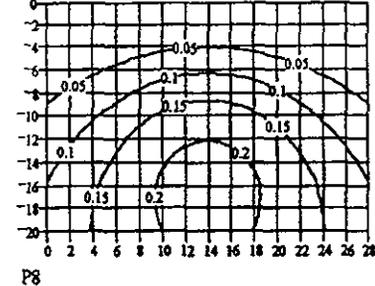
SPECIFIC MOMENT ARRAY

$$M8 := M$$

SPECIFIC SHEAR ARRAY

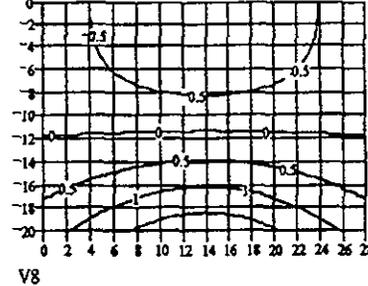
$$V8 := V$$

SIDEWALL PRESSURE FROM LOAD CASE 8 - PSF



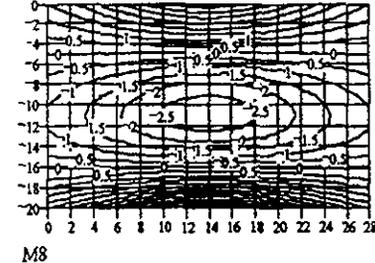
P8

SIDEWALL SHEAR FROM LOAD CASE 1 - PSF



V8

SIDEWALL MOMENT FROM LOAD CASE 1 - FT-LB



M8

$$\min(P8) = 5.69 \cdot 10^{-4}$$

$$\max(P8) = 0.22$$

$$\max(V8) = 1.84$$

$$\min(V8) = -0.93$$

$$\max(M8) = 6.01$$

$$\min(M8) = -2.79$$

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-5-01
 Revision: 0
 Page No. 24 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WCNo. TM22
 Date: 11/17/99
 Checked: 1/28/02
 Revised: _____

By: DAVID S. MESSINGER, PE
 By: L.J. JULYK
 By: _____

DSM

LOAD CASE 9: This load case is for snow load effect on the long (28') side of the tank wall. Since the tank wall load capacity is assumed to vary with depth, the bending action is assumed to be one way along the short axis. This will make this case consistent with the others cases reviewed.

Normalize the wall face pressure for snow load effect:

$$K \cdot Q_s = 3.5$$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := K \cdot Q_s$$

FILLING POINT LOAD ARRAY

$$P9 := F$$

LEFT END REACTION VECTOR

$$RL_y := \sum_{z=0}^L R(y,z,P9)$$

LEFT END FIXED MOMENT VECTOR

$$ML_y := \sum_{z=0}^L P9_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_y - \sum_{z=0}^z P9_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} := ML_y - \sum_{z=0}^z P9_{y,z} \cdot z - V_{y,z} \cdot z$$

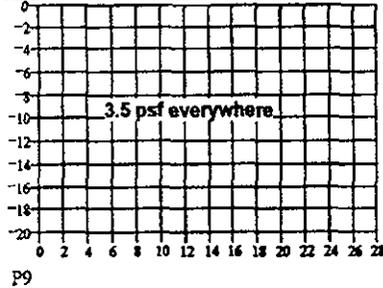
SPECIFIC MOMENT ARRAY

$$M9 := M$$

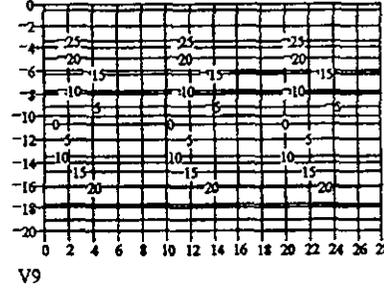
SPECIFIC SHEAR ARRAY

$$V9 := V$$

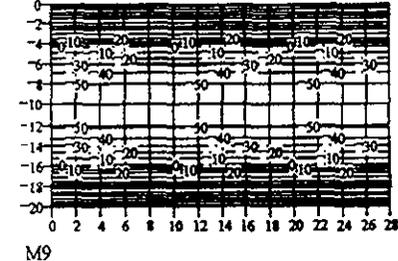
SIDEWALL PRESSURE FROM LOAD CASE 9 - PSF



SIDEWALL SHEAR FROM LOAD CASE 9 - PSF



SIDEWALL MOMENT FROM LOAD CASE 9 - FT-LB



- min(P9) = 3.5
- max(P9) = 3.5
- max(V9) = 33.24
- min(V9) = -36.74
- max(M9) = 116.34
- min(M9) = -58.61

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TW22-S-91
 Revision: 0
 Page No. 25 of 90

Client: Bebock & Wilson Hanford Company
 Subject: 241-Z-381 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PEP 290 W Area - Hanford SRA, Richland, Washington

WQNo. TW22
 Date: 11/17/88
 Checked: 1/29/90
 Revised: _____

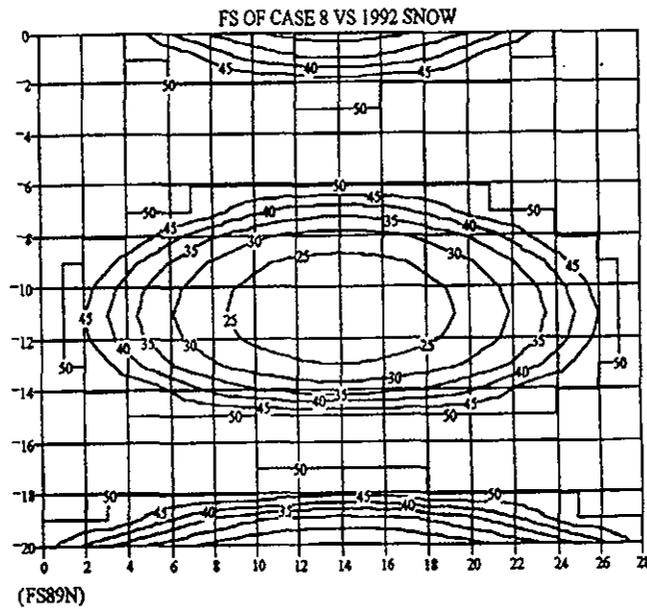
By: DAVID S. MESSINGER, PE
 By: L.J. JULYK
 By: _____

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 8 VS MAXIMUM MOMENTS PRODUCED BY THE 1992 SNOW LOADING (LOAD CASE 9) ON THE LONG WALL FACE. FACTORS OF SAFETY > 50 HAVE BEEN NORMALIZED TO 50 TO REDUCE PLOT CONGESTION.

$$FS89_{y,z} := \frac{\text{if}(M8_{y,z} > 0, \max(M9), \min(M9))}{M8_{y,z}}$$

$$FS89N_{y,z} := \text{if}(FS89_{y,z} < 50, FS89_{y,z}, 50)$$

$$\min(FS89) = 19.37 \max(FS89) = 2.69 \cdot 10^3$$



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TH22-C-01

Revision: 0

Page No. 26 of 90

Client: Babcock & Wilcox Hanford Company

WO/No. TH22

Subject: 241-Z-381 Underground Tank

Date: 11/17/98

By: DAVID S. MESSINGER, PE

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 1/24/99

By: L.J. JULYK

Location: PPF 200 W Area - Hanford Site, Richland, Washington

Revised: _____

By: _____

LOAD CASE 10: An 950 lb concentrated load located adjacent to the long tank wall at centerline and offset 0 feet to produce a 2:1 factor of safety relative to 1992, December snow load.

Reset variables for new tank orientation: $F := 0$ $z := 0, 1..20$ $y := 0, 1..28$ $L := 20$

DISCRETE LEFT END REACTION FUNCTION

$$R(y, z, F) := F_{y,z} \cdot \frac{(L-z)^2}{L^3} \cdot (3z + (L-z))$$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := (p(950, 0, 22 - z, y - 14))$$

FILLING POINT LOAD ARRAY

$$P10 := F$$

LEFT END REACTION VECTOR

$$RL_y := \sum_{z=0}^L R(y, z, P10)$$

LEFT END FIXED MOMENT VECTOR

$$ML_y := \sum_{z=0}^L P10_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_y - \sum_{z=0}^z P10_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} = ML_y - \sum_{z=0}^z P10_{y,z} \cdot z - V_{y,z} \cdot z$$

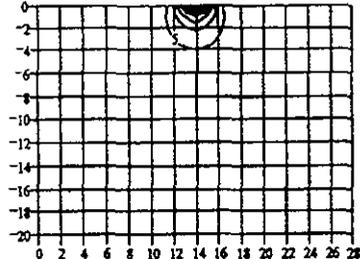
SPECIFIC MOMENT ARRAY

$$M10 := M$$

SPECIFIC SHEAR ARRAY

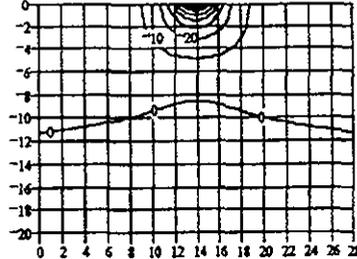
$$V10 := V$$

SIDWALL PRESSURE FROM LOAD CASE 10 - PSF



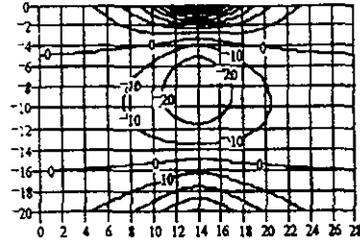
P10

SIDWALL SHEAR FROM LOAD CASE 10 - PSF



V10

SIDWALL MOMENT FROM LOAD CASE 10-FT-LB



M10

- min(P10) = 0
- max(P10) = 41.94
- max(V10) = 9.12
- min(V10) = -91.28
- max(M10) = 102.28
- min(M10) = -29.23

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 0

Page No. 28 of 90

Client: Babcock & Wilcox Hanford Company

WONo. TM22

Subject: 241-Z-341 Underground Tank

Date: 11/17/98

By: DAVID S. MESSINGER, PE

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 1/24/00

By: L. J. JULYK

Location: PPF 200 W Area - Hanford Site, Richland, Washington

Revised: _____

By: _____

LOAD CASE 11: An 2,100 lb concentrated load located normal to the long tank wall at centerline and offset 5 feet to produce a 2:1 factor of safety relative to 1992, December snow load.

Reset variables for new tank orientation: F = 0 z = 0, 1, 20 y = 0, 1, 28 L = 20

DISCRETE LEFT END REACTION FUNCTION

$$R(y, z, F) := F_{y,z} \frac{(L-z)^2}{L^3} (3z + (L-z))$$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := (p(2100, 5, 22 - z, y - 14))$$

FILLING POINT LOAD ARRAY

$$P11 := F$$

LEFT END REACTION VECTOR

$$RL_y := \sum_{z=0}^L R(y, z, P11)$$

LEFT END FIXED MOMENT VECTOR

$$ML_y := \sum_{z=0}^L P11_{y,z} \frac{(L-z)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_y - \sum_{z=0}^z P11_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} := ML_y - \sum_{z=0}^z P11_{y,z} \cdot z - V_{y,z} \cdot z$$

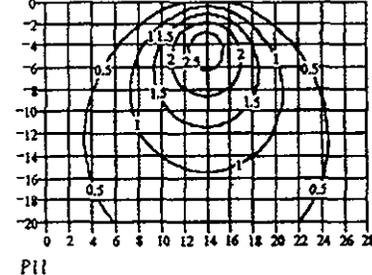
SPECIFIC MOMENT ARRAY

$$M11 := M$$

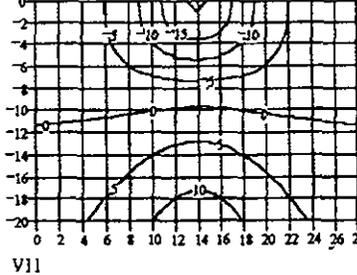
SPECIFIC SHEAR ARRAY

$$V11 := V$$

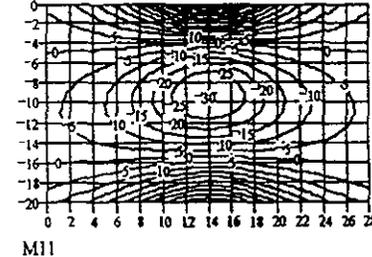
SIDEWALL PRESSURE FROM LOAD CASE 11-PSF



SIDEWALL SHEAR FROM LOAD CASE 11-PSF



SIDEWALL MOMENT FROM LOAD CASE 11-FT-LB



- min(P11) = 0
- max(P11) = 2.76
- max(V11) = 12.23
- min(V11) = -20.6
- max(M11) = 66.99
- min(M11) = -30.43

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-41

Revision: 0

Page No. 29 of 90 *DSH*

Client: Babcock & Wilcox Hartford Company

WONo. TM22

Subject: 241-Z-281 Underground Tank

Date: 11/17/88

By: DAVID S. MESSINGER, PE

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 4/24/92

By: L.J. JULYK *LJ*

Location: PPF 200 W Area - Hanford Site, Richland, Washington

Revised: _____

By: _____

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 11 VS MAXIMUM MOMENTS PRODUCED BY THE 1992 SNOW LOADING (LOAD CASE 9) ON THE LONG WALL FACE. FACTORS OF SAFETY > 5 HAVE BEEN NORMALIZED TO 5 TO REDUCE PLOT CONGESTION.

$$FS_{119}_{y,z} := \frac{\text{if}(M_{11}_{y,z} > 0, \max(M_9), \min(M_9))}{M_{11}_{y,z}}$$

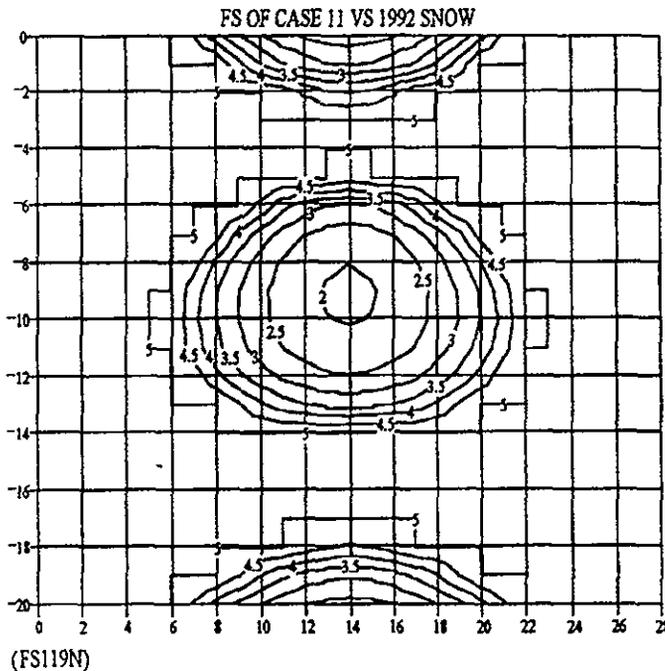
$$FS_{119N}_{y,z} := \text{if}(FS_{119}_{y,z} < 5, FS_{119}_{y,z}, 5)$$

$$\min(FS_{119}) = 1.74 \quad \max(FS_{119}) = 4.42 \cdot 10^3$$

Factors of Safety at one ft. intervals along vertical centerline.

-z FS119_{14,20-z}

0	1.74
-1	2.47
-2	4.07
-3	9.43
-4	45.54
-5	4.82
-6	2.88
-7	2.26
-8	2
-9	1.93
-10	1.97
-11	2.15
-12	2.53
-13	3.3
-14	5.3
-15	18.21
-16	20.53
-17	7.51
-18	4.44
-19	3.09
-20	2.33



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 0

Page No. 30 of 90

Client: Babcock & Wilcox Hartford Company

WONo. TM22

Subject: 241-Z-381 Underground Tank

Date: 11/17/98

By: DAVID S. MESSINGER, PE

Location: Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 1/24/99

By: L.J. JULYK

Location: PPF 200 W Area - Hartford Site, Richland, Washington

Revised:

By:

LOAD CASE 12: An 6,100 lb concentrated load located normal to the long tank wall at centerline and offset 10 feet to produce a 2:1 factor of safety relative to 1992, December snow load.

Reset variables for new tank orientation:

$$F := 0 \quad z := 0, 1, 20 \quad y := 0, 1, 28 \quad L := 20$$

DISCRETE LEFT END REACTION FUNCTION

$$R(y, z, F) := F \cdot \frac{(L - z)^2}{L^3} \cdot (3z + (L - z))$$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := (p(6100, 10, 22 - z, y - 14))$$

FILLING POINT LOAD ARRAY

$$P12 := F$$

LEFT END REACTION VECTOR

$$RL_y := \sum_{z=0}^L R(y, z, P12)$$

LEFT END FIXED MOMENT VECTOR

$$ML_y := \sum_{z=0}^L P12_{y,z} \cdot z \cdot \frac{(L - z)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_y - \sum_{z=0}^z P12_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} := ML_y - \sum_{z=0}^z P12_{y,z} \cdot z^2 - V_{y,z} \cdot z$$

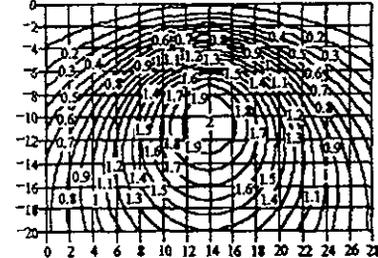
SPECIFIC MOMENT ARRAY

$$M12 := M$$

SPECIFIC SHEAR ARRAY

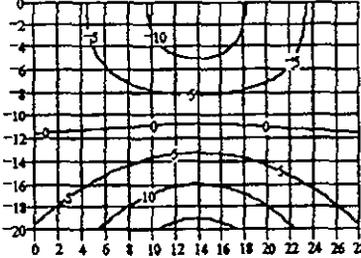
$$V12 := V$$

SIDEWALL PRESSURE FROM LOAD CASE 12-PSF



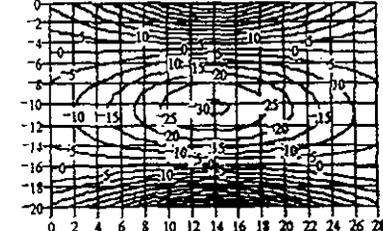
P12

SIDEWALL SHEAR FROM LOAD CASE 12-PSF



V12

SIDEWALL MOMENT FROM LOAD CASE 12-FT-LB



M12

$$\min(P12) = 0.01$$

$$\max(P12) = 2$$

$$\max(V12) = 16.47$$

$$\min(V12) = -12.6$$

$$\max(M12) = 59.08$$

$$\min(M12) = -30.7$$

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 31 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-541 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PEP 200 W Area - Hanford Site, Richland, Washington

WONo. TM22
 Date: 11/17/99
 Checked: [Signature]
 Revised: _____

By: DAVID S. MESSINGER, PE
 By: L. J. JELLYK
 By: _____

LOAD CASE 13: An 15,800 lb concentrated load located normal to the long tank wall at centerline and offset 15 feet to produce a 2:1 factor of safety relative to 1992, December snow load.

Reset variables for new tank orientation:

DISCRETE LEFT END REACTION FUNCTION $F := 0 \quad z := 0, 1, 20 \quad y := 0, 1, 28 \quad L := 20$

$$R(y, z, F) := F \cdot \frac{(L - z)^2}{L^3} \cdot (3 \cdot z + (L - z))$$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := (p(15800, 15, 22 - z, y - 14))$$

FILLING POINT LOAD ARRAY

$$P13 := F$$

LEFT END REACTION VECTOR

$$RL_y := \sum_{z=0}^L R(y, z, P13)$$

LEFT END FIXED MOMENT VECTOR

$$ML_y := \sum_{z=0}^L P13_{y,z} \cdot z \cdot \frac{(L - z)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_y - \sum_{z=0}^z P13_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} := ML_y - \sum_{z=0}^z P13_{y,z} \cdot z - V_{y,z}$$

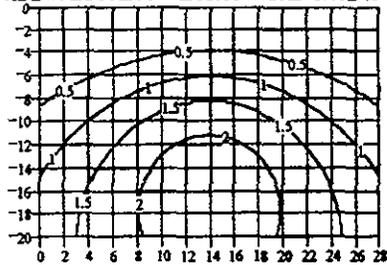
SPECIFIC MOMENT ARRAY

$$M13 := M$$

SPECIFIC SHEAR ARRAY

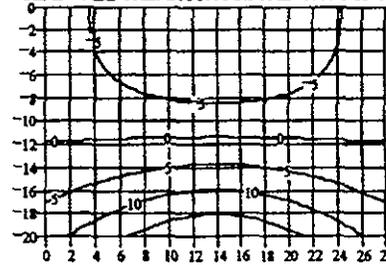
$$V13 := V$$

SIDEWALL PRESSURE FROM LOAD CASE 13-PSF



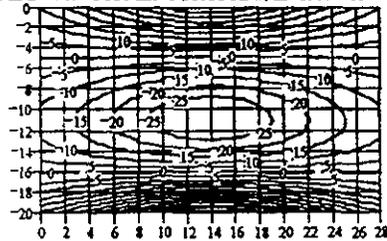
P13

SIDEWALL SHEAR FROM LOAD CASE 13-PSF



V13

SIDEWALL MOMENT FROM LOAD CASE 13-FT-LB



M13

min(P13) = 0.01
 max(P13) = 2.3
 max(V13) = 19.39
 min(V13) = -9.8
 max(M13) = 63.28
 min(M13) = -29.41

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 0

Page No. 31 of 90

Client: Babcock & Wilcox Hartford Company

Subject: 241-Z-381 Underground Tank

Lateral Load on Tank Wall from Concentrated Load at Grade

Location: PFP 200 W Area - Hanford Site, Richland, Washington

WORNo. TM22

Date: 11/17/98

Checked: [Signature]

Revised: _____

By: DAVID S. MESSINGER, PE

By: L.J. JULYK *[Signature]*

By: _____

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 12 VS MAXIMUM MOMENTS PRODUCED BY THE 1992 SNOW LOADING (LOAD CASE 9) ON THE LONG WALL FACE. FACTORS OF SAFETY > 5 HAVE BEEN NORMALIZED TO 5 TO REDUCE PLOT CONGESTION.

$$FS129_{y,z} := \frac{\text{if}(M12_{y,z} > 0, \max(M9), \min(M9))}{M12_{y,z}}$$

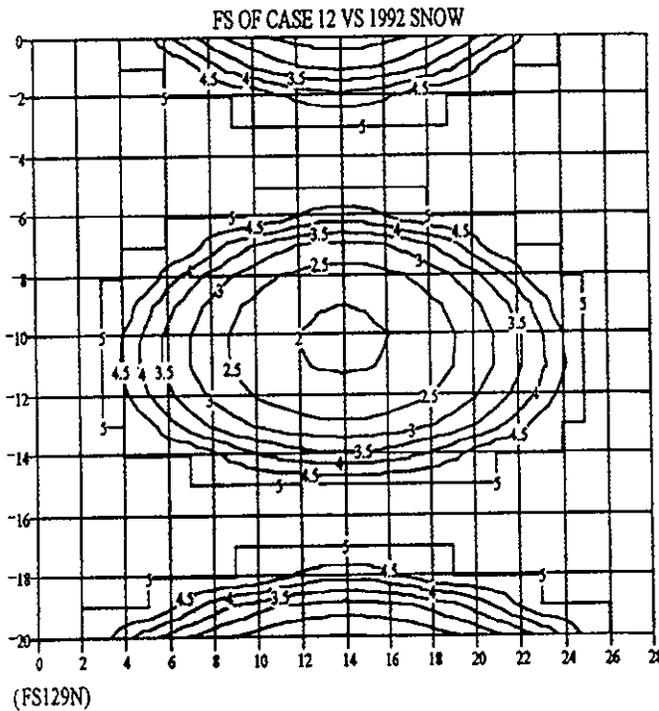
$$FS129N_{y,z} := \text{if}(FS129_{y,z} < 5, FS129_{y,z}, 5)$$

$$\min(FS129) = 1.91 \quad \max(FS129) = 1.31 \cdot 10^3$$

Factors of Safety at one ft. intervals along vertical centerline.

-z FS129_{14,20-z}

0	2.22
-1	2.92
-2	4.22
-3	7.38
-4	24.66
-5	11.18
-6	4.23
-7	2.81
-8	2.25
-9	2
-10	1.91
-11	1.95
-12	2.14
-13	2.58
-14	3.61
-15	7.46
-16	50.66
-17	8.23
-18	4.21
-19	2.73
-20	1.97



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TN22-C-01

Revision: 0

Page No. 32 of 90

Client: Babcock & Wilcox Hartford Company

WONo. TN22

Subject: 241-Z-301 Underground Tank

Date: 11/17/98

By: DAVID S. MESSINGER, PE

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: [Signature]

By: L. JULYK

Location: FFP 200 W Area - Hanford Site, Richland, Washington

Revised: _____

By: _____

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 13 VS MAXIMUM MOMENTS PRODUCED BY THE 1992 SNOW LOADING (LOAD CASE 9) ON THE LONG WALL FACE. FACTORS OF SAFETY > 5 HAVE BEEN NORMALIZED TO 5 TO REDUCE PLOT CONGESTION.

$$FS139_{y,z} := \frac{\text{if}(M13_{y,z} > 0, \max(M9), \min(M9))}{M13_{y,z}}$$

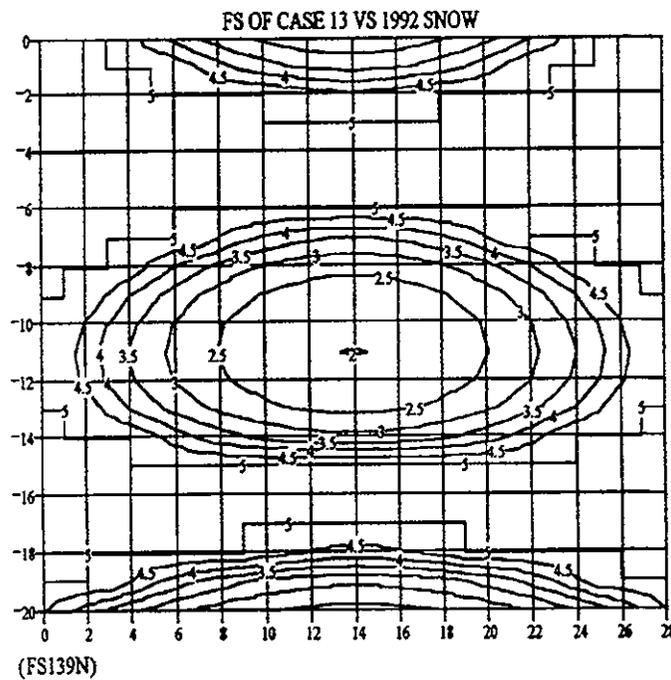
$$FS139N_{y,z} := \text{if}(FS139_{y,z} < 5, FS139_{y,z}, 5)$$

$$\min(FS139) = 1.84 \quad \max(FS139) = 255.66$$

Factors of Safety at one ft. intervals along vertical centerline.

-z FS139_{14,20-z}

0	2.61
-1	3.34
-2	4.63
-3	7.45
-4	17.94
-5	27.9
-6	5.91
-7	3.5
-8	2.63
-9	2.22
-10	2.03
-11	1.99
-12	2.09
-13	2.39
-14	3.12
-15	5.4
-16	93.85
-17	9.76
-18	4.35
-19	2.65
-20	1.84



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 33 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PEP 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/98
 Checked: 11/24/98
 Revised: _____
 By: DAVID S. MESSINGER, PE
 By: L.J. JULYK
 By: _____

LOAD CASE 14: An 38,500 lb concentrated load located normal to the long tank wall at centerline and offset 20 feet to produce a 2:1 factor of safety relative to 1992, December snow load.

Reset variables for new tank orientation:

DISCRETE LEFT END REACTION FUNCTION $F := 0 \quad z := 0, 1..20 \quad y := 0, 1..28 \quad L := 20$

$$R(y, z, F) := F_{y,z} \cdot \frac{(L-z)^2}{L^3} \cdot (3z + (L-z))$$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := (p(38500, 20, 22 - z, y - 14))$$

FILLING POINT LOAD ARRAY

$$P14 := F$$

LEFT END REACTION VECTOR

$$RL_y := \sum_{z=0}^L R(y, z, P14)$$

LEFT END FIXED MOMENT VECTOR

$$ML_y := \sum_{z=0}^L P14_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_y - \sum_{z=0}^z P14_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} = ML_y - \sum_{z=0}^z P14_{y,z} \cdot z - V_{y,z} \cdot z$$

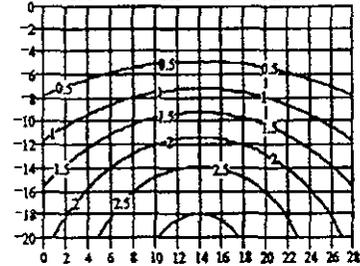
SPECIFIC MOMENT ARRAY

$$M14 := M$$

SPECIFIC SHEAR ARRAY

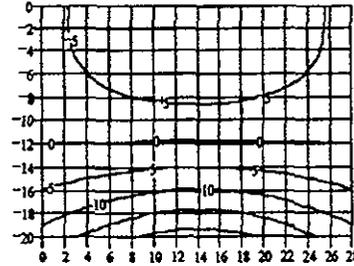
$$V14 := V$$

SIDEWALL PRESSURE FROM LOAD CASE 14-PSF



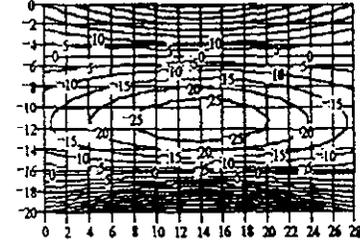
P14

SIDEWALL SHEAR FROM LOAD CASE 14-PSF



V14

SIDEWALL MOMENT FROM LOAD CASE 14-FT-LB



M14

$$\min(P14) = 0.01$$

$$\max(P14) = 3.12$$

$$\max(V14) = 22.14$$

$$\min(V14) = -8.75$$

$$\max(M14) = 67.75$$

$$\min(M14) = -29.23$$

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-G-01

Revision: 0

Page No. 34 of 90

Client: Babcock & Wilcox Hanford Company

WORK No. TM22

Subject: 241-Z-361 Underground Tank

Date: 11/17/99

By: DAVID S. MESSINGER, PE

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: [Signature]

By: L.J. JULYK

Location: PPF 200 W Area - Hanford Site, Richland, Washington

Revised: _____

By: _____

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 14 VS MAXIMUM MOMENTS PRODUCED BY THE 1992 SNOW LOADING (LOAD CASE 9) ON THE LONG WALL FACE. FACTORS OF SAFETY > 5 HAVE BEEN NORMALIZED TO 5 TO REDUCE PLOT CONGESTION.

$$FS149_{y,z} = \frac{\text{if}(M14_{y,z} > 0, \max(M9), \min(M9))}{M14_{y,z}}$$

$$FS149N_{y,z} = \text{if}(FS149_{y,z} < 5, FS149_{y,z}, 5)$$

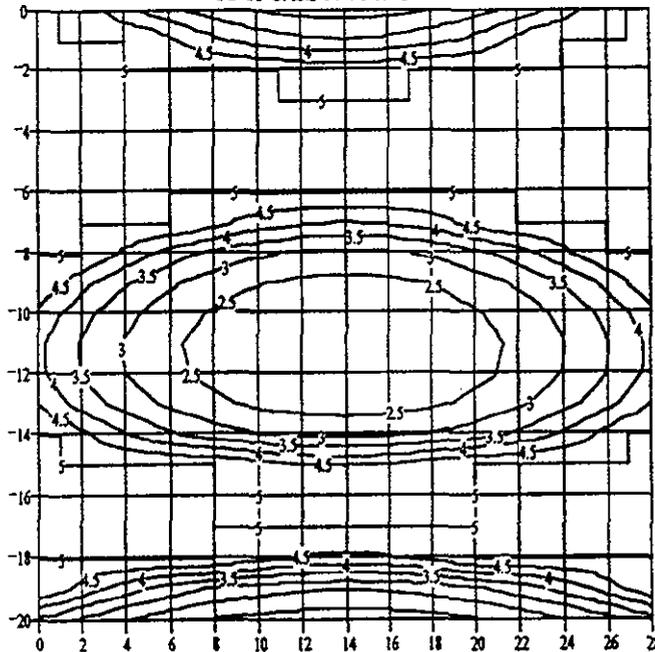
$$\min(FS149) = 1.72 \quad \max(FS149) = 3.43 \cdot 10^3$$

Factors of Safety at one ft. intervals along vertical centerline.

-z FS149_{14,20-z}

0	2.8
-1	3.55
-2	4.82
-3	7.47
-4	16.05
-5	82.82
-6	7.22
-7	3.97
-8	2.86
-9	2.35
-10	2.1
-11	2
-12	2.05
-13	2.27
-14	2.83
-15	4.5
-16	21.77
-17	11.12
-18	4.39
-19	2.55
-20	1.72

FS OF CASE 14 VS 1992 SNOW



(FS149N)

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 35 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/88 By: DAVID S. MESSINGER, PE
 Checked: 1/24/92 By: L.J. JULYK
 Revised: _____ By: _____

$r = 5 \quad Q = 3620$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q, r, 22 - z, y - 14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} \cdot z - V_{y,z} \cdot z$

$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

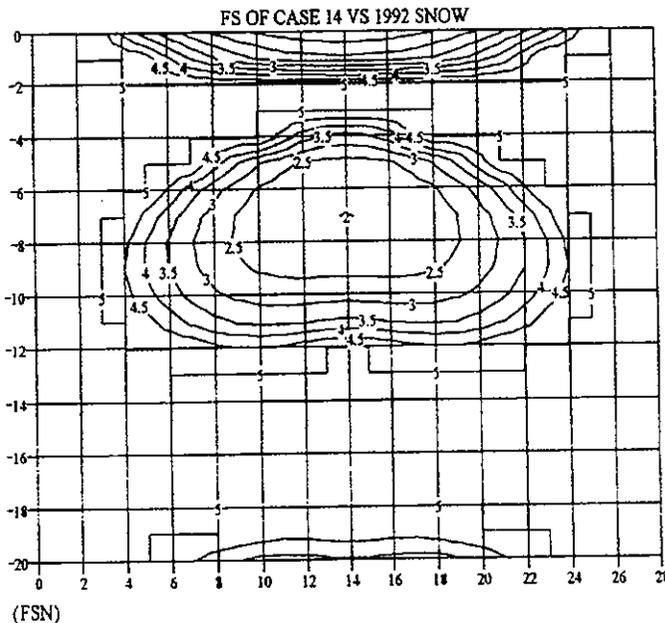
$FSN_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

$\min(FS) = 1.11 \quad \max(FS) = 812.07$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 5 \quad Q = 3620$

-z	FS _(4,20-z)
0	1.11
-1	2.1
-2	5.81
-3	17.2
-4	3.31
-5	2.29
-6	2.02
-7	2
-8	2.12
-9	2.37
-10	2.82
-11	3.59
-12	5.1
-13	9.09
-14	45.85
-15	29.62
-16	12.75
-17	8.15
-18	6.01
-19	4.78
-20	3.98



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 26 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PFP 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/98
 Checked: NBA/PP
 Revised: _____
 By: DAVID S. MESSINGER, PE
 By: L.J. JAAK
 By: _____

$r = 6 \quad Q = 3260$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q,r,22 - z,y - 14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} z \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} z - V_{y,z} z$

$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

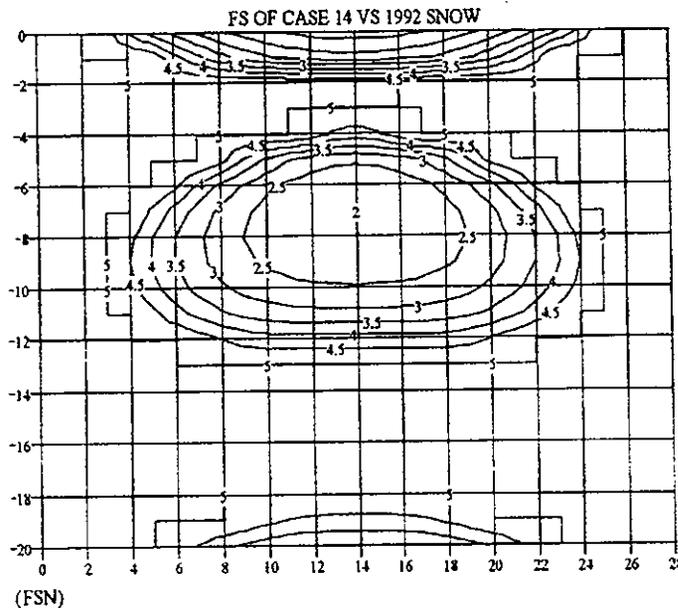
$FSN_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

$\min(FS) = 1.25 \quad \max(FS) = 4.85 \cdot 10^3$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 6 \quad Q = 3260$

-z	FS _{14,20-z}
0	1.25
-1	2.16
-2	4.99
-3	96.76
-4	4.3
-5	2.57
-6	2.12
-7	2
-8	2.04
-9	2.22
-10	2.55
-11	3.13
-12	4.24
-13	6.88
-14	20.06
-15	40.5
-16	13.24
-17	7.87
-18	5.6
-19	4.34
-20	3.55



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 37 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WONo. TM22
 Date: 11/17/98
 Checked: [Signature]
 Revised: _____
 By: DAVID S. MESSINGER, PE *DSM*
 By: L.J. KYLAK *LJK*
 By: _____

$r = 7 \quad Q = 3150$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q,r,22-z,y-14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} \cdot z - V_{y,z} \cdot z$

$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

$FSN_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

$\min(FS) = 1.37 \quad \max(FS) = 3.98 \cdot 10^3$

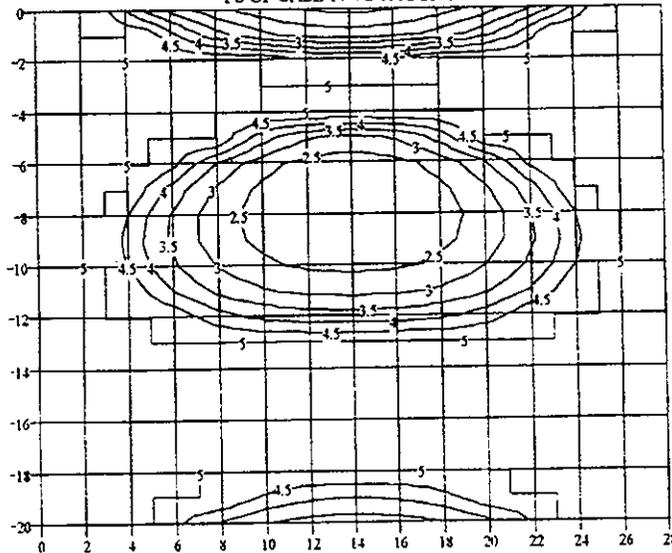
Factors of Safety at one ft. intervals along vertical centerline.

$r = 7 \quad Q = 3150$

-z FS_{14,20-z}

0	1.37
1	2.22
2	4.6
3	25.92
4	5.6
5	2.87
6	2.23
7	2.02
8	2
9	2.12
10	2.37
11	2.84
12	3.72
13	5.72
14	13.56
15	59.94
16	13.78
17	7.69
18	5.31
19	4.04
20	3.26

FS OF CASE 14 VS 1992 SNOW



(FSN)

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 38 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-381 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PFP 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/98
 Checked: 1/27/99
 Revised: _____
 By: DAVID S. MESSINGER, PE
 By: L.J. JULYK
 By: _____

$r = 8 \quad Q = 3135$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q, r, 22 - z, y - 14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y, z, F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} \cdot z - V_{y,z} \cdot z$

$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

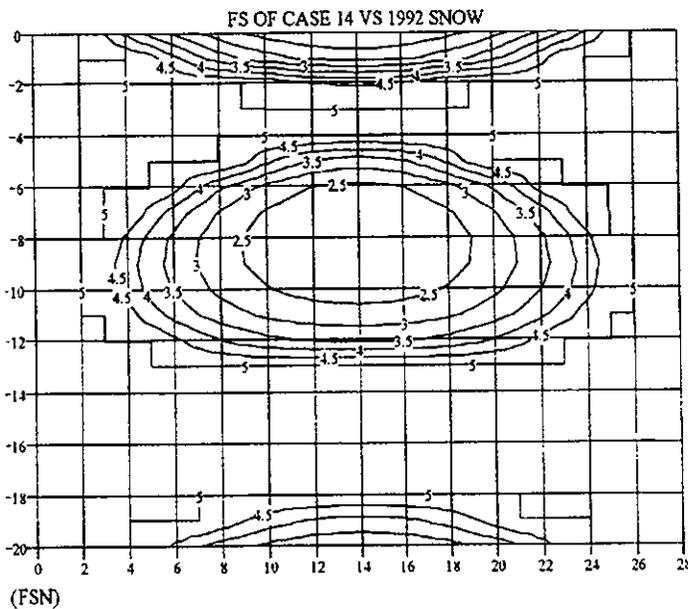
$FSN_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

$\min(FS) = 1.49 \quad \max(FS) = 1.21 \cdot 10^3$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 8 \quad Q = 3135$

-z	FS _{14,20-z}
0	1.49
-1	2.31
-2	4.44
-3	17
-4	7.52
-5	3.24
-6	2.37
-7	2.08
-8	2
-9	2.07
-10	2.28
-11	2.67
-12	3.42
-13	5.04
-14	10.62
-15	110.7
-16	14.58
-17	7.67
-18	5.15
-19	3.86
-20	3.08



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-G-01
 Revision: 0
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Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PFP 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/98
 Checked: 11/24/98
 Revised: _____
 By: DAVID S. MESSINGER, PE *DSM*
 By: L.J. JULYK *LJ*
 By: _____

$r = 9 \quad Q = 3240$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} := (p(Q,r,22 - z, y - 14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} z^2 \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} := ML_y - \sum_{z=0}^z F_{y,z} z - V_{y,z} z$

$FS_{y,z} := \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

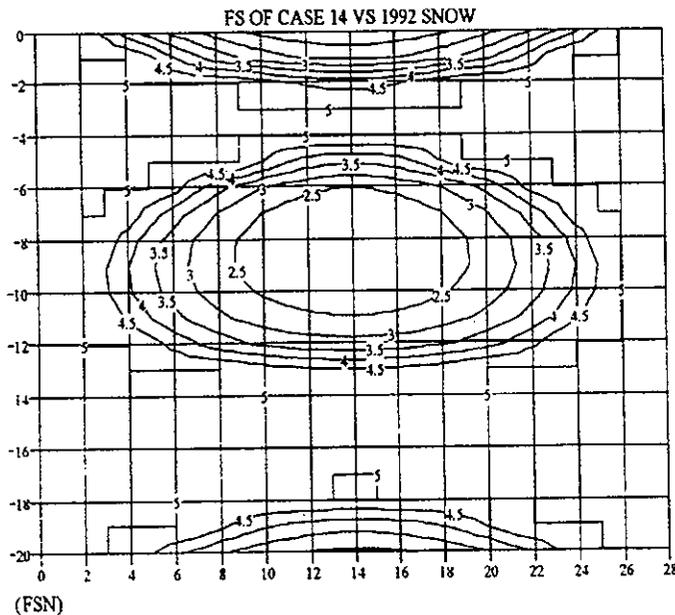
$FSN_{y,z} := \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

$\min(FS) = 1.58 \quad \max(FS) = 3.01 \cdot 10^3$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 9 \quad Q = 3240$

-z	FS _{14,20-z}
0	1.58
-1	2.38
-2	4.32
-3	13.44
-4	10.29
-5	3.6
-6	2.5
-7	2.12
-8	2
-9	2.03
-10	2.19
-11	2.53
-12	3.16
-13	4.52
-14	8.79
-15	532.5
-16	15.36
-17	7.6
-18	4.99
-19	3.68
-20	2.91



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 40 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-351 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: FPF 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/98
 Checked: 1/24/99
 Revised: _____
 By: DAVID S. MESSINGER, PE
 By: J. J. JURY

$r = 10 \quad Q = 3415$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q,r,22 - z,y - 14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} \cdot z - V_{y,z} \cdot z$

$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

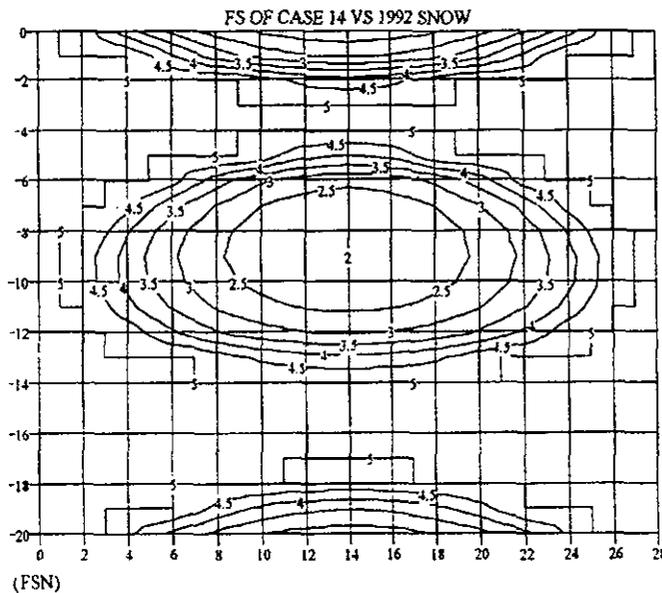
$FSN_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

$\min(FS) = 1.66 \quad \max(FS) = 1.92 \cdot 10^3$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 10 \quad Q = 3415$

-z	FS _{14,20-z}
0	1.66
-1	2.44
-2	4.25
-3	11.55
-4	14.74
-5	3.99
-6	2.63
-7	2.17
-8	2
-9	2
-10	2.13
-11	2.41
-12	2.96
-13	4.13
-14	7.57
-15	100.54
-16	16.25
-17	7.56
-18	4.85
-19	3.53
-20	2.76



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 0

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Client: Babcock & Wilcox Hanford Company

WO/No. TM22

Subject: 241-Z-361 Underground Tank

Date: 11/17/98

By: DAVID S. MESSINGER, PE

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 11/24/98

By: L.J. JULYK

Location: PPF 200 W Area - Hanford Site, Richland, Washington

Revised: _____

By: _____

$r = 11 \quad Q = 3600$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q,r,22 - z, y - 14))$

LEFT END REACTION VECTOR

$RL_y := \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y := \sum_{z=0}^L F_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} := RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} := ML_y - \sum_{z=0}^z F_{y,z} \cdot z - V_{y,z} \cdot z$

$FS_{y,z} := \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

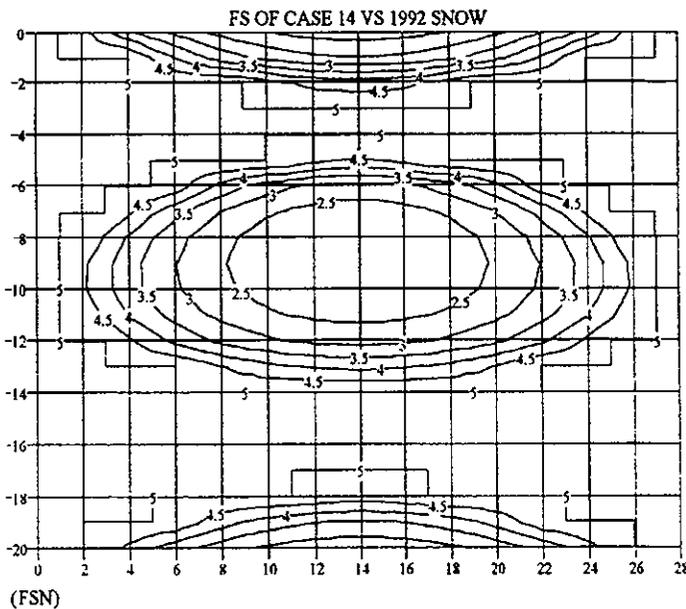
$FSN_{y,z} := \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

$\min(FS) = 1.76 \quad \max(FS) = 765.19$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 11 \quad Q = 3600$

-z	FS _{14,20-z}
0	1.76
-1	2.53
-2	4.26
-3	10.54
-4	23.37
-5	4.46
-6	2.8
-7	2.25
-8	2.04
-9	2
-10	2.1
-11	2.35
-12	2.85
-13	3.88
-14	6.79
-15	43.82
-16	17.5
-17	7.65
-18	4.8
-19	3.45
-20	2.68



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

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 Revision: 0
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Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WONo. TM22
 Date: 11/17/98
 Checked: 1/24/99
 Revised: _____
 By: DAVID S. MESSINGER, PE
 By: L.J. JULYK
 By: _____

$r = 12 \quad Q = 3860$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q,r,22 - z, y - 14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} \cdot z - V_{y,z} \cdot z$

$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

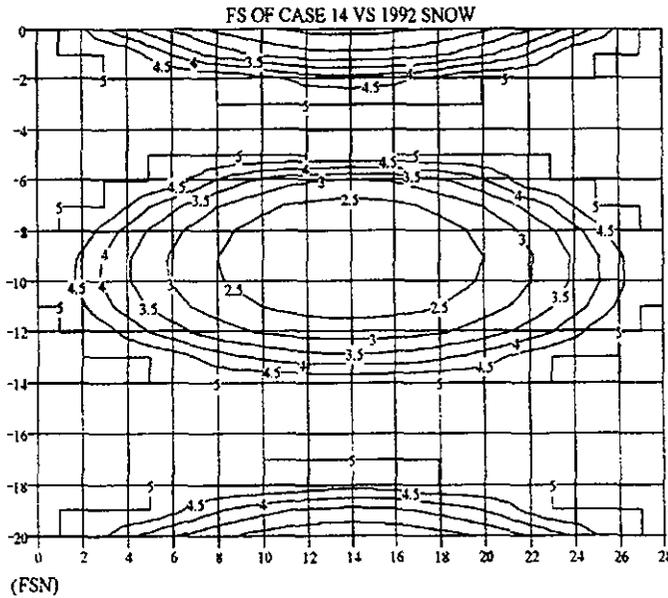
$FSN_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

$\min(FS) = 1.83 \quad \max(FS) = 2.05 \cdot 10^3$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 12 \quad Q = 3860$

-z	FS _{14,20-z}
0	1.83
-1	2.6
-2	4.25
-3	9.82
-4	44.78
-5	4.93
-6	2.95
-7	2.32
-8	2.07
-9	2
-10	2.07
-11	2.29
-12	2.73
-13	3.66
-14	6.16
-15	28.48
-16	18.8
-17	7.7
-18	4.73
-19	3.36
-20	2.58



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
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Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PFP 200 W Area - Hanford Site, Richland, Washington

WOVNo. TM22
 Date: 11/17/98 By: DAVID S. MESSINGER, PE
 Checked: [Signature] By: L.J. JULYK
 Revised: _____ By: _____

$r = 13 \quad Q = 4175$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q,r,22 - z,y - 14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} \cdot z - V_{y,z} \cdot z$

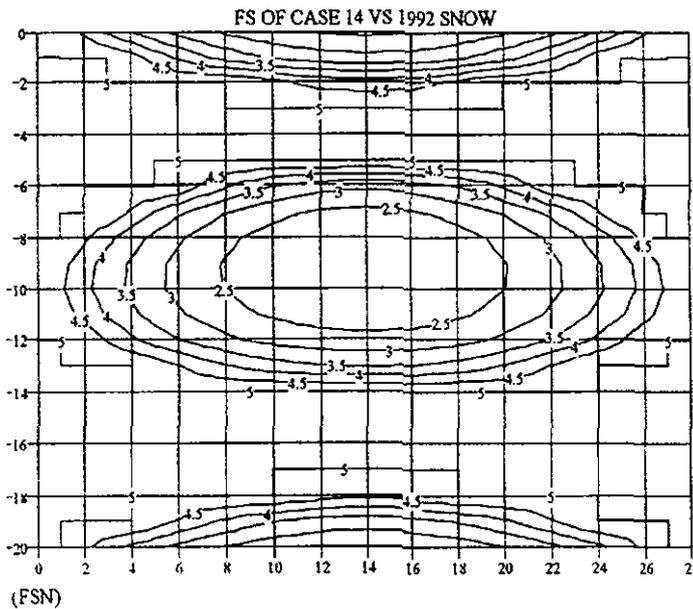
$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

$FSN_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

$\min(FS) = 1.9 \quad \max(FS) = 2.04 \cdot 10^4$

Factors of Safety at one ft. intervals along vertical centerline.
 $r = 13 \quad Q = 4175$

-z	FS _{14,20-z}
0	1.9
-1	2.65
-2	4.25
-3	9.3
-4	194.16
-5	5.43
-6	3.1
-7	2.38
-8	2.09
-9	2
-10	2.05
-11	2.24
-12	2.64
-13	3.47
-14	5.67
-15	21.35
-16	20.25
-17	7.75
-18	4.66
-19	3.28
-20	2.5



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 0

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Client: Rabcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PFP 200 W Area - Hanford Site, Richland, Washington

WORK No. TM22

Date: 11/17/98

Checked: 1/24/99

Revised: _____

By: DAVID S. MESSINGER, PE *DSM*

By: L. J. JULYK *LJ*

By: _____

$r = 14 \quad Q = 4550$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q,r,22 - z,y - 14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} \cdot z - V_{y,z} \cdot z$

$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

$FSN_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

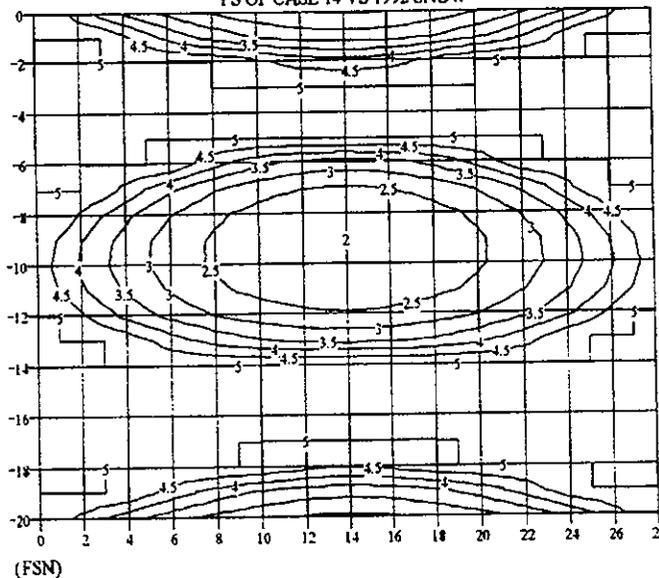
$\min(FS) = 1.95 \quad \max(FS) = 209.38$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 14 \quad Q = 4550$

-z	FS _{14,20-z}
0	1.95
-1	2.7
-2	4.25
-3	8.9
-4	209.38
-5	5.93
-6	3.24
-7	2.44
-8	2.11
-9	2
-10	2.03
-11	2.19
-12	2.55
-13	3.31
-14	5.27
-15	17.22
-16	21.86
-17	7.79
-18	4.6
-19	3.2
-20	2.42

FS OF CASE 14 VS 1992 SNOW



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revison: 0
 Page No. 15 of 20

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/89
 Checked: 11/24/92
 Revised: _____
 By: DAVID S. MESSINGER, PE
 By: L. J. JULYK
 By: _____

$r = 15 \quad Q = 4975$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q,r,22 - z, y - 14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} \cdot z - V_{y,z} \cdot z$

$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

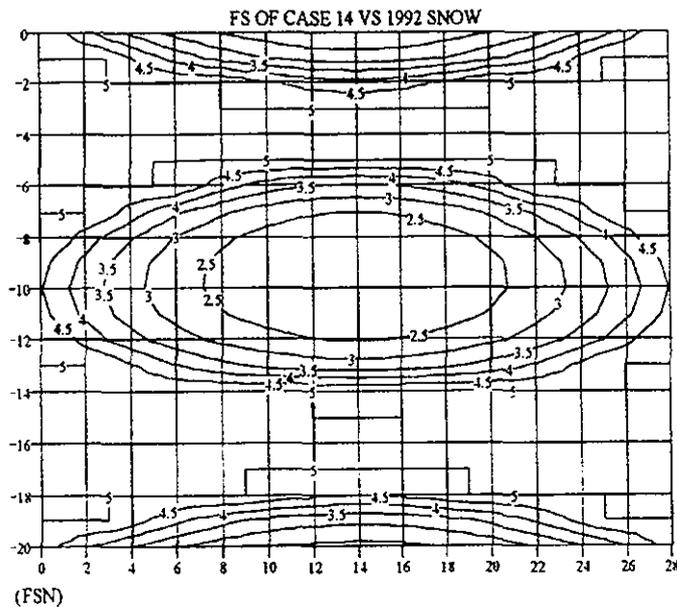
$FNS_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

$\min(FS) = 2 \quad \max(FS) = 94.88$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 15 \quad Q = 4975$

-z	FS _{14,20-z}
0	2.01
-1	2.74
-2	4.25
-3	8.59
-4	89.88
-5	6.47
-6	3.38
-7	2.5
-8	2.14
-9	2
-10	2.01
-11	2.15
-12	2.48
-13	3.18
-14	4.95
-15	14.55
-16	23.72
-17	7.85
-18	4.54
-19	3.13
-20	2.35



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 0

Page No. 46 of 90

Client: Babcock & Wilcox Hartford Company

WONo. TM22

Subject: 241Z-381 Underground Tank

Date: 11/17/98

By: DAVID S. MESSINGER, PE

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 11/18/98

By: L.J. JULYK

Location: PPF 280 W Area - Hartford Site, Richland, Washington

Revised: _____

By: _____

EVALUATE CONCENTRATED LOADS BASED ON "BOUSSINESQ" EQUATION TO DETERMINE STRESS ON A HORIZONTAL PLANE "P" AT A POINT (r,y,z) along the wall face. The wall face pressure is then assumed to be P*K where K is the "at rest pressure coefficient."

RANKINE LATERAL PRESSURE FUNCTION

$$p(Q,r,z,y) := \frac{3 \cdot Q \cdot K}{2 \cdot \pi \cdot z^2} \left[\frac{1}{1 + \left(\frac{\sqrt{r^2 + y^2}}{z} \right)^2} \right]^{\frac{3}{2}} \quad F := 0 \quad z := 0, 1, 20 \quad y := 0, 1, 15 \quad L := 15 \quad \nu := 0.27 \quad Q_s := 9.46 \quad K := \frac{\nu}{1 - \nu}$$

$$K = 0.37$$

DISCRETE LEFT END REACTION FUNCTION

$$R(y,z,F) := F \cdot \frac{(L-y)^2}{L^3} \cdot (3y + (L-y))$$

LOAD CASE 1: TENT FRAME LOAD PLUS 600 LB AT STEPOFF PAD (1) AND 800 LB AT STEPOFF PAD (2)

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := \left\{ \begin{array}{l} p(80, 2.5, 22 - z, y - 3) + p(80, 2.5, 22 - z, y - 8) + p(80, 7.5, 22 - z, y - 3) \dots \\ + p(80, 7.5, 22 - z, y - 2.5) + p(80, 7.5, 22 - z, y - 8) + p(600, 4.0, 22 - z, y - 5.5) \dots \\ + p(200, 8.0, 22 - z, y - 7.5) + p(600, 8.0, 22 - z, y - 1) \end{array} \right\} \quad \text{FILLING POINT LOAD ARRAY}$$

$$PI := F$$

LEFT END REACTION VECTOR

$$RL_z := \sum_{y=0}^L R(y,z,PI)$$

LEFT END FIXED MOMENT VECTOR

$$ML_z := \sum_{y=0}^L PI_{y,z} \cdot y \cdot \frac{(L-y)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_z - \sum_{y=0}^y PI_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} := ML_z - \sum_{y=0}^y PI_{y,z} \cdot y - V_{y,z} \cdot y$$

SPECIFIC MOMENT ARRAY

$$MI := M$$

SPECIFIC SHEAR ARRAY

$$VI := V$$

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 47 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-341 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: FFP 200 W Area - Hanford Site, Richland, Washington

WONo. TM22
 Date: 11/17/88
 Checked: [Signature]
 Revised: _____
 By: DAVID S. MESSINGER, PE [Signature]
 By: L.J. JULYK [Signature]
 By: _____

LOAD CASE 2: Pressure and total force exerted on tank endwall due to 5 point loads of 80 lb from tent frame and one 732 lb concentrated load from cart at pad (1) and no load at pad (2). Load center for pad (1) is 4 ft. from tank end wall.

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := \left(\begin{array}{l} p(80, 2.5, 22 - z, y - 3) + p(80, 2.5, 22 - z, y - 8) + p(80, 7.5, 22 - z, y - 3) \dots \\ + p(80, 7.5, 22 - z, y - 2.5) + p(80, 7.5, 22 - z, y - 8) + p(732, 4.0, 22 - z, y - 5.5) \end{array} \right) \quad \text{FILLING POINT LOAD ARRAY}$$

P2 := F

LEFT END REACTION VECTOR LEFT END FIXED MOMENT VECTOR GENERAL SHEAR ARRAY

$$RL_z := \sum_{y=0}^L R(y, z, P2) \qquad ML_z := \sum_{y=0}^L P2_{y,z} \cdot y \cdot \frac{(L-y)^2}{L^2} \qquad V_{y,z} := RL_z - \sum_{y=0}^y P2_{y,z}$$

GENERAL MOMENT ARRAY SPECIFIC MOMENT ARRAY SPECIFIC SHEAR ARRAY

$$M_{y,z} := ML_z - \sum_{y=0}^y P2_{y,z} \cdot y - V_{y,z} \cdot y \qquad M2 := M \qquad V2 := V$$

LOAD CASE 3: Pressure and total force exerted on tank endwall due to 5 point loads of 80 lb from tent frame and one 732 lb concentrated load from cart at pad (1) and no load at pad (2). Load center for pad (1) is 5 ft. from tank end wall.

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := \left(\begin{array}{l} p(80, 2.5, 22 - z, y - 3) + p(80, 2.5, 22 - z, y - 8) + p(80, 7.5, 22 - z, y - 3) \dots \\ + p(80, 7.5, 22 - z, y - 2.5) + p(80, 7.5, 22 - z, y - 8) + p(732, 5.0, 22 - z, y - 5.5) \end{array} \right) \quad \text{FILLING POINT LOAD ARRAY}$$

P3 := F

LEFT END REACTION VECTOR LEFT END FIXED MOMENT VECTOR GENERAL SHEAR ARRAY

$$RL_z := \sum_{y=0}^L R(y, z, P3) \qquad ML_z := \sum_{y=0}^L P3_{y,z} \cdot y \cdot \frac{(L-y)^2}{L^2} \qquad V_{y,z} := RL_z - \sum_{y=0}^y P3_{y,z}$$

GENERAL MOMENT ARRAY SPECIFIC MOMENT ARRAY SPECIFIC SHEAR ARRAY

$$M_{y,z} := ML_z - \sum_{y=0}^y P3_{y,z} \cdot y - V_{y,z} \cdot y \qquad M3 := M \qquad V3 := V$$

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-G-01
 Revision: 0
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Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WONo. TM22
 Date: 11/17/88
 Checked: 4/24/90
 Revised: _____

By: DAVID S. MESSINGER, PE
 By: L.J. JULYK
 By: _____

LOAD CASE 4: Pressure and total force exerted on tank endwall due to 5 point loads of 80 lb from tent frame and one 200 lb concentrated load from HPT at pad (1) and cart load of 732 lb at pad (2). Load center for pad (1) is 4 ft. from tank end wall.

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := \left[\begin{array}{l} p(80, 2.5, 22 - z, y - 3) + p(80, 2.5, 22 - z, y - 8) + p(80, 7.5, 22 - z, y - 3) \dots \\ + p(80, 7.5, 22 - z, y - 2.5) + p(80, 7.5, 22 - z, y - 8) + p(200, 4, 22 - z, y - 5.5) \dots \\ + p(732, 8.0, 22 - z, y - 1) \end{array} \right]$$

FILLING POINT LOAD ARRAY

P4 := F

LEFT END REACTION VECTOR

$$RL_z := \sum_{y=0}^L R(y, z, P4)$$

LEFT END FIXED MOMENT VECTOR

$$ML_z := \sum_{y=0}^L P4_{y,z} \cdot y \cdot \frac{(L-y)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_z - \sum_{y=0}^y P4_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} := ML_z - \sum_{y=0}^y P4_{y,z} \cdot y - V_{y,z} \cdot y$$

SPECIFIC MOMENT ARRAY

M4 := M

SPECIFIC SHEAR ARRAY

V4 := V

LOAD CASE 5: A 12,000 lb armored car located as shown in fig. 3 at position "A".

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := \left[\begin{array}{l} p(3000, 8.96, 22 - z, y - 8.96) + p(3000, 4.24, 22 - z, y - (-4.24)) \dots \\ + p(3000, 10.6, 22 - z, y - 2.12) + p(3000, 15.32, 22 - z, y - 2.60) \end{array} \right]$$

FILLING POINT LOAD ARRAY

P5 := F

LEFT END REACTION VECTOR

$$RL_z := \sum_{y=0}^L R(y, z, P5)$$

LEFT END FIXED MOMENT VECTOR

$$ML_z := \sum_{y=0}^L P5_{y,z} \cdot y \cdot \frac{(L-y)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_z - \sum_{y=0}^y P5_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} := ML_z - \sum_{y=0}^y P5_{y,z} \cdot y - V_{y,z} \cdot y$$

SPECIFIC MOMENT ARRAY

M5 := M

SPECIFIC SHEAR ARRAY

V5 := V

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-G-01
 Revision: 0
 Page No. 49 of 90

Client: Balcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WONo. TM22
 Date: 11/17/98
 Checked: 1/24/99
 Revised: _____

By: DAVID S. MESSINGER, PE *DSM*
 By: L.J. JULYK *LJ*
 By: _____

LOAD CASE 6: A 12,000 lb armored car located as shown in fig. 3 at position "B".

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := \left[\begin{array}{l} p(3000, 15.32, 22 - z, y - 2.60) + p(3000, 10.60, 22 - z, y - (2.12)) \dots \\ + p(3000, 16.96, 22 - z, y - 8.48) + p(3000, 21.68, 22 - z, y - 3.76) \end{array} \right]$$

FILLING POINT LOAD ARRAY

$$P6 := F$$

LEFT END REACTION VECTOR

$$RL_z := \sum_{y=0}^L R(y,z,P6)$$

LEFT END FIXED MOMENT VECTOR

$$ML_z := \sum_{y=0}^L P6_{y,z} \cdot y \cdot \frac{(L-y)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_z - \sum_{y=0}^y P6_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} := ML_z - \sum_{y=0}^y P6_{y,z} \cdot y - V_{y,z} \cdot y$$

SPECIFIC MOMENT ARRAY

$$M6 := M$$

SPECIFIC SHEAR ARRAY

$$V6 := V$$

LOAD CASE 7: December 1992 precipitation load primarily made up of 21 inches of snow fall accumulation. Water equivalent precipitation was 1.82 inches of water with negligible evaporation loss. Equivalent ground load is 9.46 psf.

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$K \cdot Q_s = 3.5$$

$$F_{y,z} := K \cdot Q_s$$

FILLING POINT LOAD ARRAY

$$P7 := F$$

LEFT END REACTION VECTOR

$$RL_z := \sum_{y=0}^L R(y,z,P7)$$

LEFT END FIXED MOMENT VECTOR

$$ML_z := \sum_{y=0}^L P7_{y,z} \cdot y \cdot \frac{(L-y)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_z - \sum_{y=0}^y P7_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} := ML_z - \sum_{y=0}^y P7_{y,z} \cdot y - V_{y,z} \cdot y$$

SPECIFIC MOMENT ARRAY

$$M7 := M$$

SPECIFIC SHEAR ARRAY

$$V7 := V$$

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 0

Page No. 50 of 90

Client: Babcock & Wilcox Hanford Company

WO/No. TM22

Subject: 241-Z-361 Underground Tank

Date: 11/17/98

By: DAVID S. MESSINGER, PE *DSM*

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 1/24/99

By: L.J. JULYK *LJ*

Location: PFP 200 W Area - Hanford Site, Richland, Washington

Revised: _____

By: _____

MAXIMUM PRESSURES, SHEARS AND MOMENTS FOR LOAD CASES 1 THROUGH 4

max(P1) = 4.45	max(P2) = 5	max(P3) = 3.46	max(P4) = 2.21
min(P1) = 0.01	min(P2) = -0.03	min(P3) = -0.01	min(P4) = 0.02
max(V1) = 22.98	max(V2) = 21.8	max(V3) = 17.33	max(V4) = 12.93
min(V1) = -13.23	min(V2) = -13.69	min(V3) = -11.5	min(V4) = -13.23
max(M1) = 61.44	max(M2) = 60.93	max(M3) = 48.15	max(M4) = 33.62
min(M1) = -30.95	min(M2) = -33.19	min(M3) = -25.31	min(M4) = -16.58

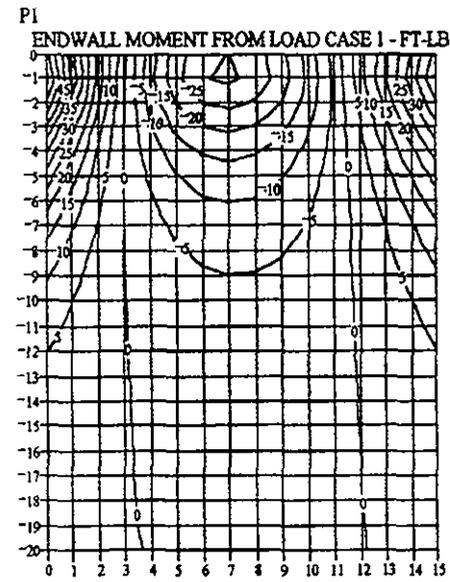
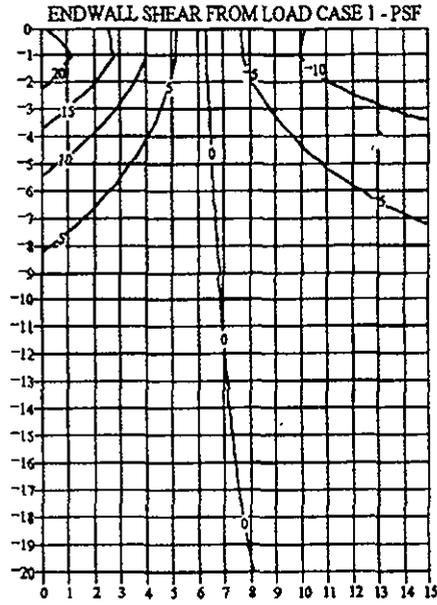
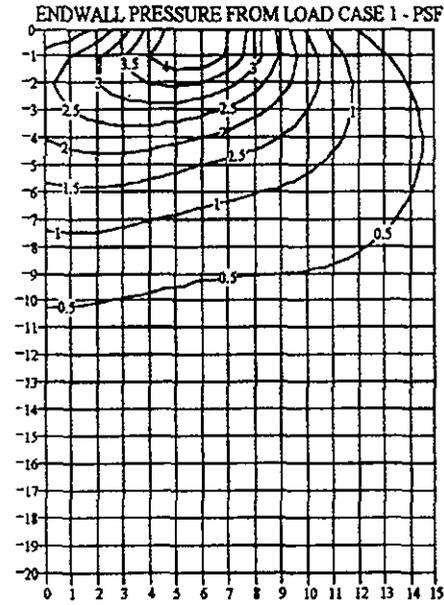
Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 51 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-341 Underground Tank
 Location: Lateral Load on Tank Wall from Concentrated Load at Grade
PEP 200 W Area - Hanford Site, Richland, Washington

WONo. TM22
 Date: 11/17/98 By: DAVID S. MESSINGER, PE
 Checked: 02/21/99 By: L.J. JULYK
 Revised: _____ By: _____



max(P1) = 4.45
 min(P1) = 0.01

 max(V1) = 22.98
 min(V1) = -13.23

 max(M1) = 61.44
 min(M1) = -30.95

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-G-01

Revision: 0

Page No. 52 of 90

Client: Babcock & Wilcox Hartford Company

WORK No. TM22

Subject: 241-Z-381 Underground Tank

Date: 11/17/98

By: DAVID S. MESSINGER, PE *DSM*

Lateral Load on Tank Wall from Concentrated Load at Grade

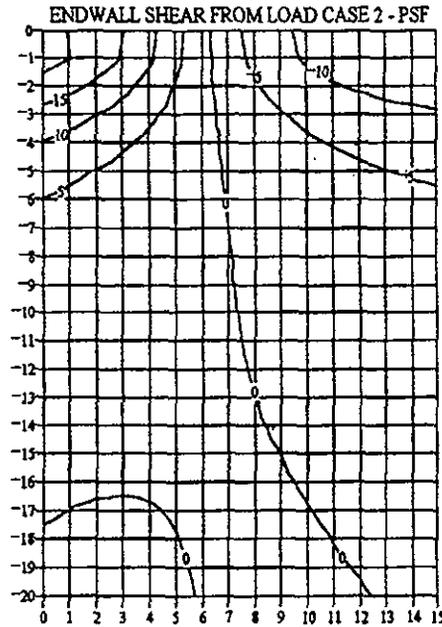
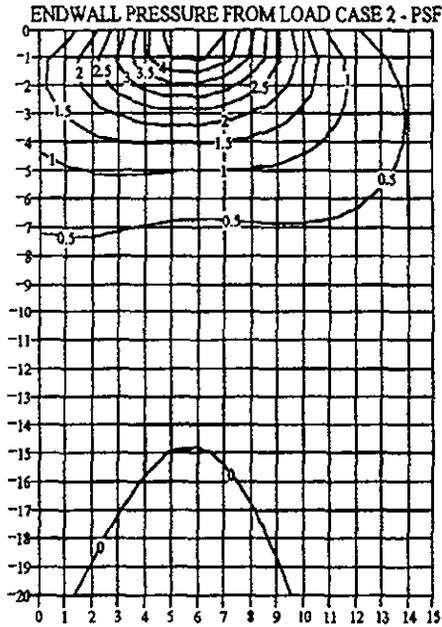
Checked: 4/24/99

By: L.J. JULYK *LJ*

Location: PPF 200 W Area - Hartford Site, Richland, Washington

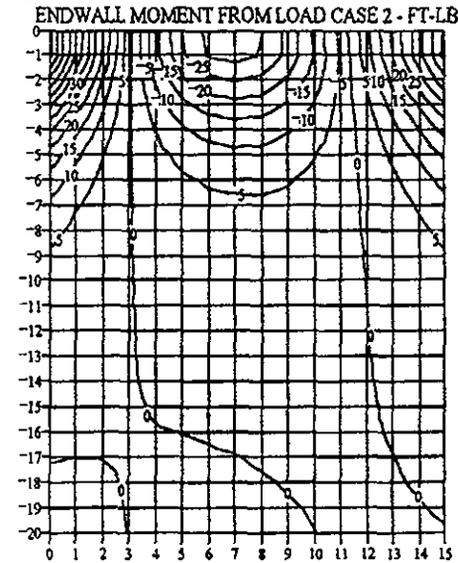
Revised: _____

By: _____



P2

V2



M2

$\max(P2) = 5$

$\min(P2) = -0.03$

$\max(V2) = 21.8$

$\min(V2) = -13.69$

$\max(M2) = 60.93$

$\min(M2) = -33.19$

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 0

Page No. 53 of 92

Client: Babcock & Wilcox Hanford Company

Subject: 241-Z-361 Underground Tank

Lateral Load on Tank Wall from Concentrated Load at Grade

Location: PFP 200 W Area - Hanford Site, Richland, Washington

WOM No. TM22

Date: 11/17/98

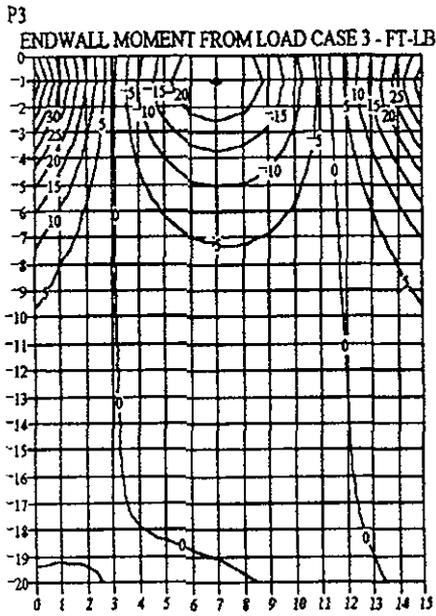
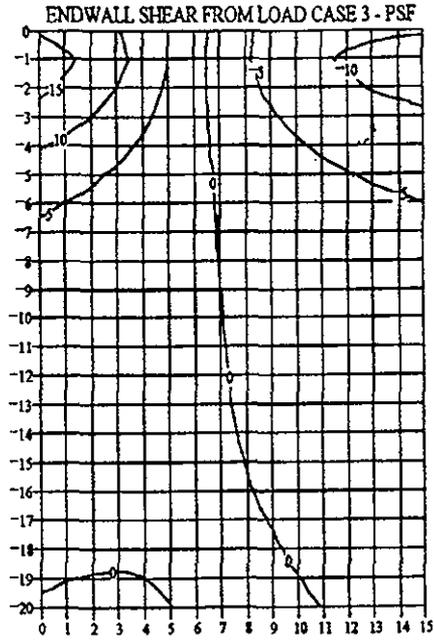
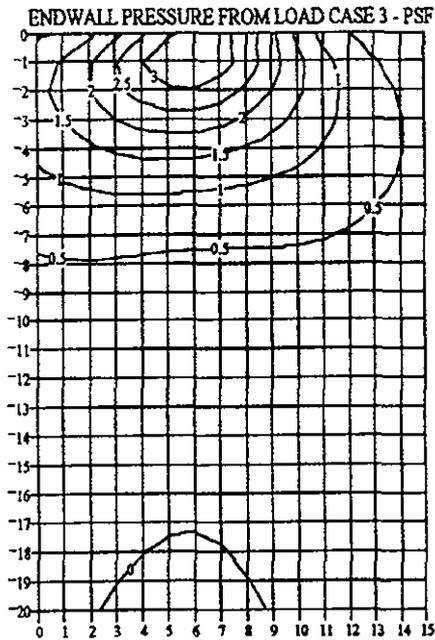
Checked: 02/2/99

Revised:

By: DAVID S. MESSINGER, PE *DSM*

By: L. J. JULYK *LJJ*

By:



max(P3) = 3.46
min(P3) = -0.01

max(V3) = 17.33
min(V3) = -11.5

max(M3) = 48.15
min(M3) = -25.31

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-G-91

Revision: 0

Page No. 54 of 90

Client: Babcock & Wilcox Hanford Company

Subject: 241-Z-381 Underground Tank

Lateral Load on Tank Wall from Concentrated Load at Grade

Location: PPF 200 W Area - Hanford Site, Richland, Washington

WG No. TM22

Date: 11/17/88

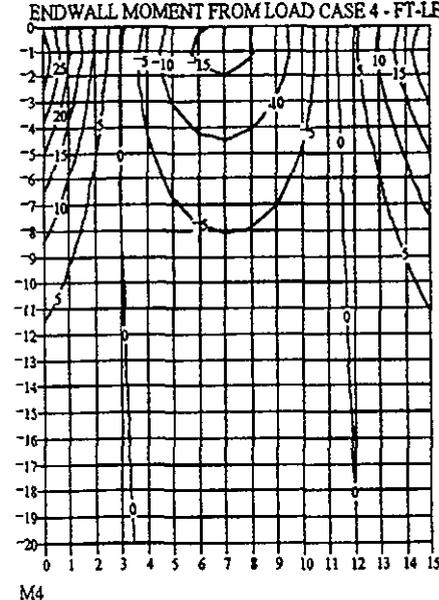
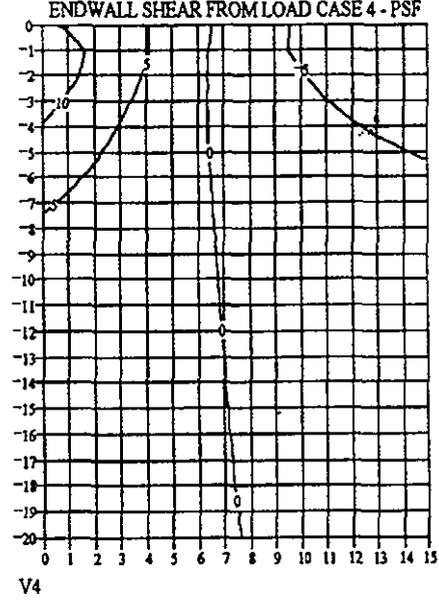
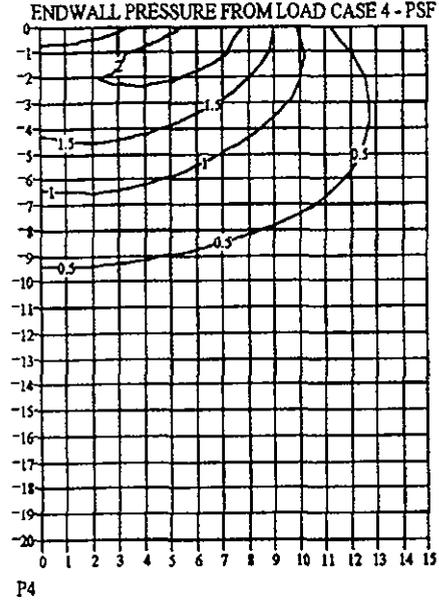
Checked: 11/24/90

Revised: _____

By: DAVID S. MESSINGER, PE

By: L.J. JULYK

By: _____



max(P4) = 2.21
 min(P4) = 0.02
 max(M4) = 33.62
 min(M4) = -16.58
 max(V4) = 12.93
 min(V4) = -7.46

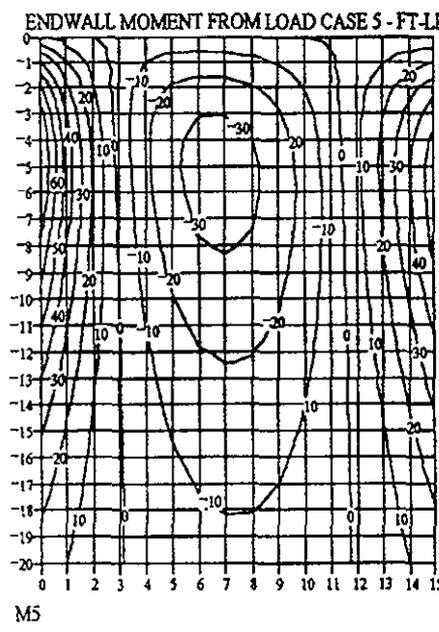
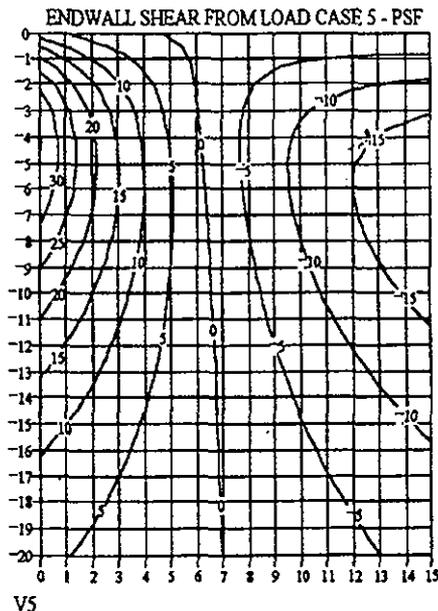
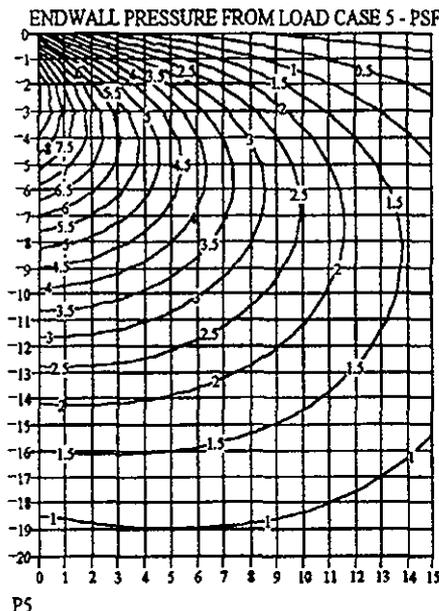
Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 55 of 90

Client: Balcock & Wilcox Hartford Company
 Subject: 241-Z-381 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PEP 200 W Area - Hartford Site, Richland, Washington

WONo. TM22
 Date: 11/17/88
 Checked: 4/24/94
 Revised: _____
 By: DAVID S. MESSINGER, PE *DSM*
 By: L.J. JULYK *LJJ*
 By: _____



max(P5) = 9.09
 min(P5) = -0.24

 max(M5) = 80.87
 min(M5) = -34.42

 max(V5) = 35.36
 min(V5) = -19.04

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 8

Page No. 56 of 90

Client: Babcock & Wilcox Hanford Company

Subject: 241-Z-361 Underground Tank

Lateral Load on Tank Wall from Concentrated Load at Grade

Location: PEP 200 W Area - Hanford Site, Richland, Washington

WQNo. TM22

Date: 11/17/98

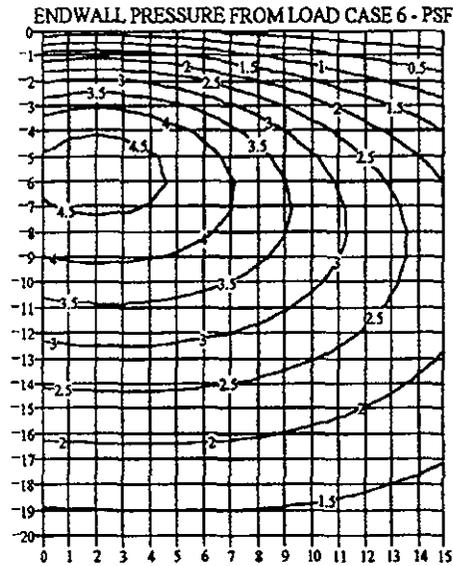
Checked: 4/24/99

Revised: _____

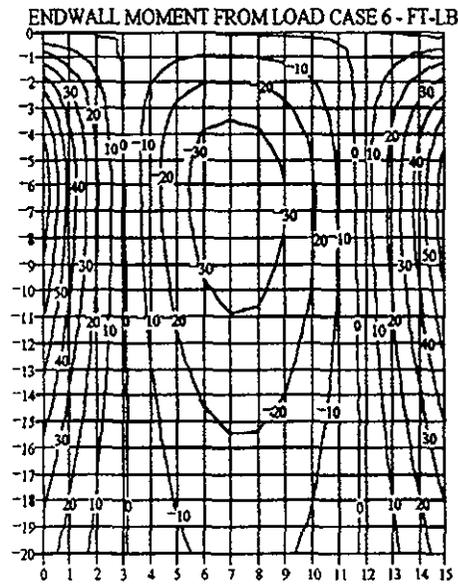
By: DAVID S. MESSINGER, PE

By: L.J. JULYK

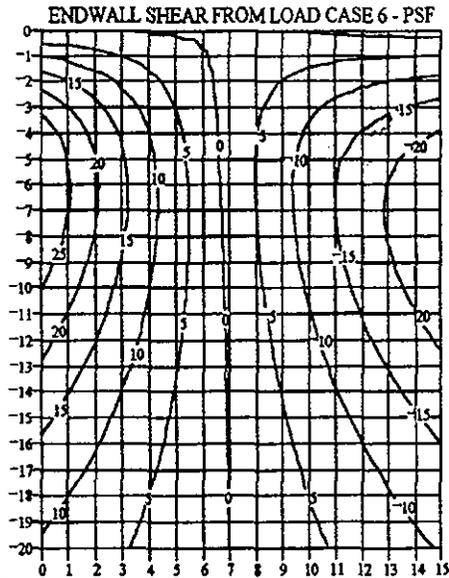
By: _____



P6



M6



V6

max(P6) = 4.7
min(P6) = -0.41

max(M6) = 76.74
min(M6) = -36.64

max(V6) = 30.07
min(V6) = -24.82

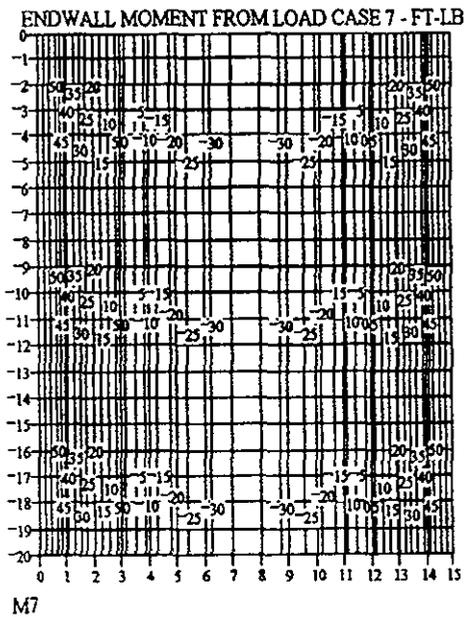
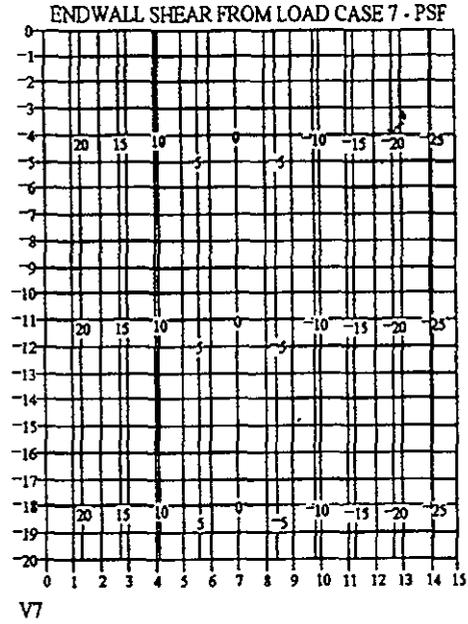
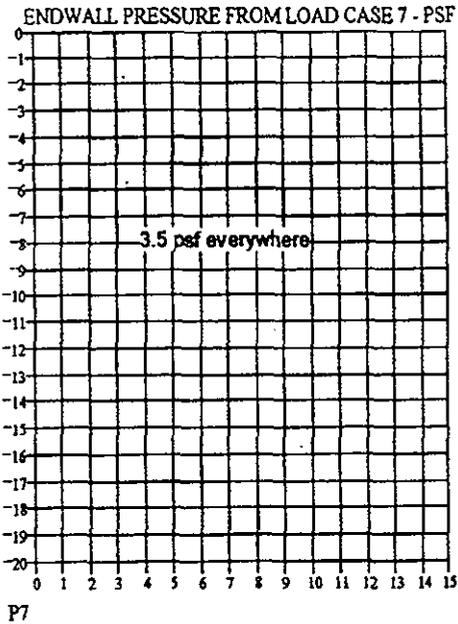
Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-G-01
 Revision: 0
 Page No. 57 of 70

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PEP 200 W Area - Hanford Site, Richland, Washington

WONo. TM22
 Date: 11/17/98
 Checked: LD/HR
 Revised: _____
 By: DAVID S. MESSINGER, PE
 By: L. J. JULYK
 By: _____



max(P7) = 3.5
 min(P7) = 3.5
 max(M7) = 65.31
 min(M7) = -32.66
 max(V7) = 24.49
 min(V7) = -27.99

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-G-91
 Revision: 0
 Page No. 58 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: FFP 290 W Area - Hanford Site, Richland, Washington

WONo. TM22
 Date: 11/17/98
 Check: 11/24/98
 Revised: _____
 By: DAVID S. MESSINGER, PE
 By: L.J. JULYK
 By: _____

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 1 VS MAXIMUM MOMENTS PRODUCED BY THE ARMORED CAR LOADING IN POSITION "A". FACTORS OF SAFETY > 10 HAVE BEEN NORMALIZED TO 10 TO REDUCE PLOT CONGESTION.

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 1 VS MAXIMUM MOMENTS PRODUCED BY THE ARMORED CAR LOADING IN POSITION "B". FACTORS OF SAFETY > 10 HAVE BEEN NORMALIZED TO 10 TO REDUCE PLOT CONGESTION.

$$FS15_{y,z} := \frac{\text{if}(M1_{y,z} > 0, \max(M5), \min(M5))}{M1_{y,z}}$$

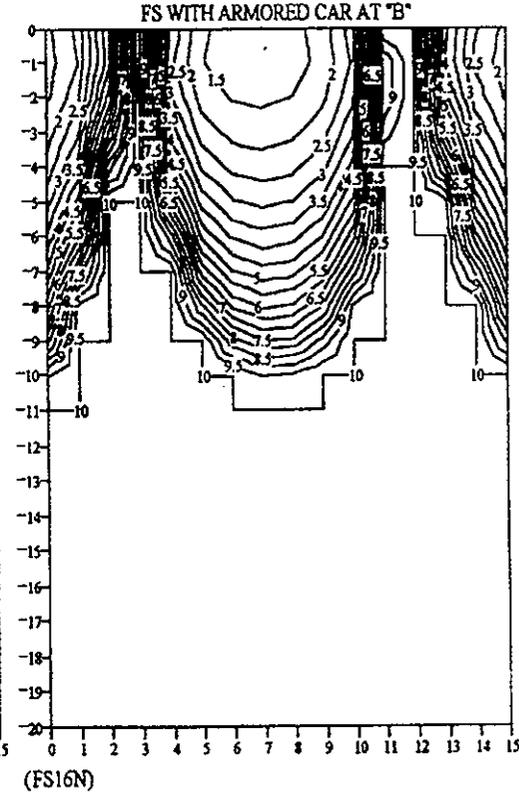
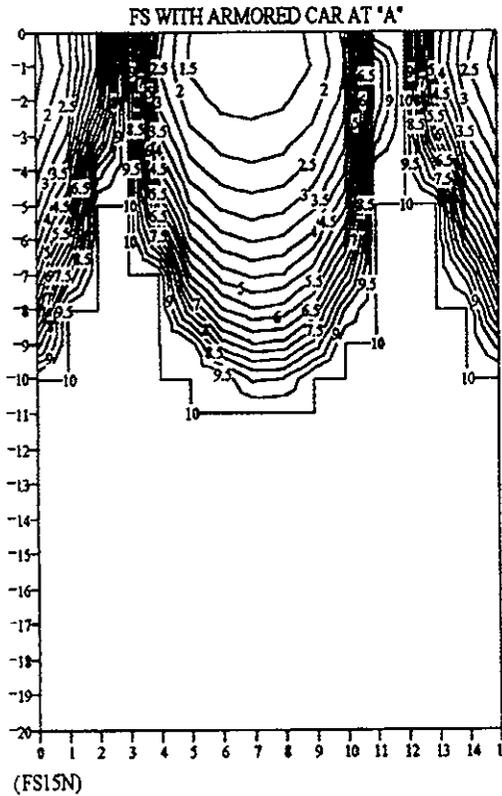
$$FS16_{y,z} := \frac{\text{if}(M1_{y,z} > 0, \max(M6), \min(M6))}{M1_{y,z}}$$

$$FS15N_{y,z} := \text{if}(FS15_{y,z} < 10, FS15_{y,z}, 10)$$

$$FS16N_{y,z} := \text{if}(FS16_{y,z} < 10, FS16_{y,z}, 10)$$

$$\min(FS15) = 1.11 \quad \max(FS15) = 6.88 \cdot 10^3$$

$$\min(FS16) = 1.18 \quad \max(FS16) = 6.53 \cdot 10^3$$



$$FS15_g := FS15_{y,20-g}$$

$$\min(FS15_g) = 5.57$$

$$FS16_g := FS16_{y,20-g}$$

$$\min(FS16_g) = 5.83$$

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 59 of 70

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-341 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/88
 Checked: 1/24/90
 Revised: _____

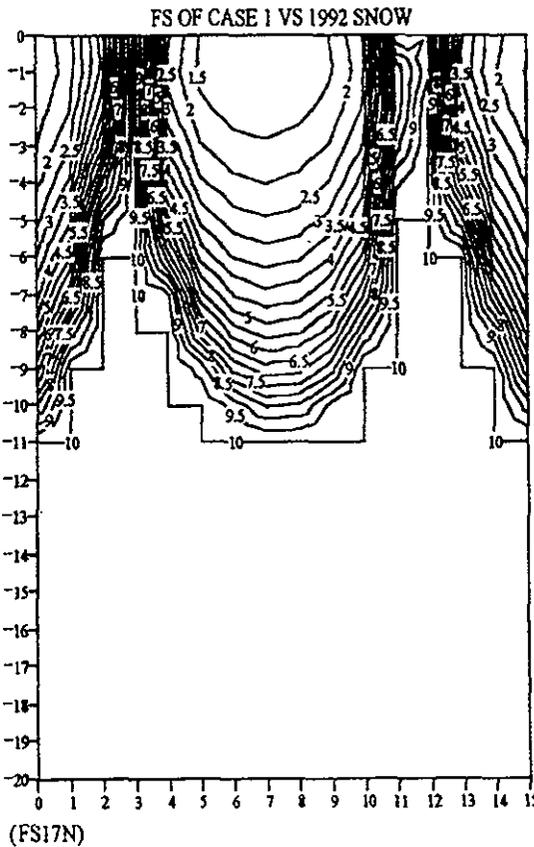
By: DAVID S. MESSINGER, PE
 By: L.J. JULYK
 By: _____

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 1 VS MAXIMUM MOMENTS PRODUCED BY THE 1992 SNOW LOADING OF 6.62 PSF ON THE WALL FACE. FACTORS OF SAFETY > 10 HAVE BEEN NORMALIZED TO 10 TO REDUCE PLOT CONGESTION.

$$FS17_{y,z} := \frac{\text{if}(M1_{y,z} > 0, \max(M7), \min(M7))}{M1_{y,z}}$$

$$FS17N_{y,z} := \text{if}(FS17_{y,z} < 10, FS17_{y,z}, 10)$$

$$\min(FS17) = 1.06 \quad \max(FS17) = 5.55 \cdot 10^3$$



$$FS17_{g_y} := FS17_{y,20-s}$$

$$\min(FS17_g) = 4.96$$

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-G-01

Revision: 0

Page No. 60 of 90

Client: Balcock & Wilcox Hanford Company
 Subject: 241-Z-351 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPP 200 W Area - Hanford Site, Richland, Washington

WONo. TM22
 Date: 11/17/88
 Checked: 11/24/92
 Revised: _____

By: DAVID S. MESSINGER, PE *DSM*
 By: L.J. JULYK *LJ*
 Revised: _____

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 2 VS MAXIMUM MOMENTS PRODUCED BY THE ARMORED CAR LOADING IN POSITION "A". FACTORS OF SAFETY > 10 HAVE BEEN NORMALIZED TO 10 TO REDUCE PLOT CONGESTION.

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 2 VS MAXIMUM MOMENTS PRODUCED BY THE ARMORED CAR LOADING IN POSITION "B". FACTORS OF SAFETY > 10 HAVE BEEN NORMALIZED TO 10 TO REDUCE PLOT CONGESTION.

$$FS25_{y,z} := \frac{\text{if}(M2_{y,z} > 0, \max(M5), \min(M5))}{M2_{y,z}}$$

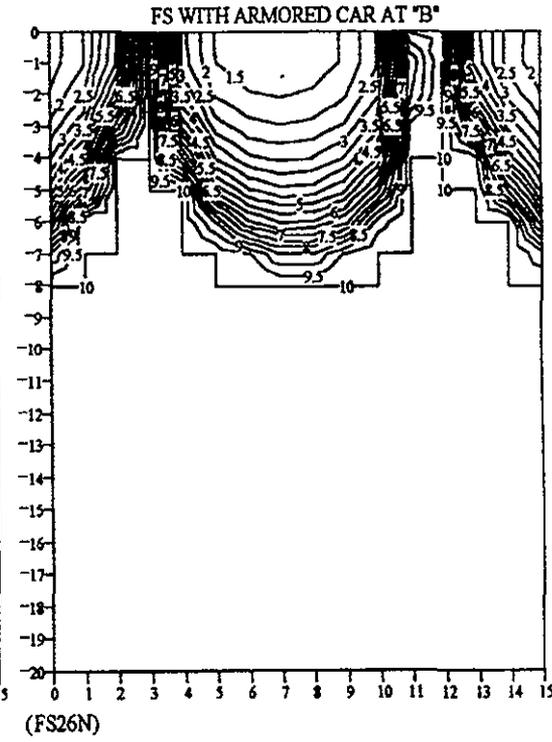
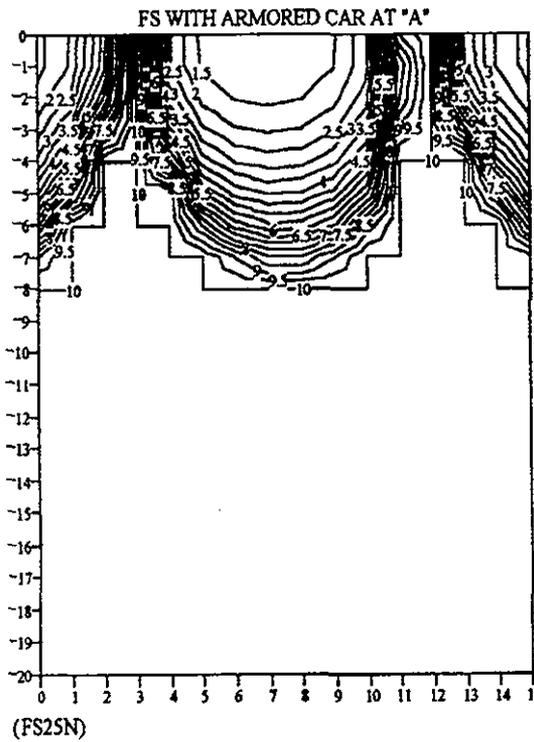
$$FS26_{y,z} := \frac{\text{if}(M2_{y,z} > 0, \max(M6), \min(M6))}{M2_{y,z}}$$

$$FS25N_{y,z} := \text{if}(FS25_{y,z} < 10, FS25_{y,z}, 10)$$

$$FS26N_{y,z} := \text{if}(FS26_{y,z} < 10, FS26_{y,z}, 10)$$

$$\min(FS25) = 1.04 \quad \max(FS25) = 1.29 \cdot 10^5$$

$$\min(FS26) = 1.1 \quad \max(FS26) = 1.22 \cdot 10^5$$



$$FS25_g = FS25_{y,20-8}$$

$$FS26_g = FS26_{y,20-8}$$

$$\min(FS25_g) = 11.31$$

$$\min(FS26_g) = 12.04$$

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 0

Page No. 61 of 90

Client: Babcock & Wilcox Hanford Company

WO/No. TM22

Subject: 241-Z-361 Underground Tank

Date: 11/17/98

By: DAVID S. MESSINGER, PE *DSM*

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 1/24/99

By: J. JULYK *JJK*

Location: PPF 200 W Area - Hanford Site, Richland, Washington

Revised: _____

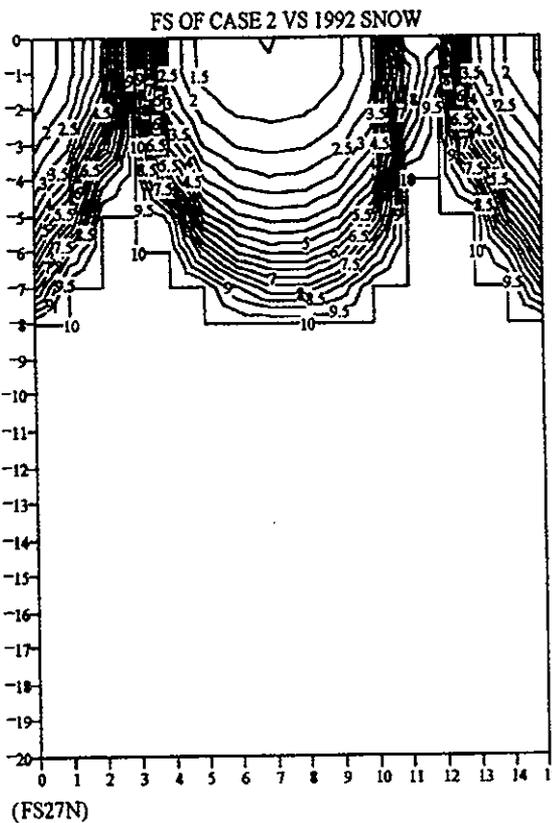
By: _____

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 2 VS MAXIMUM MOMENTS PRODUCED BY THE 1992 SNOW LOADING OF 3.5 PSF (LOAD CASE 7) ON THE WALL FACE. FACTORS OF SAFETY > 10 HAVE BEEN NORMALIZED TO 10 TO REDUCE PLOT CONGESTION.

$$FS27_{y,z} := \frac{\text{if}(M2_{y,z} > 0, \max(M7), \min(M7))}{M2_{y,z}}$$

$$FS27N_{y,z} := \text{if}(FS27_{y,z} < 10, FS27_{y,z}, 10)$$

$$\min(FS27) = 0.98 \quad \max(FS27) = 1.04 \cdot 10^5$$



$$FS27_8 := FS27_{y,20-8}$$

$$\min(FS27_8) = 10.43$$

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 0

Page No. 62 of 90

Client: Babcock & Wilcox Hanford Company

WONo. TM22

Subject: 241-Z-381 Underground Tank

Date: 11/17/89

By: DAVID S. MESSINGER, PE

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 1/24/92

By: L.J. JULYK

Location: PFP 200 W Area - Hanford Site, Richland, Washington

Revised: _____

By: _____

LOAD CASE 8: A 1,500 lb concentrated load located normal to the long tank wall at centerline and offset 15 feet to represent a temporary storage location.

Reset variables for new tank orientation:

DISCRETE LEFT END REACTION FUNCTION $F := 0 \quad z := 0, 1..20 \quad y := 0, 1..28 \quad L := 20$

$$R(y,z,F) := F_{y,z} \cdot \frac{(L-z)^2}{L^3} \cdot (3z + (L-z))$$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

FILLING POINT LOAD ARRAY

$$F_{y,z} := (p(1500, 15, 22 - z, y - 14))$$

$$P8 := F$$

LEFT END REACTION VECTOR

LEFT END FIXED MOMENT VECTOR

GENERAL SHEAR ARRAY

$$RL_y := \sum_{z=0}^L R(y,z,P8)$$

$$ML_y := \sum_{z=0}^L P8_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$$

$$V_{y,z} := RL_y - \sum_{z=0}^z P8_{y,z}$$

GENERAL MOMENT ARRAY

SPECIFIC MOMENT ARRAY

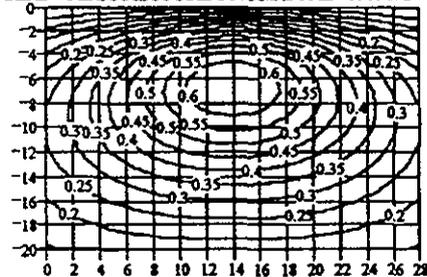
SPECIFIC SHEAR ARRAY

$$M_{y,z} := ML_y - \sum_{z=0}^z P8_{y,z} \cdot z - V_{y,z} \cdot z$$

$$M8 := M$$

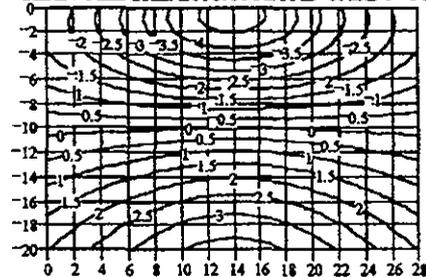
$$V8 := V$$

SIDEWALL PRESSURE FROM LOAD CASE 8 - PSF



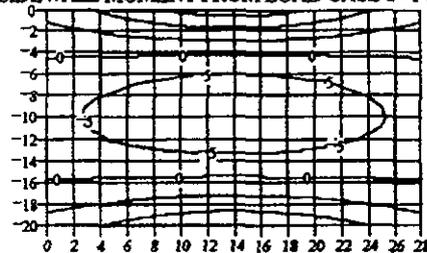
P8

SIDEWALL SHEAR FROM LOAD CASE 8 - PSF



V8

SIDEWALL MOMENT FROM LOAD CASE 8 - FT-LB



M8

$$\min(P8) = -0.05$$

$$\max(P8) = 0.65$$

$$\max(V8) = 3.69$$

$$\min(V8) = -4.71$$

$$\max(M8) = 17.49$$

$$\min(M8) = -8.83$$

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TH22-G-01
 Revision: 0
 Page No. 63 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPP 200 W Area - Hanford Site, Richland, Washington

WONo. TM22
 Date: 11/17/98
 Checked: [Signature]
 Revised: _____

By: DAVID S. MESSINGER, PE [Signature]
 By: L.J. JULYK [Signature]
 By: _____

LOAD CASE 9: This load case is for snow load effect on the long (28') side of the tank wall. Since the tank wall load capacity is assumed to vary with depth, the bending action is assumed to be one way along the short axis. This will make this case consistent with the others cases reviewed.

Normalize the wall face pressure for snow load effect:

$$K \cdot Q_s = 3.5$$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := K \cdot Q_s$$

FILLING POINT LOAD ARRAY

$$P9 := F$$

LEFT END REACTION VECTOR

$$RL_y := \sum_{z=0}^L R(y,z,P9)$$

LEFT END FIXED MOMENT VECTOR

$$ML_y := \sum_{z=0}^L P9_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_y - \sum_{z=0}^z P9_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} := ML_y - \sum_{z=0}^z P9_{y,z} \cdot z - V_{y,z} \cdot z$$

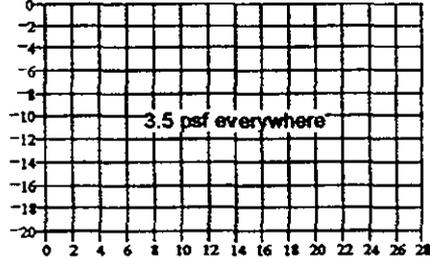
SPECIFIC MOMENT ARRAY

$$M9 := M$$

SPECIFIC SHEAR ARRAY

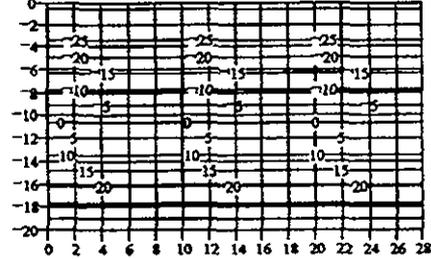
$$V9 := V$$

SIDEWALL PRESSURE FROM LOAD CASE 9 - PSF



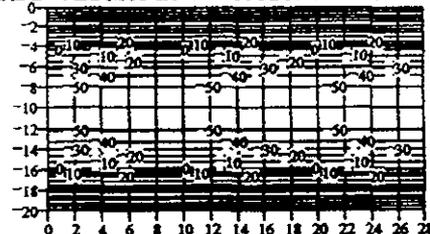
P9

SIDEWALL SHEAR FROM LOAD CASE 9 - PSF



V9

SIDEWALL MOMENT FROM LOAD CASE 9 - FT-LB



M9

$$\min(P9) = 3.5$$

$$\max(P9) = 3.5$$

$$\max(V9) = 33.24$$

$$\min(V9) = -36.74$$

$$\max(M9) = 116.34$$

$$\min(M9) = -58.61$$

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 0

Page No. 69 of 90

Client: Babcock & Wilcox Hanford Company

WONo. TM22

Subject: 241-Z-381 Underground Tank

Date: 11/17/98

By: DAVID S. MESSINGER, PE *DSM*

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 1/24/99

By: L.J. JULYK *LJ*

Location: PEP 200 W Area - Hanford Site, Richland, Washington

Revised: _____

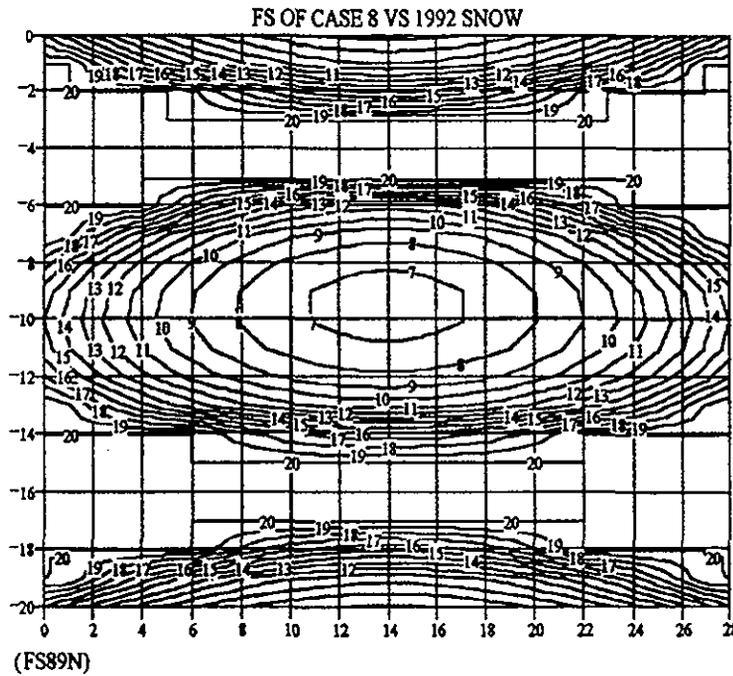
By: _____

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 8 VS MAXIMUM MOMENTS PRODUCED BY THE 1992 SNOW LOADING (LOAD CASE 9) ON THE LONG WALL FACE. FACTORS OF SAFETY > 20 HAVE BEEN NORMALIZED TO 20 TO REDUCE PLOT CONGESTION.

$$FS89_{y,z} := \frac{\text{if}(M8_{y,z} > 0, \max(M9), \min(M9))}{M8_{y,z}}$$

$$FS89N_{y,z} := \text{if}(FS89_{y,z} < 20, FS89_{y,z}, 20)$$

$$\min(FS89) = 6.64 \quad \max(FS89) = 314.68$$



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 65 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 211-Z-341 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/98
 Checked: 4/24/99
 Revised: _____

By: DAVID S. MESSINGER, PE *DSM*
 By: L. J. JULYK *LJ*
 By: _____

LOAD CASE 11: An 3,620 lb concentrated load located normal to the long tank wall at centerline and offset 5 feet to produce a 2:1 factor of safety relative to 1992, December snow load.

Reset variables for new tank orientation: F:=0 z:=0,1..20 y:=0,1..28 L:=20.

DISCRETE LEFT END REACTION FUNCTION

$$R(y,z,F) := F_{y,z} \cdot \frac{(L-z)^2}{L^3} \cdot (3z + (L-z))$$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := (p(3620, 5, 22 - z, y - 14))$$

FILLING POINT LOAD ARRAY

$$P11 := F$$

LEFT END REACTION VECTOR

$$RL_y := \sum_{z=0}^L R(y,z,P11)$$

LEFT END FIXED MOMENT VECTOR

$$ML_y := \sum_{z=0}^L P11_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_y - \sum_{z=0}^z P11_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} := ML_y - \sum_{z=0}^z P11_{y,z} \cdot z - V_{y,z} \cdot z$$

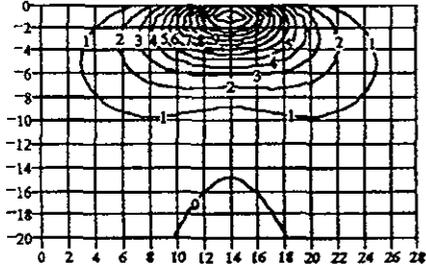
SPECIFIC MOMENT ARRAY

$$M11 := M$$

SPECIFIC SHEAR ARRAY

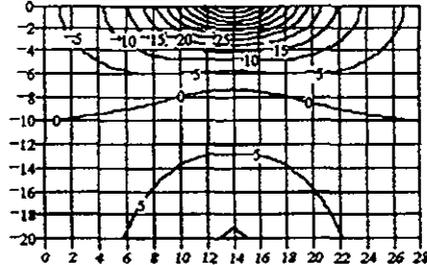
$$V11 := V$$

SIDEWALL PRESSURE FROM LOAD CASE 11-PSF



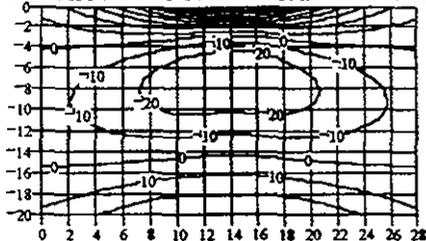
P11

SIDEWALL SHEAR FROM LOAD CASE 11-PSF



V11

SIDEWALL MOMENT FROM LOAD CASE 11-FT-LB



M11

- min(P11) = -0.1
- max(P11) = 14.08
- max(V11) = 5.69
- min(V11) = -62.01
- max(M11) = 105.12
- min(M11) = -29.35

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-G-01
 Revision: 0
 Page No. 66 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-381 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WONo. TM22
 Date: 11/17/98
 Checked: 1/29/99
 Revised: _____

By: DAVID S. MESSINGER, PE *DSM*
 By: L.J. JULYK *LJJ*
 By: _____

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 11 VS MAXIMUM MOMENTS PRODUCED BY THE 1992 SNOW LOADING (LOAD CASE 9) ON THE LONG WALL FACE. FACTORS OF SAFETY > 10 HAVE BEEN NORMALIZED TO 10 TO REDUCE PLOT CONGESTION.

$$FS119_{y,z} := \frac{\text{if}(M11_{y,z} > 0, \max(M9), \min(M9))}{M11_{y,z}}$$

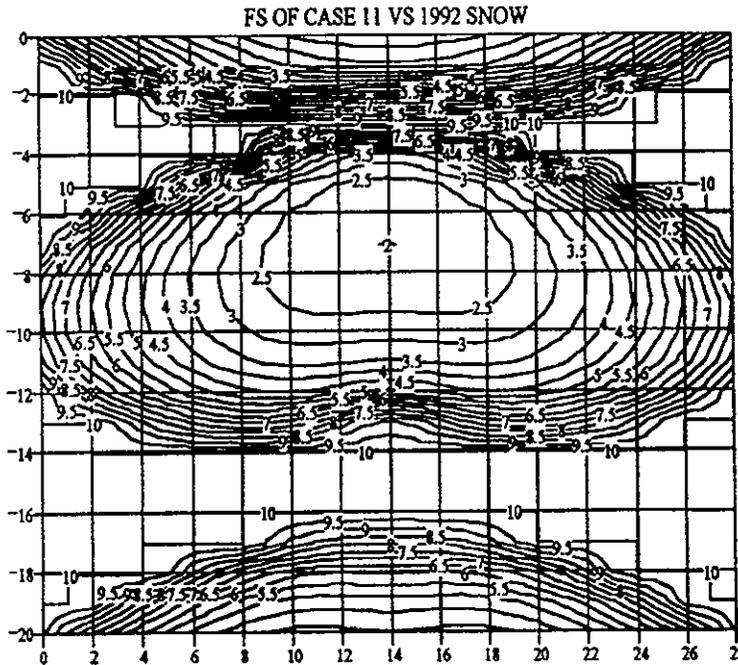
$$FS119N_{y,z} := \text{if}(FS119_{y,z} < 10, FS119_{y,z}, 10)$$

$$\min(FS119) = 1.11 \quad \max(FS119) = 812.07$$

Factors of Safety at one ft. intervals along vertical centerline.

-z FS119_{14,20-z}

0	1.11
-1	2.1
-2	5.81
-3	17.2
-4	3.31
-5	2.29
-6	2.02
-7	2
-8	2.12
-9	2.37
-10	2.82
-11	3.59
-12	5.1
-13	9.09
-14	45.85
-15	29.62
-16	12.75
-17	8.15
-18	6.01
-19	4.78
-20	3.98



(FS119N)

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 0

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Client: Babcock & Wilcox Hanford Company

WO/No. TM22

Subject: 241-Z-361 Underground Tank

Date: 11/17/98

By: DAVID S. MESSINGER, PE *DEM*

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 4/20/99

By: L.J. JULYK *LJ*

Location: FFP 200 W Area - Hanford Site, Richland, Washington

Revised: _____

By: _____

LOAD CASE 12: An 3,415 lb concentrated load located normal to the long tank wall at centerline and offset 10 feet to produce a 2:1 factor of safety relative to 1992, December snow load.

Reset variables for new tank orientation:

$$F := 0 \quad z := 0, 1..20 \quad y := 0, 1..28 \quad L := 20$$

DISCRETE LEFT END REACTION FUNCTION

$$R(y,z,F) := F_{y,z} \frac{(L-z)^2}{L^3} (3z + (L-z))$$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := (p(3415, 10, 22 - z, y - 14))$$

FILLING POINT LOAD ARRAY

$$P12 := F$$

LEFT END REACTION VECTOR

$$RL_y := \sum_{z=0}^L R(y,z,P12)$$

LEFT END FIXED MOMENT VECTOR

$$ML_y := \sum_{z=0}^L P12_{y,z} z \frac{(L-z)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_y - \sum_{z=0}^z P12_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} := ML_y - \sum_{z=0}^z P12_{y,z} z - V_{y,z} z$$

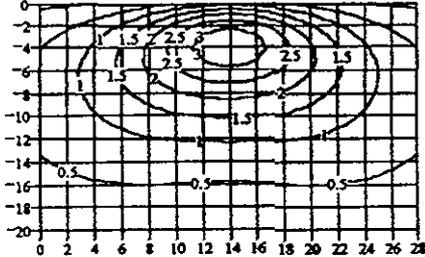
SPECIFIC MOMENT ARRAY

$$M12 := M$$

SPECIFIC SHEAR ARRAY

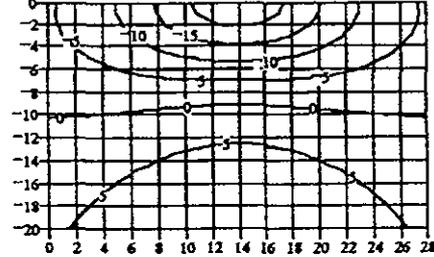
$$V12 := V$$

SIDEWALL PRESSURE FROM LOAD CASE 12-PSF



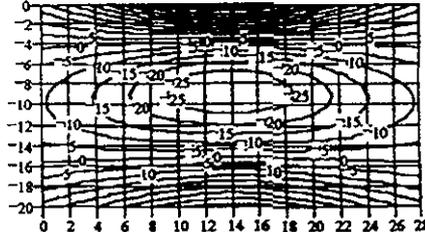
P12

SIDEWALL SHEAR FROM LOAD CASE 12-PSF



V12

SIDEWALL MOMENT FROM LOAD CASE 12-FT-LB



M12

- min(P12) = -0.07
- max(P12) = 3.32
- max(V12) = 9.19
- min(V12) = -23.37
- max(M12) = 70.08
- min(M12) = -29.31

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 0

Page No. 68 of 90

Client: Babcock & Wilcox Hanford Company

WONo. TM22

Subject: 241-Z-381 Underground Tank

Date: 11/17/98

By: DAVID S. MESSINGER, PE *DSM*

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 1/24/99

By: L.J. JULYK *LJ*

Location: PPF 209 W Area - Hanford Site, Richland, Washington

Revised: _____

By: _____

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 12 VS MAXIMUM MOMENTS PRODUCED BY THE 1992 SNOW LOADING (LOAD CASE 9) ON THE LONG WALL FACE. FACTORS OF SAFETY > 5 HAVE BEEN NORMALIZED TO 5 TO REDUCE PLOT CONGESTION.

$$FS_{129}_{y,z} := \frac{\text{if}(M_{12}_{y,z} > 0, \max(M_9), \min(M_9))}{M_{12}_{y,z}}$$

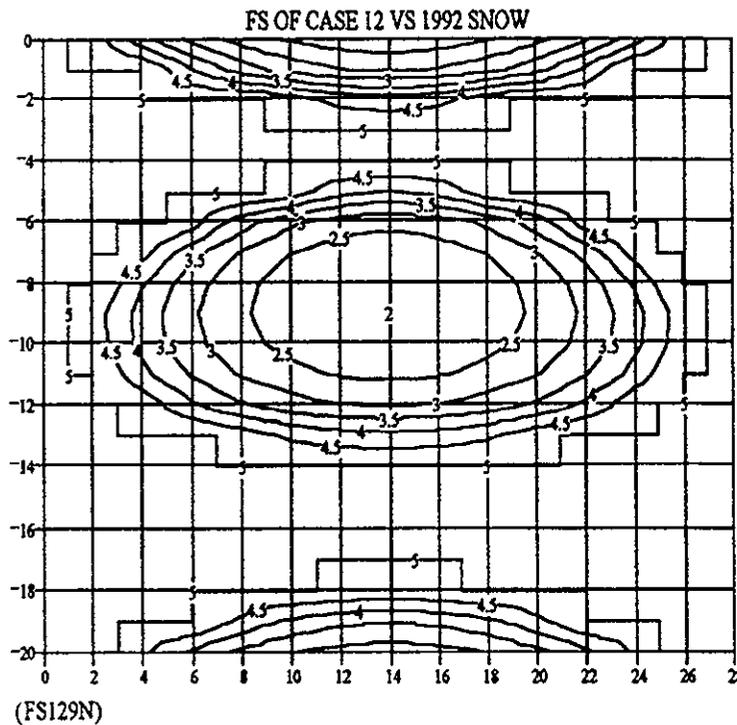
$$FS_{129N}_{y,z} := \text{if}(FS_{129}_{y,z} < 5, FS_{129}_{y,z}, 5)$$

$$\min(FS_{129}) = 1.66 \quad \max(FS_{129}) = 1.92 \cdot 10^3$$

Factors of Safety at one ft. intervals along vertical centerline.

-z FS129_{14,20-z}

0	1.66
-1	2.44
-2	4.25
-3	11.55
-4	14.74
-5	3.99
-6	2.63
-7	2.17
-8	2
-9	2
-10	2.13
-11	2.41
-12	2.96
-13	4.13
-14	7.57
-15	100.54
-16	16.25
-17	7.56
-18	4.85
-19	3.53
-20	2.76



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
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Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-341 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 209 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/98
 Checked: [Signature]
 Revised: [Signature]

By: DAVID S. MESSINGER, PE [Signature]
 By: L.J. HAYK [Signature]
 By: _____

LOAD CASE 13: An 5,000 lb concentrated load located normal to the long tank wall at centerline and offset 15 feet to produce a 2:1 factor of safety relative to 1992, December snow load.

Reset variables for new tank orientation:

DISCRETE LEFT END REACTION FUNCTION $F := 0 \quad z := 0, 1..20 \quad y := 0, 1..28 \quad L := 20$

$$R_{y,z}(F) := F_{y,z} \frac{(L-z)^2}{L^3} (3-z + (L-z))$$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := (p(5000, 15, 22 - z, y - 14))$$

FILLING POINT LOAD ARRAY

$$P13 := F$$

LEFT END REACTION VECTOR

$$RL_y := \sum_{z=0}^L R_{y,z}(P13)$$

LEFT END FIXED MOMENT VECTOR

$$ML_y := \sum_{z=0}^L P13_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_y - \sum_{z=0}^z P13_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} := ML_y - \sum_{z=0}^z P13_{y,z} \cdot z - V_{y,z} \cdot z$$

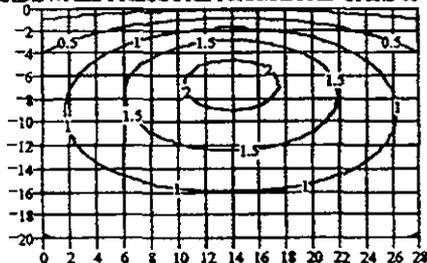
SPECIFIC MOMENT ARRAY

$$M13 := M$$

SPECIFIC SHEAR ARRAY

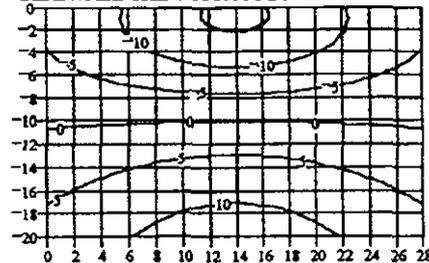
$$V13 := V$$

SIDEWALL PRESSURE FROM LOAD CASE 13-PSF



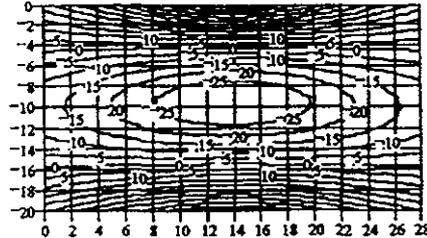
P13

SIDEWALL SHEAR FROM LOAD CASE 13-PSF



V13

SIDEWALL MOMENT FROM LOAD CASE 13-FT-LB



M13

min(P13) = -0.18
 max(P13) = 2.17
 max(V13) = 12.31
 min(V13) = -15.7
 max(M13) = 58.3
 min(M13) = -29.44

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-G-01

Revision: 0

Page No. 70 of 92 *DSM*

Client: Babcock & Wilcox Hanford Company

WO/No. TM22

Subject: 241-Z-341 Underground Tank

Date: 11/17/98

By: DAVID S. MESSINGER, PE

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 11/24/98

By: L.J. JULYK

Location: PPF 200 W Area - Hanford Site, Richland, Washington

Revised: _____

By: _____

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 13 VS MAXIMUM MOMENTS PRODUCED BY THE 1992 SNOW LOADING (LOAD CASE 9) ON THE LONG WALL FACE. FACTORS OF SAFETY > 5 HAVE BEEN NORMALIZED TO 5 TO REDUCE PLOT CONGESTION.

$$FS139_{y,z} := \frac{\text{if}(M13_{y,z} > 0, \max(M9), \min(M9))}{M13_{y,z}}$$

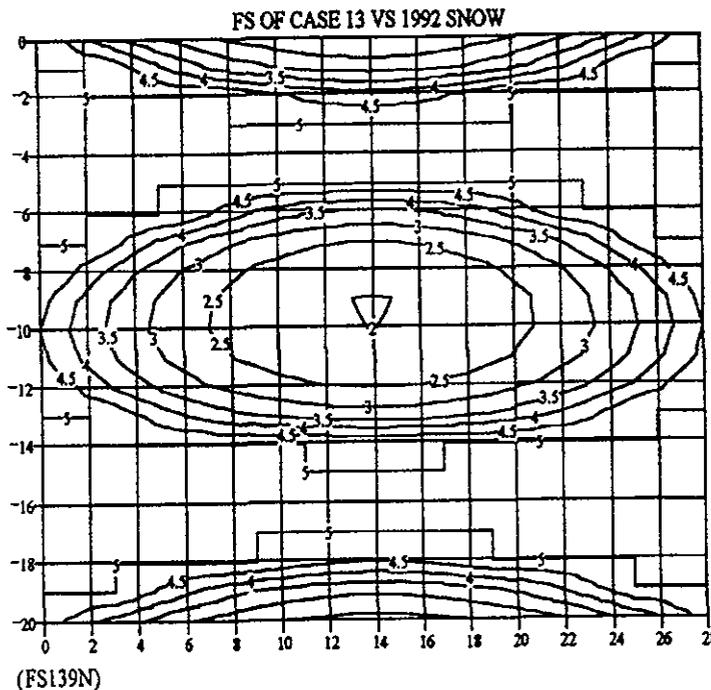
$$FS139N_{y,z} := \text{if}(FS139_{y,z} < 5, FS139_{y,z}, 5)$$

$$\min(FS139) = 1.99 \quad \max(FS139) = 94.4$$

Factors of Safety at one ft. intervals along vertical centerline.

-z FS139_{14,20-z}

0	2
-1	2.73
-2	4.23
-3	8.55
-4	89.43
-5	6.44
-6	3.37
-7	2.49
-8	2.13
-9	1.99
-10	2
-11	2.14
-12	2.47
-13	3.16
-14	4.92
-15	14.48
-16	23.6
-17	7.81
-18	4.52
-19	3.11
-20	2.34



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-G-91
 Revision: 0
 Page No. 71 of 90

Client: Babcock & Wilcox Hartford Company
 Subject: 241-Z-381 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PEP 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/98
 Checked: 1/24/02
 Revised: _____
 By: DAVID S. MESSINGER, PE *DSM*
 By: L. J. JULYK *LJJ*
 By: _____

LOAD CASE 14: An 7,850 lb concentrated load located normal to the long tank wall at centerline and offset 20 feet to produce a 2:1 factor of safety relative to 1992, December snow load.

Reset variables for new tank orientation:

DISCRETE LEFT END REACTION FUNCTION $F := 0 \quad z := 0, 1..20 \quad y := 0, 1..28 \quad L := 20$

$$R(y,z,F) := F \cdot \frac{(L-z)^2}{L^3} \cdot (3 \cdot z + (L-z))$$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} := (p(7850, 20, 22 - z, y - 14))$$

FILLING POINT LOAD ARRAY

$$P14 := F$$

LEFT END REACTION VECTOR

$$RL_y := \sum_{z=0}^L R(y,z,P14)$$

LEFT END FIXED MOMENT VECTOR

$$ML_y := \sum_{z=0}^L P14_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} := RL_y - \sum_{z=0}^z P14_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,x} := ML_y - \sum_{z=0}^z P14_{y,z} \cdot z - V_{y,z} \cdot z$$

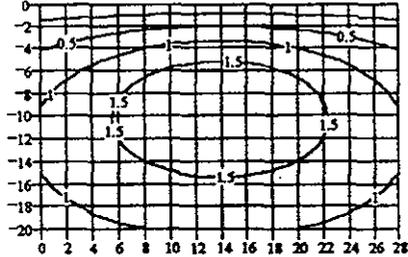
SPECIFIC MOMENT ARRAY

$$M14 := M$$

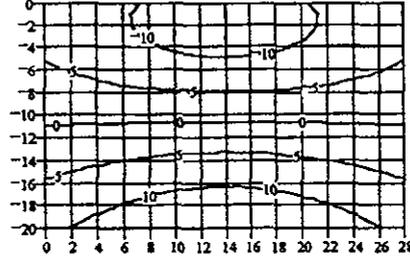
SPECIFIC SHEAR ARRAY

$$V14 := V$$

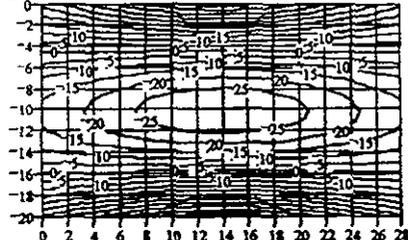
SIDEWALL PRESSURE FROM LOAD CASE 14-PSF



SIDEWALL SHEAR FROM LOAD CASE 14-PSF



SIDEWALL MOMENT FROM LOAD CASE 14-FT-LB



min(P14) = -0.38
 max(P14) = 1.92
 max(V14) = 14.69
 min(V14) = -12.56
 max(M14) = 54.48
 min(M14) = -29.36

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01

Revision: 0

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Client: Babcock & Wilcox Hanford Company

WONo. TM22

Subject: 241-Z-361 Underground Tank

Date: 11/17/98

Lateral Load on Tank Wall from Concentrated Load at Grade

Checked: 11/24/98

By: DAVID S. MESSINGER, PE

Location: PPF 200 W Area - Hanford Site, Richland, Washington

Revised: _____

By: J. JULYK

By: _____

CONTOUR PLOT OF FACTORS OF SAFETY FOR LOAD CASE 14 VS MAXIMUM MOMENTS PRODUCED BY THE 1992 SNOW LOADING (LOAD CASE 9) ON THE LONG WALL FACE. FACTORS OF SAFETY > 5 HAVE BEEN NORMALIZED TO 5 TO REDUCE PLOT CONGESTION.

$$FS149_{y,z} = \frac{\text{if}(M14_{y,z} > 0, \max(M9), \min(M9))}{M14_{y,z}}$$

$$FS149N_{y,z} = \text{if}(FS149_{y,z} < 5, FS149_{y,z}, 5)$$

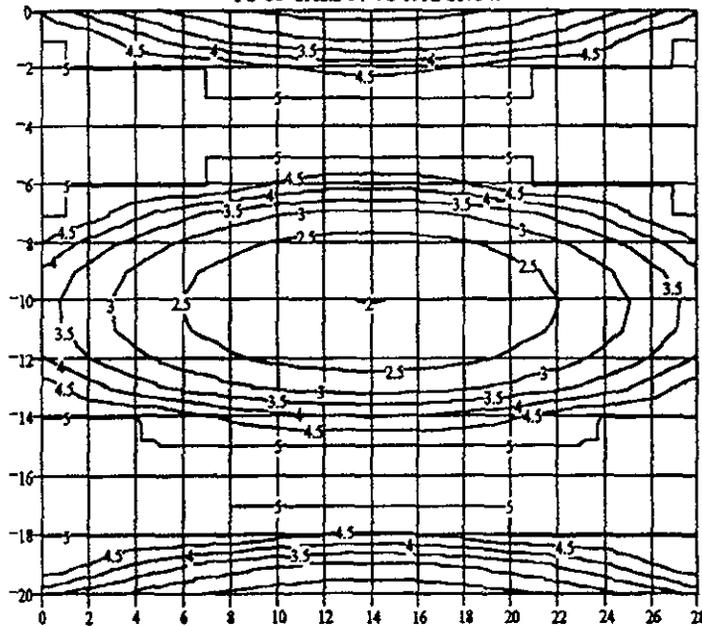
$$\min(FS149) = 2 \quad \max(FS149) = 137.8$$

Factors of Safety at one ft. intervals along vertical centerline.

-z FS149_{14,20-z}

0	2.25
-1	2.97
-2	4.36
-3	7.88
-4	30.78
-5	9.82
-6	4.12
-7	2.82
-8	2.29
-9	2.06
-10	2
-11	2.06
-12	2.29
-13	2.8
-14	4.02
-15	8.9
-16	39.35
-17	8.35
-18	4.43
-19	2.92
-20	2.14

FS OF CASE 14 VS 1992 SNOW



(FS149N)

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 73 of 93

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/99
 Checked: 1/24/00
 Revised: _____

By: DAVID S. MESSINGER, PE
 By: L. J. JULYK
 By: _____

$r := 0 \quad Q = 950$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q,r,22 - z,y - 14))$

LEFT END REACTION VECTOR

$RL_y := \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y := \sum_{z=0}^L F_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} := ML_y - \sum_{z=0}^z F_{y,z} \cdot z - V_{y,z} \cdot z$

$FS_{y,z} := \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

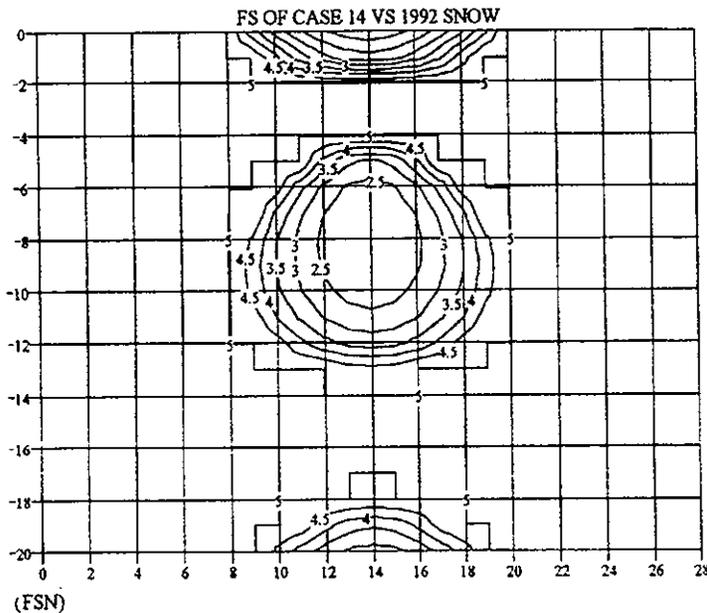
$FSN_{y,z} := \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

$\min(FS) = 1.14 \quad \max(FS) = 6.79 \cdot 10^3$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 0 \quad Q = 950$

-z	FS _{14,20-z}
0	1.14
-1	2.2
-2	5.23
-3	57.08
-4	5.11
-5	2.89
-6	2.28
-7	2.06
-8	2
-9	2.07
-10	2.26
-11	2.61
-12	3.27
-13	4.66
-14	9.05
-15	419.15
-16	15.28
-17	7.52
-18	4.89
-19	3.58
-20	2.79



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 74 of 70

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/98
 Checked: 1/24/02
 Revised: _____

By: DAVID S. MESSINGER, PE *DSM*
 By: L.J. JULYK *LJJ*
 By: _____

$r = 1 \quad Q = 1000$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q,r,22-z,y-14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} \cdot z - V_{y,z} \cdot z$

$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

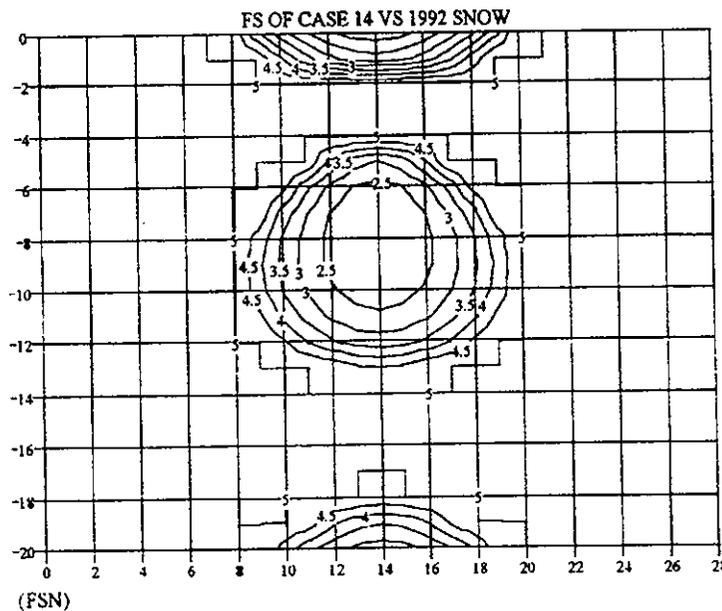
$FSN_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

$\min(FS) = 1.19 \quad \max(FS) = 5.61 \cdot 10^3$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 1 \quad Q = 1000$

-z	FS _{14,20-z}
0	1.19
-1	2.2
-2	5.01
-3	37.24
-4	5.55
-5	2.98
-6	2.31
-7	2.07
-8	2
-9	2.06
-10	2.24
-11	2.57
-12	3.2
-13	4.54
-14	8.65
-15	2.25 · 10 ³
-16	15.54
-17	7.53
-18	4.86
-19	3.54
-20	2.76



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 75 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-381 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PFP 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/98
 Checked: 1/24/99
 Revised: _____
 By: DAVID S. MESSINGER, PE *DSM*
 By: L.J. JULYK *LJ*
 By: _____

$r = 2 \quad Q := 1140$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q, r, 22 - z, y - 14))$

LEFT END REACTION VECTOR

$RL_y := \sum_{z=0}^L R(y, z, F)$

LEFT END FIXED MOMENT VECTOR

$ML_y := \sum_{z=0}^L F_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} := ML_y - \sum_{z=0}^z F_{y,z} \cdot z - V_{y,z} \cdot z$

$FS_{y,z} := \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

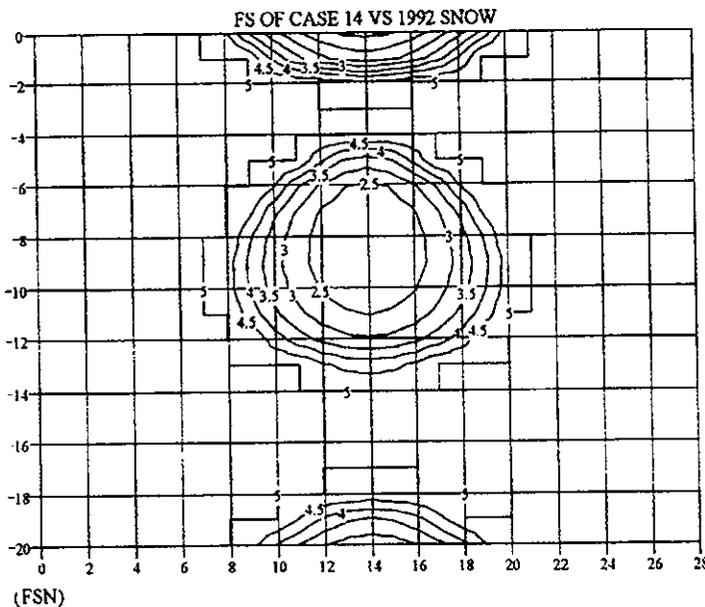
$FSN_{y,z} := \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

$\min(FS) = 1.33 \quad \max(FS) = 3.58 \cdot 10^3$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 2 \quad Q = 1140$

-z	FS _{14,20-z}
0	1.33
-1	2.25
-2	4.64
-3	20.86
-4	6.99
-5	3.25
-6	2.41
-7	2.1
-8	2
-9	2.03
-10	2.18
-11	2.49
-12	3.06
-13	4.26
-14	7.78
-15	110.51
-16	16.29
-17	7.55
-18	4.8
-19	3.47
-20	2.69



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-G-81

Revision: 0

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Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/98
 Checked: [Signature]
 Revised: _____

By: DAVID S. MESSINGER, PE *DSM*
 By: L.J. JULYK *[Signature]*
 By: _____

$r = 3 \quad Q = 1360$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(\dot{Q}, r, 22 - z, y - 14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} z \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} z - V_{y,z} z$

$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

$FSN_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

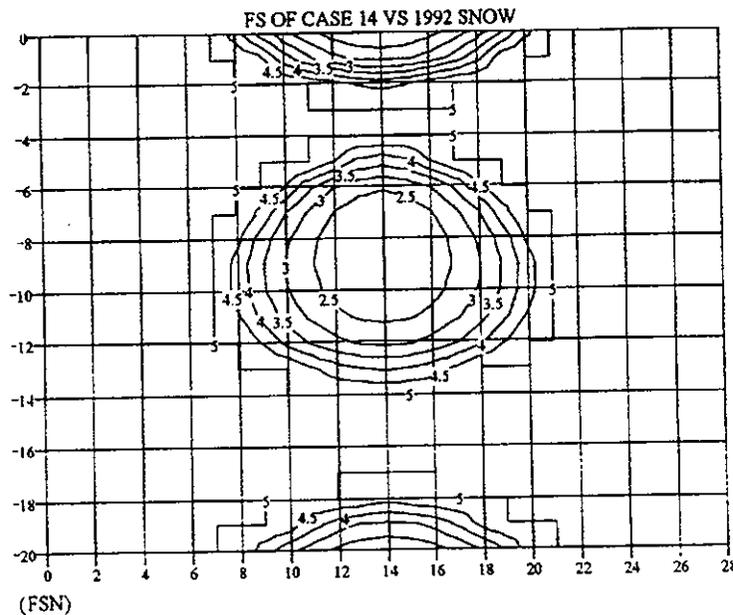
$\min(FS) = 1.49 \quad \max(FS) = 4.25 \cdot 10^3$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 3 \quad Q = 1360$

-z FS_{14,20-z}

0	1.49
-1	2.33
-2	4.37
-3	14.2
-4	10.09
-5	3.67
-6	2.55
-7	2.15
-8	2.01
-9	2
-10	2.12
-11	2.38
-12	2.89
-13	3.94
-14	6.87
-15	44.6
-16	17.43
-17	7.58
-18	4.72
-19	3.37
-20	2.59



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
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Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PFP 200 W Area - Hanford Site, Richland, Washington

WO No. TM22
 Date: 11/17/98
 Checked: 1/24/99
 Revised: _____
 By: DAVID S. MESSINGER, PE *DSM*
 By: L.J. JULYK *LJ*
 By: _____

$r = 4 \quad Q = 1650$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q,r,22 - z, y - 14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} \cdot z - V_{y,z} \cdot z$

$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

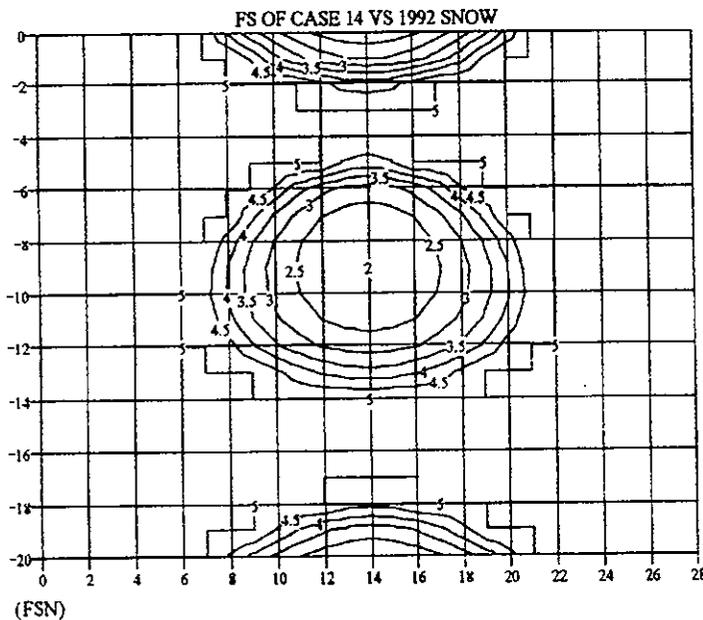
$FSN_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

$\min(FS) = 1.65 \quad \max(FS) = 9.3 \cdot 10^3$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 4 \quad Q = 1650$

-z	FS _{14,20-z}
0	1.65
-1	2.44
-2	4.25
-3	11.28
-4	17.53
-5	4.25
-6	2.76
-7	2.24
-8	2.04
-9	2
-10	2.08
-11	2.3
-12	2.75
-13	3.66
-14	6.11
-15	26.78
-16	19.1
-17	7.67
-18	4.66
-19	3.28
-20	2.5



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 78 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-381 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PFP 200 W Area - Hanford Site, Richland, Washington

WONo. TM22
 Date: 11/17/98
 Checked: HDA/AD
 Revised: _____
 By: DAVID S. MESSINGER, PE *DSM*
 By: L.J. JULYK *LJ*
 By: _____

r = 5 Q = 2025

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$$F_{y,z} = (p(Q, r, 22 - z, y - 14))$$

LEFT END REACTION VECTOR

$$RL_y = \sum_{z=0}^L R(y,z,F)$$

LEFT END FIXED MOMENT VECTOR

$$ML_y = \sum_{z=0}^L F_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$$

GENERAL SHEAR ARRAY

$$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$$

GENERAL MOMENT ARRAY

$$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} \cdot z - V_{y,z} \cdot z$$

$$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$$

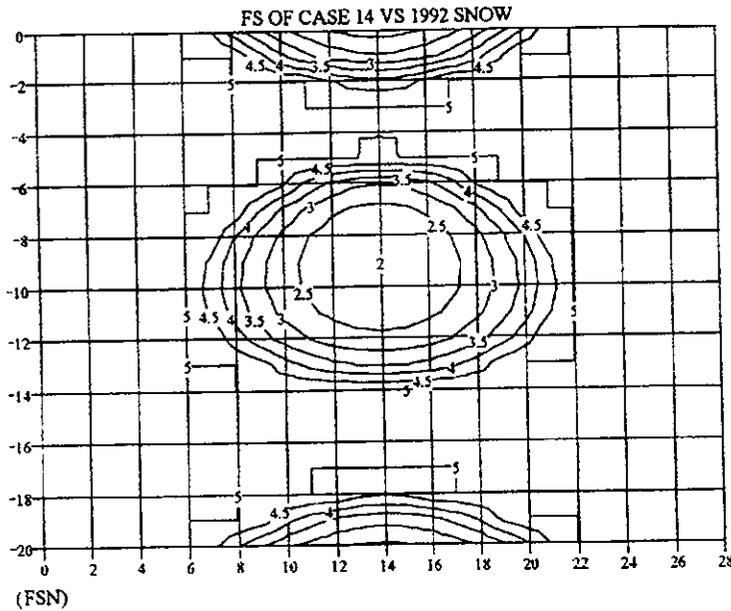
$$FSN_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$$

$$\min(FS) = 1.8 \quad \max(FS) = 4.59 \cdot 10^3$$

Factors of Safety at one ft. intervals along vertical centerline.

r = 5 Q = 2025

-z	FS _{14,20-z}
0	1.8
-1	2.56
-2	4.22
-3	9.78
-4	47.23
-5	5
-6	2.99
-7	2.34
-8	2.08
-9	2
-10	2.05
-11	2.23
-12	2.62
-13	3.42
-14	5.49
-15	18.88
-16	21.29
-17	7.78
-18	4.6
-19	3.2
-20	2.42



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 79 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WO No. TM22
 Date: 11/17/98
 Checked: [Signature]
 Revised: _____
 By: DAVID S. MESSINGER, PE DSM
 By: L.J. JULYK [Signature]
 By: _____

$r = 6 \quad Q = 2510$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q,r,22 - z,y - 14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} z \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} z - V_{y,z} z$

$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

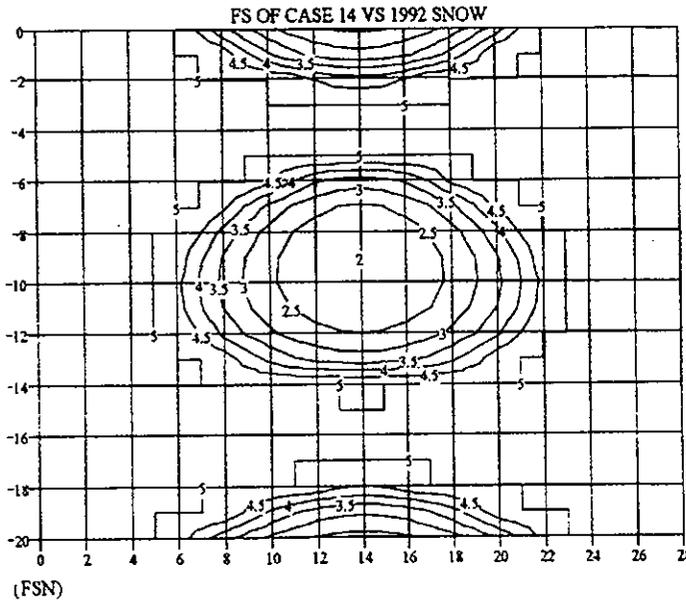
$FSN_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

$\min(FS) = 1.93 \quad \max(FS) = 2.83 \cdot 10^3$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 6 \quad Q = 2510$

-z	FS _{14,20-z}
0	1.93
-1	2.67
-2	4.21
-3	8.89
-4	244.16
-5	5.89
-6	3.24
-7	2.44
-8	2.12
-9	2
-10	2.02
-11	2.17
-12	2.5
-13	3.21
-14	4.97
-15	14.48
-16	24.08
-17	7.88
-18	4.53
-19	3.11
-20	2.32



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 80 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPP 200 W Area - Hanford Site, Richland, Washington

WONo. TM22
 Date: 11/17/98
 Checked: 11/24/98
 Revised: _____
 By: DAVID S. MESSINGER, PE DSM
 By: L.J. JULYK
 By: _____

$r = 7 \quad Q = 3100$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q,r,22-z,y-14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} \cdot z - V_{y,z} \cdot z$

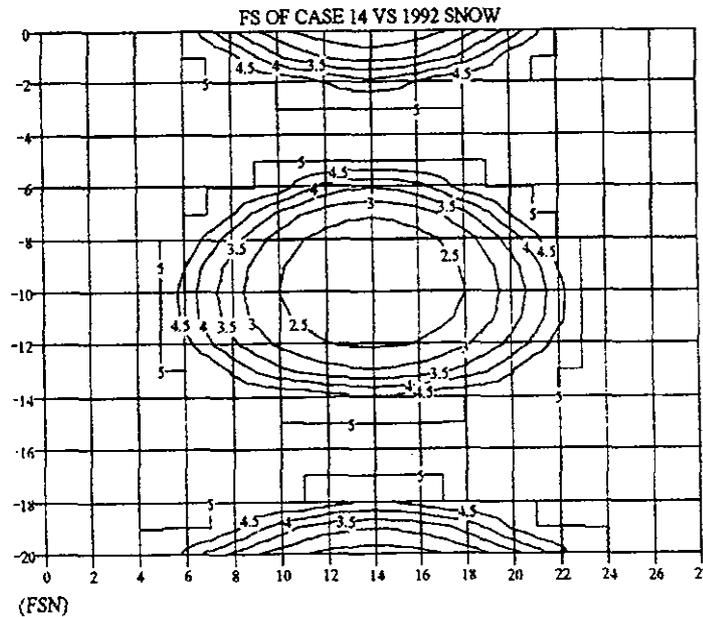
$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

$FSN_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

$\min(FS) = 2 \quad \max(FS) = 3.87 \cdot 10^3$

Factors of Safety at one ft. intervals along vertical centerline.
 $r = 7 \quad Q = 3100$

-z	FS _{14,20-z}
0	2.04
-1	2.78
-2	4.26
-3	8.39
-4	62.82
-5	6.99
-6	3.52
-7	2.57
-8	2.17
-9	2.02
-10	2
-11	2.12
-12	2.42
-13	3.04
-14	4.58
-15	11.82
-16	27.96
-17	8.04
-18	4.5
-19	3.04
-20	2.25



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 81 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/99
 Checked: [Signature]
 Revised: _____
 By: DAVID S. MESSINGER, PE *DSM*
 By: L.J. JULYK *LJJ*
 By: _____

$r = 8 \quad Q = 3820$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q,r,22 - z, y - 14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} z \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} z - V_{y,z} z$

$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

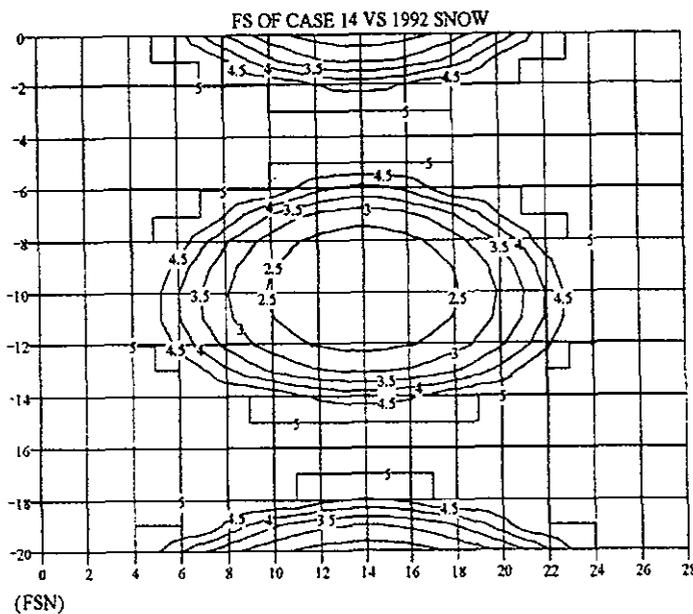
$FSN_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

$\min(FS) = 2 \quad \max(FS) = 4.02 \cdot 10^3$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 8 \quad Q = 3820$

-z	FS _{14,20-z}
0	2.16
-1	2.89
-2	4.32
-3	8.1
-4	39.63
-5	8.33
-6	3.83
-7	2.7
-8	2.24
-9	2.04
-10	2
-11	2.1
-12	2.36
-13	2.92
-14	4.27
-15	10.06
-16	33.41
-17	8.24
-18	4.48
-19	2.98
-20	2.19



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
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Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/98
 Checked: 11/24/98
 Revised: _____
 By: DAVID S. MESSINGER, PE DSM
 By: L.V. JULYK
 By: _____

$r = 9 \quad Q = 4720$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q, r, 22 - z, y - 14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} \cdot z - V_{y,z} \cdot z$

$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

$FSN_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

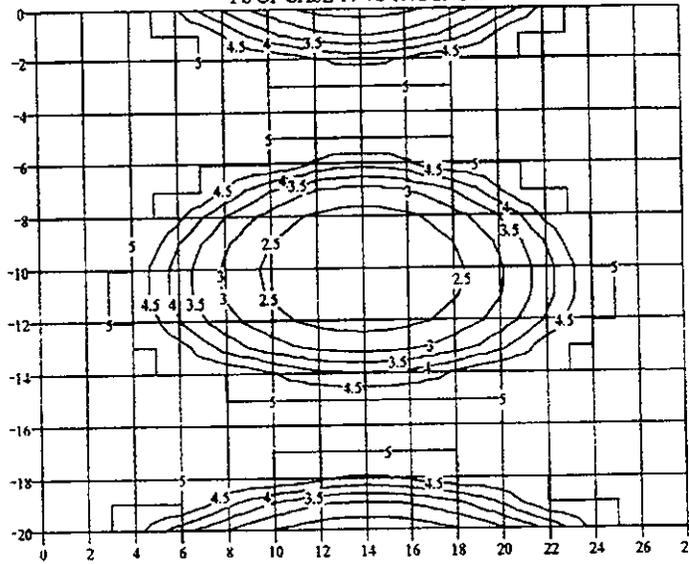
$\min(FS) = 2 \quad \max(FS) = 1.69 \cdot 10^3$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 9 \quad Q = 4720$

-z	$FS_{y,z,20-z}$
0	2.25
-1	2.98
-2	4.37
-3	7.88
-4	30.58
-5	9.88
-6	4.13
-7	2.82
-8	2.3
-9	2.07
-10	2
-11	2.07
-12	2.29
-13	2.8
-14	4.01
-15	8.78
-16	41.13
-17	8.43
-18	4.44
-19	2.92
-20	2.12

FS OF CASE 14 VS 1992 SNOW



(FSN)

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 83 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WO No. TM22
 Date: 11/17/98
 Checked: 11/24/98
 Revised: _____
 By: DAVID S. MESSINGER, PE
 By: L.J. JULYK
 By: _____

$r := 10 \quad Q := 5830$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q,r,22 - z, y - 14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} z \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} z - V_{y,z} z$

$FS_{y,z} := \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

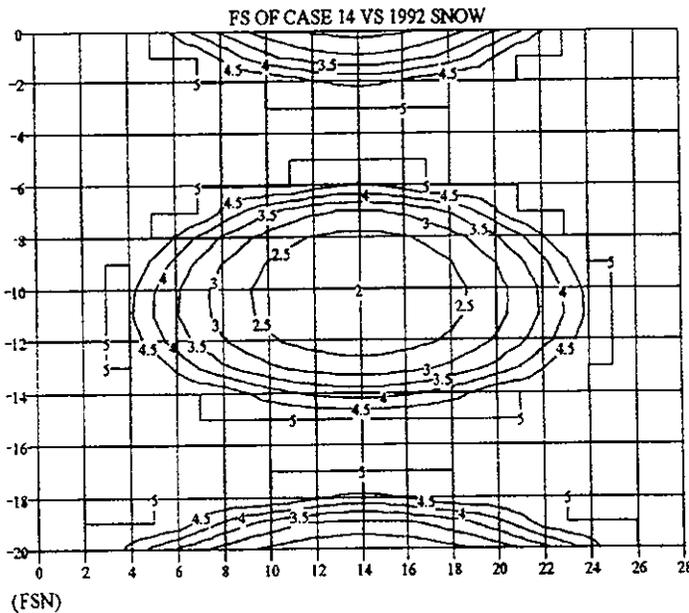
$FSN_{y,z} := \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

$\min(FS) = 2 \quad \max(FS) = 1.37 \cdot 10^3$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 10 \quad Q = 5830$

-z	FS _{14,20-z}
0	2.32
-1	3.05
-2	4.42
-3	7.72
-4	25.8
-5	11.69
-6	4.43
-7	2.94
-8	2.35
-9	2.09
-10	2
-11	2.04
-12	2.24
-13	2.69
-14	3.78
-15	7.81
-16	53.01
-17	8.61
-18	4.41
-19	2.86
-20	2.06



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 84 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/98
 Checked: [Signature]
 Revised: _____
 By: DAVID S. MESSINGER, PE DSM
 By: L.J. JULYK [Signature]
 By: _____

$r = 11 \quad Q = 7160$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q,r,22-z,y-14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} \cdot z - V_{y,z} \cdot z$

$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

$FSN_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

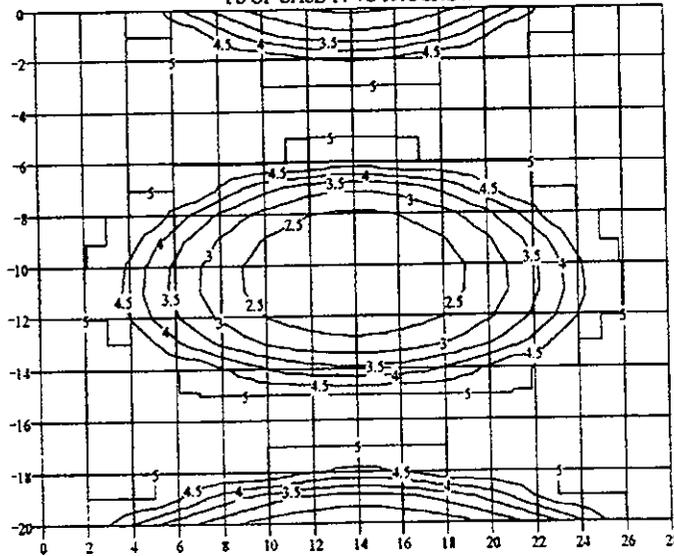
$\min(FS) = 2 \quad \max(FS) = 2.14 \cdot 10^3$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 11 \quad Q = 7160$

-z	FS _{14,20-z}
0	2.4
-1	3.13
-2	4.47
-3	7.63
-4	22.96
-5	13.88
-6	4.74
-7	3.07
-8	2.41
-9	2.12
-10	2
-11	2.03
-12	2.2
-13	2.61
-14	3.6
-15	7.09
-16	73.87
-17	8.83
-18	4.39
-19	2.81
-20	2.01

FS OF CASE 14 VS 1992 SNOW



(FSN)

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 85 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PFP 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/98
 Checked: [Signature]
 Revised: _____
 By: DAVID S. MESSINGER, PE *DSM*
 By: L.J. JULYK *[Signature]*
 By: _____

$r = 12 \quad Q = 8800$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q,r,22 - z,y - 14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} \cdot z - V_{y,z} \cdot z$

$FS_{y,z} = \frac{if(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

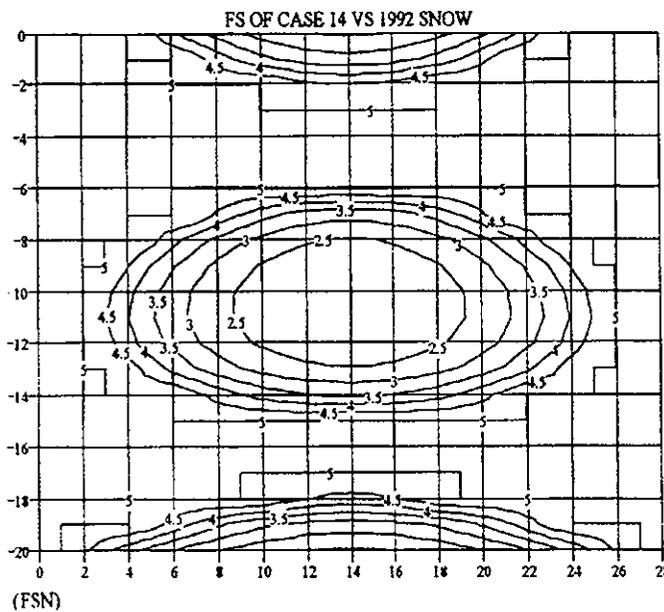
$FSN_{y,z} = if(FS_{y,z} < 5, FS_{y,z}, 5)$

$\min(FS) = 1.95 \quad \max(FS) = 1.36 \cdot 10^3$

Factors of Safety at one ft intervals along vertical centerline.

$r = 12 \quad Q = 8800$

-z	FS _{14,20-z}
0	2.45
-1	3.18
-2	4.5
-3	7.54
-4	20.99
-5	16.42
-6	5.03
-7	3.17
-8	2.47
-9	2.14
-10	2
-11	2.01
-12	2.16
-13	2.54
-14	3.44
-15	6.51
-16	118.09
-17	9.02
-18	4.36
-19	2.75
-20	1.95



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-G-41
 Revision: 0
 Page No. 86 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WQNo. TM22
 Date: 11/17/98
 Checked: 1/24/99
 Revised: _____
 By: DAVID S. MESSINGER, PE DSM
 By: L.J. JULYK
 By: _____

$r = 13 \quad Q = 10800$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q, r, 22 - z, y - 14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y, z, F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} z \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} z$

$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

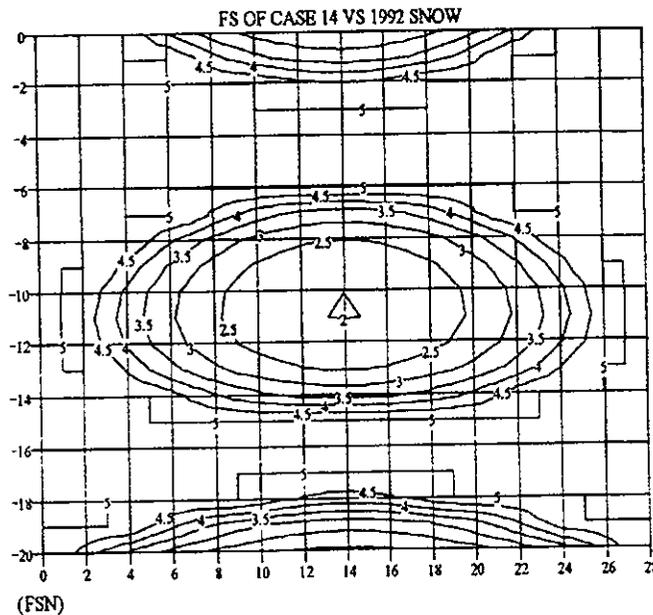
$FSN_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

$\min(FS) = 1.9 \quad \max(FS) = 1.42 \cdot 10^3$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 13 \quad Q = 10800$

-z	FS _{14, 20 - z}
0	2.5
-1	3.22
-2	4.52
-3	7.45
-4	19.55
-5	19.41
-6	5.3
-7	3.27
-8	2.51
-9	2.15
-10	2
-11	1.99
-12	2.12
-13	2.47
-14	3.29
-15	6.02
-16	276.6
-17	9.21
-18	4.33
-19	2.7
-20	1.9



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 27 of 40

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-381 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/98
 Checked: 11/24/98
 Revised: _____
 By: DAVID S. MESSINGER, PE
 By: J.J. JALYK

$r = 14 \quad Q = 13000$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} = (p(Q,r,22 - z, y - 14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} z \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} = ML_y - \sum_{z=0}^z F_{y,z} z^2 - V_{y,z} z$

$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

$FSN_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

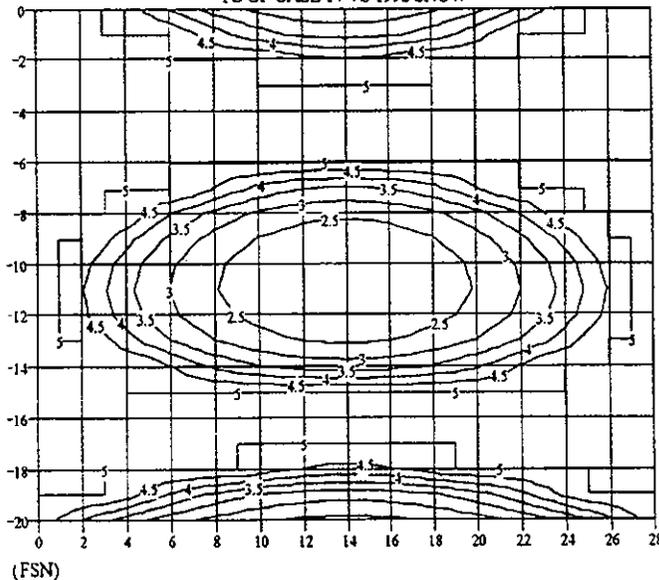
$\min(FS) = 1.88 \quad \max(FS) = 495.91$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 14 \quad Q = 13000$

-z	FS _{14,20-z}
0	2.57
-1	3.31
-2	4.61
-3	7.5
-4	18.76
-5	23.38
-6	5.65
-7	3.41
-8	2.59
-9	2.2
-10	2.03
-11	2
-12	2.12
-13	2.44
-14	3.22
-15	5.72
-16	495.91
-17	9.55
-18	4.37
-19	2.69
-20	1.88

FS OF CASE 14 VS 1992 SNOW



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 39 of 90

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PFP 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/98
 Checked: 9/24/99
 Revised: _____
 By: DAVID S. MESSINGER, PE
 By: L.J. JULYK
 By: _____

$r = 15 \quad Q = 15750$

SPECIFIC PRESSURE ARRAY FOR WALL FACE

$F_{y,z} := (p(Q,r,22 - z, y - 14))$

LEFT END REACTION VECTOR

$RL_y = \sum_{z=0}^L R(y,z,F)$

LEFT END FIXED MOMENT VECTOR

$ML_y = \sum_{z=0}^L F_{y,z} \cdot z \cdot \frac{(L-z)^2}{L^2}$

GENERAL SHEAR ARRAY

$V_{y,z} = RL_y - \sum_{z=0}^z F_{y,z}$

GENERAL MOMENT ARRAY

$M_{y,z} := ML_y - \sum_{z=0}^z F_{y,z} \cdot z - V_{y,z} \cdot z$

$FS_{y,z} = \frac{\text{if}(M_{y,z} > 0, \max(M9), \min(M9))}{M_{y,z}}$

$FSN_{y,z} = \text{if}(FS_{y,z} < 5, FS_{y,z}, 5)$

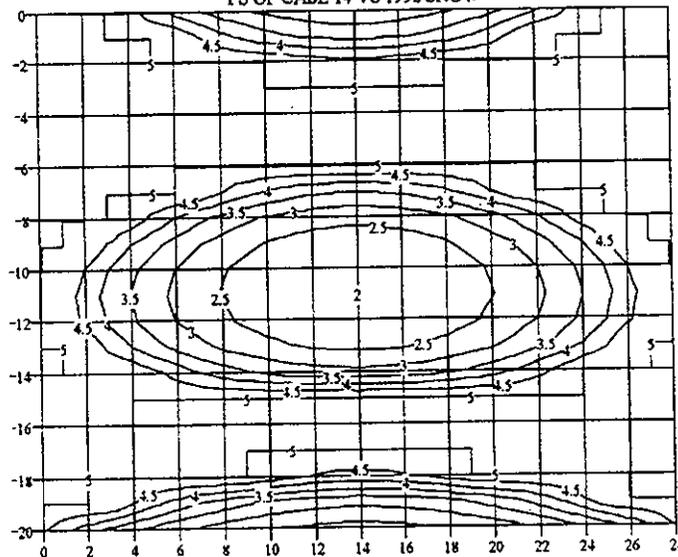
$\min(FS) = 1.84 \quad \max(FS) = 256.47$

Factors of Safety at one ft. intervals along vertical centerline.

$r = 15 \quad Q = 15750$

-z	FS _{14,20-z}
0	2.62
-1	3.36
-2	4.65
-3	7.47
-4	18
-5	27.99
-6	5.93
-7	3.52
-8	2.64
-9	2.23
-10	2.04
-11	2
-12	2.1
-13	2.4
-14	3.13
-15	5.41
-16	94.15
-17	9.79
-18	4.36
-19	2.66
-20	1.84

FS OF CASE 14 VS 1992 SNOW



(FSN)

Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 89 of 12

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: FFP 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/98 By: DAVID S. MESSINGER, PE
 Checked: 1/24/99 By: L.J. JULYK
 Revised: _____ By: _____

i = 0..16

i	vr _i	vQ _i
0	0	950
1	1	1000
2	2	1140
3	3	1360
4	4	1650
5	5	2025
6	6	2510
7	7	3100
8	8	3135
9	9	3240
10	10	3415
11	11	3600
12	12	3860
13	13	4175
14	14	4550
15	15	4975
16	20	7850

$Q_{allow}(r) := \text{linterp}(vr, vQ, r)$

r = 0..20

n := 2

$vs := \text{regress}(vr, vQ, n)$

$Q_{allow_p}(r) := \text{interp}(vs, vr, vQ, r)$

$Q_{allow_p}(r) = \sum_{k=0}^n vs_{k+3} \cdot r^k$

vs =

3
3
2
957.41
163.59
8.14

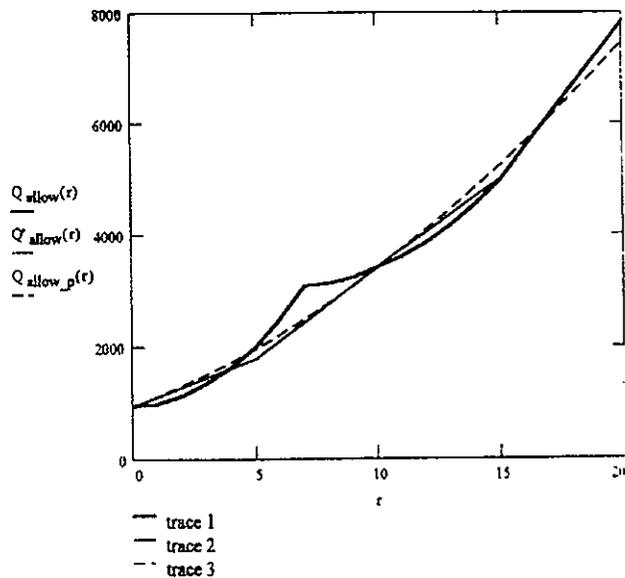
j = 0..4

j	vr' _j	vQ' _j
0	0	950
1	5	1800
2	10	3415
3	15	5000
4	20	7850

$Q'_{allow}(r) := \text{linterp}(vr', vQ', r)$

r = 0..20

r	Q _{allow} (r)	Q' _{allow} (r)	Q _{allow_p} (r)	Q' _{allow_p} (r)
0	950	950	957	957
1	1000	1120	1129	1129
2	1140	1290	1317	1317
3	1360	1460	1521	1521
4	1650	1630	1742	1742
5	2025	1800	1979	1979
6	2510	2123	2232	2232
7	3100	2446	2502	2502
8	3135	2769	2787	2787
9	3240	3092	3089	3089
10	3415	3415	3408	3408
11	3600	3732	3742	3742
12	3860	4049	4093	4093
13	4175	4366	4460	4460
14	4550	4683	4844	4844
15	4975	5000	5244	5244
16	5550	5570	5660	5660
17	6125	6140	6092	6092
18	6700	6710	6541	6541
19	7275	7280	7006	7006
20	7850	7850	7487	7487



Fluor Daniel Northwest, Inc.

EVALUATION ANALYSIS

Calc No. TM22-C-01
 Revision: 0
 Page No. 97 of 97

Client: Babcock & Wilcox Hanford Company
 Subject: 241-Z-361 Underground Tank
Lateral Load on Tank Wall from Concentrated Load at Grade
 Location: PPF 200 W Area - Hanford Site, Richland, Washington

WO/No. TM22
 Date: 11/17/98 By: DAVID S. MESSINGER, PE DSM
 Checked: 1/24/99 By: L.J. JULYK
 Revised: _____ By: _____

Example Application - Load Case 1 N := 7

i = 0..N

i	Q _i	r _i
0	80	2.5
1	80	2.5
2	80	7.5
3	80	7.5
4	80	7.5
5	600	4
6	200	8
7	600	8

$$\sum_{i=0}^N \frac{Q_i}{Q_{allow}(r_i)} = 0.82$$

$$\sum_{i=0}^N \frac{Q_i}{Q_{allow_p}(r_i)} = 0.84$$

$$\frac{2 \cdot 80}{950} + \frac{3 \cdot 80}{1800} + \frac{600}{950} + \frac{200 + 600}{1800} = 1.38$$

$$\sum_{i=0}^N \frac{Q_i}{Q'_{allow}(r_i)} = 0.87 \quad \text{or}$$

$$\frac{2 \cdot 80}{950 + \frac{2.5}{5} \cdot 850} + \frac{3 \cdot 80}{1800 + \left(\frac{7.5 - 5}{5}\right) \cdot 1615} + \frac{600}{950 + \frac{4}{5} \cdot 850} + \frac{200 + 600}{1800 + \left(\frac{8 - 5}{5}\right) \cdot 1615} = 0.87$$

Method

Linear interpolation of Q_{allowable}
 (16 discrete zones)

Second order regression of Q_{allowable}
 (16 discrete zones)

Constant allowable within original 4
 discrete zone (0-5, 5-10, 10-15, and
 15-20)

Linear interpolation of allowable
 within original 4 discrete zones
 (0-5, 5-10, 10-15, and 15-20)

APPENDIX: H

BRIDGE AND FOUNDATION DESIGN



DESIGN ANALYSIS

Calc. No. BLC-Z361-R3
 Revision 0
 Page No. 1 of 26

Client: Characterization Equipment
 Subject: Analysis of Core Sampling Platform

WO/Job No. _____

Date: 3/29/99
 Checked: 3/29/99
 Revised: _____

By: B. L. Coverdell
 By: [Signature]
 By: _____

1.0 OBJECTIVE These calculations determine the structural adequacy of the core sampling platform for use in sample tank 241-Z-381. The platform is considered performance category 2 (PC2) per Engineering Design and Evaluation, HNF-PRO-097. The platform supports a core sample truck weighing 32,000 lb and ten people each weighing 200 lb for a total weight of 35000 lb. An 85 mph wind loading is also considered, however, this is not combined with the live loading due to personnel. Also, the live load due to stopping of the core sample truck shall be considered. Seismic loading is not considered a credible design load since this is a temporary structure. The platform working stresses will be calculated and compared to the allowable working stresses in American Institute of Steel Construction, AISC 1989.

2.0 DESIGN INPUTS

2.1 Drawing: H-2-85633

3.0 ASSUMPTIONS

- 3.1 Seismic loading is not considered to be a credible scenario since the platform is a temporary structure.
- 3.2 The center of pressure and the center of gravity are coincident.
- 3.3 The uplift due to 85 mph wind will be neglected. This is conservative for two reasons: overturning of the core sample truck has already been analyzed and determined not be of concern (WHC 1995) and the uplift force would reduce the total load on the platform.
- 3.4 Given 3.2 and that the Cg is nearly over the rear axle, all the overturning force due to wind loading will be applied to the rear axle.
- 3.5 The 2 mph velocity of core truck is based on operational experience.
- 3.6 For analysis purposes, the worst case scenario of the core sample truck on the platform is with the rear axle of the truck directly over the center of the platform. This load case requires that two platforms be used since the front axle extend onto it due to the length of the truck.

4.0 METHODS OF ANALYSIS (Hand calculations completed in Mathcad ver. 8.0)**5.0 REFERENCES**

- 5.1 AISC, 1989, *Manual of Steel Construction*, 9th Edition, American Institute of Steel Construction, Chicago, Illinois.
- 5.2 ASCE, 1996, *Minimum Design Loads for Buildings and Other Structures*, ANSI/ASCE 7-95, American Society of Civil Engineers, Reston, Virginia.
- 5.3 Blodgett, O W, 1991, *Design of Welded Structures*, Fourteenth Printing, The James F. Lincoln Arc Welding Foundation, Cleveland, Ohio.
- 5.4 Coverdell, 1999, *Design Loads and Center of Gravity For Core Sample Truck #1*, LMHC-9951531, Lockheed Martin Hanford Corp., Richland, Washington.
- 5.5 FDH, 1987, *Engineering and Design and Evaluation*, HNF-PRO-097, Fluor Daniel Hanford, Inc., Richland, Washington.
- 5.6 WHC, 1995, *Structural Evaluation for Core Sampling Trucks, RMCS Operations, 200 Area*, WHC-SD-WM-DA-215, Westinghouse Hanford Company.

6.0 FINDINGS AND CONCLUSIONS The calculations in this below determined that the core sampling platform is adequate to support the 32000 lb core sample truck plus the weight of 10 people plus 1000 lb due to cask and cask stand for a total of (35000 lb). *NOTE: the casks and cask stand are positioned between two platforms side-by-side.*

7.0 Load Cases Following are the load cases to be considered in these calculations.

- NOTE: 1) Dead weight of the beams was considered and found to be negligible.
 2) Core sampling operations cease in sustained winds in excess of 25 mph.

7.1 LL (Core Sample Truck) + LL (Core Sample Truck Stopping) + LL (Cask) + LL (Humans) + Wind (25 mph).

7.2 LL (Core Sample Truck) + LL (Cask) + Wind (85 mph).

8.0 CALCULATIONS

8.1 Live Loads and core sample truck Cg location.

- $P_{truck} := 32000 \cdot lb$ Live load due to core sample truck, Coverdell, 1999.
 $P_{human} := 2000 \cdot lb$ Live load due to humans, Coverdell, 1999.
 $P_{cask} := 1000 \cdot lb$ Live load due to casks and casks stand. NOTE: In service, this equipment will not be placed directly on a single platform but will be supported between two platforms.
 $P_{front} := 11000 \cdot lb$ Weight of core sample truck front axle as record by the state of Washington.
 $P_{rear} := 21000 \cdot lb$ Weight of core sample truck rear axle as recorded by the state of Washington.
 $Cg_x := 156 \cdot in$ Horizontal distance to CG of sample truck. Measured from center of front axle, WHC 1995.
 $Cg_y := 64.3 \cdot in$ Vertical distance from top of platform to CG of sample truck, Coverdell 1999.

8.2 Determine the maximum wind force on the core sample truck given that the truck is performance category 2 (PC2) and for a 25 mph wind.

- $K_z := .85$ Exposure category C, table 6-3 of ASCE 1996.
 $K_{zt} := 1$ Per paragraph 6.5.5 of ASCE 1996.
 $I := 1.07$ Importance factor (HNF-PRO-097, 1997).
 $V_{85} := 85$ Wind velocity per (HNF-PRO-097, 1997).
 $q_{z_{85}} := .00256 \cdot K_z \cdot K_{zt} \cdot I \cdot V_{85}^2 \cdot \frac{lb}{ft^2}$ $q_{z_{85}} = 16.822 \frac{lb}{ft^2}$ Velocity pressure.
 $G := .85$ Gust effect factors determined from paragraph 6.6.1 of ASCE 1996.
 $C_f := 1.5$ From Table 6-8 of ASCE 1996 given a height of 10 ft.
 $A_f := 36128 \cdot in^2$ Surface area of truck from WHC 1995.
 $P_{w_{85}} := q_{z_{85}} \cdot G \cdot C_f \cdot A_f$ $P_{w_{85}} = 5381 \cdot lb$ Wind force on core sample truck.
 $V_{25} := 25$ 25 mph Wind velocity. This is the maximum wind velocity the operations will use the core sample truck in.
 $q_{z_{25}} := .00256 \cdot K_z \cdot K_{zt} \cdot I \cdot V_{25}^2 \cdot \frac{lb}{ft^2}$ $q_{z_{25}} = 1.455 \frac{lb}{ft^2}$ Velocity pressure.
 $P_{w_{25}} := q_{z_{25}} \cdot G \cdot C_f \cdot A_f$ $P_{w_{25}} = 465 \cdot lb$ Wind force on core sample truck.

8.3 Determine the force applied to the platform by a core sample truck stopping.

- $V_1 := 2\text{-mph}$ Maximum velocity of core sample truck based on operational experience.
- $V_2 := 0\text{-mph}$ Final velocity of core sample truck.
- $m := 35000\text{-lb}$ Mass of core sample truck in lbs mass.
- $t := .6\text{-sec}$ Estimated time required to stop core sample truck based on operational experience.

Use Kinetic Energy Theory

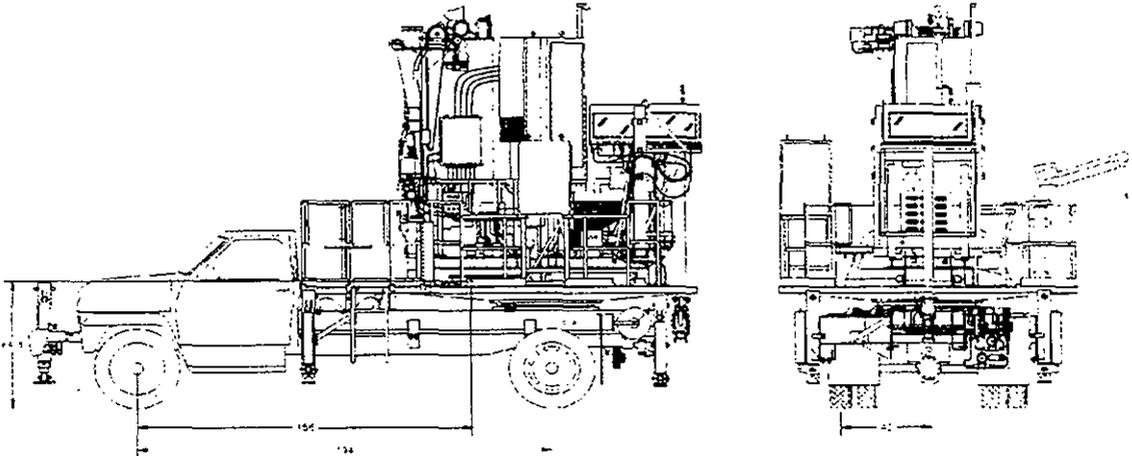
$$d := \frac{V_1 - V_2 \cdot t}{2} \quad d = 10.56\text{-in} \quad \text{Distance required to stop core sample truck given an initial velocity of 2 mph.}$$

Work done = K. E.

$$P_{\text{stop}} \cdot d := \frac{1}{2} \cdot m \cdot V_1^2$$

$$P_{\text{stop}} := \frac{\frac{1}{2} \cdot m \cdot V_1^2}{d} \quad P_{\text{stop}} = 5318\text{-lbf} \quad \text{Longitudinal force required to stop truck.} \quad P_{\text{stop}} := 5318\text{-lb}$$

8.4 Determine the increased reaction force on the rear axle due to a 85 mph wind loading and a 25 mph wind loading.



$e_1 := 84\text{-in}$	Distance between tire center lines on rear axle.
$e_2 := 194\text{-in}$	Distance between centerlines of front and rear tires.
$r_{\text{rear85}} := \frac{Cg_x \cdot P_{w_85}}{e_2}$	$r_{\text{rear85}} = 4327\text{ lb}$ 85 mph wind force on rear axle, WHC 1995.
$r_{\text{rear25}} := \frac{Cg_x \cdot P_{w_25}}{e_2}$	$r_{\text{rear25}} = 374\text{ lb}$ 25 mph wind force on rear axle, WHC 1995.
$r_{w_85} := \frac{Cg_y \cdot r_{\text{rear85}}}{e_1}$	$r_{w_85} = 3312\text{ lb}$ Additional force on one side of rear axle due to 85 mph wind loading, WHC 1995.
$r_{w_25} := \frac{Cg_y \cdot r_{\text{rear25}}}{e_1}$	$r_{w_25} = 287\text{ lb}$ Additional force on one side of rear axle due to 25 mph wind loading. 46" obtained from 84" rear axle tire width / 2, WHC 1995.

8.5 The allowable stresses for A36 and A500 Grade B material per AISC 1989 are shown below.

$\sigma_{y_a36} := 36000 \frac{\text{lb}}{\text{in}^2}$	Yield stress of A36 material.
$\sigma_{t_a36} := 0.6 \cdot \sigma_{y_a36}$	$\sigma_{t_a36} = 21600 \frac{\text{lb}}{\text{in}^2}$ The allowable tensile stress.
$\sigma_{b_a36} := 0.66 \cdot \sigma_{y_a36}$	$\sigma_{b_a36} = 23760 \frac{\text{lb}}{\text{in}^2}$ The allowable strong bending stress.
$\tau_{v_a36} := 0.4 \cdot \sigma_{y_a36}$	$\tau_{v_a36} = 14400 \frac{\text{lb}}{\text{in}^2}$ The allowable shear stress.
$\sigma_{y_a500} := 46000 \frac{\text{lb}}{\text{in}^2}$	Yield stress of A500 Grade B material.
$\sigma_{t_a500} := 0.6 \cdot \sigma_{y_a500}$	$\sigma_{t_a500} = 27600 \frac{\text{lb}}{\text{in}^2}$ The allowable tensile stress.
$\sigma_{b_a500} := 0.66 \cdot \sigma_{y_a500}$	$\sigma_{b_a500} = 30360 \frac{\text{lb}}{\text{in}^2}$ The allowable strong bending stress.
$\tau_{v_a500} := 0.4 \cdot \sigma_{y_a500}$	$\tau_{v_a500} = 18400 \frac{\text{lb}}{\text{in}^2}$ The allowable shear stress.

8.6 Calculate the maximum horizontal and vertical loadings for load cases one and two.

Load Case One

$P_{\text{vert1}} := \frac{P_{\text{rear}}}{2} + \frac{P_{\text{cask}}}{2} + \frac{P_{\text{human}}}{4} + r_{w_25}$	$P_{\text{vert1}} = 11787\text{ lb}$	Vertical Loading: 1/2 rear axle load + 1/2 the cask load + human load evenly distributed over the four legs of a platform + 25 mph wind load.
$P_{\text{horz1}} := P_{\text{stop}}$	$P_{\text{horz1}} = 5318 \cdot \text{lb}$	Horizontal Loading due to truck stopping.
$P_{w_25} = 465.494\text{ lb}$	The lateral loading due to a 25 mph wind is negligible.	

Load Case Two

$$P_{vert2} := \frac{P_{rear}}{2} + \frac{P_{cask}}{2} + r_{w_85}$$

$$P_{vert2} = 14312 \text{ lb}$$

Vertical Loading: 1/2 rear axle load + 1/2 cask load + 85 mph wind load.

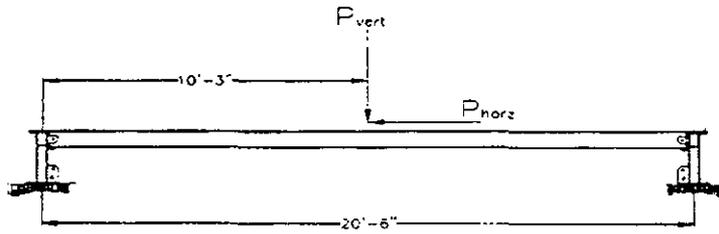
$$P_{horz2} := P_{w_85}$$

$$P_{horz2} = 5381 \text{ lb}$$

Horizontal Loading due to wind.

Note: Load case two is the governing load case and will be used for all analysis, however, the horizontal load due to stop of the core sample truck will be used when deemed applicable.

8.7 Determine the maximum stresses in the W8x18 using the loads calculated above. Consider the two W8x18s to be a simply supported beam. Use the formulas from AISC 1989, Page 2-298, Diagram 7 to determine the maximum bending stress and shear stress.



$L := 246\text{-in}$ Length of beam.

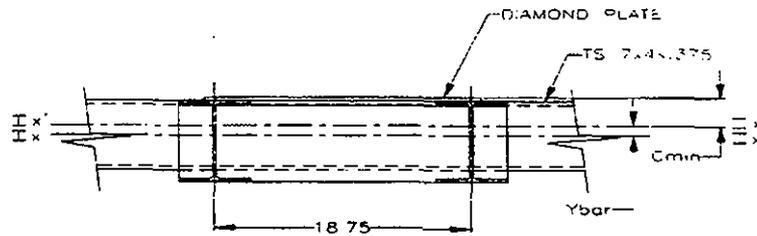
$E := 30 \cdot 10^6 \frac{\text{lb}}{\text{in}^2}$ Modulus of elasticity.

$A_{W8x18} := 5.26 \cdot \text{in}^2$ Cross sectional area of a W8x18.

$I_x := 61.9 \cdot \text{in}^4$ Moment of inertia for a W8x18 about x-x axis.

$I_y := 7.97 \cdot \text{in}^4$ Moment of inertia for a W8x18 about y-y axis.

Determine the actual section modulus of the built-up section (W8x18s and 3/16 in. diamond plate).



$$I_{x_pl} := \frac{1}{12} \cdot 20 \cdot \text{in} \cdot \left(\frac{3}{16} \cdot \text{in}\right)^3$$

$$I_{x_pl} = 0.011 \cdot \text{in}^4$$

Moment of inertia of the diamond plate.

$$A_{pl} := \frac{3}{16} \cdot \text{in} \cdot 20 \cdot \text{in}$$

$$A_{pl} = 3.75 \cdot \text{in}^2$$

Cross sectional area of the diamond plate.

$$y_{pl} := 4.07 \cdot \text{in} + \frac{\frac{3}{16} \cdot \text{in}}{2}$$

$$y_{pl} = 4.164 \cdot \text{in}$$

Distance from the horizontal centerline of the W8x18s to the centroid of the diamond plate.

$$y_{bar} := \frac{y_{pl} \cdot A_{pl}}{2 \cdot A_{W8x18} + A_{pl}}$$

$$y_{bar} = 1.094 \cdot \text{in}$$

Distance from horizontal centerline of the W8x18s to the neutral axis.

$c_{min} := 4.07 \cdot \text{in} + \frac{3}{16} \cdot \text{in} - y_{bar}$	$c_{min} = 3.163 \cdot \text{in}$	Minimum distance from neutral axis to outer most point of built-up beam.
$c_{max} := 4.07 \cdot \text{in} + y_{bar}$	$c_{max} = 5.164 \cdot \text{in}$	Maximum distance from neutral axis to outer most point of built-up beam.
$d_{pl} := c_{min} - \frac{\frac{3}{16} \cdot \text{in}}{2}$	$d_{pl} = 3.07 \cdot \text{in}$	Distance from neutral axis to centroid of plate.
$I_{pl} := I_{x_{pl}} + A_{pl} \cdot d_{pl}^2$	$I_{pl} = 35.344 \cdot \text{in}^4$	Moment of inertia of the diamond plate (parallel axis theorem).
$I_{x'} := 2 \cdot I_x + I_{pl}$	$I_{x'} = 159.144 \cdot \text{in}^4$	Moment of inertia for the entire built-up section.
$d := \frac{18.75 \cdot \text{in}}{2}$		Distance from centerline to outer most fiber of W8x18s.
$I_{y'} := 2 \cdot (I_y + A_{W8x18} \cdot d^2)$	$I_{y'} = 940.549 \cdot \text{in}^4$	$I_{y'}$ does not include diamond plate.
$S_{x'} := \frac{I_{x'}}{c_{max}}$	$S_{x'} = 30.817 \cdot \text{in}^3$	Section modulus of W8x18s and 3/16 in. plate about x' axis.
$S_{y'} := \frac{I_{y'}}{\left(\frac{d + 5.25 \cdot \text{in}}{2}\right)}$	$S_{y'} = 128.622 \cdot \text{in}^3$	Section modulus of W8x18s and 3/16 in. plate about y axis.

Determine the maximum tensile stress on the W8x18s.

$\sigma_t := \frac{P_{horz1}}{2 \cdot A_{W8x18}}$	$\sigma_t = 505.513 \frac{\text{lb}}{\text{in}^2}$
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Answer := if($\sigma_t < \sigma_{t_a36}$, "OK", "No Good") Answer = "OK" Beams are adequate per AISC 1989, Page 5-40.

Determine the maximum bending stresses on the W8x18s.

$Mx_{max} := \frac{P_{vert2} \cdot L}{4}$	$Mx_{max} = 880205 \cdot \text{in} \cdot \text{lb}$	Maximum moment in the W8x18 built-up section per AISC 1989, Page 2-298, Diagram 7 (pinned ends).
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$\sigma_{bx} := \frac{Mx_{max}}{S_{x'}}$	$\sigma_{bx} = 28562 \frac{\text{lb}}{\text{in}^2}$	Maximum stress in the W8x18 built-up section.
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Answer := if($\sigma_{bx} < 1.33 \cdot \sigma_{b_a36}$, "OK", "No Good") Answer = "OK" Beams are adequate per AISC 1989, Page 5-45, Equation F1-1. NOTE: use 1/3 allowable stress increase per AISC 1989, Page 5.30.

$My_{max} := \frac{P_{horz2} \cdot L}{4}$	$My_{max} = 165469 \cdot \text{in} \cdot \text{lb}$	Maximum moment in the W8x18 built-up section per AISC 1989, Page 2-298, Diagram 7 (pinned ends).
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$\sigma_{by} := \frac{My_{max}}{S_{y'}}$	$\sigma_{by} = 1286 \frac{\text{lb}}{\text{in}^2}$	Maximum stress in the W8x18 built-up section.
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Answer := if($\sigma_{by} < 1.33 \cdot \sigma_{b_a36}$, "OK", "No Good") Answer = "OK" Beams are adequate per AISC 1989, Page 5-45, Equation F1-1. NOTE: use 1/3 allowable stress increase per AISC 1989, Page 5-30.

AISC 1989 requires that the load cases that exclude wind be checked also. In these calculations this would be considered load case 1 even though a 25 mph wind is considered. The lateral loading due to an 85 mph wind is also considered (conservative).

$$M_{x \max} := \frac{P_{\text{vert}} \cdot L}{4} \quad M_{x \max} = 724872 \cdot \text{in} \cdot \text{lb} \quad \text{Maximum moment in the W8x18 built-up section per AISC 1989, Page 2-298, Diagram 7 (pinned ends).}$$

$$\sigma_{bx} := \frac{M_{x \max}}{S_{x'}} \quad \sigma_{bx} = 23522 \frac{\text{lb}}{\text{in}^2} \quad \text{Maximum stress in the W8x18 built-up section.}$$

Answer := if($\sigma_{bx} < \sigma_{b_{a36}}$, "OK", "No Good") Answer = "OK" Beams are adequate per AISC 1989, Page 5-45, Equation F1-1.

$$M_{y \max} := \frac{P_{\text{horz}} \cdot L}{4} \quad M_{y \max} = 330938 \cdot \text{in} \cdot \text{lb} \quad \text{Maximum moment in the W8x18 built-up section per AISC 1989, Page 2-298, Diagram 7 (pinned ends).}$$

$$\sigma_{by} := \frac{M_{y \max}}{S_{y'}} \quad \sigma_{by} = 2573 \frac{\text{lb}}{\text{in}^2} \quad \text{Maximum stress in the W8x18 built-up section.}$$

Answer := if($\sigma_{by} < \sigma_{b_{a36}}$, "OK", "No Good") Answer = "OK" Beams are adequate per AISC 1989, Page 5-45, Equation F1-1.

Determine the maximum shear stress on the W8x18s.

$$A_{\text{web}} := 8.14 \cdot \text{in} \cdot 0.23 \cdot \text{in} \quad A_{\text{web}} = 1.872 \cdot \text{in}^2 \quad \text{Only the web will take shear in the vertical direction.}$$

$$\tau_{v_{\text{vert}}} := \frac{P_{\text{vert}}}{2 \cdot A_{\text{web}}} \quad \tau_{v_{\text{vert}}} = 3822.315 \frac{\text{lb}}{\text{in}^2} \quad \text{The maximum vertical shear stress. OK}$$

Answer := if($\tau_{v_{\text{vert}}} < \tau_{v_{a36}}$, "OK", "No Good") Answer = "OK" Beams are adequate per AISC 1989, Page 5-45, Equation F1-1.

$$A_{\text{flan}} := 2 \cdot (5.25 \cdot \text{in} \cdot 0.33 \cdot \text{in}) \quad A_{\text{flan}} = 3.465 \cdot \text{in}^2 \quad \text{Only the flanges will carry the shear in the transversal direction.}$$

$$\tau_{v_{\text{lat}}} := \frac{P_{\text{horz}}}{2 \cdot A_{\text{flan}}} \quad \tau_{v_{\text{lat}}} = 388.248 \frac{\text{lb}}{\text{in}^2} \quad \text{The maximum lateral shear stress. OK}$$

Answer := if($\tau_{v_{\text{lat}}} < \tau_{v_{a36}}$, "OK", "No Good") Answer = "OK" Beams are adequate per AISC 1989, Page 5-49, Equation F4-1.

8.8 Determine the adequacy of the weld connecting the 3/16 in. diamond plate to the W8x18s.

$$V := \tau_{v_{\text{vert}}} \quad V = 3822.315 \frac{\text{lb}}{\text{in}^2} \quad \text{Vertical shear force.}$$

$$Q := \left(22 \cdot \text{in} \cdot \frac{3}{16} \cdot \text{in} \right) \cdot \frac{8.14 \cdot \text{in} + \frac{3}{16} \cdot \text{in}}{2} \quad Q = 17.175 \cdot \text{in}^3 \quad \text{First moment with respect to the neutral axis.}$$

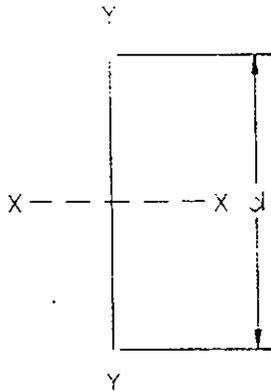
$$I := \frac{\frac{3}{16} \cdot \text{in} \cdot (22 \cdot \text{in})^3}{12} \quad I = 166.375 \cdot \text{in}^4 \quad \text{Moment of inertia of 3/16 in. plate.}$$

$$q := \frac{Q \cdot V}{I} \quad q = 6.819 \cdot 10^5 \frac{\text{lb}}{\text{ft}} \quad \text{Horizontal shear flow.}$$

$$\tau_{weld_act} := \frac{6 \cdot in \cdot q}{2}$$

$$\tau_{weld_act} = 1183.773 \frac{lb}{in^2}$$

Shearing force on each 3" weld.



Weld Geometry.

$$d := 3 \cdot in$$

The length of the weld.

$$w_a := \frac{3}{16} \cdot in$$

The actual weld size.

$$\sigma_{base} := 36000 \frac{lb}{in^2}$$

Yield stress of the base metal.

$$\sigma_{weld} := 70000 \frac{lb}{in^2}$$

Weld metal strength.

Allowable Shear:

$$\tau_{weld_all} := \text{if} \left[0.4 \cdot \sigma_{base} \leq 0.707 \cdot 0.3 \cdot \sigma_{weld}, 0.4 \cdot \sigma_{base}, 0.707 \cdot (0.3) \cdot \sigma_{weld} \right]$$

$$\tau_{weld_all} = 14400 \frac{lb}{in^2}$$

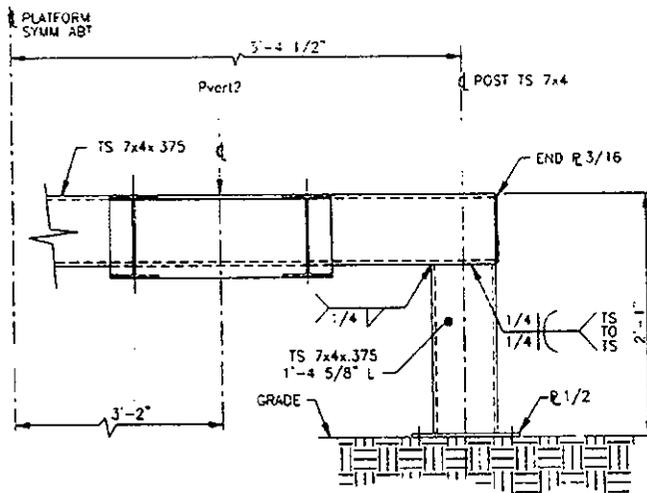
The margin of safety:

$$MS := \frac{\tau_{weld_all}}{\tau_{weld_act}} - 1$$

$$MS = 11.164$$

OK

8.9 Determine the adequacy of the TS 7X4X3/8 beams, consider the beam to be simply supported. Use the formula from AISC 1989, Page 2-298, Diagram 9.



$$a := 26.25 \cdot in$$

Distance from centerline of W8x18 built-up section to centerline of TS 7X4X3/8.

$$A_c := 7.33 \cdot in^2$$

Cross sectional area TS 7X4X3/8.

$$S_x := 12.6 \cdot in^3$$

Strong axis section modulus for a TS 7x4x3/8.

$$S_y := 9.06 \cdot in^3$$

Weak axis section modulus for a TS 7x4x3/8.

The actual moments and stresses in the TS 7x4x3/8.

$$\sigma_t := \frac{P_{\text{horz2}}}{A_c} \quad \sigma_t = 367 \frac{\text{lb}}{\text{in}^2} \quad \text{Maximum tensile stress due to lateral wind loading.}$$

Answer := if($\sigma_t < \sigma_{t_a500}$, "OK", "No Good") Answer = "OK" Beams are adequate per AISC 1989, Page 5-40.

$$M_{bx} := \frac{P_{\text{vert2}}}{2} \cdot a \quad M_{bx} = 187849 \cdot \text{in} \cdot \text{lb}$$

The maximum bending moment about the strong axis in the TS 7x4x3/8s.

$$M_{by} := \frac{P_{\text{horz2}}}{2} \cdot a \quad M_{by} = 70627 \cdot \text{in} \cdot \text{lb}$$

The maximum bending moment about the weak axis in the TS 7x4x3/8s.

$$\sigma_{bx} := \frac{M_{bx}}{S_x} \quad \sigma_{bx} = 14909 \frac{\text{lb}}{\text{in}^2}$$

The maximum strong axis bending stress. OK

Answer := if($\sigma_{bx} < 1.33 \cdot \sigma_{b_a500}$, "OK", "No Good") Answer = "OK" Beams are adequate per AISC 1989, Page 5-45, Equation F1-1. NOTE: use 1/3 allowable stress increase per AISC 1989, Page 5.30.

$$\sigma_{by} := \frac{M_{by}}{S_y} \quad \sigma_{by} = 7795 \frac{\text{lb}}{\text{in}^2}$$

The maximum weak axis bending stress. OK

Answer := if($\sigma_{by} < 1.33 \cdot \sigma_{b_a500}$, "OK", "No Good") Answer = "OK" Beams are adequate per AISC 1989, Page 5-45, Equation F1-1. NOTE: use 1/3 allowable stress increase per AISC 1989, Page 5.30.

Determine the maximum shear stress on the TS 7x4x3/8s.

$$A_{\text{web}} := 2 \cdot \left(7.0 \cdot \text{in} \cdot \frac{3}{8} \cdot \text{in} \right) \quad A_{\text{web}} = 5.25 \cdot \text{in}^2$$

Only the web will take shear in the vertical direction.

$$\tau_{v_vert} := \frac{P_{\text{vert2}}}{A_{\text{web}}} \quad \tau_{v_vert} = 2726 \frac{\text{lb}}{\text{in}^2}$$

The maximum vertical shear stress. OK

Answer := if($\tau_{v_vert} < \tau_{v_a500}$, "OK", "No Good") Answer = "OK" Beams are adequate per AISC 1989, Page 5-49, Equation F4-1.

$$A_{\text{flan}} := 2 \cdot \left(4.0 \cdot \text{in} \cdot \frac{3}{8} \cdot \text{in} \right) \quad A_{\text{flan}} = 3 \cdot \text{in}^2$$

Only the flanges will carry the shear in the transversal direction.

$$\tau_{v_trans} := \frac{P_{\text{horz2}}}{2 \cdot A_{\text{flan}}} \quad \tau_{v_trans} = 448 \frac{\text{lb}}{\text{in}^2}$$

The maximum transverse shear stress. OK

Answer := if($\tau_{v_trans} < \tau_{v_a500}$, "OK", "No Good") Answer = "OK" Beams are adequate per AISC 1989, Page 5-49, Equation F4-1.

Check interaction.

$$\frac{\sigma_t}{\sigma_{t_a500}} = 0.013$$

Since this is less than 0.15, use the following to check interaction.

$$\frac{\sigma_t}{\sigma_{t_a500}} + \frac{\sigma_{bx} + \sigma_{by}}{\sigma_{b_a500}} = 0.761 \quad \text{OK}$$

8.10 Determine the adequacy of the TS 7x4x3/8 columns.

$b := 25 \cdot \text{in}$ See sketch on previous page.

$r := 1.57 \cdot \text{in}$ Radius of gyration.

$K := 1$

$l := 24 \cdot \text{in} - 7 \cdot \text{in}$ $l = 17 \cdot \text{in}$ See drawing H-2-85633 for length.

$\frac{K \cdot l}{r} = 10.828$ Use 11.

$\sigma_{a_a500} := 29170 \cdot \frac{\text{lb}}{\text{in}^2}$ The allowable axial compressive stress from AISC 1989, Table C-50, Page 3-17.

$\sigma_a := \frac{P \text{ vert}2}{A_c}$ $\sigma_a = 976 \cdot \frac{\text{lb}}{\text{in}^2}$ The maximum axial compressive stress. OK

Answer := if $\sigma_a < \sigma_{a_a500}$, "OK", "No Good" Answer = "OK" Beams are adequate per AISC 1989, Page 5-49, Equation F3-3.

$M_{bx} := \frac{P \text{ vert}2}{2} \cdot a$ $M_{bx} = 187849 \cdot \text{in} \cdot \text{lb}$ Maximum moment about the strong axis.

$M_{by} := \frac{P \text{ horz}1}{4} \cdot a$ $M_{by} = 34899 \cdot \text{in} \cdot \text{lb}$ Maximum moment about the weak axis (to be conservative the longitudinal loading due to the core sample truck stopping is included).

$\sigma_{bx} := \frac{M_{bx}}{S_x}$ $\sigma_{bx} = 14909 \cdot \frac{\text{lb}}{\text{in}^2}$ The maximum strong axis bending stress. OK

Answer := if $\sigma_{bx} < \sigma_{b_a500}$, "OK", "No Good" Answer = "OK" Beams are adequate per AISC 1989, Page 5-45, Equation F1-1.

$\sigma_{by} := \frac{M_{by}}{S_y}$ $\sigma_{by} = 3852 \cdot \frac{\text{lb}}{\text{in}^2}$ The maximum weak axis bending stress. OK

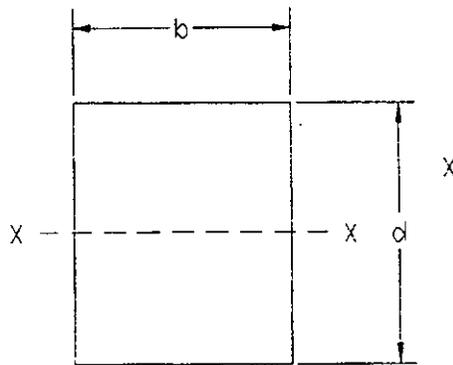
Answer := if $\sigma_{by} < \sigma_{b_a500}$, "OK", "No Good" Answer = "OK" Beams are adequate per AISC 1989, Page 5-45, Equation F1-1.

$\frac{\sigma_a}{\sigma_{a_a500}} = 0.033$ Since this is less than 0.15, use the following to check interaction.

$\frac{\sigma_a}{\sigma_{a_a500}} + \frac{\sigma_{bx} + \sigma_{by}}{\sigma_{b_a500}} = 0.651$ OK

8.11 Determine the adequacy of the fillet weld connecting the two TS 7X4X3/8.

The weld connecting the TS 7x4x3/8 to the 1/2 in. base plate is the same size and will carry the same loads, therefore, these calculations will also check the TS to base plate weld.



Weld Geometry:

- $b := 7\text{-in}$ Weld width.
- $d := 4\text{-in}$ Weld length.
- $w_a := \frac{1}{4}\text{-in}$ Weld size.
- $\sigma_{\text{base}} := 46000 \cdot \frac{\text{lb}}{\text{in}^2}$ Yield stress of the base metal.
- $\sigma_{\text{weld}} := 70000 \cdot \frac{\text{lb}}{\text{in}^2}$ Weld metal strength.

Connection Loads:

- $F_x := \frac{P_{\text{horz}2}}{4}$ $F_y := 0\text{-lb}$ $F_z := \frac{P_{\text{vert}2}}{2}$
- $M_x := 0\text{-in}\cdot\text{lb}$ $M_y := \frac{P_{\text{vert}2}}{4} \cdot a$ $M_z := 0\text{-in}\cdot\text{lb}$

Weld Properties Per Blodgett 1991

- $C_x := \frac{b}{2}$ $C_x = 3.5\text{-in}$ The distance to the outer fiber in the x-direction.
- $C_y := \frac{d}{2}$ $C_y = 2\text{-in}$ The distance to the outer fiber in the y-direction.
- $A_w := 2 \cdot (b + d)$ $A_w = 22\text{-in}$ The linear area of the weld.
- $S_{wx} := b \cdot d + \frac{d^2}{3}$ $S_{wx} = 33.333\text{-in}^2$ The linear section modulus about the x-axis.
- $S_{wy} := d \cdot b + \frac{b^2}{3}$ $S_{wy} = 44.333\text{-in}^2$ The linear section modulus about the y-axis.
- $J_w := \frac{(b + d)^3}{6}$ $J_w = 221.833\text{-in}^3$ The linear polar moment of inertia.

Linear Weld Stress:

$$f_w := \sqrt{\left(\frac{F_z}{A_w} + \frac{M_x}{S_{wx}} + \frac{M_y}{S_{wy}}\right)^2 + \left(\frac{F_x}{A_w} + \frac{M_z \cdot C_y}{J_w}\right)^2 + \left(\frac{F_y}{A_w} + \frac{M_z \cdot C_x}{J_w}\right)^2} \quad f_w = 2444.64 \frac{\text{lb}}{\text{in}}$$

Required Fillet Weld Size:

$$w_r := \text{if} \left[\frac{f_w}{0.4 \cdot \sigma_{\text{base}}} < \frac{f_w}{0.707 \cdot 0.3 \cdot \sigma_{\text{weld}}}, \frac{f_w}{0.4 \cdot \sigma_{\text{base}}}, \frac{f_w}{0.707 \cdot (0.3) \cdot \sigma_{\text{weld}}} \right] \quad w_r = 0.133\text{-in}$$

0.707 is for shear through throat of fillet weld, 0.3 is allowable stress reduction factor for shear through throat of fillet weld and 0.4 is for shear on base metal. See AISC 1989, Table J2.5, Page 5-70.

The Margin of Safety:

$$\text{MS} := \frac{w_a}{w_r} - 1 \quad \text{MS} = 0.882 \quad \text{OK}$$

8.12 Determine the adequacy of the 7/16 in x 1 ft plate and angle connecting the two W 8x18s to the TS 7x4x3/8.

$$A_c := \left(\frac{7}{16} \text{ in} + \frac{3}{8} \text{ in} \right) \cdot 24.75 \text{ in}$$

$$A_c = 20.109 \text{ in}^2$$

Combined cross sectional area of plate and angle for shear calculation.

$$\tau_v := \frac{P_{\text{vert}2}}{A_c}$$

$$\tau_v = 711.722 \frac{\text{lb}}{\text{in}^2}$$

Answer := if($\tau_v < \tau_{v_a36}$, "OK", "No Good") ; Answer = "OK"

Beams are adequate per AISC 1989, Page 5-49, Equation F4-1.

8.13 Determine the adequacy of the ramp. Wind loads are not to be considered in the analysis of the ramp.

$$A_c := 2 \cdot 2.86 \text{ in}^2$$

$$A_c = 5.72 \text{ in}^2$$

Cross sectional area of an L 4x4x3/8.

$$l := 25 \text{ in}$$

Maximum ramp column length from H-2-85633

$$K := 1$$

$$r := 1.23 \text{ in}$$

Radius of gyration.

$$\frac{K \cdot l}{r} = 20.325$$

Use 21

$$S := 2 \cdot 1.52 \text{ in}^3$$

L 4x4x3/8 section modulus.

$$\sigma_{a_a36} := 20540 \frac{\text{lb}}{\text{in}^2}$$

Allowable compressive stress from AISC 1989, Table C-36, Page 3-16.

Check the L 4x4x3/8 in. columns for adequacy.

$$\sigma_a := \frac{P_{\text{rear}}}{2 \cdot A_c}$$

$$\sigma_a = 1836 \frac{\text{lb}}{\text{in}^2}$$

Maximum axial compressive stress. NOTE: tire load is spread evenly over all 2 columns.

Answer := if($\sigma_a < \sigma_{a_a36}$, "OK", "No Good") ; Answer = "OK"

Check the maximum shear and bending in the L 4x4x3/8.

$$L := 48 \text{ in}$$

Distance between ramp columns.

$$M_{\text{max}} := \frac{\left(\frac{P_{\text{vert}2}}{4} \cdot L \right)}{4}$$

$$M_{\text{max}} = 42937 \text{ in} \cdot \text{lb}$$

The maximum moment in a single L 4x4x3/8 treating it as a simply supported beam.

$$\sigma_b := \frac{M_{\text{max}}}{S}$$

$$\sigma_b = 14124 \frac{\text{lb}}{\text{in}^2}$$

Maximum bending stress. OK

Answer := if($\sigma_b < \sigma_{b_a36}$, "OK", "No Good") ; Answer = "OK"

Beams are adequate per AISC 1989, Page 5-45, Equation F1-1.

$$\tau_v := \frac{P_{\text{horz}2}}{2 \cdot A_c}$$

$$\tau_v = 470 \frac{\text{lb}}{\text{in}^2}$$

Maximum shear on a single L 4x4x3/8

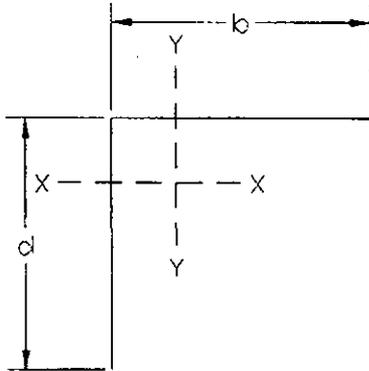
Answer := if($\tau_v < \tau_{v_a36}$, "OK", "No Good") ; Answer = "OK"

Beams are adequate per AISC 1989, Page 5-49, Equation F4-1.

8.15 Determine the adequacy of the weld connecting a ramp beam to a ramp column.

This set of calculations determines the adequacy of the weld configuration show in the figure below. The actual weld configuration is different but this is an adequate representation of it and is conservative.

Per AISC 1989, the required weld size checks both the shear on the base metal and the shear through the throat of the fillet weld to ensure that failure will not occur.



Weld Geometry:

- $b := 1\text{-in}$ Weld width.
- $d := 1\text{-in}$ Weld length.
- $w_a := \frac{1}{4}\text{-in}$ The actual weld size.
- $\sigma_{\text{base}} := 36000 \frac{\text{lb}}{\text{in}^2}$ Yield stress of the base metal.
- $\sigma_{\text{weld}} := 70000 \frac{\text{lb}}{\text{in}^2}$ Weld metal strength.

Connection Loads:

- $F_x := 0\text{-lb}$
- $F_y := 0\text{-lb}$
- $F_z := \frac{P_{\text{rear}}}{4}$
- $M_x := 0\text{-in}\cdot\text{lb}$
- $M_y := 0\text{-in}\cdot\text{lb}$
- $M_z := 0\text{-in}\cdot\text{lb}$

Weld Properties per Blodgett 1991

- $C_x := \frac{d^2}{2 \cdot (b+d)}$ $C_x = 0.25\text{-in}$ The distance to the outer fiber in the x-direction.
- $C_y := \frac{b^2}{2 \cdot (b+d)}$ $C_y = 0.25\text{-in}$ The distance to the outer fiber in the y-direction.
- $A_w := b + d$ $A_w = 2\text{-in}$ The linear area of the weld.
- $S_{wx} := \text{if} \left[\frac{4 \cdot b \cdot d + d^2}{6} < \frac{d^2 \cdot (4 \cdot b + d)}{6 \cdot (2 \cdot b + d)}, \frac{4 \cdot b \cdot d + d^2}{6}, \frac{d^2 \cdot (4 \cdot b + d)}{6 \cdot (2 \cdot b + d)} \right]$ $S_{wx} = 0.278\text{-in}^2$ The linear section modulus about the x-axis.
- $S_{wy} := \text{if} \left[\frac{4 \cdot d \cdot b + b^2}{6} < \frac{b^2 \cdot (4 \cdot d + b)}{6 \cdot (2 \cdot d + b)}, \frac{4 \cdot d \cdot b + b^2}{6}, \frac{b^2 \cdot (4 \cdot d + b)}{6 \cdot (2 \cdot d + b)} \right]$ $S_{wy} = 0.278\text{-in}^2$ The linear section modulus about the y-axis.
- $J_w := \frac{(b+d)^4 - 6 \cdot b^2 \cdot d^2}{12 \cdot (b+d)}$ $J_w = 0.417\text{-in}^3$ The linear polar moment of inertia

Linear Weld Stress:

$$f_w := \sqrt{\left(\frac{F_z}{A_w} + \frac{M_x}{S_{wx}} + \frac{M_y}{S_{wy}} \right)^2 + \left(\frac{F_x}{A_w} + \frac{M_z \cdot C_y}{J_w} \right)^2 + \left(\frac{F_y}{A_w} + \frac{M_z \cdot C_x}{J_w} \right)^2}$$

$f_w = 2625 \frac{\text{lb}}{\text{in}}$

Required Fillet Weld Size:

$$w_r := \text{if} \left[\frac{f_w}{0.4 \cdot \sigma_{\text{base}}}, \frac{f_w}{0.707 \cdot 0.3 \cdot \sigma_{\text{weld}}}, \frac{f_w}{0.4 \cdot \sigma_{\text{base}}}, \frac{f_w}{0.707 \cdot (0.3) \cdot \sigma_{\text{weld}}} \right] \quad w_r = 0.177 \cdot \text{in}$$

0.707 is for shear through throat of fillet weld, 0.3 is allowable stress reduction factor for shear through throat of fillet weld and 0.4 is for shear on base metal. See AISC 1989, Table J2.5, Page 5-70.

The Margin of Safety:

$$MS := \frac{w_a}{w_r} - 1$$

$$MS = 0.414$$

OK

1.0 OBJECTIVE This set of calculations sizes and determines the adequacy of bolts attaching the Core Sampling platform to the foundation provided by FDNW. The foundation and platform combination is provided to span tank 241-Z-361 without side loading the tank walls.

2.0 DESIGN INPUTS

2.1 Design drawing H-2-85633

3.0 ASSUMPTIONS

3.1 Due to the slotted holes in the base plate (see figure below), only two bolts on any leg will be assumed to support any lateral loading.

3.2 Due to the design of the foundation, moment frame with diagonal bracing on all sides, no moments shall be transferred to the foundation

4.0 METHODS OF ANALYSIS (Hand Calculations)

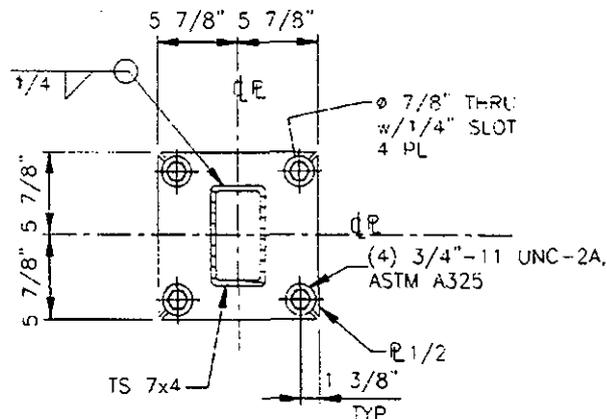
5.0 REFERENCES

5.1 AISC, 1989, Manual of Steel Construction, 9th Edition, American Institute of Steel Construction, Chicago Illinois.

5.2 WHC, 1995, Structural Evaluation for the Core Sampling Trucks RMCS Operations 200 Area, WHC-SD-WM-DA-215 Rev. 0, Westinghouse Hanford Company.

6.0 FINDINGS AND CONCLUSIONS (8) 3/4" A325 bolts x 3" long minimum shall be used to attach the platform to the foundation. Calculations below determined that the bolts are adequate for attaching the platform to the foundation.

7.0 CALCULATIONS



BASE PLATE DETAIL (4 PLACES)

Given the 7/8" dia slotted holes shown in the figure on the previous page, use ASTM A325 3/4" bolts x for attaching the platform to the foundation.

$A_k := .302 \text{ in}^2$ The minimum root area for a 3/4" bolt (AISC 1989, Page 4-147).

$\tau_{\text{allow}} := 21000 \frac{\text{lb}}{\text{in}^2}$ The maximum shear on the bolt (AISC 1989, Table 2, Page 5-269. Bolt threads are assumed to be in the shear plane for (conservative).

$\sigma_{t_allow} := 44000 \frac{lb}{in^2}$ The maximum tensile stress on an A325 bolt per AISC 1989, Table 2, Page 5-269.

From WHC, 1995, Page A12, the wind loading on the core sample truck will not cause overturning of the core sample truck. For this reason, there is no tensile loading on the bolted connection.

$F_w := P_{w_85}$ $F_w = 5381 \text{ lb}$ Loading due to 85 mph wind.

$F_{max} := F_w$ $F_{max} = 5381.113 \cdot lb$ Maximum force on the two bolt pattern.

$\tau_{act} := \frac{F_{max}}{4 \cdot A_k}$ $\tau_{act} = 4454.564 \frac{lb}{in^2}$ Actual bolt stress. Assumed force is distributed on two legs of platform (conservative).

$MS := \frac{\tau_{allow}}{\tau_{act}} - 1$ $MS = 3.714$ Answer := if($MS \geq 0$, "OK", "No Good") Answer = "OK"

Determine the maximum tensile loading on the 3/4" bolts.

$F_{bolt} := \frac{P_{vert2}}{2} \cdot a$ $F_{bolt} = 9886.771 \text{ lb}$ The force on each bolt.

$\sigma_t := \frac{F_{bolt}}{A_k}$ $\sigma_t = 32738 \frac{lb}{in^2}$

$MS := \frac{\sigma_{t_allow}}{\sigma_t} - 1$ $MS = 0.344$ Answer := if($MS \geq 0$, "OK", "No Good") Answer = "OK"

1.0 OBJECTIVE This set of calculations determines the adequacy of lateral bracing. The foundations that this platform will be placed on, when sampling from tank 241-Z-361, are not suitable for resisting the induced moment from the platforms. For this reason, the platforms must be stiffened to resist the induced moment. Diagonal bracing on both the lateral and longitudinal sides shall be used to resist the induced moments. Also, tie rods shall be added in the longitudinal direction to the base of each leg for increased stiffness. The diagonal bracing and tie rod designs are shown on ECN 651132.

2.0 DESIGN INPUTS

2.1 Design drawing H-2-85633

2.2 Engineering Change Notice, 639132 and 651132.

3.0 ASSUMPTIONS

4.0 METHODS OF ANALYSIS (Hand Calculations)

5.0 REFERENCES

5.1 AISC, 1989, *Manual of Steel Construction*, 9th Edition, American Institute of Steel Construction, Chicago Illinois.

5.2 Blodgett, O W, 1991, *Design of Welded Structures*, Fourteenth Printing, The James F. Lincoln Arc Welding Foundation, Cleveland, Ohio.

6.0 FINDINGS AND CONCLUSIONS The force applied to the diagonal bracing is 3000 lb and the force applied to the tie rod is 14300 lb. The calculations determined that the diagonal bracing and longitudinal tie rods are adequate as design.

7.0 CALCULATIONS

7.1 Properties, Geometry and Loads.

$\sigma_y := 36000 \frac{\text{lb}}{\text{in}^2}$ Yield stress of A36 carbon steel.

$L := 20.5 \text{ ft}$ Length of Characterization platform (H-2-85633).

$h := 25 \text{ in}$ Height of Characterization platform (H-2-85633).

$w := 10.75 \text{ ft}$ Width of Characterization platform (H-2-85633).

$F_L := \frac{5400 \cdot \text{lb}}{2}$ Maximum longitudinal force due to sudden stopping of core sample truck.

$F_w := \frac{5400 \cdot \text{lb}}{2}$ Maximum lateral force due to wind.

7.2 Determine internal force carried by the wire rope diagonal bracing.

$\theta_L := \text{atan}\left(\frac{L}{h}\right)$ $\theta_L = 84.197 \text{ deg}$ Angle of diagonal bracing on longitudinal side.

$\theta_w := \text{atan}\left(\frac{w}{h}\right)$ $\theta_w = 79.03 \text{ deg}$ Angle of diagonal bracing on lateral side.

$F_{L_diag} := \frac{F_L}{\sin(\theta_L)}$ $F_{L_diag} = 2713.907 \cdot \text{lb}$ Maximum diagonal force required to resist longitudinal loading.

Connection Loads:

$$F_x := 0 \cdot \text{lb} \qquad F_y := F \cdot \sin(11 \cdot \text{deg}) \qquad F_z := F \cdot \cos(11 \cdot \text{deg})$$

$$M_x := F \cdot e \qquad M_y := 0 \cdot \text{in} \cdot \text{lb} \qquad M_z := 0 \cdot \text{in} \cdot \text{lb}$$

Weld Properties per Blodgett 1991:

$C_x := \frac{b}{2}$	$C_x = 0.25 \cdot \text{in}$	The distance to the outer fiber in the x-direction.
$C_y := \frac{d}{2}$	$C_y = 1.5 \cdot \text{in}$	The distance to the outer fiber in the y-direction.
$A_w := 2 \cdot d$	$A_w = 6 \cdot \text{in}$	The linear area of the weld.
$S_{wx} := \frac{d^2}{3}$	$S_{wx} = 3 \cdot \text{in}^2$	The linear section modulus about the x-axis.
$S_{wy} := b \cdot d$	$S_{wy} = 1.5 \cdot \text{in}^2$	The linear section modulus about the y-axis.
$J_w := \frac{d \cdot (3 \cdot b^2 + d^2)}{6}$	$J_w = 4.875 \cdot \text{in}^3$	The linear polar moment of inertia.

Linear Weld Stress:

$$f_w := \sqrt{\left(\frac{F_z}{A_w} + \frac{M_x}{S_{wx}} + \frac{M_y}{S_{wy}}\right)^2 + \left(\frac{F_x}{A_w} + \frac{M_z \cdot C_y}{J_w}\right)^2 + \left(\frac{F_y}{A_w} + \frac{M_z \cdot C_x}{J_w}\right)^2} \qquad f_w = 788.606 \frac{\text{lb}}{\text{in}}$$

Required Weld Size:

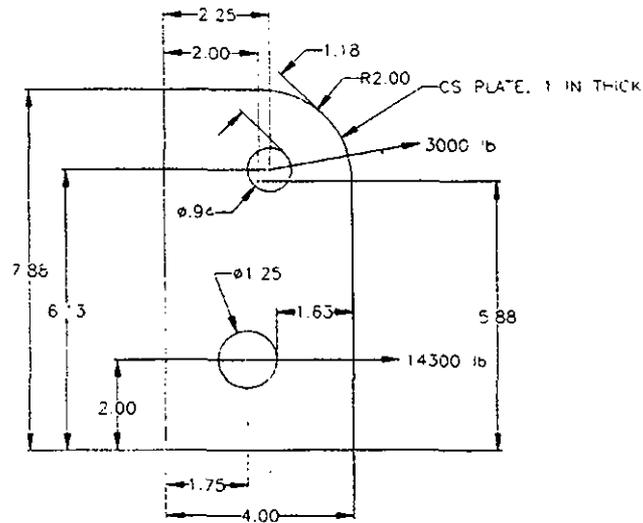
$$w_r := \text{if} \left[\frac{f_w}{0.4 \cdot \sigma_{\text{base}}} \leq \frac{f_w}{0.707 \cdot 0.3 \cdot \sigma_{\text{weld}}}, \frac{f_w}{0.4 \cdot \sigma_{\text{base}}}, \frac{f_w}{0.707 \cdot (0.3) \cdot \sigma_{\text{weld}}} \right] \qquad w_r = 0.053 \cdot \text{in}$$

0.707 is for shear through throat of fillet weld, 0.3 is allowable stress reduction factor for shear through throat of fillet weld and 0.4 is for shear on base metal. See AISC 1989, Table J2.5, Page 5-70.

The margin of safety:

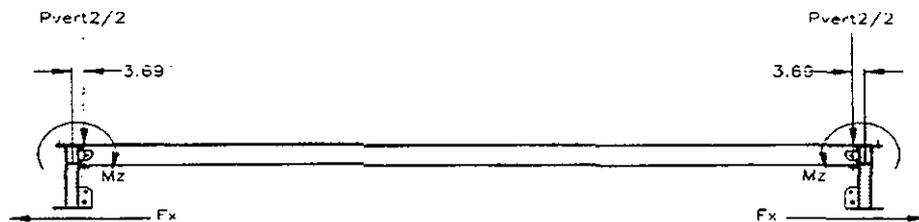
$$MS := \frac{w_a}{w_r} - 1 \qquad MS = 3.707 \qquad \text{OK}$$

7.5 Determine the adequacy of the lower diagonal bracing hole and tie rod hole.



Based on the calculations above the lower shackle hole for diagonal bracing is adequate (dimensions and loading are identical). The weld will be checked after calculating the adequacy of the tie rod hole.

7.6 Determine the adequacy of the tie rod hole. The foundation designed by Fluor Daniel Northwest cannot withstand large moments, for this reason tie rods are installed to withstand the moments due to eccentric loading of the TS 7x4x3/8 columns.



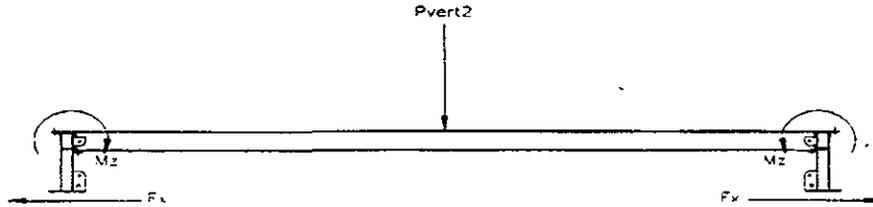
$$e_4 := 3.69 \cdot \text{in}$$

$$M_z := \frac{P_{vert2}}{4} \cdot e_4$$

$$M_z = 6602 \cdot \text{in} \cdot \text{lb}$$

Moment in column

This moment is too small. Consider the shear connection to be a moment connection and use a 10,000 lb load. This is conservative.



$P_{vert_temp} := 10000 \cdot \text{lb}$ Vertical loading on column for structural analysis of tie rod and associated equipment.

$$M_z := \frac{P_{vert_temp} \cdot L}{8} \quad M_z = 307500 \cdot \text{in} \cdot \text{lb} \quad \text{Moment on column.}$$

$$F_x := \frac{M_z}{25 \cdot \text{in} - \frac{7 \cdot \text{in}}{2}} \quad F_x = 14302 \quad \text{Force at base to resist moment.}$$

Determine the adequacy of the tie rod hole.

$A_c := 1.625 \cdot \text{in} \cdot 1 \cdot \text{in}$ Cross sectional area between the hole and the outer edge.

$$\tau_{hole} := \frac{F_x}{A_c} \quad \tau_{hole} = 8801 \frac{\text{lb}}{\text{in}^2}$$

Answer := if($\tau_{hole} < \tau_{v_a36}$, "OK", "No Good") Answer = "OK" Hole will resist tear-out of shackle supporting the tie rod.

Determine the adequacy of the tie rod.

$D := 1.25 \cdot \text{in}$ Diameter of tie rod.

$$A_{c_tie} := \frac{\pi}{4} \cdot D^2 \quad A_{c_tie} = 1.227 \cdot \text{in}^2 \quad \text{Cross sectional area of tie rod.}$$

$$\sigma_t := \frac{F_x}{A_{c_tie}} \quad \sigma_t = 11654.583 \frac{\text{lb}}{\text{in}^2} \quad \text{Tensile load on tie rod.}$$

Answer := if($\sigma_t < \sigma_{t_a36}$, "OK", "No Good") Answer = "OK" Hole will resist tear-out of shackle supporting the tie rod.

Determine the adequacy of associated rigging hardware.

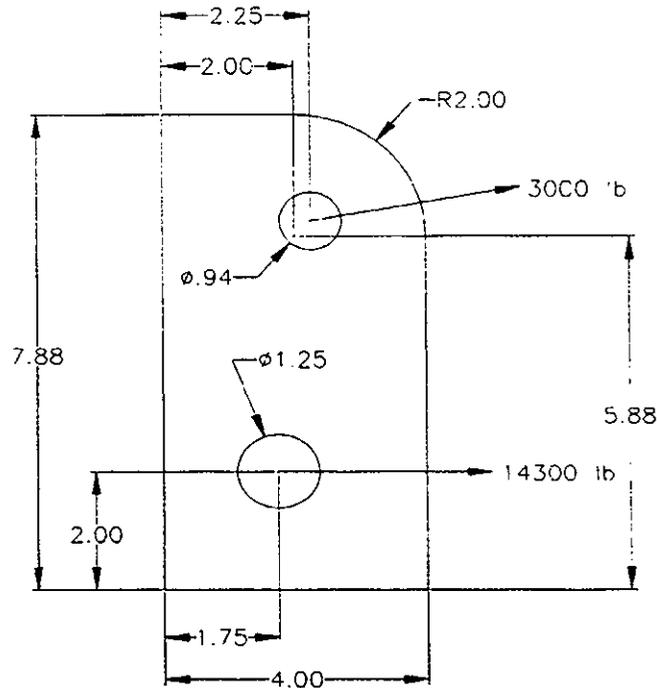
Wire Cables: Wire cables are to be used for all diagonal bracing and shall be capable of supporting a 3000 lb. load. Cable size shall be determined by either Dyncorp Fabrication Services or Hoisting and Rigging.

Shackles: A 4 3/4 ton shackle is used for diagonal bracing (9500 lb) and the maximum diagonal bracing loading is 3000 lb, therefore, the shackles are adequate.

Tumbuckles: The tumbuckles are rated at 15,200 lb. This is greater than the axial load of 14,300 lb, therefore, the shackles are adequate.

NOTE: all of these items have a proof strength of greater than or equal to two (2).

7.7 Determine the adequacy of the weld attaching the shackle pin plate to the TS 7x4x3/8.



Determine the location of the weld centroid.

$d := 3.875 \cdot \text{in}$

Length of weld in the horizontal direction. Note: plate is longer than base plate.

$b := 7.88 \cdot \text{in}$

Length of weld in the vertical direction.

$N_x := \frac{d^2}{2 \cdot (b + d)}$

$N_x = 0.639 \cdot \text{in}$

Distance from bottom to Cg of weld.

$N_y := \frac{b^2}{2 \cdot (b + d)}$

$N_y = 2.641 \cdot \text{in}$

Distance from left side to Cg of weld.

Calculate the forces and moments on weld centroid.

$F_{\text{horz}} := F_x + F \cdot \cos(11 \cdot \text{deg})$

$F_{\text{horz}} = 17247.207 \text{ lb}$

Horizontal Loading on the plate.

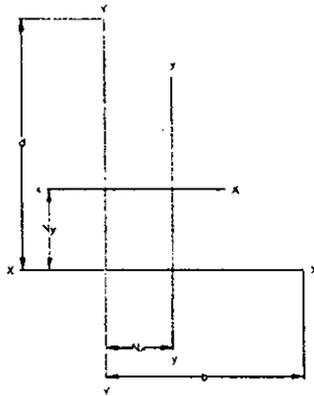
$F_{\text{vert}} := F \cdot \sin(11 \cdot \text{deg})$

$F_{\text{vert}} = 572.427 \text{ lb}$

Vertical Loading on the plate.

$M_{z_weld} := F_x \cdot (N_y - 2 \cdot \text{in}) + F \cdot \cos(11 \cdot \text{deg}) \cdot (5.88 \cdot \text{in} - N_y) + F \cdot \sin(11 \cdot \text{deg}) \cdot (4 \cdot \text{in} - N_x)$

$M_{z_weld} = 20632.535 \cdot \text{in} \cdot \text{lb}$



Weld Geometry:

- $b := 3.875 \text{ in}$ Weld width.
- $d := 7.88 \text{ in}$ Weld length.
- $w_a := \frac{1}{4} \text{ in}$ The actual weld size.
- $\sigma_{\text{base}} := 46000 \frac{\text{lb}}{\text{in}^2}$ Yield stress of the base metal.
- $\sigma_{\text{weld}} := 70000 \frac{\text{lb}}{\text{in}^2}$ Weld metal strength.

Connection Loads:

- $F_x := F \text{ horz}$ $F_y := -F \text{ vert}$ $F_z := 0 \text{ lb}$
- $M_x := 0 \text{ in}\cdot\text{lb}$ $M_y := 0 \text{ in}\cdot\text{lb}$ $M_z := M_{z_weld}$

Weld Properties per Blodgett 1991

- $C_x := \frac{d^2}{2 \cdot (b+d)}$ $C_x = 2.641 \text{ in}$ The distance to the outer fiber in the x-direction.
- $C_y := \frac{b^2}{2 \cdot (b+d)}$ $C_y = 0.639 \text{ in}$ The distance to the outer fiber in the y-direction.
- $A_w := 2 \cdot (b+d)$ $A_w = 23.51 \text{ in}$ The linear area of the weld.
- $S_{wx} := 2 \cdot \text{if} \left[\frac{4 \cdot b \cdot d + d^2}{6} < \frac{d^2 \cdot (4 \cdot b + d)}{6 \cdot (2 \cdot b + d)}, \frac{4 \cdot b \cdot d + d^2}{6}, \frac{d^2 \cdot (4 \cdot b + d)}{6 \cdot (2 \cdot b + d)} \right]$ $S_{wx} = 30.961 \text{ in}^2$ The linear section modulus about the x-axis.
- $S_{wy} := 2 \cdot \text{if} \left[\frac{4 \cdot d \cdot b + b^2}{6} < \frac{b^2 \cdot (4 \cdot d + b)}{6 \cdot (2 \cdot d + b)}, \frac{4 \cdot d \cdot b + b^2}{6}, \frac{b^2 \cdot (4 \cdot d + b)}{6 \cdot (2 \cdot d + b)} \right]$ $S_{wy} = 9.023 \text{ in}^2$ The linear section modulus about the y-axis.
- $J_w := 2 \cdot \frac{(b+d)^4 - 6 \cdot b^2 \cdot d^2}{12 \cdot (b+d)}$ $J_w = 191.399 \text{ in}^3$ The linear polar moment of inertia.

Linear Weld Stress:

$$f_w := \sqrt{\left(\frac{F_z}{A_w} + \frac{M_x}{S_{wx}} + \frac{M_y}{S_{wy}} \right)^2 + \left(\frac{F_x}{A_w} + \frac{M_z \cdot C_y}{J_w} \right)^2 + \left(\frac{F_y}{A_w} + \frac{M_z \cdot C_x}{J_w} \right)^2}$$

$f_w = 843.644 \frac{\text{lb}}{\text{in}}$

Required Fillet Weld Size:

$$w_r := \text{if} \left[\frac{f_w}{0.4 \cdot \sigma_{\text{base}}} < \frac{f_w}{0.707 \cdot 0.3 \cdot \sigma_{\text{weld}}}, \frac{f_w}{0.4 \cdot \sigma_{\text{base}}}, \frac{f_w}{0.707 \cdot (0.3) \cdot \sigma_{\text{weld}}} \right]$$

$w_r = 0.046 \text{ in}$

0.707 is for shear through throat of fillet weld, 0.3 is allowable stress reduction factor for shear through throat of fillet weld and 0.4 is for shear on base metal. See AISC 1989, Table J2.5, Page 5-70.

The Margin of Safety:

$$MS := \frac{w_a}{w_r} - 1$$

$MS = 4.453$ **OK**

$F_{max} := 5300 \cdot lb$ The 5300 lb load will result in either stopping of the core sample truck and/or enough noise and vibration for the driver and other operators to take notice and stop the core sample truck before the truck is driven off the side of the platform.

$r := 6 \cdot in$ Height of plate.
 $M := r \cdot F_{max}$ $M = 31800 \cdot in \cdot lb$ Maximum moment in the plate.

Check the adequacy of the pins.

$d := 1.5 \cdot in$ Diameter of the pin.
 $I_{pin} := \frac{\pi \cdot d^4}{64}$ $I_{pin} = 0.249 \cdot in^4$ Moment of inertia of the pin.

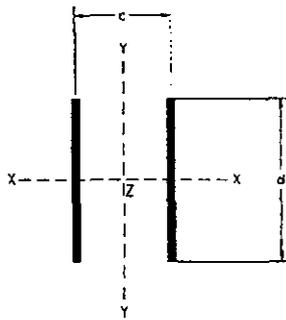
$A_{pin} := \frac{\pi}{4} \cdot d^2$ $A_{pin} = 1.767 \cdot in^2$ Cross sectional area of the pin.

$M_{max} := \frac{M}{3}$ 3 pins will absorb the applied moment.

$\sigma_b := \frac{M_{max} \cdot \frac{d}{2}}{I_{pin}}$ $\sigma_b = 31991.322 \cdot \frac{lb}{in^2}$

$MS := \frac{\sigma_{y_a36}}{\sigma_b} - 1$ $MS = 0.125$ OK Since this is an accident scenario the yield stress is used for the allowable stress.

Determine the maximum stress on the weld



Weld Geometry.

$b := 1.5 \cdot in$ The width of the weld.
 $d := 1 \cdot in$ The length of the weld.
 $w_a := \frac{3}{8} \cdot in$ The actual weld size.
 $\sigma_{base} := 36000 \cdot \frac{lb}{in^2}$ Yield stress of the base metal.
 $\sigma_{weld} := 70000 \cdot \frac{lb}{in^2}$ Weld metal strength.

Connection Loads:

$F_x := 0 \cdot lb$ $F_y := 0 \cdot lb$ $F_z := \frac{F_{max}}{3}$

$M_x := \frac{F_{max} \cdot 5.5 \cdot in}{3}$ $M_y := 0 \cdot in \cdot lb$ $M_z := 0 \cdot in \cdot lb$

Weld Properties per Blodgett 1991:

$C_x := 2 \cdot \frac{b}{2}$ $C_x = 1.5 \cdot in$ The distance to the outer fiber in the x-direction.
 $C_y := 2 \cdot \frac{d}{2}$ $C_y = 1 \cdot in$ The distance to the outer fiber in the y-direction.

$A_w := 4 \cdot d$	$A_w = 4 \cdot \text{in}$	The linear area of the weld.
$S_{wx} := 2 \cdot \frac{d^2}{3}$	$S_{wx} = 0.667 \cdot \text{in}^2$	The linear section modulus about the x-axis.
$S_{wy} := 2 \cdot (b \cdot d)$	$S_{wy} = 3 \cdot \text{in}^2$	The linear section modulus about the y-axis.
$J_w := 2 \cdot \frac{d \cdot (3 \cdot b^2 + d^2)}{6}$	$J_w = 2.583 \cdot \text{in}^3$	The linear polar moment of inertia.

Linear Weld Stress:

$$f_w := \sqrt{\left(\frac{F_z}{A_w} + \frac{M_x}{S_{wx}} + \frac{M_y}{S_{wy}}\right)^2 + \left(\frac{F_x}{A_w} + \frac{M_z \cdot C_y}{J_w}\right)^2 + \left(\frac{F_y}{A_w} + \frac{M_z \cdot C_x}{J_w}\right)^2} \quad f_w = 15016.667 \frac{\text{lb}}{\text{in}}$$

Required Weld Size:

$$w_r := \text{if} \left(\frac{f_w}{\sigma_{\text{base}}} \leq \frac{f_w}{.707 \cdot \sigma_{\text{weld}}}, \frac{f_w}{\sigma_{\text{base}}}, \frac{f_w}{.707 \cdot \sigma_{\text{weld}}} \right) \quad w_r = 0.303 \cdot \text{in}$$

The margin of safety:

$$MS := \frac{w_a}{w_r} - 1 \quad MS = 0.236 \quad \text{OK}$$

Check bending of the fence.

$$I_{\text{plate}} := \frac{47 \cdot \text{in} \cdot \left(\frac{3}{8} \cdot \text{in}\right)^3}{12} \quad I_{\text{plate}} = 0.207 \cdot \text{in}^4 \quad \text{Minimum moment of inertia of the plate.}$$

$$c := \frac{\frac{3}{8} \cdot \text{in}}{2} \quad \text{Distance from centroid of the plate to the outer most fiber.}$$

$$\sigma_b := \frac{M \cdot c}{I_{\text{plate}}} \quad \sigma_b = 28868.085 \frac{\text{lb}}{\text{in}^2} \quad \text{Maximum bending stress in the plate.}$$

$$MS := \frac{\sigma_{y_{a36}}}{\sigma_b} - 1 \quad MS = 0.247 \quad \text{OK Since this is an accident scenario the yield stress is used for the allowable stress.}$$

Determine the adequacy of the bumpers. The bumpers are constructed from 4x4x1/4 in angle and are used to prevent a the core sample truck from rolling off the end of the platform. The bumpers are attached to the platform using a minimum of two A325 bolts.

Use Kinetic Energy Theory

$$V := 2 \cdot \text{mph} \quad \text{Maximum velocity of the core sample truck on the ramps or platform.}$$

$$h := \frac{V^2}{2 \cdot g} \quad h = 1.605 \cdot \text{in} \quad \text{This the height required to stop the core sample truck. Since the actual height is 4 in. OK}$$

Fluor Daniel Northwest	CALCULATION IDENTIFICATION AND INDEX	Page <u>6</u> of <u>6</u> Date <u>3/19/99</u>																				
<p>This sheet shows the status and description of the attached Design Analysis sheets.</p> <p>Discipline <u>Structural</u> W/Job No. <u>65100231/TM12</u> Calculation No. <u>TM12-C-01</u></p> <p>Project No. & Name Calculation Item <u>Foundation Design, Truck Ramp Platform, Over Tank 241-Z-361</u></p> <p>These calculations apply to:</p> <p>Dwg. No. <u>H-2-829739 Sht 1</u> Rev. No. <u>0</u></p> <p>Dwg. No. <u>H-2-829739 Sht 2</u> Rev. No. <u>0</u></p> <p>Other (Study, CDR) Rev. No.</p> <p>The status of these calculations is:</p> <p><input type="checkbox"/> Preliminary Calculations</p> <p><input checked="" type="checkbox"/> Final Calculations</p> <p><input type="checkbox"/> Check Calculations (On Calculation Dated)</p> <p><input type="checkbox"/> Void Calculation (Reason Voided)</p> <p>Incorporated in Final Drawings? <input type="checkbox"/> Yes <input type="checkbox"/> No</p> <p>This calculation verified by independent "check" calculations? <input type="checkbox"/> Yes <input type="checkbox"/> No</p> <p>Original and Revised Calculation Approvals:</p> <table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th style="width:25%;"></th> <th style="width:25%; text-align: center;">Rev. 0 Signature/Date</th> <th style="width:25%; text-align: center;">Rev. 1 Signature/Date</th> <th style="width:25%; text-align: center;">Rev. 2 Signature/Date</th> </tr> </thead> <tbody> <tr> <td>Originator</td> <td style="text-align: center;"><u>Greg Hill</u> 3/19/99</td> <td></td> <td></td> </tr> <tr> <td>Checked by</td> <td style="text-align: center;"><u>[Signature]</u> 3/25/99</td> <td></td> <td></td> </tr> <tr> <td>Approved by</td> <td style="text-align: center;"><u>[Signature]</u> 3/31/99</td> <td></td> <td></td> </tr> <tr> <td>Checked Against Approved Vendor Data</td> <td></td> <td></td> <td></td> </tr> </tbody> </table>				Rev. 0 Signature/Date	Rev. 1 Signature/Date	Rev. 2 Signature/Date	Originator	<u>Greg Hill</u> 3/19/99			Checked by	<u>[Signature]</u> 3/25/99			Approved by	<u>[Signature]</u> 3/31/99			Checked Against Approved Vendor Data			
	Rev. 0 Signature/Date	Rev. 1 Signature/Date	Rev. 2 Signature/Date																			
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<u>1-3</u>	<u>Objective, Criteria, Methods, References, Assumptions, Conclusion</u>																					
<u>4-12</u>	<u>Body of Calculation</u>																					
<u>Attachment A</u> <u>5 pages</u>	<u>Design Loads from LMHC on Letter LMHC-9951531, 3/15/99</u>																					
<u>Attachment B</u> <u>8 pages</u>	<u>Finite Element Program Run 3D Computer Output</u>																					

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Objective: This calculation will provide the technical documentation for the truck ramp platform that will be placed over and around Tank 241-Z-361. Side loading limitations on Tank 241-Z-361 preclude the use of a conventional foundation system. The truck ramp platform foundation will incorporate a helical screw-in type anchor.

Criteria:

- Design Loads from LMHC on Letter LMHC-9951531, dated 3/15/99 (Attachment A of this calculation)
- Steel Design is in accordance with the American Institute of Steel Construction (AISC) 9th
- Helical anchor design is in accordance with A.B. Chance Company, Engineering F. Binder, 5/94

Method:

- 1) Hand Calculations
- 2) RISA Technologies, RISA 3-D Version 3.0 (Finite Element Program)

References:

- 1) Dwg H-2-85633 Sht 1, Rev. 0
- 2) American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Highway Bridges, 16th ed 1976
- 3) American Institute of Steel Construction (AISC) Manual of Steel Construction 9th ed
- 4) A.B. Chance Company, Engineering F. Binder, 5/94
- 5) An Introduction to Geotechnical Engineering, Holtz & Kovacs, 1981
- 6) RISA Technologies, RISA 3-D Version 3.0
- 7) Foundation Analysis & Design, Bowles 4th ed

E-NW-1223 (1)

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		Checked By	<u>L.J. Julyk</u>
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Assumptions: Design values for the helical screw-in type anchors are a function of the soil parameters at the site where the anchors will be installed. Since there was no official soil report identifying the actual soil conditions around Tank 241-Z-361, the soil conditions are assumed to be of a dry sandy nature with the following unit weight profile. The unit weight of the sandy soil was assumed to be 86 pcf for the first 5 feet which corresponds to loose dry sand. From 5 feet to 25 feet, the unit weight of the sandy soil was assumed to be 120 pcf which corresponds to a dense dry sand. The angle of internal friction for the sandy soil at a depth of 25 feet was assumed to be 35° .

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Conclusion: The truck ramp platform foundation will consist of a series of W8x28 framing beams which are supported by the helical screw-in anchors. From the assumed soil parameters, a 10" \varnothing helical anchor will be sufficient to carry the design loads provided by LHMCO. Since the soil parameters are assumed values however, the 10:1 correlation between installation torque and ultimate soil bearing capacity recommended by R.B. Chance Company will be observed. All anchors will be installed to a minimum specified depth and minimum specified torque.

Review of the installation procedures for these anchors indicates there will be negligible load induced on the surrounding soil during installation and as long as the anchors are installed so the helical bearing parts are below the tank bottom, there will be no loads transmitted to the tank walk from the anchors.

Results from this calculation are shown on DWG H-2-829739
Shts 1 and 2

E-NW-1234

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The following are the weights given by LMHC
(Refer to Attachment A.)

Platform: 4200 lbs. (Conservatively use 5,000 lbs.)
X-Ray Cart: 5000 lbs.
Cask Stand & 5 Casks: 3000 lbs.
10 people @ 200 lbs. ea.: 2000 lbs.

Total = 15,000 lbs

This load will be divided up evenly between the four posts of a ramp.

load per post = $15,000 \div 4 = 3,750$ lbs

Core Sample Truck: 35,000 lbs.; Conservatively use an AASHTO classification H20 Truck w/ total load of 40,000 lbs.
Rear axle load of 32,000 lbs

The rear axle load will be divided up between two posts

load per post = $32,000 \div 2 = 16,000$ lbs

Ramp: 1200 lbs (Current design calls for Ramps to be supported on ground, hence inclusion of Ramp load is conservative)
Since ramp is triangular, take $\frac{2}{3}$ the load as the reaction on the elevated end and divide between two posts

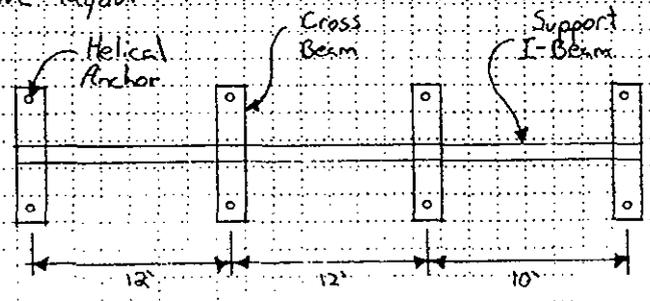
load per post = $(\frac{2}{3})(1200) \div 2 = 400$ lbs

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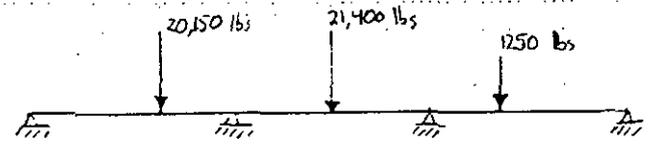
Total Load = $3750 + 16,000 + 400 = 20,150$ lbs.

- Use 20,150 lbs/past for the platform that is landed with the core sample truck.
- Use $5000 \div 4 = 1,250$ or 1250 lbs/past for the platform that is not landed with the Core Sample Truck.

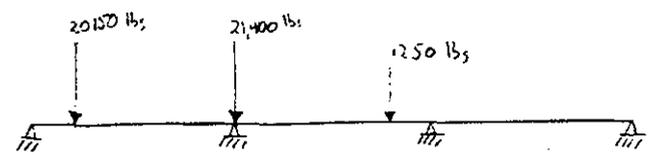
The foundation layout will look similar to the following conservative layout



Load Case 1



Load Case 2



Use Load spacing of 10 feet as shown on H-2-85633 Sit 1

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Reactions and Support I-Beam stress are determined by Risa 3.D. Output is shown in Attachment B.

The Support I-Beam of a W8x28 is adequate

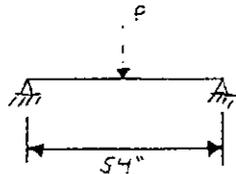
Load Case	V _{max} (kips)	Allowable Shear (kips)	f _b (ksi)	Allowable Bending Stress (ksi)
1	7.7	0.4(36) = 14.4	7.67	0.6(36) = 21.6
2	9.72		13.97	

Attachment B page no. 3

The cross beam will be initially sized for a 10" helical anchor. The helical anchors require a minimum 5d (or 50" spacing) (Recommendation from A.B. Chance Co.)

Loads on the Cross Beam come from Reaction Loads from Risa 3.D. plus an additional platform load. Although these loads are actually separated, conservatively combine and apply at midspan.

$$P = 25,450 + 1,250 + (12' \text{ tributary length of } W8 \times 28) = 27,036 \text{ lbs.}$$



$$M = \frac{PL}{4} = \frac{27036 (54)}{4} = 364,986 \text{ in-lbs}$$

$$S_{req} = \frac{M}{F_b} = \frac{364,986}{(0.6)(36,000)} = 16.90 \text{ in}^3$$

Use W8x28 $w/s = 24.3 \text{ in}^3$
 (AISC Manual Steel Construction 9th Chapter F pg 5-45)

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Check Shear

$$h/t_w = 8/5/16 = 25.6$$

$$380/\sqrt{F_y} = 380/\sqrt{36} = 63.3 > 25.6$$

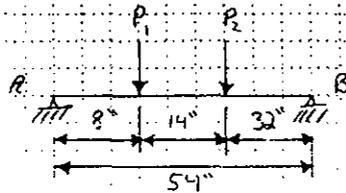
$$\therefore F_v = .4 F_y$$

(AISC Manual of Steel Construction 9th Sect. F4 pg. 5-49)

$$F_v = (.4)(36) = 14.4 \text{ Ksi}$$

$$f_v = 27036 / (8)(5/16) = 10,814 \text{ psi} < 14,400 \text{ psi} \quad \text{OK}$$

Check Load on Anchor



$$P_1 = 25,450 \text{ lbs}$$

$$P_2 = 1250 \text{ lbs} + (12' \text{ tributary length of } W8 \times 28) = 1586 \text{ lbs}$$

$$\sum M_e = 0 : (46)(25,450) + (32)(1586) = 54 R_A$$

$$R_A = 22,619 \text{ lbs}$$

$$\text{Add } (1/2)(4.5)(28) = 63 \text{ lbs}$$

$$\text{Total } R_A = 22619 + 63 = 22682 \text{ lbs}$$

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Web yielding W8x28

Maximum load will conservatively correspond to the maximum end reaction.

(AISC Manual of Steel Construction 9th pg. 2-31)

Allowable $P_{max} = (0.66) F_{yw} t_w (N + 2.5K)$

$F_{yw} = 36 \text{ Kips}$ $N = 6.535$
 $t_w = 0.285 \text{ in}$ $K = 15/16$

$P_{max} = (0.66)(36)(0.285)(6.535 + (2.5)(15/16)) = 60.12 \text{ Kips}$

Web Crippling W8x28

(AISC Manual of Steel Construction 9th pg. 2-31)

Allowable $P_{max} = 6.75 t_w^2 \left[1 + 3 \left(\frac{N}{d} \right) \left(\frac{t_w}{t_f} \right)^{1.5} \right] \sqrt{F_{yw} t_f / t_w}$

$t_f = 0.465$ $d = 8.06$

$P_{max} = (6.75)(0.285)^2 \left[1 + 3 \left(\frac{6.535}{8.06} \right) \left(\frac{0.285}{0.465} \right)^{1.5} \right] \sqrt{36(0.465/0.285)} = 91.06 \text{ Kips}$

P_{max} for web crippling and yielding are greater than 25,450 lb reaction loads. Therefore web stiffeners are not required.

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Helical Anchors Main Loads

- Use a tank depth of 22 feet below grade for sizing of helical anchors.
- Soil conditions will be considered as dense dry sand at the 25 ft depth.
- Soil conditions will be considered as loose dry sand to a depth of 5 feet.

Anchor sizing will follow design procedures outlined by R.B. Chance Company, Engineering, F. Binder.

Depth	Soil Type	Specific Gravity *	Unit Weight
0-5 ft	Loose Dry Sand	1.38	86 lb/ft ³
5-25 ft	Dense Dry Sand	2.23	140 lb/ft ³ **

* Specific Gravity is taken from An Introduction to Geotechnical Engineering by Holtz & Kovacs © 1981. Table 4-2 pg 105

** Use a Unit Weight of 120 lb/ft³ for Dense Dry Sand, more in line with values obtained at Hanford.

ENW-123

FLUOR DANIEL NORTHWEST

CALCULATION SHEET

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$$\text{Ultimate Bearing Capacity} = \bar{q} N_q$$

$$\bar{q} = (86)(5) + (20)(120) = 2830$$

N_q is dependent on ϕ , the angle of internal friction

ϕ for dense dry consolidated drain sand $43^\circ - 50^\circ$

(Foundation Analysis and Design, Bowles 4th ed.)
Table 2-6 pg. 84

Conservatively use $\phi = 35^\circ$

According to the N_q -vs- ϕ figure from R.B. Chance Co.

for $\phi = 35^\circ$ $N_q \approx 25$

$$\text{Ultimate Bearing Capacity} = (2830)(25) = 70,750 \text{ lbs/ft}^2$$

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		Date	

Capacity of 10" helix

$A_{net} = 76.4 \text{ in}^2$ (A.B. Chance Company, Engineering F. Binder)

$Q_{ult} = (70,750) \cdot (76.4/144) = 37,537 \text{ lbs/helix}$

Apply a safety factor of 2 to obtain Allowable Capacity:

$Q_{all, 10} = 37,537 \div 2 = 18,768 \text{ lbs/helix}$

$Q_{all, 10} = 18,768 \text{ lbs/helix}$ represents an estimated capacity of the 10" helix anchor at a depth of 25 feet. It is important to note that this is an estimated capacity based on the assumed soil parameters.

$Q_{all, 10} = 18,768 \text{ lbs/helix}$ indicates that a 10" helical anchor can be installed to the design load of 22,619 lbs. near the minimum depth of 23 ft. Soil parameters other than the assumed parameters are highly likely. The critical aspect of the 10" helical anchor installation will be the ultimate bearing capacity of the soil at the depth of the 10" helix. A.B. Chance Co. indicates a 10:1 correlation between installation torque and ultimate soil bearing capacity. Based on the 10:1 correlation and the actual soil conditions, the design load requirement of 22,619 lbs can be met at the minimum depth of 23 feet or deeper as required to meet the 10:1 ratio

Minimum Installation Torque: Working Load = 22,619 lbs

Ultimate Load = $(2)(22,619) = 45,238 \text{ lbs}$

Minimum Installation Torque = $45,238 \div 10 = 4,524 \text{ ft}\cdot\text{lb}$

E-NW-1024

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Helical Anchors: Lateral Loads

- Design procedure will follow that of the helical anchors for the main loads with the same soil parameters.
- A single 10" helical anchor will be considered and evaluated at various depths installed at 45°
- Lateral Load = 5400 lbs (Refer to Attachment A)

Depth	\bar{q}	Bearing Capacity	Quit w/ S.F. 2
10	1030	25,750	6,831 lbs/helix
12	1270	31,750	8,422 lbs/helix
15	1630	40,750	10,810 lbs/helix

- Lateral Load of 5400 lbs @ 45° = 7637 lbs axial
- A single 10" helical anchor installed @ 45° with a min. depth of 15' is adequate.
- Minimum Installation Torque: $(7637)(2) = 10 = 1527$ ft-lbs

Weld Capacity of 1/4" fillet weld, 4" long to secure helical anchor to foundation.

$(3)(70)(.707)(.74)(4") = 14,849$ lbs > 7,637 lbs ∴ OK

(AISC Manual of Steel Construction, 9th Table J2.5 pg 570)

Lockheed Martin Hanford Corporation
P.O. Box 1500
Richland, WA 99352-1505



March 15, 1999

LMHC-9951531

Mr. G. A. Lisle
Fluor Daniel Northwest, Inc B4-39
Post Office Box 1050
Richland, Washington 99352

Dear Mr. Lisle:

DESIGN LOADS AND CENTER OF GRAVITY FOR CORE SAMPLE TRUCK #1

- References: (1) HNF-PRO-097, 1997, Rev. 0, "Engineering Design and Evaluation," Fluor Daniel Hanford, Inc., Richland, Washington.
- (2) WHC-SD-WM-DA-215, Rev. 0, 1996, "Core Sampling Trucks RMCS Operations 200 Area," Westinghouse Hanford Company.

This letter transmits design loads and center of gravity information for core sample truck #1. These loads are to be used in the design of a foundation. The foundation will be used to support the Characterization Project Operation platforms during core sampling operations of tank 241-Z-361. The design loads due to dead weight are the following:

Ramp:	1,200 lb. ea.
Platform:	4,200 lb.
Core Sample Truck:	32,000 lb.
X-ray Cart:	5,000 lb.
Cask Stand & 5 Casks:	3,000 lb.
10 People @ 200 lb. ea.:	2,000 lb.

The required design live load is due to sudden stopping of a core sample truck. This was determined to be 5,400 lb. in the longitudinal direction (Attachment). The maximum wind loading for a Performance Category Three natural phenomenon hazard (Reference 1) was determined to be 5,400 lb. in the lateral direction.

Calculation TM12-C-01
Attachment A pg 1 of 5

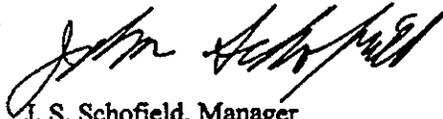
Mr. G. A. Lisle
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March 15, 1999

LMHC-9951531

The center of gravity (Cg) in the horizontal direction for core sample truck #1 was determined from the vertical loading on all three jacks and the distance between jacks. This loading is approximately 10,667 lb. for each jack. The distance between front and rear jacks is 24 ft, resulting in a distance to the Cg of 16 ft from the centerline of the front jack. The height of the Cg was determined by referencing the Structural Evaluation for the Core Sampling Trucks RMCS Operations 200 Area (Reference 2). This height was determined to be 64.3 inches from the bottom of the truck tires (ground height).

If there are any questions, please call me on 373-2245 or Mr. Brad Coverdell on 373-0598.

Very truly yours,



J. S. Schofield, Manager
Characterization Field Engineering
Tank Waste Remediation Systems

meg

Attachment

Calculation TM12-C-01
Attachment A pg 2 of 5

LMHC-9951531

ATTACHMENT

DESIGN LOADS AND CENTER OF GRAVITY
FOR CORE SAMPLE TRUCK #1

Consisting of 3 pages,
Including cover page

Calculation ~~TM12-C-01~~ TM12-C-01
Attachment A pg 3 of 5

COGEMA Engineering Corp.

Calc. No. _____
 Revision 0
 Page No. _____

DESIGN ANALYSIS

Client: Characterization Equipment
 Subject: Core Sample Truck Longitudinal Force Calculations
 Location: _____

WO/Job No. _____
 Date: 3/3/99
 Checked: 3-8-99
 Revised: _____
 By: B. L. Coverdell *MLP 3/8/99*
 By: [Signature]

- 1.0 **OBJECTIVE** Determine the maximum longitudinal force due to a core sample truck stopping and wind the wind loading.
- 2.0 **DESIGN INPUTS** Drawings H-2-690000 and H-2-85633
- 3.0 **ASSUMPTIONS**
 - 3.1 Time for Core Sample truck to stop = .6 sec.
 - 3.2 Maximum truck velocity and time required for a core sample truck to stop are both based on operational experience.
- 4.0 **METHODS OF ANALYSIS** (Hand Calculations)
- 5.0 **REFERENCES**
 - 5.1 AASHTO, 1989, *Standard Specification for Highway Bridges*, 14th Edition, American Association of State Highway and Transportation Officials.
 - 5.2 ASCE, 1996, *Minimum Design Loads for Buildings and Other Structures*, ANSI/ASCE 7-95, American Society of Civil Engineers, Reston, Virginia.
 - 5.3 Beer and Johnson, 1984, *Vector Mechanics for Engineers*, Fourth Edition, McGraw-Hill Book Company, New York, New York.
 - 5.4 HNF-PRO-097, 1997, *Engineering Design and Evaluation*, HNF-PRO-097, Rev. 0, Flour Daniel Hanford, Richland, Washington.
 - 5.5 WHC, 1995, *Structural Evaluation for the Core Sampling Trucks RMCS Operations, 200 Area*, WHC-SD-WM-DA-215, Rev. 0, Westinghouse Hanford Company.
- 6.0 **FINDINGS AND CONCLUSIONS** The maximum longitudinal force by a core sample truck on a platform is 5400 lb and the maximum lateral loading is by wind and is also 5400 lb.

7.0 CALCULATIONS

- $V_1 = 2$ -mph Maximum velocity of core sample truck based on operational experience.
- $V_2 = 0$ -mph Final velocity of core sample truck.
- $m = 35000$ -lb Mass of core sample truck in lbs mass.
- $t = .6$ -sec Estimated time required to stop core sample truck based on operational experience.

Use Kinetic Energy Theory

$$d = \frac{(V_1 - V_2)^2 t}{2} \quad d = 0.9 \text{ ft}$$

Work done = K. E.

$$F \cdot d = \frac{1}{2} m \cdot V_1^2$$

Calculation ~~For~~ TM12-C-01
 Attachment R pg 4 of 5

BTE 2/8/99
VSK 3/8/99

$$F := \frac{1}{2} m \cdot V_1^2 \quad F = 5318.3 \cdot \text{lb} \cdot \text{ft} \quad \text{Longitudinal force required to stop truck.}$$

Minimum longitudinal force required by AASHTO for bridges. $F_L = 5\%$ of LL.
 $F_L := .05 \cdot m \quad F_L = 1750 \text{ lb} \quad \text{Longitudinal force required by AASHTO.}$

Determine the maximum wind force on the core sample truck given that the truck is performance category 2 (PC2).

$K_z := .85 \quad \text{Exposure category C, table 6-3 of ASCE 1996.}$

$K_{zt} := 1 \quad \text{Per paragraph 6.5.5 of ASCE 1996.}$

$I := 1.07 \quad \text{Importance factor (HNF-PRO-097, 1997).}$

$V := 85 \quad \text{Wind velocity per (HNF-PRO-097, 1997).}$

$$q_z := .00256 \cdot K_z \cdot K_{zt} \cdot I \cdot V^2 \cdot \frac{\text{lb}}{\text{ft}^2} \quad q_z = 16.8 \cdot \frac{\text{lb}}{\text{ft}^2} \quad \text{Velocity pressure.}$$

$G := .85 \quad \text{Gust effect factors determined from paragraph 6.6.1 of ASCE 1996.}$

$C_f := 1.5 \quad \text{From Table 6-8 of ASCE 1996 given a height of 10 ft.}$

$A_f := 36128 \cdot \text{in}^2 \quad \text{Surface area of truck from WHC 1995.}$

$$F := q_z \cdot G \cdot C_f \cdot A_f \quad F = 5381.1 \text{ lb} \quad \text{Wind force on core sample truck.}$$

Calculation TM12-C-01
Attachment A pg 5 of 5

RISA-3D (R) version 3.01

Fluor Daniel, Inc.

Job :
Page: 1
Date: 3/24/99
File: 361ZC

```

=====
Units..... US Standard
Steel Code..... AISC 9th Edition ASD
Allowable Stress Increase Factor.. 1.333
Include Shear Deformation..... Yes
Include Warping..... Yes
No. of Sections for Member Calcs.. 5
Do Redesign..... Yes
P-Delta Analysis Tolerance..... 0.50%
Vertical Axis..... Y
    
```

```

=====< Joint Coordinates >=====
Joint      X      Y      Z      Joint
No         Coordinate Coordinate Coordinate Temperature
-----ft-----ft-----ft-----%F-----
    1         0.000         0.000         0.000         0.00
    2        12.000         0.000         0.000         0.00
    3        24.000         0.000         0.000         0.00
    4        34.000         0.000         0.000         0.00
    
```

```

=====< Boundary Conditions >=====
Joint  +----- Translation -----+ +----- Rotation -----+
No      X      Y      Z      Mx      My      Mz
-----K/in-----K/in-----K/in-----K-ft/rad---K-ft/rad---K-ft/rad---
    1 Reaction Reaction Reaction Reaction Reaction Reaction
    2 Reaction Reaction Reaction Reaction Reaction Reaction
    3 Reaction Reaction Reaction Reaction Reaction Reaction
    4 Reaction Reaction Reaction Reaction Reaction Reaction
    
```

```

=====< Materials (General) >=====
Material  Young's  Shear  Poisson's  Thermal  Weight  Yield
Label     Modulus  Modulus Ratio   Coef.   Density  Stress
-----Ksi-----Ksi-----10^5%F-----K/ft3-----Ksi-----
STL       29000.00  11154.00  0.3000  0.65000  0.490    36.00
    
```

```

=====< Sections >=====
Section  Database Material  As  As  I  I  Torsion T
Label    Shape   Label  Area yy zz  yy  zz  J  C
-----in^2-----in^4-----in^4-----in^4-----
BEAM    W8X28      STL    8.25 1.2 1.2  21.70  98.00  0.54
    
```

```

=====< Members >=====
Member  Joints  x Axis Section End Releases  Offsets  Inactive?
No      I    J    K  Rotate  Set  I: MMM J: MMM I-End  J-End Label  Length
-----xyzxyz-xyzxyz-----in-----in-----ft-----
    1    1    2          BEAM          12.00
    2    2    3          BEAM          12.00
    3    3    4          BEAM          10.00
    
```

Calculation TM12-C-01
Attachment B pg 1 of 8

RISA-3D (R) Version 3.01

Fluor Daniel, Inc.

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```

===== < Basic Load Case Data > =====
BLC      Basic Load Case      Load Type Totals
No.      Description              Nodal  Point Dist. Surface
-----
  1      Major Load Between Foundation      3
  2      Major Load Over Foundation      1      2
    
```

```

===== < Member Point Loads, BLC 1 > =====
Member  Joints
        I      J      Direction      Magnitude      Location
        -----K,K-ft-----ft or %-----
  1      1      2      Y      -20.150      %66.000
  2      2      3      Y      -21.400      %50.000
  3      3      4      Y      -1.250      %40.000
    
```

```

===== < Joint Loads/Enforced Displacements, BLC 2 > =====
Joint  Is this a Load or      Direction
Number a Displacement?      (X, Y, Z, Mx, My, Mz)      Magnitude
-----K,K-ft, in, rad-----
  2      L      Y      -21.400
    
```

```

===== < Member Point Loads, BLC 2 > =====
Member  Joints
        I      J      Direction      Magnitude      Location
        -----K,K-ft-----ft or %-----
  1      1      2      Y      -20.150      %17.000
  2      2      3      Y      -1.250      %83.000
    
```

```

===== < Joint Displacements, LC 1 : Load Case 1 > =====
Joint  +----- Translation -----+ +----- Rotation -----+
No.    X      Y      Z      X Rotate  Y Rotate  Z Rotate
-----in-----in-----in-----rad-----rad-----rad-----
  1      0.000  0.000  0.000  0.00000  0.00000  0.00000
  2      0.000  0.000  0.000  0.00000  0.00000  0.00000
  3      0.000  0.000  0.000  0.00000  0.00000  0.00000
  4      0.000  0.000  0.000  0.00000  0.00000  0.00000
    
```

```

===== < Reactions, LC 1 : Load Case 1 > =====
Joint  +----- Forces -----+ +----- Moments -----+
No.    X      Y      Z      Mx      My      Mz
-----K-----K-----K-----K-ft-----K-ft-----K-ft-----
  1      0.00  5.40  0.00  0.00  0.00  18.45
  2      0.00  25.45  0.00  0.00  0.00  -3.71
  3      0.00  11.51  0.00  0.00  0.00  -30.30
  4      0.00  0.44  0.00  0.00  0.00  -1.20
Totals: 0.00  42.80  0.00
Center of Gravity Coords (X,Y,Z) (ft) : 13.938, 0.000, 0.000
    
```

Calculation TM12-C-01
Attachment B pg 2 of 8

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=====< Member Section Forces, LC 1 : Load Case 1 >=====

Member	Joints		Sec	Axial K	Shear	Shear	Torque K-ft	Moment	Moment
	I	J			y-y K	z-z K		y-y K-ft	z-z K-ft
1	1-	2	1	0.00	5.40	0.00	0.00	0.00	18.45
			2	0.00	5.40	0.00	0.00	0.00	2.24
			3	0.00	5.40	0.00	0.00	0.00	-13.98
			4	0.00	-14.75	0.00	0.00	0.00	-8.43
			5	0.00	-14.75	0.00	0.00	0.00	35.81
2	2-	3	1	0.00	10.70	0.00	0.00	0.00	32.10
			2	0.00	10.70	0.00	0.00	0.00	0.00
			3	0.00	-10.70	0.00	0.00	0.00	-32.10
			4	0.00	-10.70	0.00	0.00	0.00	0.00
			5	0.00	-10.70	0.00	0.00	0.00	32.10
3	3-	4	1	0.00	0.81	0.00	0.00	0.00	1.80
			2	0.00	0.81	0.00	0.00	0.00	-0.22
			3	0.00	-0.44	0.00	0.00	0.00	-1.00
			4	0.00	-0.44	0.00	0.00	0.00	0.10
			5	0.00	-0.44	0.00	0.00	0.00	1.20

=====< Member Stresses, LC 1 : Load Case 1 >=====

Member	Sec	Axial Ksi	Shear	Shear	Bending			
			y-y Ksi	z-z Ksi	y-top Ksi	y-bot Ksi	z-top Ksi	z-bot Ksi
1	1	0.00	2.82	0.00	-9.10	9.10	0.00	0.00
	2	0.00	2.82	0.00	-1.10	1.10	0.00	0.00
	3	0.00	2.82	0.00	6.90	-6.90	0.00	0.00
	4	0.00	-7.70	0.00	4.16	-4.16	0.00	0.00
	5	0.00	-7.70	0.00	-17.67	17.67	0.00	0.00
2	1	0.00	5.59	0.00	-15.84	15.84	0.00	0.00
	2	0.00	5.59	0.00	0.00	0.00	0.00	0.00
	3	0.00	-5.59	0.00	15.84	-15.84	0.00	0.00
	4	0.00	-5.59	0.00	0.00	0.00	0.00	0.00
	5	0.00	-5.59	0.00	-15.84	15.84	0.00	0.00
3	1	0.00	0.42	0.00	-0.89	0.89	0.00	0.00
	2	0.00	0.42	0.00	0.11	-0.11	0.00	0.00
	3	0.00	-0.23	0.00	0.49	-0.49	0.00	0.00
	4	0.00	-0.23	0.00	-0.05	0.05	0.00	0.00
	5	0.00	-0.23	0.00	-0.59	0.59	0.00	0.00

Calculation TM12-C-01
Attachment B pg 3 of 8

RISA-3D (R) Version 3.01

Fluor Daniel, Inc.

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=====
 < Member Deflections, LC 1 : Load Case 1 >
 =====

Member	Sec	Translation			x Rotate	Defls as L/n Ratios	
		x	y	z		L/n (y)	L/n (z)
		in	in	in	rad		
1	1	0.000	0.000	0.000	0.00000	NC	NC
	2	0.000	-0.036	0.000	0.00000	4034.7	NC
	3	0.000	-0.084	0.000	0.00000	1722.1	NC
	4	0.000	-0.058	0.000	0.00000	2498.4	NC
	5	0.000	0.000	0.000	0.00000	NC	NC

2	1	0.000	0.000	0.000	0.00000	NC	NC
	2	0.000	-0.059	0.000	0.00000	2459.3	NC
	3	0.000	-0.117	0.000	0.00000	1229.7	NC
	4	0.000	-0.059	0.000	0.00000	2459.3	NC
	5	0.000	0.000	0.000	0.00000	NC	NC

3	1	0.000	0.000	0.000	0.00000	NC	NC
	2	0.000	-0.002	0.000	0.00000	NC	NC
	3	0.000	-0.004	0.000	0.00000	NC	NC
	4	0.000	-0.002	0.000	0.00000	NC	NC
	5	0.000	0.000	0.000	0.00000	NC	NC

=====
 < Member AISC Unity Checks, LC 1 : Load Case 1 >
 =====

Member	Joints		Unity	Shear		Fa	Fb yy	Fb zz	Cb	Cm yy	Cm zz	ASD	
	I	J		Chk	Loc								Chk
													Eqn
1	1	2	0.818	5	0.535	4y	14.35	27.00	21.60	1.00	0.60	0.85	H1-2
2	2	3	0.733	3	0.388	1y	14.35	27.00	21.60	1.00	0.60	0.85	H1-2
3	3	4	0.041	1	0.029	1y	16.01	27.00	21.60	1.00	0.60	0.85	H1-2

Calculation TM12-C-01
 Attachment B pg 7 of 8

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Fluor Daniel, Inc.

Job :
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```

=====
Units..... US Standard
Steel Code..... AISC 9th Edition ASD
Allowable Stress Increase Factor.. 1.333
Include Shear Deformation..... Yes
Include Warping..... Yes
No. of Sections for Member Calcs.. 5
Do Redesign..... Yes
P-Delta Analysis Tolerance..... 0.50%
Vertical Axis..... Y
    
```

```

===== < Joint Coordinates > =====
Joint      X      Y      Z      Joint
No         Coordinate  Coordinate  Coordinate  Temperature
-----
          ft         ft         ft         %F
-----
1          0.000      0.000      0.000      0.00
2          12.000     0.000      0.000      0.00
3          24.000     0.000      0.000      0.00
4          34.000     0.000      0.000      0.00
    
```

```

===== < Boundary Conditions > =====
Joint      Translation      Rotation
No         X      Y      Z      Mx      My      Mz
-----
          K/in  K/in  K/in  K-ft/rad  K-ft/rad  K-ft/rad
-----
1 Reaction Reaction Reaction Reaction Reaction Reaction
2 Reaction Reaction Reaction Reaction Reaction Reaction
3 Reaction Reaction Reaction Reaction Reaction Reaction
4 Reaction Reaction Reaction Reaction Reaction Reaction
    
```

```

===== < Materials (General) > =====
Material  Young's  Shear  Poisson's  Thermal  Weight  Yield
Label     Modulus  Modulus  Ratio  Coef.  Density  Stress
-----
          Ksi     Ksi     Ratio  10^5/F  K/ft3    Ksi
-----
STL       29000.00  11154.00  0.3000  0.65000  0.490    36.00
    
```

```

===== < Sections > =====
Section  Database  Material  As  As  I  I  Torsion I
Label    Shape    Label    Area  yy  zz  yy  zz  J  C
-----
          in^2  in^4  in^4  in^4  in^4  in^4
-----
BEAM     W8X28     STL      8.25  1.2  1.2  21.70  98.00  0.54
    
```

```

===== < Members > =====
Member  Joints  x Axis  Section  End Releases  Offsets  Inactive?
No      I      J      K  Rotate  Set  I: MMM J: MMM I-End  J-End Label  Length
-----
          xyxyz-xyzxyz  in  in  in
-----
1        1      2          BEAM          12.00
2        2      3          BEAM          12.00
3        3      4          BEAM          10.00
    
```

Calculation TM12-C-01
Attachment B pg 5 of 8

RISA-3D (R) Version 3.01

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=====< Member Section Forces, LC 2 : Load Case 2 >=====

Member	Joints I - J	Sec	Axial K	Shear y-y K	Shear z-z K	Torque K-ft	Moment y-y K-ft	Moment z-z K-ft
1	1- 2	1	0.00	18.60	0.00	0.00	0.00	28.32
		2	0.00	-1.55	0.00	0.00	0.00	-8.14
		3	0.00	-1.55	0.00	0.00	0.00	-3.49
		4	0.00	-1.55	0.00	0.00	0.00	1.15
		5	0.00	-1.55	0.00	0.00	0.00	5.80
2	2- 3	1	0.00	0.10	0.00	0.00	0.00	0.36
		2	0.00	0.10	0.00	0.00	0.00	0.07
		3	0.00	0.10	0.00	0.00	0.00	-0.22
		4	0.00	0.10	0.00	0.00	0.00	-0.51
		5	0.00	-1.15	0.00	0.00	0.00	1.76
3	3- 4	1	0.00	0.00	0.00	0.00	0.00	0.00
		2	0.00	0.00	0.00	0.00	0.00	0.00
		3	0.00	0.00	0.00	0.00	0.00	0.00
		4	0.00	0.00	0.00	0.00	0.00	0.00
		5	0.00	0.00	0.00	0.00	0.00	0.00

=====< Member Stresses, LC 2 : Load Case 2 >=====

Member	Sec	Axial Ksi	Shear y-y Ksi	Shear z-z Ksi	Bending Ksi			
					y-top	y-bot	z-top	z-bot
1	1	0.00	9.72	0.00	-13.97	13.97	0.00	0.00
	2	0.00	-0.81	0.00	4.02	-4.02	0.00	0.00
	3	0.00	-0.81	0.00	1.72	-1.72	0.00	0.00
	4	0.00	-0.81	0.00	-0.57	0.57	0.00	0.00
	5	0.00	-0.81	0.00	-2.86	2.86	0.00	0.00
2	1	0.00	0.05	0.00	-0.18	0.18	0.00	0.00
	2	0.00	0.05	0.00	-0.04	0.04	0.00	0.00
	3	0.00	0.05	0.00	0.11	-0.11	0.00	0.00
	4	0.00	0.05	0.00	0.25	-0.25	0.00	0.00
	5	0.00	-0.60	0.00	-0.87	0.87	0.00	0.00
3	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Calculation TM12-C-01
Attachment B pg 7 of 8

RISA-3D (R) Version 3.01

Fluor Daniel, Inc.

Job :
 Page: 8
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=====< Member Deflections, LC 2 : Load Case 2 >=====

Member	Sec	Translation			x Rotate	Defls as L/n Ratios	
		x	y	z		L/n (y)	L/n (z)
		in	in	in	rad		
1	1	0.000	0.000	0.000	0.00000	NC	NC
	2	0.000	-0.028	0.000	0.00000	5071.7	NC
	3	0.000	-0.030	0.000	0.00000	4869.4	NC
	4	0.000	-0.012	0.000	0.00000	NC	NC
	5	0.000	0.000	0.000	0.00000	NC	NC
2	1	0.000	0.000	0.000	0.00000	NC	NC
	2	0.000	-0.001	0.000	0.00000	NC	NC
	3	0.000	-0.002	0.000	0.00000	NC	NC
	4	0.000	-0.002	0.000	0.00000	NC	NC
	5	0.000	0.000	0.000	0.00000	NC	NC
3	1	0.000	0.000	0.000	0.00000	NC	NC
	2	0.000	0.000	0.000	0.00000	NC	NC
	3	0.000	0.000	0.000	0.00000	NC	NC
	4	0.000	0.000	0.000	0.00000	NC	NC
	5	0.000	0.000	0.000	0.00000	NC	NC

=====< Member AISC Unity Checks, LC 2 : Load Case 2 >=====

Member	Joints	Unity	Shear		Fa	Fb yy	Fb zz	Cb	Cm yy	Cm zz	ASD
	I - J	Chk	Loc	Chk	Loc	Ksi	Ksi	Ksi			Eqn
1	1 2	0.647	1	0.675	1y	14.35	27.00	21.60	1.00	0.60	0.85 H1-2
2	2 3	0.040	5	0.042	5y	14.35	27.00	21.60	1.00	0.60	0.85 H1-2
3	3 4	0.000	1	0.000	1y	16.01	27.00	21.60	1.00	0.60	0.60 H1-1

Calculation TM12-C-01
 Attachment B pg 8 of 8

APPENDIX: I

EVALUATION OF NOZZLES B, E, F & G

LETTER REPORT

RE-EVALUATION OF TANK 241-Z-361 NOZZLES A, B, E, F, AND G FOR
LOAD INDUCED BY SAMPLING EQUIPMENT

Prepared by

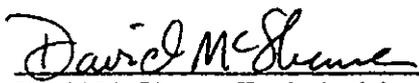
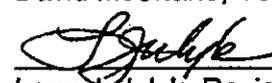
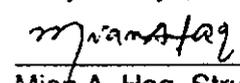
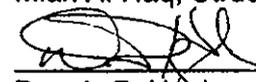
FLUOR DANIEL NORTHWEST, INC.

April 1999

Prepared for

B & W HANFORD COMPANY

Contract 915, Release 021

 _____ David McShane, Technical Author	<u>4/15/99</u> Date
 _____ Larry J. Julyk, Reviewer	<u>4/15/99</u> Date
 _____ Mian A. Haq, Structural Engineering Lead	<u>4/15/99</u> Date
 _____ Dennis P. Hughes, Area Manager	<u>4/15/99</u> Date

LETTER REPORT**RE-EVALUATION OF TANK 241-Z-361 NOZZLES A, B, E, F, AND G FOR
LOAD INDUCED BY SAMPLING EQUIPMENT****INTRODUCTION**

This report provides the results of the structural analysis performed on the 8-inch (nozzles A, B, F, and G) and 6-inch (nozzle E) pipe risers of Tank 241-Z-361 in preparation for sampling (see Appendix A for a sketch of the Tank). Tank 241-Z-361 has been out of service for several years and Babcock & Wilcox Hanford Company (BWHC) is in process of characterizing the waste left in the tank. Before the waste could be sampled, breather filters have been mounted on the tank. Sampling of the contents of the tank will be made through the risers evaluated in this report.

Tank 241-Z-361 is a rectangular underground tank built of reinforced concrete with a carbon steel liner on the sides and bottom. The tank has eight carbon steel pipe risers ranging from 2-inch to 8-inch in diameter. Previously, Fluor Daniel Northwest, Inc. (FDNW), evaluated all of the pipe risers (Reference 1) to determine the riser capacity and validate the load limits of 100 lbs. horizontal and vertical and 50 ft-lb torque established in the "Justification for Continued Operation of Tank 241-Z-361" (Ref 6). FDNW also evaluated 3-inch (nozzle H) and 8-inch (nozzle A or B) to determine if the nozzles could withstand the loading from a breather filter unit. (Ref 2)

This evaluation is performed by FDNW at the request of BWHC by Contract 915, Release 021.

SUMMARY AND CONCLUSION

The 8-inch risers (nozzles A, B, F, and G) were analyzed to determine if the risers would support a 1500 lb vertical load, a 250 lb horizontal load, and a 100 ft-lb torque induced by the sampling process. The evaluation demonstrates that nozzle A, B, F, and G can withstand the loading. The 6-inch riser, nozzle E, was analyzed for an applied loading of 1500 lbs vertical, 100 lbs horizontal, and a 50 ft-lb torque. The installation details for the nozzle E are not available. Therefore an additional support will be required to transfer the loading for the sampling process to the ground. A detail of that support is located in Appendix A.

APPROACH / EVALUATION

The risers were evaluated using hand calculations. For nozzles A, B, F, and G first, the riser pipe was analyzed as a cantilever column assuming no lateral support from the soil. Since the properties of the weld of the embedded plate or base plate to the riser pipe and the pipe riser are approximately the same, one analysis will cover both the weld and the pipe. Second, for nozzles A and B the embedded plate and concrete were analyzed by evaluating the punching shear of the embedded plate on the concrete. For nozzles F and G the base plate was evaluated for the bearing stress on the concrete. The support for nozzle E was evaluated by examining the bearing stress applied to the ground.

The analysis of the nozzles is located in Appendix B.

RECOMMENDATIONS

Based on the analysis performed, Nozzles A, B, F, and G are adequate to withstand the load induced by the sampling process. The strength of nozzle E is indeterminate and to use this nozzle for sampling, it is recommended that additional support be installed. Due to the high vertical load, (1500 lbs) great care must be exercised to assure that the 2000-lb limit for loading the top of the tank is not exceeded.

REFERENCES

1. Letter report, "Engineering Load Evaluation of the Risers on Tank 241-Z-361", dated January 1998, Task Order PF820, by Fluor Daniel Northwest, Inc. Richland, Washington
2. Letter, D.P. Hughes, Area Manager, Fluor Daniel Northwest, Inc., to A. L. Ramble, B&W Hanford Company, "Engineering Load Evaluation of the Riser on Tank 241-Z-361", dated 2/10/98 (CO-98-037)
3. Letter report, "Re-Evaluation of 3-inch and 8-inch Risers for Breather Filter Mounting on Tank 241-Z-361", dated June 1998, Task Order PF820, by Fluor Daniel Northwest, Inc. Richland, Washington
4. Statement of Work for Fluor Daniel Northwest, cc:mail from Brad Norman to David McShane, dated March 25, 1999.
5. HCF-PRO-097, Project Hanford Procedures, Engineering Design and Evaluation
6. HNF-2024, "Justification for Continued Operation for Tank 241-Z-361, dated January 1998, BWHC, Richland, Washington.

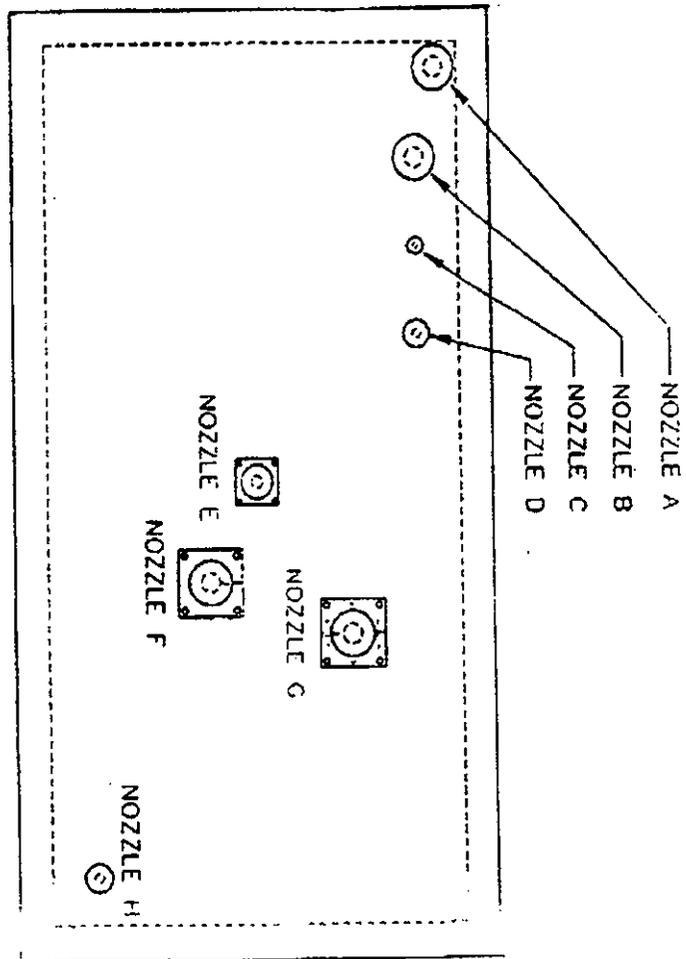
APPENDIX A
TANK SKETCHES

A-1

I-5

APPENDIX A - TANK SKETCH

SHEET A2 OF 4

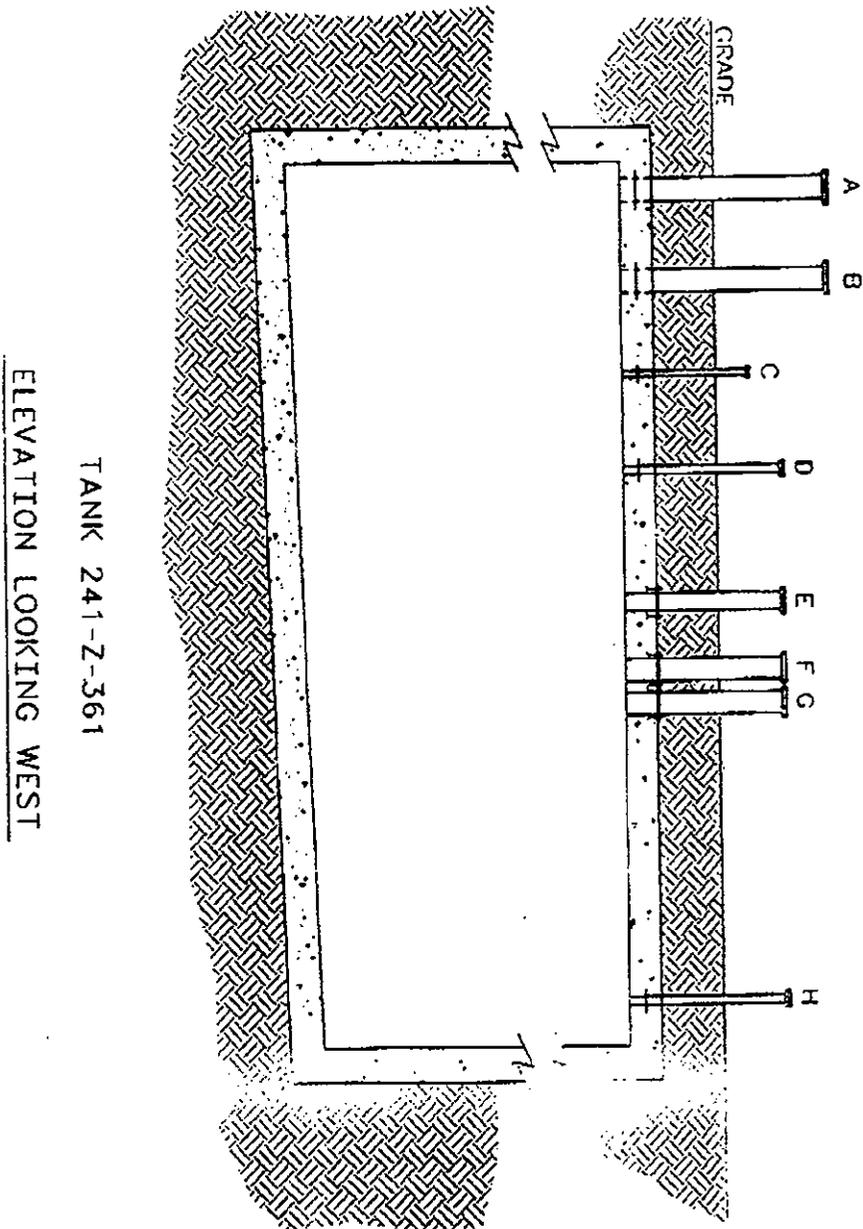


TANK 241-Z-361

PLAN VIEW

APPENDIX A - TANK SKETCH

SHEET A3 OF 4

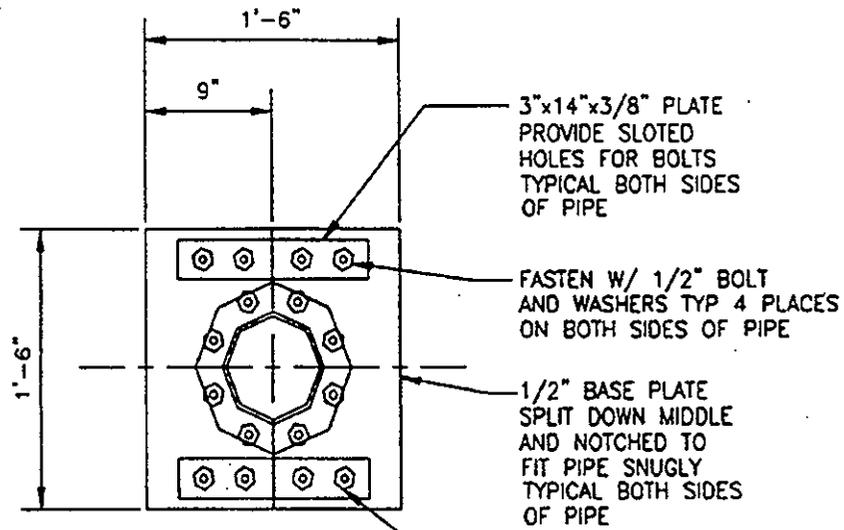


TANK 241-Z-361

ELEVATION LOOKING WEST

APPENDIX A - NOZZLE E PROPOSED MODIFICATION

SHEET A4 OF 4



TOP VIEW

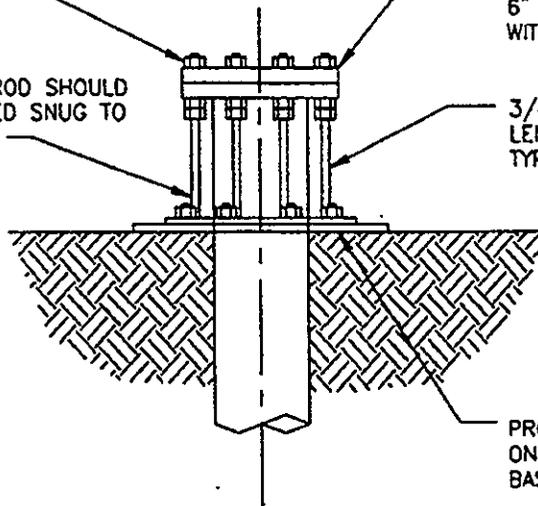
TAP BASE PLATE AS
REQUIRED FOR 1/2" BOLTS

(3) 3/4" NUTS W/
WASHER TYPICAL
8 PLACES

THREADED ROD SHOULD
BE INSTALLED SNUG TO
BASE PLATE

EXISTING
6" PIPE RISER
WITH BLIND FLANGE

3/4" THREADED ROD.
LENGTH AS REQUIRED
TYPICAL 8 PLACES



FRONT VIEW

APPENDIX B
CALCULATIONS

B-1

I-9

CALCULATIONS AND SKETCHES SHEET

Page 2 of 13

FLUOR DANIEL NORTHWEST

DEPARTMENT: Civil	ORIGINATED BY: <i>David M. Shea</i>	DATE: 4-15-99
CONTRACT/TASK ORDER No.: 65100231-PP012	CHECKED BY: <i>J. Galyk</i>	DATE: 4/15/99
LOCATION: 200 West PFP	REVISED BY:	DATE:
SUBJECT: Evaluation of Nozzles A, B, E, F, and G on PFP Tank 241-Z-361 for the loading from the sampling		

OBJECTIVE

This calculation will analyze Nozzles A, B, E, F, and G on PFP Tank 241-Z-361. Sheets 3 and 4 of this calculation show where the nozzles are located.

METHODS

Hand Methods using standard engineering practices.

REFERENCES

1. AISC, Manual of Steel Construction, Allowable Stress Design, Ninth Edition
2. ACI 318R Building Code Requirement for reinforced Concrete
3. Design of Welded Structures, Blodgett
4. Crane, Flow of Fluids Through Valve, Fitting and Pipe, Technical Paper No. 410
5. Drawings H-2-16024, H-2-16640, and H-2-90718 Sht 3
6. FCN 25603
7. Uniform Building Code 1997
8. Statement of Work (Attachment A)
9. Calculation PP012-C-02, Rev. 0, Riser Analysis for PFP Tank 241-Z-361

CONCLUSION

Riser A and B, are 8-inch pipe installed as part of the original construction, will withstand the 1500 lb vertical, 250 lb horizontal and 100 ft-lb loads which could be applied during sampling process. The specific results are tabulate on pages 9 and 10.

Riser E, a 6 inch pipe which was installed after the original construction could not be analyzed due to insufficient design data. Specifically, the size and thickness of the base plate, and the location and diameter of the anchor bolts. An alternate method of supporting riser E was determined and will withstand the 1500 lb vertical load from sampling. The support is shown on page 13. By comparison to the analysis of the other risers and engineering judgement nozzle E is adequate to resist the 100 lb horizontal and 50 ft-lb torque.

Risers F and G are 8 inch pipe installed after the original construction using a base plate and embedded bolts. These risers will withstand the 1500 lb vertical, 250 lb horizontal and 100 ft-lb loads which could be applied during sampling process. The specific results are tabulate on pages 9 and 11.

CALCULATION**Nozzle Configuration:**

Tank 241-Z-361 has eight nozzles. A sketch of the nozzle locations is shown on page 3 and 4. This Sketch provides an identification letter for each nozzle. Details of how the nozzles are secured to the concrete are shown on Page 5.

CALCULATIONS AND SKETCHES SHEET

FLUOR DANIEL NORTHWEST

DEPARTMENT: Civil

ORIGINATED BY: *David McQueen* DATE: 4-15-99

CONTRACT/TASK ORDER No.:
65100231-PP012

CHECKED BY: *D. J. Dyk* DATE: 4/15/99

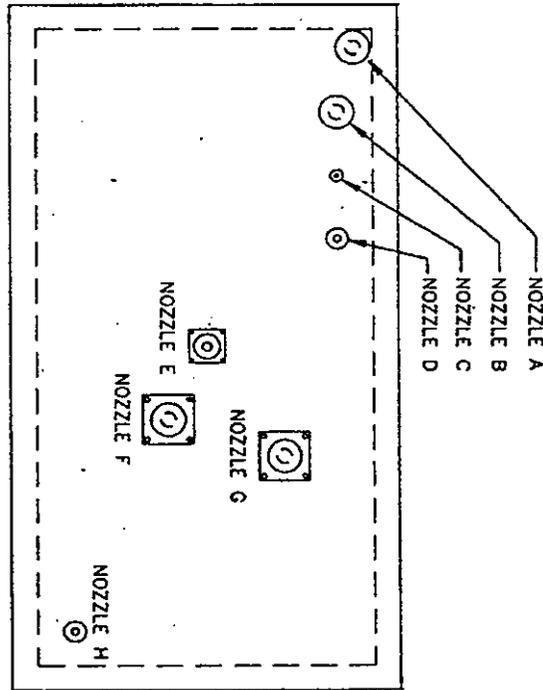
LOCATION: 200 West PFP

REVISED BY:

DATE:

SUBJECT: Evaluation of Nozzles A,B, E, F, and G on PFP Tank 241-Z-361 for the loading from the sampling

TANK 241-Z-361
PLAN VIEW



CALCULATIONS AND SKETCHES SHEET

FLUOR DANIEL NORTHWEST

DEPARTMENT: Civil

ORIGINATED BY: *David M. Shea* DATE: 4-15-99

CONTRACT/TASK ORDER No.:
65100231-PP012

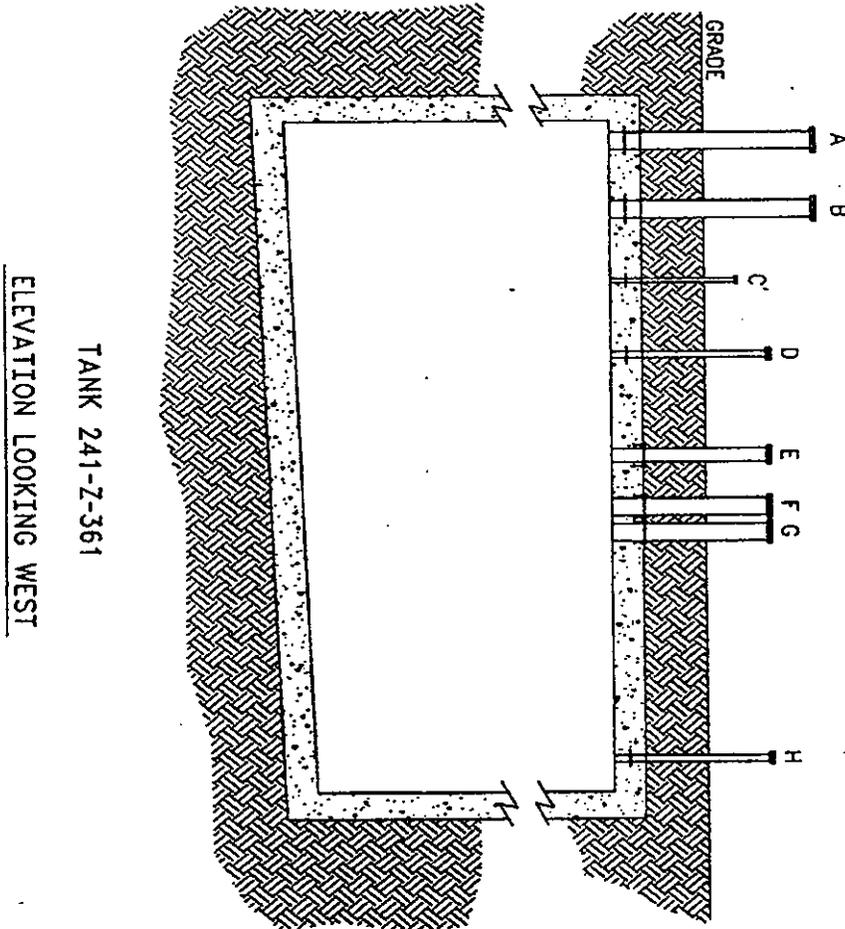
CHECKED BY: *Spudyl* DATE: 4/15/99

LOCATION: 200 West PFP

REVISED BY:

DATE:

SUBJECT: Evaluation of Nozzles A,B, E, F, and G on PFP Tank 241-Z-361 for the loading from the sampling



CALCULATIONS AND SKETCHES SHEET

FLUOR DANIEL NORTHWEST

DEPARTMENT: Civil	ORIGINATED BY: <i>David McShane</i>	DATE: 4-15-99
CONTRACT/TASK ORDER No.: 65100231-PP012	CHECKED BY: <i>J. Galph</i>	DATE: 4/15/99
LOCATION: 200 West PFP	REVISED BY:	DATE:
SUBJECT: Evaluation of Nozzles A,B, E, F, and G on PFP Tank 241-Z-361 for the loading from the sampling		

Nozzles A, B, C, D, and H

These risers were installed with the original construction using the embedded nozzle detail shown on Page 5. Pictures of the tank interior, taken in 1975, show that all metal below the water line has corroded away. Metal above the water line is badly rusted but is still there. The pictures show the underside of the concrete top be discolored but the lines from the form boards are still visible demonstrating that the top is still intact.

Nozzles E, F, and G

These risers were installed in the mid 1970's using a base plate with embedded bolts (see page 5). Riser E was installed at a different time and there is insufficient data (ie base plate thickness, and size of embedded bolts) is available to analyze this nozzle. Riser F and G were installed by Field Change Notice (FCN) 25603 after the use of steam in the tank was discontinued. Therefore, the risers will have minimal degradation due to corrosion.

ASSUMPTIONS

1. The thickness of the base metal of risers A and B will be decreased by one half to account for corrosion. This reduction amount to more than 1.5 mils per year. This is greater than the corrosion allowance for the double shell tanks and therefore is conservative.
2. The outside of the pipe was not affected by corrosion.
3. The weld of risers A and B to the embedded plate is an all around fillet weld with the same thickness as the embedded plate.
4. On risers A and B the outside of the pipe embedded in the concrete was not affected by corrosion.
5. For risers A and B the embedded plate will be assumed to be placed a the middle of the concrete top.
6. The distance from the embedded plate to the reinforcing steel will be four inches.
7. When analyzing the concrete for punching shear the strength of the reinforcing steel will be neglected.
8. The Yield Stress for carbon steel will be 36 ksi.
9. The positive effect of the soil depth on the unbraced length will be conservatively neglected.

CALCULATIONS AND SKETCHES SHEET

FLUOR DANIEL NORTHWEST

DEPARTMENT: Civil	ORIGINATED BY: <i>David M. Jones</i>	DATE: 4-15-99
CONTRACT/TASK ORDER No.: 65100231-PP012	CHECKED BY: <i>[Signature]</i>	DATE: 4/15/99
LOCATION: 200 West PFP	REVISED BY:	DATE:
SUBJECT: Evaluation of Nozzles A, B, E, F, and G on PFP Tank 241-Z-361 for the loading from the sampling		

10. Due to the temporary nature of the sampling activity no seismic load will be included in the analysis.
11. Nozzles A and B may be cut shorter to facilitate the sampling equipment. The analysis will be performed with the full length.

APPLIED LOADS

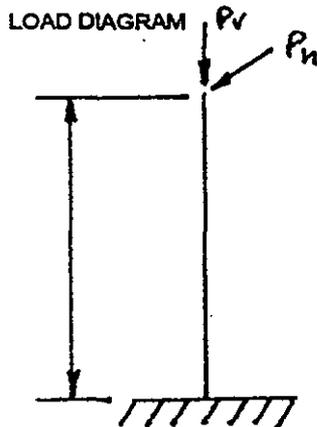
As directed in the statement of work (attachment A) one load case will be applied to the nozzles:

- For nozzles A, B, F, and G: 1500 lb vertical load, 250 lb horizontal load, and 100 ft-lb torque
- For nozzle E: 1500 lb vertical load, 100 lb horizontal load, and 50 ft-lb torque.

NOZZLE ANALYSIS: (Nozzles A, B, F, and G)

First, the pipe risers will be analyzed as cantilever column with the length of the column being from the top of the flange to the top of the embedded or surface mounted plate. Since the properties of the pipe riser and the weld of the pipe riser to the embedded or surface mounted plate are approximately the same, this one analysis will cover both. Second, for nozzles A and B the embedded plate and concrete will be analyzed evaluating the punching shear on the concrete. For nozzle F and G the base plate will be evaluated.

Column Analysis



Physical properties are tabulated on page 8.

Stresses at the Support

Axial $f_a = P_v/a$
 Shear $f_v = (P_h/a) + (P_t \cdot c/J)$
 Bending $f_b = (P_h \cdot l \cdot c)/I$

Allowable Stresses (AISC)

$F_a = 36 \text{ ksi} \cdot C_a$ (table 3 AISC, pg 5-119)
 $F_v = .4 \cdot 36 \text{ ksi}$
 $F_b = .6 \cdot 36 \text{ ksi}$

Interaction Equation

$(f_a/F_a) + (f_v/F_v) + (f_b/F_b) \leq 1$

Tabulated Results are shown on Page 9

CALCULATIONS AND SKETCHES SHEET

FLUOR DANIEL NORTHWEST

DEPARTMENT: Civil

ORIGINATED BY: *David McPherson* DATE: 4-15-99

CONTRACT/TASK ORDER No.: 65100231-PP012

CHECKED BY: *[Signature]* DATE: 4/15/99

LOCATION: 200 West PFP

REVISED BY:

DATE:

SUBJECT: Evaluation of Nozzles A,B, E, F, and G on PFP Tank 241-Z-361 for the loading from the sampling

Nozzle Data for design purposes

Riser Identification (see page 5)	Installation Detail (see page 5)	Nominal Riser Pipe Size (in)	Embedded Pipe Dia (in)	Length (in)	Nominal Wall Thickness (in)	Nominal Area (in ²)	Reduced Wall Thickness (in)	Reduced Area (in ²)	Moment of Inertia I (in ⁴)	Torsional moment of inertia J (in ⁴)
A and B	A	8	13.5	72	0.32	8.4	0.18	4.28	38.35	76.7
F and G	B	8	N/A	48	0.32	8.4	N/A	N/A	72.49	144.98

Riser Identification (see page 5)	Installation Detail (see page 5)	Radius of OD (in)	Radius of Gyration r (in)	k/r	k/r/Cc ²	Ca ²	Allowable Stresses		
							Compression (psi)	Bending (psi)	Shear (psi)
A and B	A	4.31	2.88	50.52	0.40	0.51	18324	21600	14400
F and G	B	4.31	2.94	34.31	0.27	0.55	19858	21600	14400

- a. $r = (I/A)^{1/2}$ (ref Blockset page 2-2-7)
- b. $J = 2 \cdot I \cdot r$ (ref Blockset 2.10-1)
- c. Ca is from table 3 of the AISC Page 5-119
- d. Cc = 126.1 (ref AISC Page 5-120)
- e. AISC Table C-C2.1 page 5-135, Fixed-free end restraints

CALCULATIONS AND SKETCHES SHEET

FLUOR DANIEL NORTHWEST

DEPARTMENT: Civil

ORIGINATED BY: *David McGee* DATE: 4-15-99

CONTRACT/TASK ORDER No.:
65100231-PP012

CHECKED BY: *J. G. [Signature]* DATE: 4/15/99

LOCATION: 200 West PFP

REVISED BY:

DATE:

SUBJECT: Evaluation of Nozzles A,B, E, F, and G on PFP Tank 241-Z-361 for the loading from the sampling

AISC Code Based
PIPE COLUMN LOAD EVALUATION

Riser Identification	Applied Load			Calculated Stresses			Combined Stresses	
	Vertical Pv (lbs)	Horizontal Ph (lbs)	Torsion Pt (ft-lbs)	Axial fa (psi)	Shear fv (psi)	Bending fb (psi)	fa + fb + fv	
							Value	Acceptable Value ≤ 1
A and B	1500	250	100	350.47	125.84	2024.12	0.12	Yes
F and G	1500	250	100	178.57	65.44	713.89	0.05	Yes

CALCULATIONS AND SKETCHES SHEET

FLUOR DANIEL NORTHWEST

DEPARTMENT: Civil

ORIGINATED BY: *David McHugh* DATE: 4-15-99

CONTRACT/TASK ORDER No.:
65100231-PP012

CHECKED BY: *Boyd* DATE: 4/15/99

LOCATION: 200 West PFP

REVISED BY:

DATE:

SUBJECT: Evaluation of Nozzles A, B, E, F, and G on PFP Tank 241-Z-361 for the loading from the sampling

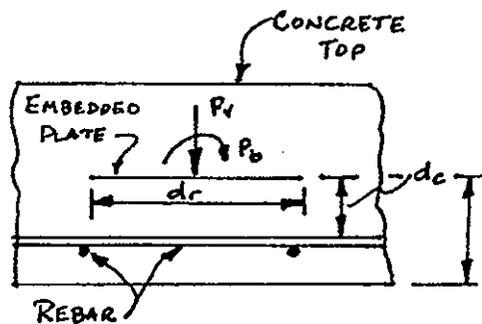
Concrete Analysis for Risers A and B

This analysis will compare the actual shear load (Vu) to the allowable shear load (Vn) per ACI to determine the factor of safety. The load factors will be included in the Vn term. A factor of safety greater than 2 will be acceptable.

Terms and Definition:

- Vu = the actual factored shear load
- LL = Live Load
- DL = Dead Load (the dead load will be neglected)
- Vc = the allowable shear load of the concrete
- Vs = the allowable shear load of the steel (=0, assumption 7)
- Vn = the allowable shear load
- $\phi = 0.85$

Load Diagram



Allowable Shear Load (Vn)

$$V_n = V_c + V_s$$

$$V_c = 4 \cdot f_c' \cdot b_o \cdot d_c$$

$$V_n = 4 \cdot 3000 \cdot 42.41 \cdot 4 = 37166 \text{ lbs}$$

$$V_n = \phi (V_c + V_s) = 31591 \text{ lbs}$$

Actual shear

$$V_u = 1.7(LL) + 1.4(DL)$$

$$LL = (P_v + (2 \cdot P_b / d_c)) = 1500 + (2 \cdot 18000 / 13.5)$$

$$V_u = 1.7 \cdot 4167 = 7084 \text{ lbs}$$

Determine Factor of Safety

$$F_s = V_n / V_u \geq 2$$

$$F_s = .85(V_n) / 1.7LL$$

$$F_s = 31591 / 7084 = 4.5 \geq 2 \text{ ACCEPTABLE}$$

Physical Properties

- $d_c = 4"$
- $b_o =$ Circumference of the embedded plate
- $b_o = 42.41$ inches
- $f_c' = 3000$ psi
- $d_r = 13.5$ (see page 8)

CALCULATIONS AND SKETCHES SHEET

FLUOR DANIEL NORTHWEST

DEPARTMENT: Civil

ORIGINATED BY: *David M. Jones*

DATE: 4/15/99

CONTRACT/TASK ORDER No.:
65100231-PP012CHECKED BY: *Boyle*

DATE: 4/15/99

LOCATION: 200 West PFP

REVISED BY:

DATE:

SUBJECT: Evaluation of Nozzles A, B, E, F, and G on PFP Tank 241-Z-361 for the loading from the sampling

Concrete Analysis for Risers F and G

Explanation of Analysis

The loads applied to the concrete are resisted by the base plate, embedded bolts, and the bearing of the riser on the grout/ concrete below the base plate. This is a complex system to analyze since each component is resisting a portion of each load. To conservatively simplify the analysis the loads will be analyzed as follows:

1. The vertical load (P_v) will be resisted by the base plate bearing on the concrete. This is conservative since the load would also be resisted by the bond between the concrete grout and the pipe.
2. The Horizontal (P_h) and the Torsional (P_t) loads will be resisted by the embedded bolts. This is conservative since the horizontal load would be resisted by the bearing of the pipe on the concrete and torsional load resisted by the bond between the pipe and the grout. There are 6 embedded bolts installed to account for the variation in the base plate hole size and the alignment of the embedded bolts only 3 bolts will be considered effective.
3. The Bending Moment (P_b) will be resisted by the bearing of the pipe below the base plated bearing on the concrete. For this analysis the pipe will pivot about the base plate applying a load to one side of the pipe. This is conservative since the moment will also be resisted by the base plate transferring a tension load to the embedded bolts.

Analysis

The analysis performed in calculation PP012-C-02, for this portion of risers F and G, was done with larger loads than required by this load case in this calculation. Therefore, the base plate, anchor bolts and the local stress on the concrete is acceptable by comparison to this analysis. The loads used in the previous calculation were 3000 lbs vertical, 500 lbs horizontal, and 400 ft-lb in torsion (Reference 9 pages 11 through 13).

NOZZLE E

Installation details for Nozzle E are not available. Therefore an alternate method for supporting the 1500 lb sampling load is required which will transfer the applied load to the ground. See page 13 for a sketch of the support.

Analysis

When evaluating the steel components of the 8-inch pipe risers only 12% of the allowable stress was used. Reference the results for nozzles A and B on page 9. Due to this low stress the steel components of the 6-inch nozzle E are acceptable by comparison and engineering judgement. The load transferred to the ground must be resisted by the soil bearing pressure. This transfer is made through threaded rods connected to the flange to an added base plate. See page 12 for the arrangement of the hanger. Note that the load transferred to the ground from the 100 lb horizontal load is not considered significant relative to the remaining bearing pressure margin available and therefore not included in the analysis.

CALCULATIONS AND SKETCHES SHEET

FLUOR DANIEL NORTHWEST

DEPARTMENT: Civil

ORIGINATED BY: *Don M. Stue*

DATE: 4-15-99

CONTRACT/TASK ORDER No.:
65100231-PP012CHECKED BY: *[Signature]*

DATE: 4/15/99

LOCATION: 200 West PFP

REVISED BY:

DATE:

SUBJECT: Evaluation of Nozzles A, B, E, F, and G on PFP Tank 241-Z-361 for the loading from the sampling

Evaluation of the rods:

There will be eight 3/4" threaded rods transferring the load to the base plate. The load in each rod will be:

$$L_r = P_v / n_r$$

$$L_r = 1500 / 8 = 188 \text{ lbs}$$

L_r = Load per rod

P_v = 1500 lbs

n_r = number of thread rods = 8

The load of 188 lbs transfer through the nuts to the rod is acceptable by engineering judgement.

Analysis of the rod for compression:

$$f_s = L_r / a_n$$

$$f_s = 188 / .302 = 623 \text{ psi}$$

f_s = actual stress

a_n = net area of the rod (ref 1)

The stress of 621 psi is acceptable by engineering judgement.

Evaluation of the bearing pressure on soil:

Allowable Bearing Pressure = 2000 psf

Bearing Pressure (BP) = $P_v / (\text{area of the plate} - \text{area of the pipe})$

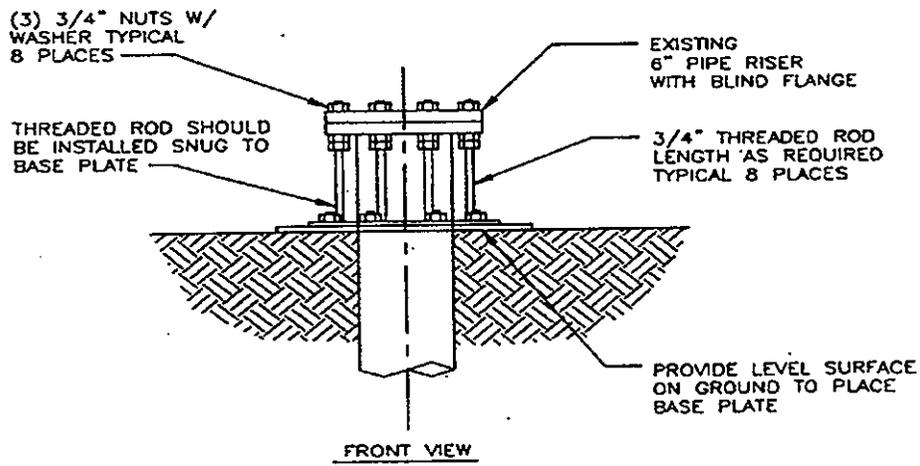
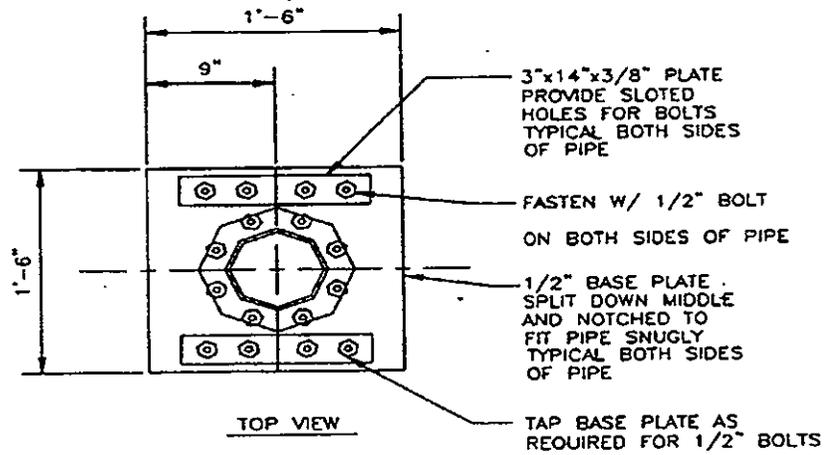
$$BP = 1500 / (18^2 - (3.14 * 6.625^2 / 4))$$

$$BP = 5.2 \text{ psi} = 746.0 \text{ psf} \leq 2000 \text{ psf} \therefore \text{ACCEPTABLE}$$

CALCULATIONS AND SKETCHES SHEET

FLUOR DANIEL NORTHWEST

DEPARTMENT: Civil	ORIGINATED BY: <i>David McShane</i>	DATE: 4-15-99
CONTRACT/TASK ORDER No.: 65100231-PP012	CHECKED BY: <i>Spulph</i>	DATE: 4/15/99
LOCATION: 200 West PFP	REVISED BY:	DATE:
SUBJECT: Evaluation of Nozzles A, B, E, F, and G on PFP Tank 241-Z-361 for the loading from the sampling		



NOZZLE E PROPOSED MODIFICATION

McShane, David S

ATTACHMENT A

From: Norman, Bradford F
Sent: Monday, April 12, 1999 9:51 AM
To: McShane, David S
Cc: Haq, Mian A; Hughes, Dennis P
Subject: Riser loads for remaining unanalyzed risers

Good morning,

This memo is to provide information for load analysis. This memo goes in hand with the sheet that was Dropped off on Dave's desk last Thursday. We would like to analyze the remaining 8" risers to accommodate the following loads: 1,500 pound vertical load, 250 pound lateral load and 100 pounds of torque. These numbers correspond to the red numbers added to the sheet dropped off in Dave's office. One note: Risers A & B will be trimmed to approximately 18 inches above grade (ECN is currently being written). Analyze risers for 42" present height, we will just be conservative with allowable loads on new heights. Also analyze the rest of risers for red marked loads on sheet.

Please provide calculations to verify these analyzed loads and a letter report to transmit your results. If there are any questions I can be reached at 376-7864. Again time is of importance, I would hope that the calculations could be signed off by Wednesday (Dave thought this was reasonable) and then the letter report shortly there after.

Brad Norman