This document was too large to scan as a single document. It has been divided into smaller sections.

Section 1 of 4

Document Information			
Document #	RPP-24544	Revision	1C
Title	DEMONSTRATION BULK VITRIFICATION SYS INDEPENDENT QUALIFIED REGISTERED PROFESSIONAL ENGINEER (IQRPE) & RCRA REVIEW PACKAGE		
Date	04/25/2006		
Originator	SHUFORD DH	ORG CO	CH2M
Recipient		Recipient Co.	
References			
Keywords			
Projects			
Other Information			

CH2M HILL ENGINEERING CHANGE NOTICE	1a. ECN 723118 R 4
Page 1 of 2 ☒ DM ☐ FM ☐ TM	1b. Proj. ECN - - R

2. Simple Modification	3. Design Inputs – For full ECNs, record information on the ECN-1 Form (not required for Simple Modifications)	4. Date
☒ Yes ☐ No		4/20/2006

5. Originator's Name, Organization, MSIN, & Phone No.	6. USQ Number	7. Related ECNs
M.W. Leonard, Closure Projects Engineering Support, S7-67	No. - - - R- ☒ N/A	ECN-723118, Revisions 0, 1, 2 & 3

8. Title	9. Bldg. / Facility No.	10. Equipment / Component ID	11. Approval Designator
Incorporate In-Container Vitrification (ICV) System Design Information	DBVS/241-G	N/A	ER

12. Engineering Documents/Drawings to be Changed (Incl. Sheet & Rev. Nos.)	13. Safety Designation	14. Expedited/Off-Shift ECN?
RPP-24544, Revision 1b	☐ SC ☐ SS ☐ GS ☒ N/A	☐ Yes ☒ No

15a. Work Package Number	15b. Modification Work Completed	15c. Restored to Original Status (TM)	16. Fabrication Support ECN?
N/A	N/A Responsible Engineer / Date	N/A Responsible Engineer / Date	☐ Yes ☒ No

17. Description of the Change (Use ECN Continuation pages as needed)

This ECN revises RPP-24544, Revision 1b, "Demonstration Bulk Vitrification System IQRPE/RCRA Design Review Package" to include the In-Container Vitrification System (ICV) information in Section 2.6.

Problem: The ICV System portion of the IQRPE/RCRA design package has been completed and requires release/configuration control.

Solution: Update RPP-24544 with RCRA design information on the ICV System so EPA and WDOE can review and approve.

Analysis: The original release and subsequent additions to RPP-24544 are listed below:
- RPP-24544, Revision 0, Released on EDT-821657 incorporated Section 2.1 Waste Receipt System
- RPP-24544, Revision 1, Released on ECN-723118, Revision 0, incorporated Section 2.3 Secondary Waste System
- RPP-24544, Revision 1a, Released on ECN-723118, Revision 1, incorporated Section 2.2 Waste Dryer System.
- RPP-24544, Revision 1b, Released on ECN-723118, Revision 3, incorporated Section 2.4, Dried Waste Handling System.

EPA and WDOE comments on released portions of the document were resolved and incorporated where available.

18. Justification of the Change (Use ECN Continuation pages as needed)

This update to RPP-24544 is to incorporate DBVS In-Container Vitrification System RCRA design information and was performed in accordance with the DBVS project schedule.

No USQ screening is necessary. This document is being transmitted to the Department of Energy, Office of River Protection. A Documented Safety Analysis (DSA) will be prepared for DBVS upon completion of final design. Design changes made after publication of the DSA will require a USQ screening.

19. ECN Category

☒ Direct Revision
☐ Supplemental
☐ Void/Cancel

ECN Type

☐ Supersedure
☐ Revision

20. Distribution

Name	MSIN	Name	MSIN
DH Shuford	S7-67	MJ Sutey	S7-70
FR Miera	H6-03	JE Van Beek	S7-67
TH May	S7-67	CA Rieck	S7-67
MW Leonard	S7-67	RR True	R3-26
SE Carlson	S7-67	RL Brown	S7-75
WE Bryan	S7-67	JC Hoffman	S7-67
MA Fish	S7-67 .	^CH2M EQRG	R1-14

Release Stamp

APR 25 2006
DATE:
STA: 15
HANFORD RELEASE
ID: 65

A-6003-563.1 (09/05)

CH2M HILL ENGINEERING CHANGE NOTICE

☒ DM ☐ FM ☐ TM

1a. ECN 723118 R5 4 MWL

1b. Proj. ECN - - R

21. Revisions Planned (Include a brief description of the contents of each revision)

ECN-723118, R5 is planned to incorporate the information for the Main Off-Gas Treatment System, Section 2.5 and be released as RPP-24544, Revision 1d.

Note: All revisions shall have the approvals of the affected organizations as identified in block 11 "Approval Designator," on page 1 of this ECN.

22. Commercial Grade Item Dedication Numbers (associated with this design change)

N/A

23. Engineering Data Transmittal Numbers (associated with this design change, e.g., new drawings, new documents)

N/A

24. Other Non Engineering (not in HDCS) documents that need to be modified due to this change

Type of Document	Document Number	Update Completed On	Responsible Engineer (print/sign and date)
Alarm Response Procedure			
Operations Procedure			
Maintenance Procedure			

Type of Document	Document Number	Type of Document	Document Number
N/A			

25. Field Change Notice(s) Used?

☐ Yes ☒ No

If Yes, Record Information on the ECN-2 Form, attach form(s), include a description of the interim resolution on ECN Page 1, block 17, and identify permanent changes.

NOTE: ECNs are required to record and approve all FCNs issued. If the FCNs have not changed the original design media then they are just incorporated into the design media via an ECN. If the FCN did change the original design media then the ECN will include the necessary engineering changes to the original design media.

26. Design Verification Required?

☐ Yes ☒ No

If Yes, as a minimum attach the one page checklist from TFC-ENG-DESIGN-P-17.

27. Approvals

Facility/Project Signatures		Date
Resp. Engineer	DH Shuford [signature]	20Apr2006
Resp. Manager	MJ Sutey [signature]	4/24/06
Quality Assurance		
IS&H Engineer		
NS&L Engineer		
Environ. Engineer	FR Miera [signature]	4/24/06
Engineering Checker	MW Leonard [signature]	4/20/06
Other	RL Brown (Rad Con) [signature]	4/24/06
Other	JE Van Beek (PM) [signature]	4/24/06
Other		
Other		
Other		
Other		
Other		
Other		

A/E Signatures		Date
Originator/Design Agent		
Professional Engineer		
Project Engineer		
Quality Assurance		
Safety		
Designer		
Environ. Engineer		
Other		
Other		

DEPARTMENT OF ENERGY / OFFICE OF RIVER PROTECTION

Signature or a Control Number that tracks the Approval Signature

ADDITIONAL SIGNATURES

RPP-24544, Rev. 1c

Demonstration Bulk Vitrification System IQRPE/RCRA Design Review Package

D.H. Shuford
CH2M HILL Hanford Group, Inc.
Richland, WA 99352
U.S. Department of Energy Contract DE-AC27-99RL14047

EDT/ECN: 723118, R4 UC:
Cost Center: Charge Code: 501907
B&R Code: Total Pages: ~~408~~ 337 4 v.f 4-25-06

Key Words: Design Review, Independent Qualified Registered Professional Engineer, Supplemental Treatment, Bulk Vitrification, IQRPE

Abstract: The Supplemental Treatment Test and Demonstration Project is a research, development and demonstration (RD&D) project with the goal of providing the suitability of Bulk Vitrification as an acceptable process for the treatment of tank farm Low Activity Waste. This document provides design information for the regulator's approval in accordance with the requirements of the RD&D permit issued for the project.

APR 25 2006
DATE:
STA: 15
HANFORD RELEASE
ID: 65

J. D. Aardal 4/25/06
Release Approval Date

Release Stamp

Approved For Public Release

A-6002-767 (03/01)

Tank Farm Contractor (TFC)
RECORD OF REVISION

(1) Document Number: RPP-24544

(2) Title
Demonstration Bulk Vitrification System IQRPE/RCRA Design Review Package

Change Control Record

(3) Revision	(4) Description of Change - Replace, Add, and Delete Pages	Authorized for Release	
		(5) Resp. Engr. (print/sign/date)	(6) Resp. Mgr. (print/sign/date)
0	Initial release	See EDT 821657	See EDT 821657
0A	Direct revision - see ECN 722947, R0	See ECN 722947, R0	See ECN 722947, R0
1	Direct revision - see ECN 723811, R0	see ECN 723811, R0	see ECN 723811, R0
1a	Direct revision - see ECN 723811, R1	See ECN 723811, R1	See ECN 723811, R1
1b	Direct revision - see ECN 723118, R3	See ECN 723118, R3	see ECN 723118, R3
1c RS	Direct revision - see ECN 723118, R4	D.H. Shuford 4/24/06 S.E. CARLSON FOR [signature]	M.J. Sutey [signature] 4/24/06

RPP-24544
Revision 1c

Demonstration Bulk Vitrification System IQRPE/ RCRA Design Review Package

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
Office of River Protection under Contract DE-AC27-99RL14047

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RPP-24544
Revision 1c

Demonstration Bulk Vitrification System IQRPE/ RCRA Design Review Package

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J. D. Aardal 4/25/2006
Release Approval Date

Executive Summary

EXECUTIVE SUMMARY

This document provides design information for the Demonstration Bulk Vitrification System In-Container Vitrification System as well as an overview of the system. This information is provided in accordance with the requirements of Permit No. WA 7890008967, "PERMIT FOR DANGEROUS AND OR MIXED WASTE RESEARCH, DEVELOPMENT, AND DEMONSTRATION."

Specific design information is provided in this report for the In-Container Vitrification System, with details for installation and the Demonstration Bulk Vitrification System site to follow in a separate installation package. Specific design information discussed in the report is presented in the following areas:

- System description,
- System location,
- Calculations,
- System sketches,
- Design codes and standards,
- Waste assessment,
- Controls,
- Secondary containment and leak detection,
- Corrosion assessment,
- Inspection schedule, and
- Installation assessment.

Where information regarding treatment, management, and disposal of the radioactive source, byproduct material and/or special nuclear components of mixed waste (as defined by the *Atomic Energy Act of 1954*, as amended) has been incorporated into this document, it is not incorporated for the purpose of regulating the radiation hazards of such components under the authority of Chapter 70.105 of the *Revised Code of Washington* and its implementing regulations but is provided for information purposes only.

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APPENDICES

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List of Terms

LIST OF TERMS

Editor's Note: The List of Terms and Trademarks include callouts from previous packages.

AMEC	AMEC Earth and Environmental, Inc.
ASME	American Society of Mechanical Engineers
AWTE	ancillary waste transfer enclosure
DBVS	Demonstration Bulk Vitrification System
DCRS	Dryer and Condensate Recovery System
Ecology	Washington State Department of Ecology
EPDM	ethylene propylene diene monomer
ETF	Effluent Treatment Facility
HEGA	high-efficiency gas adsorber
HEPA	high-efficiency particulate air
HIHTL	hose-in-hose transfer line
ICV™	In-Container Vitrification™
IDF	Integrated Disposal Facility
ILAW	immobilized low-activity waste
IQRPE	Independent Qualified Registered Professional Engineer
ISO	International Organization for Standardization
LAW	low-activity waste
MCS	Monitoring and Control System
OGTS	Main Off-Gas Treatment System
P&ID	piping and instrumentation diagram
PFD	process flow diagram
RD&D	Research, Development, and Demonstration
S-109 WRS	Single-shell Tank 241-S-109 Waste Retrieval System
SCR	selective catalytic reduction
SST	Single-shell Tank

TRADEMARKS

ANSYS	Registered trademark of Swanson Analysis Systems, Inc.
Carboline	Registered trademark of Carboline Company.
Crosby	Registered trademark of the Crosby Group, Inc.
GeoMelt	Registered trademark of the Geosafe Corporation.
ICV	Trademark of AMEC, Inc.
In-Container Vitrification	Trademark of AMEC, Inc.
Hilti	Registered trademark of Hilti Aktiengesellschaft.
Kaowool	Trademark of Thermal Ceramics.
Loctite	Registered trademark of Henkel Loctite.
MathCAD	Registered trademark of Mathsoft Engineering & Education, Inc.
National Electrical Code	Registered trademark of the National Fire Protection Association.
Overkote	Registered trademark of the Rust-Oleum Corporation.
RESCO	Registered trademark of RESCO Products, Inc.
Rust-Oleum	Registered trademark of the Rust-Oleum Corporation.
SolidWorks	Registered trademark of SolidWorks Corporation.
Thermaline	Registered trademark of Carboline Company.
Vibrocast	Registered trademark of RESCO Products, Inc.

2.6 ICV System

2.6 IN-CONTAINER VITRIFICATION SYSTEM

The ICV box is the container that will receive the dried waste mixture from the Waste Dryer System via the Dried Waste Handling System (see Section 2.4). After material transfer into the box, the dried waste mixture is vitrified (treated) in the ICV box. Gases produced during the vitrification process are vented to the OGTS (see Section 2.5).

On completion of the melt process and after a prescribed cooling period (time to be developed during testing with non-regulated material), shielding in the form of top-off soil is added to the ICV box. Sufficient top-off soil is added such that the interior of the box is at least 90 percent full and dose rates at the top of the box are as low as reasonably achievable. The top-off soil is delivered from the top-off soil impingement tanks located in the melt area enclosure and is metered into the box via the top-off soil feed chutes. Top-off soil is also added through the waste feed chutes using the Dried Waste Handling System (clean soil is passed through the waste dryer to the Dried Waste Handling System).

After addition of the top-off soil, the ICV box ports are sealed and the AWTE is disconnected from the ICV box; the filled box is transported from the melt area to the storage and sampling area to continue cooling. Once sufficiently cooled, the box is sampled in the sampling area and then moved to the temporary storage area in readiness for transportation to its permanent disposal location.

2.6.1 System Description

The ICV System is comprised of the ICV box and the air pallet caster system. The ICV box [*Resource Conservation and Recovery Act of 1976* container] is comprised of a reinforced steel container lined with insulating materials, which contains the waste in its initial dry form as well as its molten and final solid vitreous form. Further, the ICV box provides containment for the top-off fill material added to the box post-melt and includes box lid gaskets, waste and soil fill port seals, electrode seals, and a HEPA breather filter installed post melt.

The air pallet caster system is a portable frame levitated on an air film that engages the bottom of the ICV box to lift and move the ICV box to various locations within the DBVS site (e.g., from the box preparation area to the melt station, box cooling location, box sampling location, and storage locations [see Appendix C6, Drawing F-145579-00-D-0007]). The ICV box is supported by curbs at the processing stations and on the storage pad (see Drawings F-145579-00-B-0022 and 145579-00-B-0025 in Appendix C6)

Preparation and assembly of the ICV box for use is also covered in this section; however, dry waste feed and top-off control systems are discussed in the Dried Waste Handling System description (see Section 2.4).

2.6.1.1 In-Container Vitrification Box (Specification 145579-D-SP-023). The ICV box is based on a standard 50-yd^3 roll-off box with modifications and designed to be water tight; withstand the hydraulic and thermal loads of the molten glass and the weight of the total contents of insulation, sand, refractory, glass, and top-off materials. The ICV box is shown in Drawing F-145579-35-D-0004 in Appendix C6.

The ICV box, complete with lid and port caps, will be delivered to the site on a flatbed truck and offloaded into the ICV box preparation building. The sealing gaskets for the area between the lid and box will not be installed on the ICV box for shipment to prevent premature crushing of the gasket. See datasheet 145579-D-DS-050.1 for seal details (Appendix G6).

The ICV box lid is an integral lid and vent hood that is installed on the ICV box at assembly and remains on the box through processing and ultimately goes to the disposal site. It will be fastened to the top flange of the ICV box and is sealed to it with bolts, nuts, and a refractory gasket. The ambient air inlet penetration on the ICV box is connected to a HEPA filtered inlet stack via ducting that passes through the AWTE.

The ICV box HEPA breather filter is installed after top-off soil is introduced into the ICV box and just before the AWTE disconnect. The ICV box HEPA breather filter will function to avoid pressurization/de-pressurization during cooling and storage.

The ICV box lid will also have ports in wells for electrodes that will be hung in electrically insulating bushings that seal to the lid as well as to the electrodes (for electrode and accessories detail see Data Sheet 145579-D-DS-029.1 in Appendix G6). There will be five ports for material charge into the ICV box: three for top-off soil and two for waste feed. The material feed ports will be capped, which seal to the ICV box lid. After moving an empty box into the melt area, these caps will be removed to allow the material chutes to extend out of the box and into the AWTE to connect with the material feed chutes.

Caps will be placed onto the open ports and electrode wells for storage/burial once all the chutes and electrode extensions have been disconnected and are clear of the ports and wells.

2.6.1.2 In-Container Vitrification Box Assembly. Once the ICV box has been received at the box assembly building, the box lid is removed and the box insulation, sand, refractory panels (container liners), and starter path (including protective covering) are installed inside the ICV box. The box instrumentation, instrumentation wiring harness and electrodes are assembled in the ICV box, and the box lid is installed in the box assembly building before the assembled box is moved to the melt area using an air pallet. The foundation for this building is shown on Drawing H-14-106797 (see Appendix C6).

Insulation board is used in box assembly at both ends of the container to allow for some thermal expansion along the length of the box. The ICV box will be lined in order from the steel wall (or insulation at the ends) inward with:

1. Silica sand;
2. Insulation board (used only on box ends); and
3. Castable refractory panels.

The assembled ICV box and its contents are shown in Drawing F-145579-35-D-0004 in Appendix C6. The silica sand acts as a melt barrier for any glass leaks if the refractory fails and as a cushion for the refractory panels to allow for differential thermal movement between the lining and the metal box.

The refractory panels are the primary containment of the melt, but also prevent fume from escaping into the outer box area and provide shielding against the radioactive materials inside the box.

Activities currently identified to be performed prior to moving the assembled ICV box to the melt area include the following tests and inspections:

- Proper installation and sealing of refractory materials.
- Installed thermocouples are tested for continuity.
- Starter path material, including protective cover, has been properly installed with the electrodes into the box.
- A continuity test is performed to ensure contact between the electrodes and starter material.

2.6.1.3 ICV Box Transporter (Data Sheet 145579-D-DS-012.1). In-Container Vitrification boxes are moved around using air pallets. The air pallet uses a variety of "casters" to literally float heavy loads on a film of air. The air pallets use a similar technology to hovercrafts. By using the air pallets, the operator is able to precisely place and align the load in a limited workspace. The air pallet is designed to have a low profile to fit under the ICV box when mounted on curbs. Basic pneumatic components, such as air regulators and hoses, are used; therefore, the air pallets will operate in most environments. The air pallet is a self-contained unit complete with an on-board, diesel-driven compressor power unit supplying air for lift and drive/steerage system.

After leaving the box assembly building, the ICV boxes are moved to the melt area by air pallet.

2.6.1.4 Box Cooling, Sampling, and Storage Area. Once the filled ICV boxes are ready to leave the melt area, the boxes are moved by air pallet to the box cooling area. Once cooled, the box is moved to the sample station, if required, and then to the storage area. For general arrangement drawings of these areas, see Drawing 145579-00-D-0007 in Appendix C6. For foundation drawings and analysis, see Section 2.6.3. The boxes are core sampled in the sampling area (see Section 2.6.1.5) and then moved to the storage area for final cooling and to await removal from the DBVS site.

2.6.1.5 In-Container Vitrification Core Sampling. The ICV box has a sample port built into the ICV box sidewall (see Drawing F-145579-35-D-0004 in Appendix C6). Design details for the ICV box core sampling system and interface details are still in development. The core sampling design currently in development involves the use of a commercial drill rig to create and retrieve the core samples. Effluents generated as a result of the sampling operation will be properly characterized and managed.

2.6.2 System Location

The various components of the ICV System span from the south end of the DBVS site to the north end of the site. At the south end of the site, ICV boxes are received and assembled in the ICV container preparation and assembly enclosure. Once the ICV boxes have been properly prepared, the boxes are moved by air pallet to the melt area where the boxes receive dried waste, the waste is vitrified, and top-off soil added after processing. When vitrification is complete and the box is ready to be moved, the box is moved by air pallet to the box storage and sampling area.

2.6.3 Calculations

Calculations for the ICV System are described in the following paragraphs and provided in Appendix A6.

The melt area access routes for movement of the ICV boxes by air pallet will have concrete foundations. The melt area access slabs are identified as Foundations #16 and #17 on Drawing H-14-106792 (see Appendix C6). Analysis of the melt area access slabs is contained in Calculation 145579-C-CA-013 (see Appendix A6).

The box sampling and storage area will have a concrete foundation; this foundation is identified as Foundation #18 on Drawing H-14-106790 in Appendix C6. The building foundation detail is shown on Drawing H-14-106797, with the associated calculation being 145579-C-CA-014 (see Appendices C6 and A6, respectively). Analysis of the box sampling and storage area foundation is contained in Calculation 145579-C-CA-013. Analysis of the support curbs is contained in Calculation 145579-B-CA-004 (see Appendix A6).

Analyses of the ICV box weight and center of gravity have been performed in Calculations 145579-D-CA-010 and 145579-D-CA-028, respectively (see Appendix A6). The box structural analysis is provided in Calculation 145579-D-CA-011 (see Appendix A6). Heat transfer calculations to determine the temperature of the outer skin of the box walls and bottom (145579-D-CA-001) and lid (145579-D-CA-060) are provided in Appendix A6.

2.6.4 In-Container Vitrification System Drawings and Sketches

The ICV box is shown in the Bulk Vitrification ICV Container Data Sheet (F-145579-35-D-0004 in Appendix C6).

For a drawing of the melt area that shows the arrangement of the air pallets, ICV box, AWTE, material feed silos and chutes, and the melt area structure, see Drawings F-145579-00-D-0041 and -0051 in Appendix C6.

2.6.5 Design Codes and Standards

The design codes and standards that apply to the ICV System are identified in Table 2-11. Applicable and relevant portions of the design codes and standards are flowed down into the specifications, drawings, and calculations. See Section 3.0 for complete reference information.

Table 2-11. Design Codes and Standards for the In-Container Vitrification System. (2 sheets)

Design Code or Standard	Design Code or Standard
10 CFR 830	ASTM A 269
10 CFR 835	ASTM A 307
29 CFR 1910	ASTM A 312/A 312M
40 CFR 264	ASTM A 351/A 351M-03
ACI-318-02	ASTM A 354
ACI-330R	ASTM A 500
AGS-G001-1998	ASTM A 563a
AISC (Allowable Stress Design)	ASTM A 992
AISC-LRFD	ASTM B 187/B 187M-03
ANSI C63.16	ASTM F 436
ANSI/ISA-82.02.01	AWS D1.1/D1.1M
ANSI/ISA-82.02.02	AWS D1.6
ASCE-07	AWS QC-1
ASCE 7-98	HNF-2962
ASME B&PV Code Section IX	HNF-SD-GN-ER-501
	IEC 61000-4-2
ASME B16.5	IEEE Std 142
ASME B18.2.1	IEEE C2
ASME B30.20	IEEE C62.41.1
ASME B30.9	ISA-82.03
ASME B31.3	NFPA 70
ASME NQA-1	RPP-8530
ASME PCC-1	SAE J429

Table 2-11. Design Codes and Standards for the In-Container Vitrification System. (2 sheets)

Design Code or Standard	Design Code or Standard
ASME Y14.5M	TFC-ENG-STD-06
ASNT SNT-TC-1A	TFC-ESHQ-QC-C-03
ASTM A 36/A 36M	UBC 1997
ASTM A 105	UL 508A
ASTM A 108	UL 840
ASTM A 193/A 193M	WAC 173-303-630
ASTM A 194/A 194M	WAC 173-400

2.6.6 Waste Assessment

For all waste contacting equipment in the ICV System, the maximum estimated contact radiation dose is 10^4 Rad unless otherwise stated in the specifications (Appendix G6). Testing with both simulant and actual tank waste has been, and is being performed at the crucible, engineering, and full-scale. These tests have determine the compatibility of the selected ICV box components (e.g., refractory materials) with the waste in its various states – dried, molten, and solid glass – and the processing conditions present in the ICV. Future tests at full-scale will confirm selected ICV components. Properties of the dried waste were previously discussed in Section 2.4.6.

2.6.7 Controls

Controls for the process, pressure control, and an overview of the interlock philosophy for the ICV System are described in the following sections. Reference to specific instrumentation are provided to assist the reader; however, it should be noted that these "currently assigned identification numbers" may change as detailed fabrication information is received from the suppliers of equipment.

2.6.7.1 Process Control. Dried waste will be fed to the ICV boxes in batches. Approximately eight dryer batches are required to make one ICV box. This will result in a glass level that is approximately 14 in. below the top of the refractory. The glass level in each box will be monitored and controlled based on readings from the thermocouple tree 35-LE-106 (see Drawing F-145579-35-A-0100 in Appendix D6) installed in the ICV boxes. The ICV box temperature is monitored using thermocouples installed inside each ICV box. The ICV box will be maintained by the OGTS at a negative pressure with respect to atmospheric conditions as indicated by 35-PIT-118 (see Drawing 35-A-0100 in Appendix D6) during the melt and during dried waste or top-off soil feed.

Operational steps for the filling, processing, and addition of more dried waste are under development through testing with non-regulated material. Criteria such as when to add material, the rate at which to add material, and data feedback when material addition should be ceased are examples of parameters being identified. The currently identified operating scenario is discussed below.

The ICV box is moved into position beneath the AWTE. Once in position the ICV Box is hooked-up to the power supply, feed chutes, and the OGTS. This is followed by connecting the instrumentation wiring harness. Prior to dried waste addition, the connection of the ICV box at the melt station is checked for excessive leaks using a low flow condition at the ICV box air inlet (low flow condition is discussed further in Section 2.6.7.3).

Approximately two batches of dried waste are added to the box before starting the melt. After this is completed, the power supply to the ICV box is turned on and the melting of the soil/waste mixture starts from the bottom and progresses in an upward direction. No more feed is received from the dryer until the first batches have been melted. Control of the dried waste feed from the waste dryer to the ICV box was discussed in Section 2.4.7.1 (Dried Waste Handling System).

The melting process is initiated using the starter material at the bottom of the ICV container and the application of power through the electrodes. Power levels are increased gradually during start-up, with the joule-heating process requiring high voltage because of the resistance of the starter material. As material is heated and melts, the resistance decreases and high current (low voltage) is required to achieve the desired power level. Indication of the melt's progress is provided by the installed thermocouples, ratio of voltage to current (indication of resistance) and power level (determined by the product of voltage and current). Start-up will follow a power ramp-up schedule to a target nominal operating level. Both the start-up schedule and target nominal operating level are being determined through full-scale testing with nonregulated simulant material.

Once these initial batches are melted, sequential addition of approximately 6 batches of dried product then begins. Transfer of each batch of material from the dryer to the ICV box takes several hours. During the transfer time, the dryer rotation can be reduced at times to avoid excessive particle size reduction.

Once all of the required dryer loads have been placed in the ICV box, the melt is then allowed to continue to complete the vitrification process. In all, approximately 8 batches of dried waste product are melted. Upon completion of the last batch of dried waste processing, a small (approximately one-third of a normal batch) clean soil batch is added and melted on top of the last batch. After all batches of material have been processed top-off soil is added through the five chutes. Top-off soil added through the dried waste chutes is controlled by the Dried Waste Handling Equipment (control of material described in Section 2.4.7.1). Clean top-off soil is pneumatically conveyed to non-regulated soil impingement tanks, located above the melt area, prior to each melt. After the melt is complete and adequately cooled, top-off soil is gravity fed into the ICV box as controlled by the sequencing of Top-off Soil Rotary Valves (34-D85-050, 34-D85-051, and 34-D85-052 on Drawing F-145579-34-A-0101) and Top-off Soil Feed Chute Air Lock Assemblies (34-D88-035, 34-D88-036, and 34-D88-037 on Drawing F-145579-34-A-0101) located below the top-off soil impingement tanks. Specific use of the impingement tank weight indication in this operation will be developed as DBVS operational procedures are developed.

2.6.7.2 Pressure Control. Pressure is controlled through adjustment of the flow through the ICV lid (see 35-HV-114). Flow into of the ICV box is monitored by 35-FE-112A, -112B, and -112C. After processing is complete, the ICV box breather filter is installed just prior to movement to the cooling station. The ICV box HEPA breather filter will function to avoid pressurization/depressurization during cooling and storage.

2.6.7.3 System Interlock Philosophy. To mitigate the electrical hazard during normal operation of the facility, only one Kirk key will be available to either access the melt area enclosure or energize the ICV box electrodes.

Drawing F-145579-35-A-0100 (see Appendix D6) shows a number of interlock actions associated with low flow into the ICV box. Actions for the Safety Hardwired Interlock (I6) were discussed in Sections 2.4 and 2.5. Two of the actions for the Control System (safety related) Interlock (I7) were also discussed in Sections 2.4 and 2.5. The action specific for the ICV System is shown in Table 2-12. In the event of low inlet flow, the power to the electrodes will be discontinued to slow down the gas generation rate from the melting process.

Table 2-12. In-Container Vitrification System Interlock.

Condition	Interlock Code	Action
Low ICV Inlet Air Flow from Drawing F-145579-35-A-0100	I7 (control system)	Shuts down electrode power (35-JIC-110)

2.6.8 Containment

During processing, the ICV box is connected to the OGTS and maintained at a negative pressure relative to atmosphere and the AWTE. Gases generated, and any particulate suspended, during the process are directed to and treated by the OGTS. As described above, the ICV box [RCRA container] provides primary containment for the dried, molten and gaseous waste form. A spill or release of molten waste during the vitrification process is detected by thermocouples in the melt are, directly beneath the ICV box. Visual inspection of the ICV box is used in other locations to identify a spill or release of molten or dry waste, consistent with accessibility limitations.

2.6.9 Corrosion Assessment

The ICV box is fabricated from carbon steel. An independent corrosion expert has reviewed the specification and associated data sheet and indicated a concern for scaling of the carbon steel in air at the processing temperatures. Full-scale testing with non-regulated simulant material has been performed with a representative ICV box; no significant scaling of the ICV container was observed.

2.6.10 Inspection Schedule

Inspection of all ICV boxes will be performed by a supplier at the supplier's facility to ensure that the supplier complies with the design requirements. The inspection will include the following:

- Evaluation of welds to verify no cracking or lack of fusion;
- Confirmation that no punctures, scrapes of protective coatings, cracks, corrosion, or other structure damage are present;
- Performance of box tightness test to verify no leaks are present;

Inspections of ICV box assembly are performed as described in Section 2.6.1.2.

After waste has been processed in an ICV box, inspection of the ICV box(s) is performed in conjunction with another activity occurring in the DBVS container storage area, such as sampling or placement of an ICV box on the storage pad. Inspection of the ICV box at the ICV package preparation area is done to confirm the ICV box is ready for use.

2.6.11 Installation Assessment

The drawings and sketches referenced in Section 2.6.4 illustrate the projected completed assembly of the installed ICV System equipment on the DBVS site. Refinement of the drawings and development of installation details will be performed as detailed drawings and installation instructions from equipment suppliers are received. Standard industrial construction methods will be used to place modules or equipment on the DBVS site. Construction and interconnection of piping, instrumentation, electrical and control cable, and other components, will also be performed using standard industrial practices. Proper installation will be verified by a combination of pre-installation assessments, installation assessments, and post-installation tests. Installation assessments will consist of verifying proper installation of the ICV System during installation and will include an independent inspection by an IQRPE or a Qualified Independent Inspector.

Pre-installation assessments will verify the site is ready for installation of the equipment. The melt area structure foundation construction documents will be reviewed to verify proper installation and on-site inspection and testing will verify proper placement and installation of the anchor bolts. Likewise, the condition of the cast-in-place concrete installed per Section 03300 of the CH2M HILL (2004) will be verified in the ICV System areas where ICV boxes will be handled.

Walk-down crews will verify completeness of mechanical, electrical, and MCS installation in accordance with written procedures using as-built drawings. These crews will verify component labeling.

After assembly, the system will undergo instrumentation and equipment testing and integrated testing of the complete DBVS facility. The process feed chutes and process connections in the melt area will be leak tested in accordance with requirements stated in the installation instructions. Instrumentation and equipment tests will include remote actuation of valves and pumps. Integrated functional testing of the DBVS facility will be performed using noncontaminated, nonregulated test materials.

Upon completion of the installation assessments and tests, an inspection report documenting the results of the ICV System installation will be prepared by the IQRPE. The inspection results will be documented in the report and included in the Operating Record. This record will be accessible at the DBVS site and will contain:

1. An as-built site plan;
2. An as-built drawing set of the installed ICV System;
3. Inspection notes, photographs, and any other material used to document inspection activities;
4. Documentation of any defects discovered;
5. Documentation of tightness testing results;
6. A signed and dated statement certifying the corrosion protection system (if installed); and
7. A statement signed by the IQRPE certifying the proper installation of the ICV System.

3.0 References

3.0 REFERENCES

Editor's Note: The References include citations from previous packages.

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Appendix A6

APPENDIX A6

IN-CONTAINER VITRIFICATION SYSTEM

[a]Calculation 145579-C-CA-013 has been reviewed and approved by the IQRPE (see Design Assessment Report No. DR-004). Calculation not provided in this Design Review Package.

[b]Calculation 145579-C-CA-014 has been reviewed and approved by the Department of Ecology under a separate submittal. Calculation not provided in this Design Review Package.

145579-B-CA-004

amec

CALCULATION COVER SHEET

CALC. NO.: 145579-B-CA-004 REV: 3 DATE: 24 March 2006

CALC. TITLE: ICV™ Box Support Curbs Type 'C' and 'D' and 'E'

PROJECT NO.: 145579 PROJECT TITLE: Final DBVS Design

Design Verification Required: ☐ Yes ☐ No

Calculation Type: ☐ Scoping ☐ Preliminary ☒ Final

Superseded by Calculation No.: ____________ ☐ Voided

ORIGINAL AND REVISED CALCULATIONS/ANALYSIS APPROVAL

REV.	ORIGINATOR:	DATE:	CHECKED:	DATE:	APPROVED	DATE
0	Paul Meyer	08-Mar-05	Divana Whitley	08-Mar-05	Tony Heim	08-Mar-05
1	Paul Meyer	10-Mar-05	Divana Whitley	10-Mar-05	Tony Heim	10-Mar-05
2	Paul Meyer	04-Jun-05	Divana Whitley	04-Jun-05	Tony Heim	05-Jun-05
3	Paul Meyer	24-Mar-06	Divana Whitley	24 Mar 06	[signature]	24-Mar-06

AFFECTED DOCUMENTS

DOCUMENT NUMBER:	TITLE:	REV. NO.:	DISC. LEAD INITIALS
F-145579-00-B-0018	Bulk Vitrification Miscellaneous Steel Structures	1	PM
F-145579-00-B-0025	Bulk Vitrification Melt Area Steel Curbs	F	PM

RECORD OF REVISION

REV. NO.	REASON FOR REVISION:
0	Initial Issue
1	Revised after Internal review. No change to design or drawing.
2	Type "E" curbs added. Performance Category of ICV™ Box support curbs adjusted to match Design Authority ruling.
3	Revised in response to CH2M Review. Attachment 1 updated to latest revisions of curb drawings. Associated shield wall layout and foundation drawings added for reference. Attachment 2 replaced entirely. Numerous new load cases and conditions added. Attachment 3 updated with calculation from air pallet manufacturer showing travel speed. Attachment 6 added. Attachment 7 added. Attachment 8 added. Attachment 9 added.

amec

CALCULATION SHEET

CALC. NO.: 145579-B-CA-004 REV: 3 DATE: 24 March 2006

CALC. TITLE: ICV™ Box Support Curbs Type 'C' and 'D' and 'E'

PROJECT NO.: 145579 PROJECT TITLE: Final DBVS Design

ATTACHMENTS

DOCUMENT NUMBER/ID:	TITLE:	TOTAL PAGES
Attachment 1	ICV™ Box Support Curb Drawings and associated location and foundation drawings.	9
Attachment 2	Support Curbs Type 'C' and 'D' and 'E' detailed calculations	50
Attachment 3	Travel speed data from ICV™ Box Transporter Manufacturer – AeroGo	3
Attachment 4	E-mail containing Design Authority ruling on ICV™ Box Curbs Performance Category.	2
Attachment 5	Friction coefficient reference – from the AISC Manual of Steel Construction Load and Resistance Factor Design 3rd edition 2001	2
Attachment 6	ICV™ Box weight summary from Calculation 145579-D-CA-010 Box Weight Calculations Revision F.	1
Attachment 7	ICC-ES Legacy Report 5608 - Hilti HDA Metric self-undercutting concrete anchors, and Manufacturer's data	8
Attachment 8	Effect of Heat on Structural Steel and Box design temperature references from ASD Design Manual and ICV Box Structural Analysis (Calculation 145579-D-CA-011 Rev 1)	3
Attachment 9	Estimated displacement of ICV™ Box due to seismic event	14

ORIGINATOR:	DATE:	CHECKER:	DATE:
[signature]	MAR 24 2006	[signature]	March 24/06

CALCULATION SHEET

amec

CALC. NO.:	145579-B-CA-004	REV: 3	DATE: 24 March 2006
CALC. TITLE:	ICV™ Box Support Curbs Type 'C' and 'D' and 'E'		
PROJECT NO.:	145579	PROJECT TITLE:	Final DBVS Design

1 INTRODUCTION

1.1 Purpose

The purpose of this calculation is to verify the design of the ICV™ box support curbs type 'C' and 'D' and 'E' and their anchorage to the supporting concrete pads. Types C, D and E are fabricated from structural steel sections, while types A and B are precast concrete. The designs of support curbs types A and B are verified in a separate calculation 145579-C-CA-013.

1.2 Scope

The scope of this calculation includes determining the Natural Phenomenon Hazard (NPH) loads that the ICV™ box places on its supporting steel curbs. These loads are then applied to the curbs in combinations applicable to the service condition and location of the curbs. Verification is made that the curbs and their anchorages will be able to resist the forces resulting from these load combinations. An estimate is made of potential displacement of the ICV™ box due to seismic action.

2 BASIS

2.1 Design Inputs

The ICV™ box curb layouts are provided on drawing F-145579-00-B-0022. The details for the type C, D and E curbs are shown on drawings F-145579-00-B-0018 and 0025. These drawings are included in attachment 1.

Calculation 145579-D-CA-010 provides the box weight, and drawings of the ICV™ box itself. Critical pages from this calculation are provided in attachment 6. The calculation and included ICV™ box drawings are reference 4.

2.2 Criteria

From: TFC-ENG-STD-06 Rev B-1, October 27, 2003.

The ICV™ box is Performance Category PC-2 when in the Melt Area and is Performance Category PC-0 elsewhere. This was provided by the Design Authority in an e-mail, a copy of which is included as attachment 4. While in the Melt Area, the box rests on type E curbs. Type E curbs are checked against applicable site NPHs at a PC-2 Level. Temperature and impact effects are considered.

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CALCULATION SHEET

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CALC. NO.:	145579-B-CA-004	REV: 3	DATE: 24 March 2006
CALC. TITLE:	ICV™ Box Support Curbs Type 'C' and 'D' and 'E'		
PROJECT NO.:	145579	PROJECT TITLE:	Final DBVS Design

Type C curbs support the box in the southwest corner of ICV™ Box Storage Area. Type C curbs are checked against gravity, live and wind loads at a PC-1 level.

Type D curbs support the box while it is being prepared in the ICV™ Box Assembly Building. Type D curbs are checked against gravity and live loads at a PC-1 level. Conservatively, the Type D curbs are checked against gravity load from a full box.

Design Loads:

Dead Load: This includes the self-weight of the curbs and attached stiffeners and plates. The case of "dead load only" is clearly trivial as it represents a steel curb sitting unloaded on the flat concrete surface. For the purposes of load combinations in the UBC, the box full or empty weight will be included as a "dead" load in combination with wind and seismic loads as appropriate. This is consistent with the requirement in UBC section 1634.1.3 for seismic loads.

Live Load: As the box is movable, it is considered a "live" load on the curbs. Box empty and full weights are calculated in a separate document 145579-D-CA-010. Copies of key pages are included in attachment 6.

The calculated weight when in the Melt station is 209,302 pounds. The calculated weight when grouted and placed on the storage pad is 217,582 pounds.

The weight of the empty box, without glass, top-off soil or grout is 105,401 pounds. This is the condition of the box when it leaves the ICV™ Box Assembly Building.

When considering gravity and seismic loads, a heavier box is more critical, whereas when considering wind loads, a lighter box is critical. To provide an additional margin of safety, the following box weight values will be used for the "full" and "empty" cases:

Full: 240,000 lb. full ICV™ Box including all components and the grout allowance.
Empty: 100,000 lb. empty ICV™ Box, ready to receive soil and waste.

Impact Load: Considered live loads in ASCE 7, impact loads on the ICV™ box support curbs do not occur in combination with other loads. The worst-case impact loading on the curbs consists of a fully-loaded ICV™ box transporter hitting an empty curb. The case where a fully loaded box resting on a curb is hit by an empty transporter is not considered, as the mass of the unloaded transporter is much less than that of the loaded transporter, and therefore the impact force will be substantially less. The design impact force is 4,000 pounds, based on the tractive effort of the transporter drive, as well as calculations of the kinetic energy of a loaded box transporter versus a design passenger vehicle collision load.

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CALCULATION SHEET

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Wind Load: 3-second gust 85 mph, Importance factor 1.00, Exposure Category "C" Wind load only applies to the type "C" curbs as the other two curb types are located within enclosures and not subject to wind.

Snow Load and Volcanic Ashfall: The ground snow load on the Hanford site is 15 psf. The ashfall load on the Hanford site is 3 psf for PC-1 SSCs and 5 psf for PC-2 SSCs. Curbs type D and E, are located under roofs and the box is not subject to snow or ashfall. Type C Curbs are located outdoors, so snow and ash loads are possible. The combined snow and ash load is ~20 psf, or approximately 4000 pounds over the top surface of the box. This is significantly less than the 22,400 pound "margin of safety" allowed for in the box "full" live load. For the purposes of this calculation, the snow and ash load is considered to be included as an allowance within the total box "full" live load. This is conservative.

Seismic Load: The Hanford site is in UBC Seismic Zone 2B. While in the Melt Area on type E curbs, the ICV™ Box is Performance Category PC-2 and the supporting structure must resist seismic loads. The importance factor "I" is listed as 1.25 in the UBC for "Essential Facilities". However, in TFC-ENG-STD-06, references are made suggesting the use of a 1.5 factor for all PC-2 systems and components; therefore we have used 1.5 for "I." This is a conservative change, resulting in a higher design seismic load and therefore a greater degree of safety in the design. Seismic loads do not apply to the box on Type C curbs while in the storage area or on type D curbs while inside the ICV™ Box Assembly Building. See attachment 4.

Flood Load: The DBVS site is at elevation 663 feet and is not in any of the flood areas identified in HNF-SD-GN-ER-501 *Natural Phenomena Hazards, Hanford Site, Washington*. Flood loads may safely be ignored.

Groundwater Pressure Load: The DBVS site is at nominal elevation 663 feet. The Geotechnical report notes that groundwater levels are approximately 300 feet below the ground surface. Groundwater pressure may safely be ignored.

Thermal Load: To accommodate thermal expansion long-slotted bolt holes have been used for all anchors in all three curb types, except 6 anchors near the centre in each curb. The non-slotted holes provide shear resistance against north-south forces. All holes can resist tensile forces and east-west shear forces. The long-slotted holes permit unconstrained thermal expansion or contraction as demonstrated in the attached calculation, and therefore no thermal stresses occur. A calculation determining the maximum allowable temperature changes is made based on the size of the slotted holes.

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Additional Thermal Effect: As requested by CH2M in a review of the previous revision of this calculation, consideration is given to the effect of elevated temperature on the type E curbs when subjected to gravity loading. The requested design check is for one curb to be subjected to gravity loading at a temperature of 1058 degrees Fahrenheit. This is the same temperature used to verify the structural design of the ICV™ box itself in Reference 8. A portion of Reference 8, together with a page from the AISC ASD Design manual indicating the reduced yield strength of structural steel at elevated temperature is included in attachment 8. The check in the attached detailed calculation is made at the same elevated temperature under combined gravity and seismic loading, which is conservative. This check does not negate the requirement that the concrete foundation be maintained at a temperature no greater than 212 degrees Fahrenheit.

Lightning: The entire DBVS site will have a grounding grid installed. Pigtails are provided from the grounding grid through foundations for attachment to the supported equipment. No plans are in place at this time to ground the curbs. Lightning protection of the ICV™ box is not within the scope of this calculation.

2.3 Assumptions

1. Mechanical or other means will be used to limit the temperature of the concrete surface below and adjacent to the curbs to no more than 212 degrees Fahrenheit. As demonstrated in the attached calculations, the long slotted holes in the base of the curbs can accommodate an increase in temperature to beyond 500 degrees Fahrenheit at the bottom of the curbs, and will therefore not limit expansion of the curbs, preventing any significant thermal stresses.

2. The maximum travel speed of a loaded ICV™ box transporter will be 40 feet per minute. This is the value provided by AeroGo for their proposed design, as included in attachment 3. If the actual speed of the loaded ICV™ box transporter is significantly higher, then this calculation must be revised.

3. The ICV™ box will not be placed on the type "C" curbs until it has been prepared in the ICV™ box assembly building and includes all components of the full box except glass, top-off soil and grout. The empty metal box without lid, electrodes, refractory, etc., will not be stored on these curbs. This allows for a reasonable minimum weight of the box to be established for wind design. In typical operation the box will be filled with glass and top-off soil prior to being placed on the type C curbs, so this assumption is conservative.

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PROJECT NO.:	145579	PROJECT TITLE:	Final DBVS Design		

3 REFERENCES

1. *Uniform Building Code*, 1997. International Conference of Building Officials, Whittier, California, USA.

2. *ACI Manual of Concrete Practice*, 1997. American Concrete Institute, Farmington Hills, Michigan, USA.

3. ASCE 7-02 *Minimum Design Loads for Buildings and Other Structures*, 2002. American Society of Civil Engineers, Reston, Virginia.

4. Calculation 145579-D-CA-010 Rev F, October 20, 2005. *ICV™ Box Weight Calculations*. Includes drawings of the ICV™ box as attachment 11.

5. TFC-ENG-STD-06 Rev B-1, *Design Loads for Tank Farm Facilities*, Issued October 22, 2003 by CH2M Hill Hanford Group Inc. Hanford, Washington.

6. HNF-SD-GN-ER-501 Rev 1B, *Natural Phenomena Hazards, Hanford Site, Washington*. As revised by ECN 672877, May 15, 2002. Numatec Hanford Company, Richland, Washington.

7. DOE-STD-1020-2002 *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities* Jan 2002. DOE, Washington, D.C.

8. Calculation 145579-D-CA-011 Rev 1, January 24, 2006. *ICV™ Box Structural Analysis*.

9. Report of Geotechnical Engineering Services, Bulk Vitrification Process Partial DBVS Richland Washington. April 2004. AMEC E&E Inc., Portland, OR.

10. *AISC Manual of Steel Construction – Load & Resistance Factor Design, 3rd Edition* 2003, 2nd Printing, American Institute of Steel Construction Chicago, IL.

11. *AISC Manual of Steel Construction – Allowable Stress Design, 9th Edition*, 1989, 3rd Printing, American Institute of Steel Construction Chicago, IL.

12. Calculation 145579-C-CA-013 Rev 3, March 24, 2006. *ICV™ Box Storage Slab and Access Slabs (foundations #16, 17, 18)*

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4 METHODS

Forces on the curbs and anchors, due to dead load, live load, seismic and wind loads have been calculated using the Uniform Building Code (UBC) and ASCE-7.

Dead loads of the curbs are calculated based on the total length of the steel members from which they are fabricated plus the weight of stiffeners present. The dead load of the curbs themselves are left out of load combinations as the curbs are directly and uniformly supported on the concrete foundations. No stresses in the curbs are caused by the self-weight of the curbs in this condition. Under lateral loading, the dead load of the curbs has a slight beneficial effect in resisting overturning. It is conservative to ignore this slight beneficial effect. The total weight of the curbs is less than 2% of the weight of a fully loaded box, and any slight decrease in calculated lateral seismic load caused by ignoring the curbs weight is more than offset by the use of the conservative 240,000 pound design load in the Melt Area; an increase of 15% as discussed below.

The weight of the ICV™ box on the curbs is a "live" load as defined in the UBC, (it can either be "on" the curbs or "off" the curbs) but is considered as a "dead" load for the purposes of calculating seismic loads and the ability of the curbs to resist wind loads. In the absence of the ICV™ box, the curbs are not loaded by gravity, and the wind and seismic loads are clearly insignificant compared to the loads with the box present. It is clear by inspection that the critical loading conditions for the ICV™ box Support curbs occur when the ICV™ box is on the curbs.

The weight of the full box is conservatively shown as 240,000 pounds when placed on the curbs. The weight of the box when empty is conservatively shown as 100,000 pounds.

For the Type C curbs, the full box weight represents an increase of 10% (22,418 pounds) over the calculated value of 217,582 pounds from reference 4. As noted in the Design Loads section, the approximate design value of snow and ash load on the box when outdoors would be 4,000 pounds. Snow and ash loads are assumed to be included in the 22,418 pound "safety margin" and are not calculated separately. This is conservative.

For Type C curbs the empty box weight is used when calculating the ability of the curbs to resist wind loads, which is conservative. In normal operations, the box will weight in excess of 200,000 pounds when it is placed on the type C curbs.

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However, to be conservative, it is assumed that the "worst case" scenario involves a box that has been fully prepared in the ICV™ Box Assembly Building being stored on curbs in the ICV™ Box Storage Area, where the box would be exposed to the design wind loads. As such, an empty box weight of 100,000 pound is used for checking the anchorage of the type C curbs. This is 5% (5,401 pounds) less than the calculated value of 105,400 pounds from reference 4 and is conservative.

For Type D curbs, the assumed weight of the full box represents an increase of 128% (134,599 pounds) over the calculated value of 105,401 pounds from reference 4. Type D curbs are indoors and are subject to gravity loads due to the box weight and impact loads only, so the use of the substantially higher box weight is conservative.

For Type E curbs the assumed weight of the full box represents an increase of 15% over the calculated value of 209,302 pounds from reference 4. Type E curbs are located in the Melt Area and are not subject to wind loads due to the presence of the shield walls. The type E curbs are subject to gravity, seismic and impact loads. In all cases, these loads are highest for a fully loaded box.

Seismic loads are calculated based on the box being completely full, which is conservative for the case where a box is only partly filled.

In normal operation, the type D and E curbs might only be subjected to impact from a transporter carrying an empty box (the box is empty when it is brought to the Melt Area from the ICV™ Box Assembly Building) but a conservative design check is made for the 4000 pound force of impact from a transporter carrying a full box for all three types of curbs.

The friction coefficient between the ICV™ box and the steel curbs is taken as 0.33. This is taken from reference 10 and is included as attachment 5. The lowest value of 0.33 is conservatively used in these calculations. For the purpose of deriving lateral forces on the top of the curbs, it is determined that 100% of the seismic or wind force is transmitted from the box to the curbs without slippage. The seismic load per UBC 97 is calculated to be 0.252 times the weight of the box. Conservatively placing a 0.9 factor on Dead load gives an effective friction coefficient of 0.3, which is still greater than 0.252, and therefore the full seismic load will be transferred to the curbs.

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Vertical forces on the curbs due to dead and live loads are derived using the methods of UBC-97. Lateral loads due to wind are calculated using the methods of ASCE 7. Lateral loads due to earthquake are calculated using the methods of UBC-97. Additional vertical forces on the curbs are created due to the overturning effect of the loads on the ICV™ box acting at a height well above the underside of the curbs. These secondary vertical forces are added or subtracted from the gravity forces so as to create the most significant effect on the curbs.

Vertical forces on the curbs are presumed to act at a distance of 3/16 inch off-centre from the vertical axis of the curbs, creating an additional overturning moment. The value of 3/16 inch is based on the specified installation tolerances for the curbs. This additional moment is combined with the overturning moment due to lateral loads so as to give the greatest effect on the curbs.

Curbs strengths are analyzed using AISC Allowable Stress Design (ASD) methods. AISC ASD methods are adapted slightly to account for the unique configuration of the rolled steel W-section curbs resting on the concrete foundations. Resistance to vertical and lateral loads is analyzed for the stiffened beam web sections. Member strengths are conservatively based on elastic (rather than plastic) analyses and section moduli.

Since the concrete foundations that will support the curbs have already been cast-in-place, the curbs will be field secured to the existing foundations using drill-in undercut-type anchors. Curbs will have fixed anchorage near their centres, with slotted holes provided towards the north and south ends of the curbs, allowing for unrestricted thermal expansion and contraction.

In attachment 9, a supplementary calculation is made that combines vertical and horizontal seismic forces to estimate potential box displacement due to a seismic event. This calculation follows the methods shown in Hanford Engineering Development Laboratory (HEDL) DTRF No A-3886, S.F. Wagener. 1980; which is provide along with the calculation. The seismic ZPA values at the tank farms for horizontal (H=0.215 g) and vertical (V= 0.157 g) response were provided by CH2M Hill, and copy of the confirming e-mail is provided with the calculation. Using the given values of H, V and a friction coefficient of μ=0.33, it was determined that the box does not move. A further calculation was made in which the given values of H and V were increased by 50%. As seen below, this resulted in some theoretical movement of the box.

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5 RESULTS AND CONCLUSIONS

Type C curbs are loaded by gravity, impact and wind. The maximum stress in the curbs occurs under combined wind and gravity loading and is 9.1% of allowable. There is no uplift load on the anchors due to wind loading. The maximum tensile load on the anchors securing the type C curbs occurs under impact load and is 40% of allowable. The maximum shear load on the anchors securing the type C curbs occurs under impact loading and is 15% of allowable.

Type D curbs are loaded by gravity and impact. The maximum stress in the curbs occurs under gravity loading and is 5.1% of allowable. The maximum tensile load on the anchors securing the type D curbs occurs under impact loading and is 36% of allowable. The maximum shear load on the anchors securing the type D curbs occurs under impact loading and is 15% of allowable.

Type E curbs are loaded by gravity, seismic and impact. The maximum stress in the curbs occurs under combined seismic and gravity loading and is 6.1% of allowable. A check of the stress on the type E curbs at elevated temperature combined with seismic and gravity loads shows that the curbs are stressed to 11.1% of allowable. The maximum tensile load on the anchors securing the type E curbs occurs under combined seismic and gravity loading and is 13.1% of allowable. The maximum shear load on the anchors securing the type E curbs occurs during a seismic event assuming no friction between the curbs and the concrete foundation and is 63% of allowable. Deflection of the top of the curbs is maximum during a seismic event and is $3x10^{-4}$ inches, or effectively zero.

Slotted holes in the base of the curbs allow for unrestrained expansion or contraction from below the site design ambient temperature (-25 degrees F) to the maximum design temperature of the ICV™ box base (+1058 degrees F)

As shown in attachment 9, the estimated sliding displacement of the ICV™ box due to a site Design Basis Earthquake is zero using unfactored seismic loads. Using an importance factor of 1.5 on both the lateral and vertical component of the seismic forces results in an estimated total box displacement of 0.02 inches.

All values noted above are acceptable. The curbs have been added to the PDMS (3-D) computer model of the project. Curb and foundation drawings are attached.

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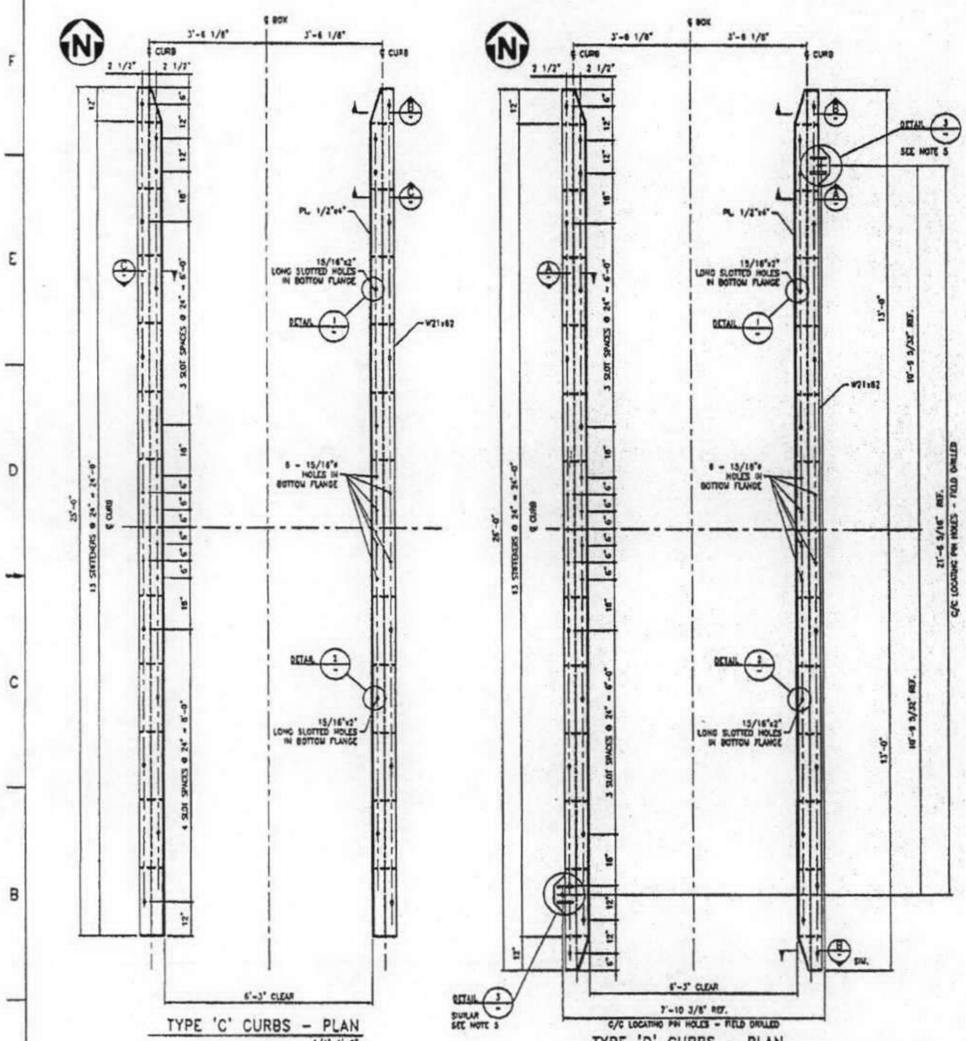
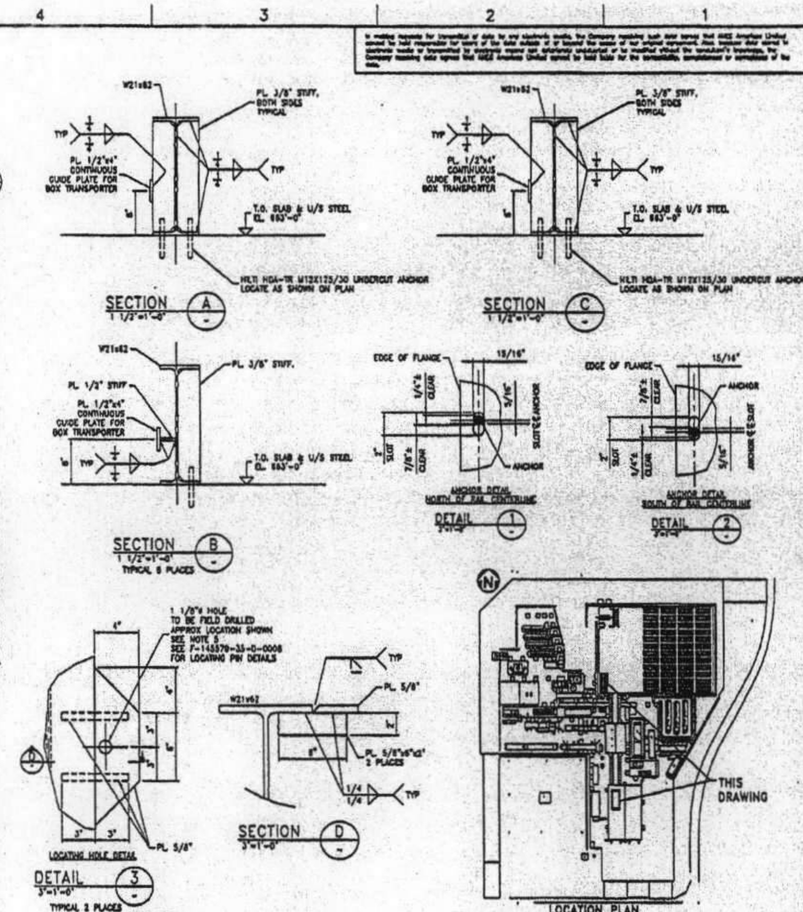
145579-B-CA-004

Attachment 1

ICV™ Box Support Curb Drawings and Associated Location and Foundation Drawings





NOTES:

1. ALL CONSTRUCTION SHALL CONFORM TO CONSTRUCTION SPECIFICATION 145579-0-SP-001.

2. FOR GENERAL NOTES & STRUCTURAL STEEL DETAILS SEE DRAWINGS F-145579-00-B-0001 TO 0004.

3. CURBS SHALL HAVE MAX. CAMBER AND SWEEP OF 3/16". INSTALL CONVEX SIDE UP. MAINTAIN 6'-3" CLEARANCE BETWEEN CURBS AT ALL LOCATIONS. TOLERANCE ±3/16".

4. FOR SUPPORTING DESIGN CALCULATIONS SEE 145579-B-CA-004.

5. FIELD DRILL 1-1/8" DIAMETER HOLES AS SHOWN. THESE HOLES ASSIST IN ACCURATE PLACEMENT OF THE ICV BOX. HOLES TO BE LOCATED AND DRILLED BY OTHERS USING A SAMPLE ICV BOX AS A TEMPLATE DURING COMMISSIONING PHASE.

6. ALL DRILL-IN ANCHORS SHALL BE INSTALLED IN CONFORMANCE WITH THE REQUIREMENTS FOR SPECIAL INSPECTION AS LISTED IN CHAPTER 17 OF THE UNIFORM BUILDING CODE AND ICBO REPORT ER-5608. AT SLOTTED HOLES, NUTS SECURING CURB SHALL BE SNUG-TIGHT ONLY.

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145579-FINAL DBVS DESIGN

U.S. DEPARTMENT OF ENERGY

Office of River Protection

BULK VITRIFICATION MISCELLANEOUS STEEL STRUCTURES

Attachment: I

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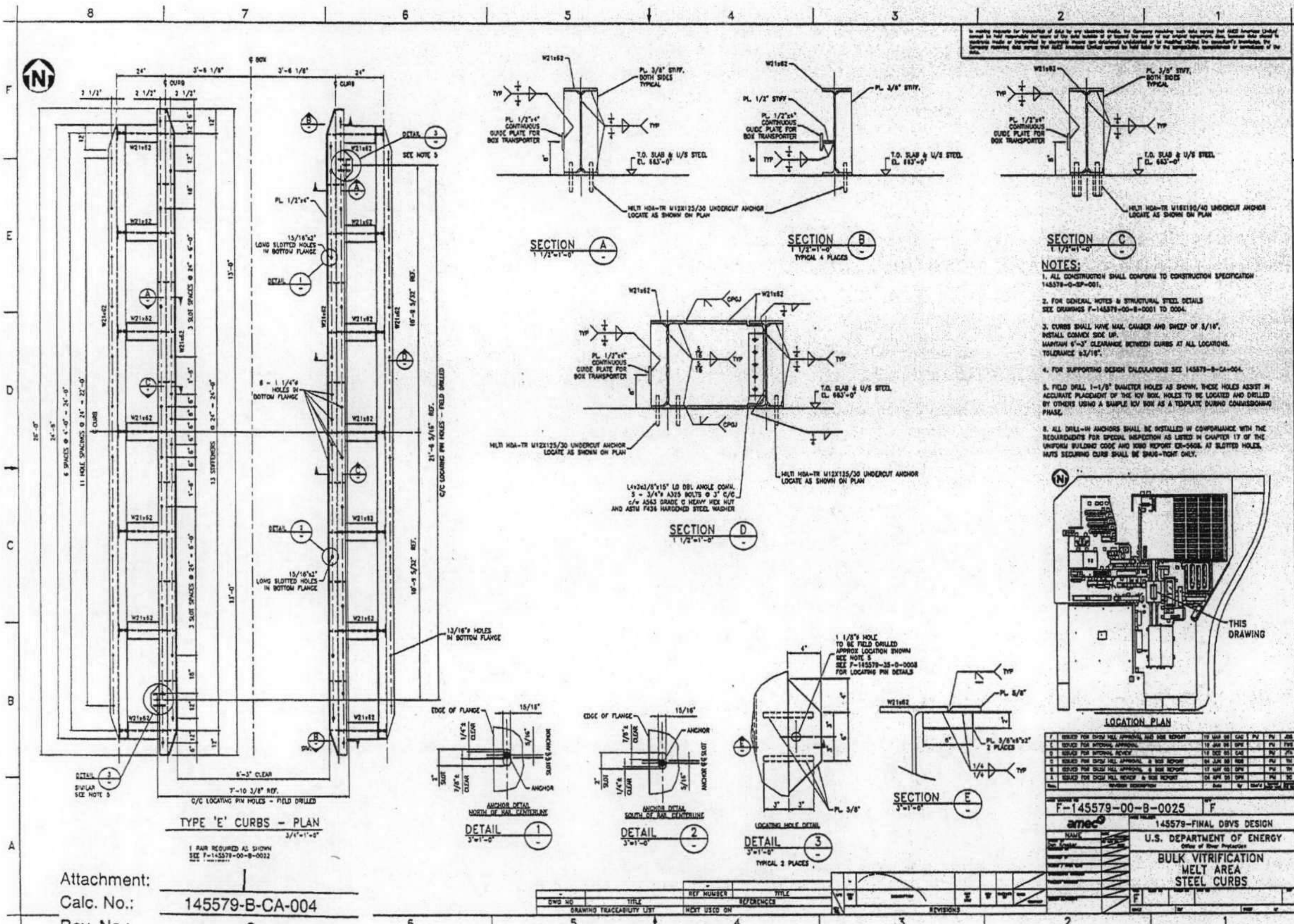
Sheet 1 of 9



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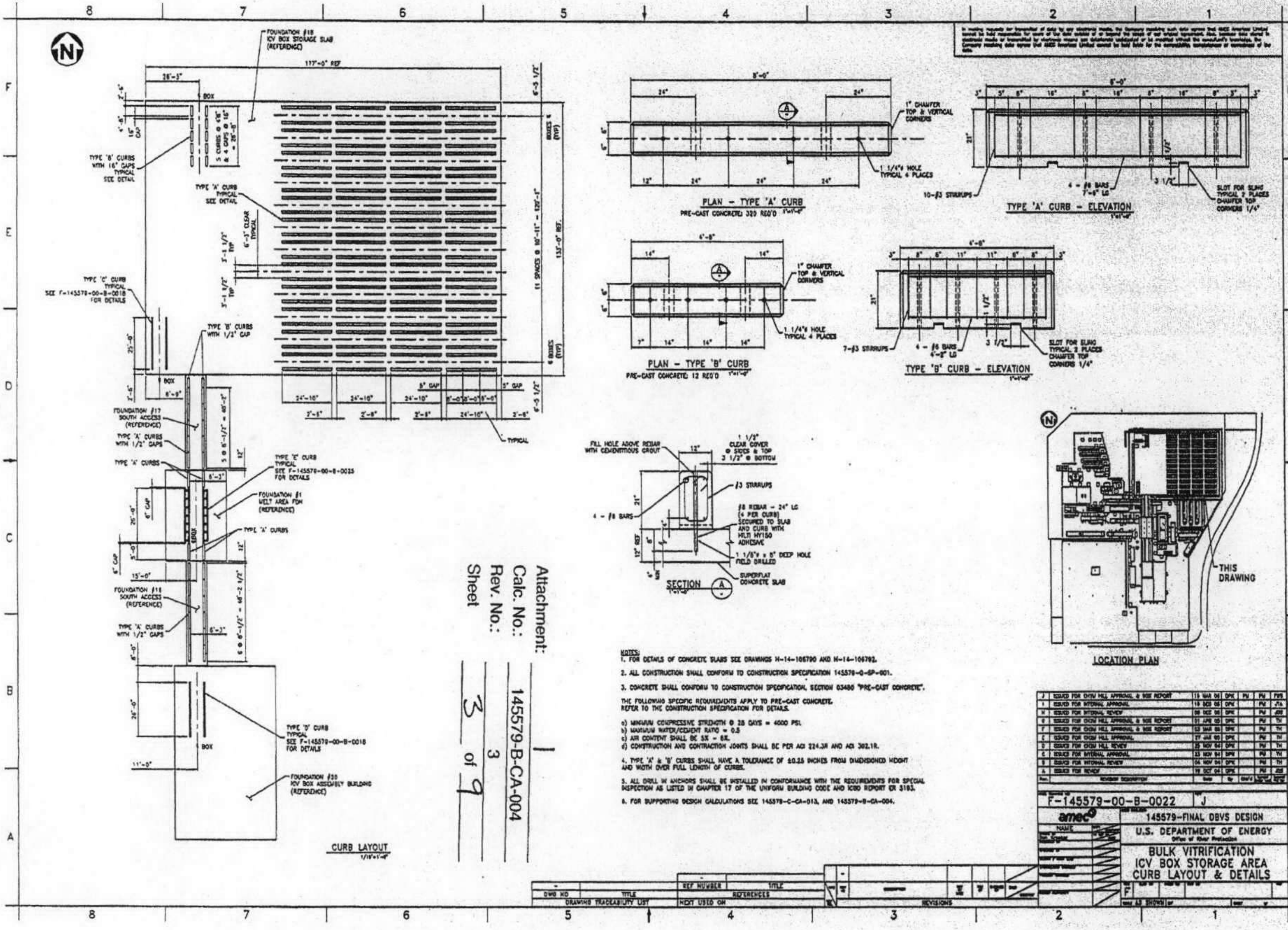

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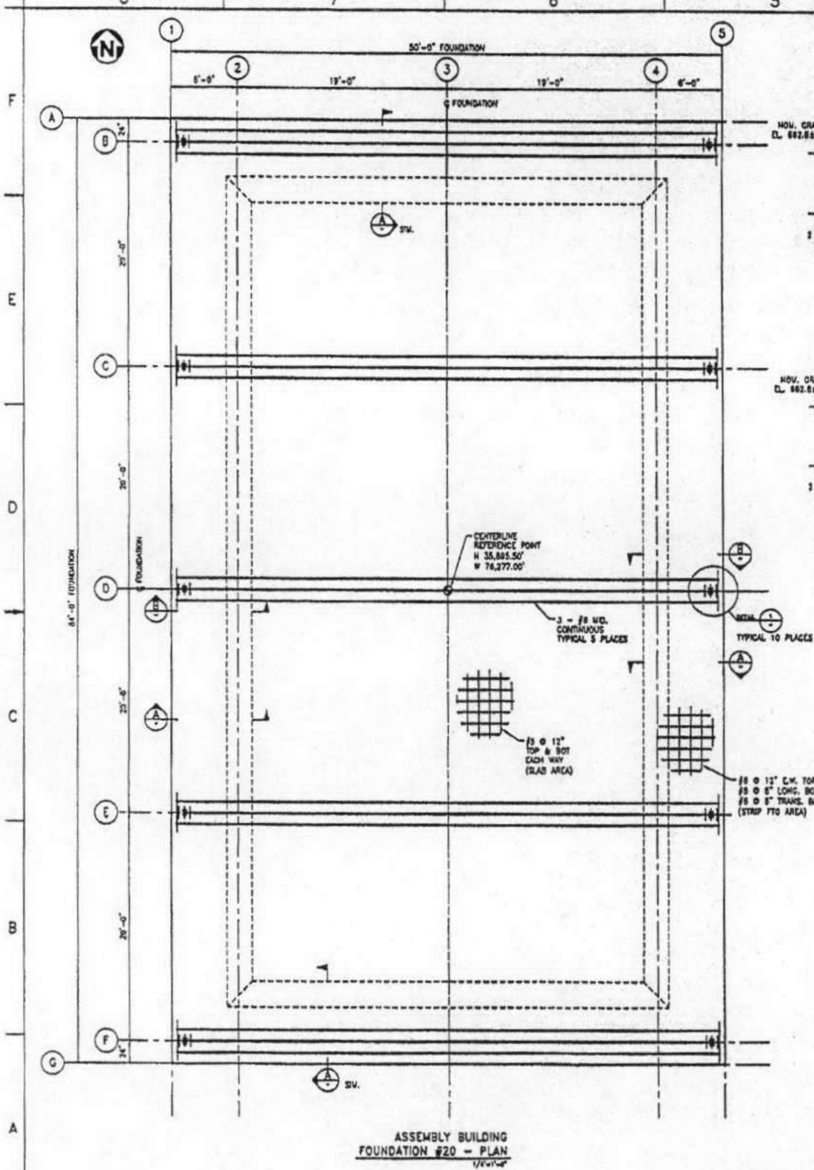

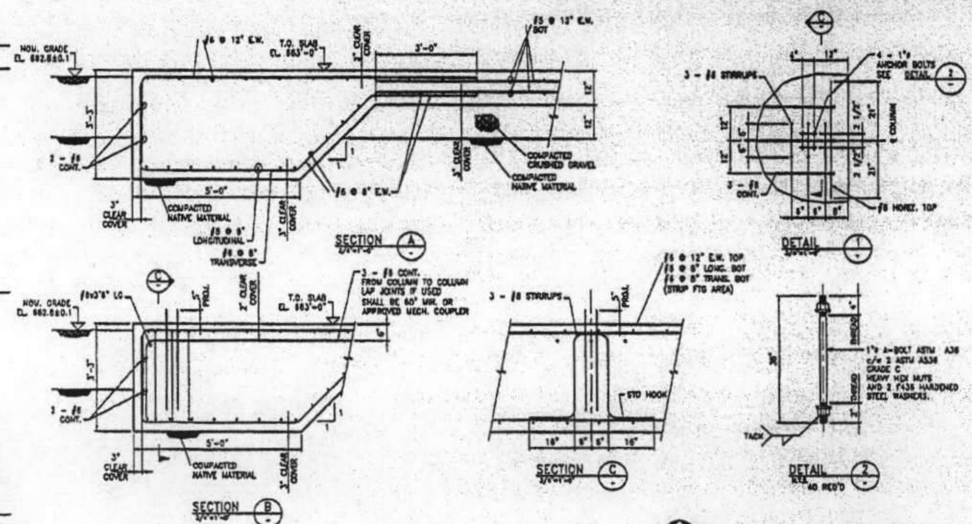

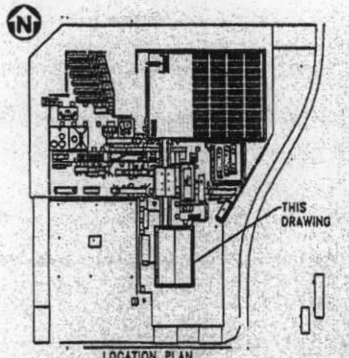

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NOTES:

FOR GENERAL NOTES AND FOUNDATION LOCATIONS REFER TO DRAWING H-14-106789 "BULK VITRIFICATION - CIVIL SITE IMPROVEMENTS"

FOR DESIGN CRITERIA & MATERIAL SPECIFICATIONS SEE CONSTRUCTION SPECIFICATION 145579-Q-SF-002.

1. PRE-ENG METAL BUILDING RIGID FRAMES SHALL USE ANCHOR BOLT PATTERN SHOWN AND SHALL HAVE "PINNED" BASES.

2. MAXIMUM DESIGN LOADS AT RIGID FRAME BASES (UNFACTORED) FROM CALCULATION 145579-C-CA-014.

VERTICAL	(DOWN)	= 114000LB
	(UP)	= 17500LB
HORIZONTAL	(E/W)	= 19000LB
	(N/S)	= 15000LB

3. ENDWALL AND DOOR FRAMING WILL BE SECURED TO FOUNDATION USING DRILLED AND GROUTED ANCHORS. DESIGN AND SUPPLY BY PRE-ENGINEERED METAL BUILDING VENDOR.

4. CONCRETE SHALL CONFORM TO CONSTRUCTION SPECIFICATION SECTION 3300 "CAST-IN-PLACE CONCRETE".

THE FOLLOWING SPECIFIC REQUIREMENTS APPLY TO CAST-IN-PLACE CONCRETE. REFER TO THE CONSTRUCTION SPECIFICATION FOR DETAILS.

a) MINIMUM COMPRESSIVE STRENGTH @ 28 DAYS = 4000 PSI.
b) MAXIMUM WATER/CEMENT RATIO = 0.5
c) AIR CONTENT SHALL BE 3% - 8%.
d) CONSTRUCTION AND CONTRACTION JOINTS SHALL BE PER ACI 224.3R AND ACI 302.1R.

5. COMPACTED CRUSHED GRAVEL AND COMPACTION OF NATIVE MATERIAL SHALL CONFORM TO CONSTRUCTION SPECIFICATION SECTION 02220.

Rev.	Revision Description	Date	By			
0	ISSUED FOR CONSTRUCTION	01 APR 05	DPW		PW	TW
D	ISSUED FOR CH2M HILL APPROVAL	27 JAN 05	DPW		PW	TW
C	ISSUED FOR CH2M HILL REVIEW	7 DEC 04	DPW		PW	TW
B	ISSUED FOR INTERNAL APPROVAL	29 NOV 04	DPW		PW	TW
A	ISSUED FOR INTERNAL REVIEW	19 NOV 04	DPW		PW	TW

H-14-106797 0

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145579-FINAL DBVS DESIGN

U.S. DEPARTMENT OF ENERGY

BULK VITRIFICATION
ICV BOX ASSEMBLY BUILDING
FDN - PLAN & DETAILS

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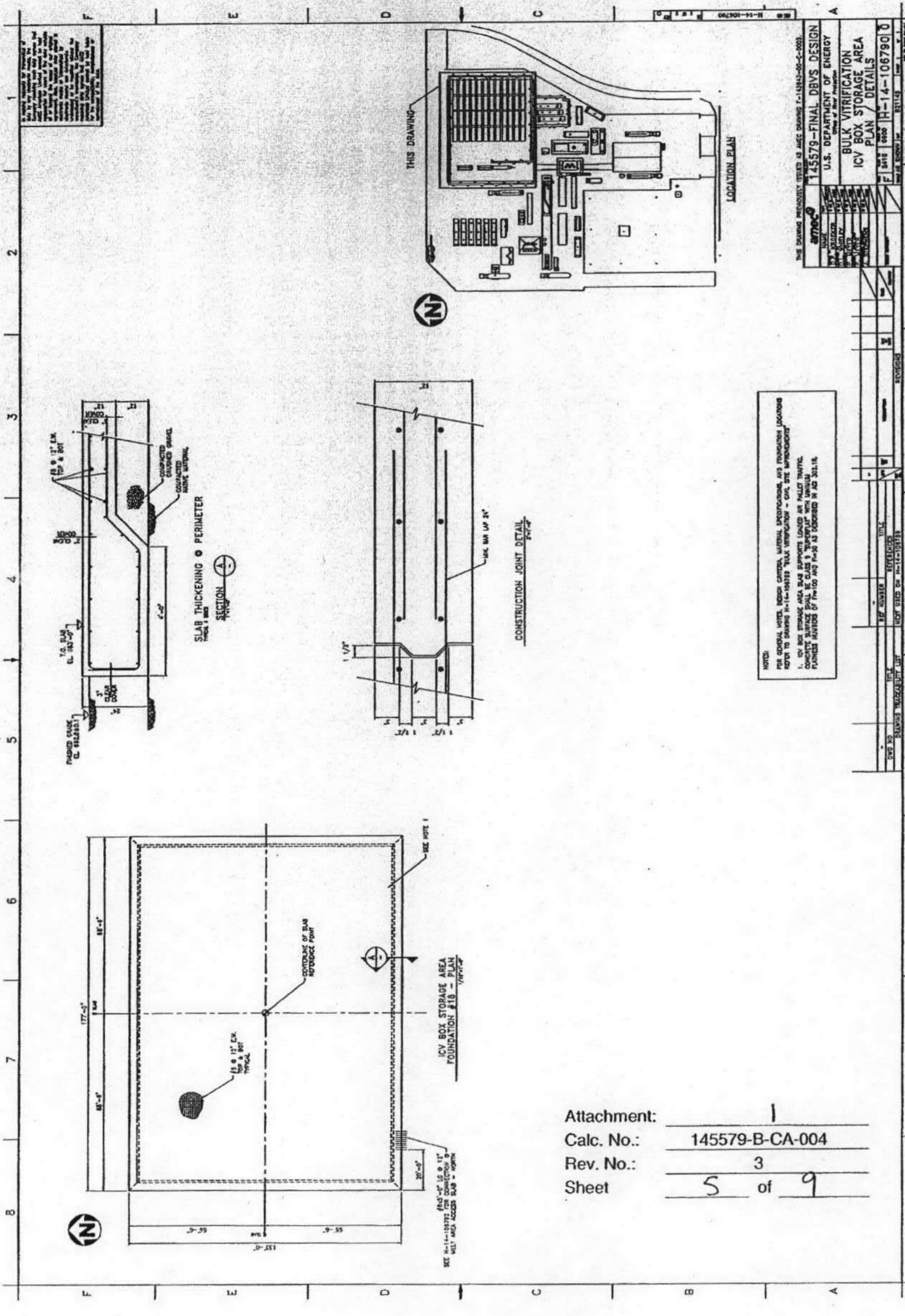
AS NOTED



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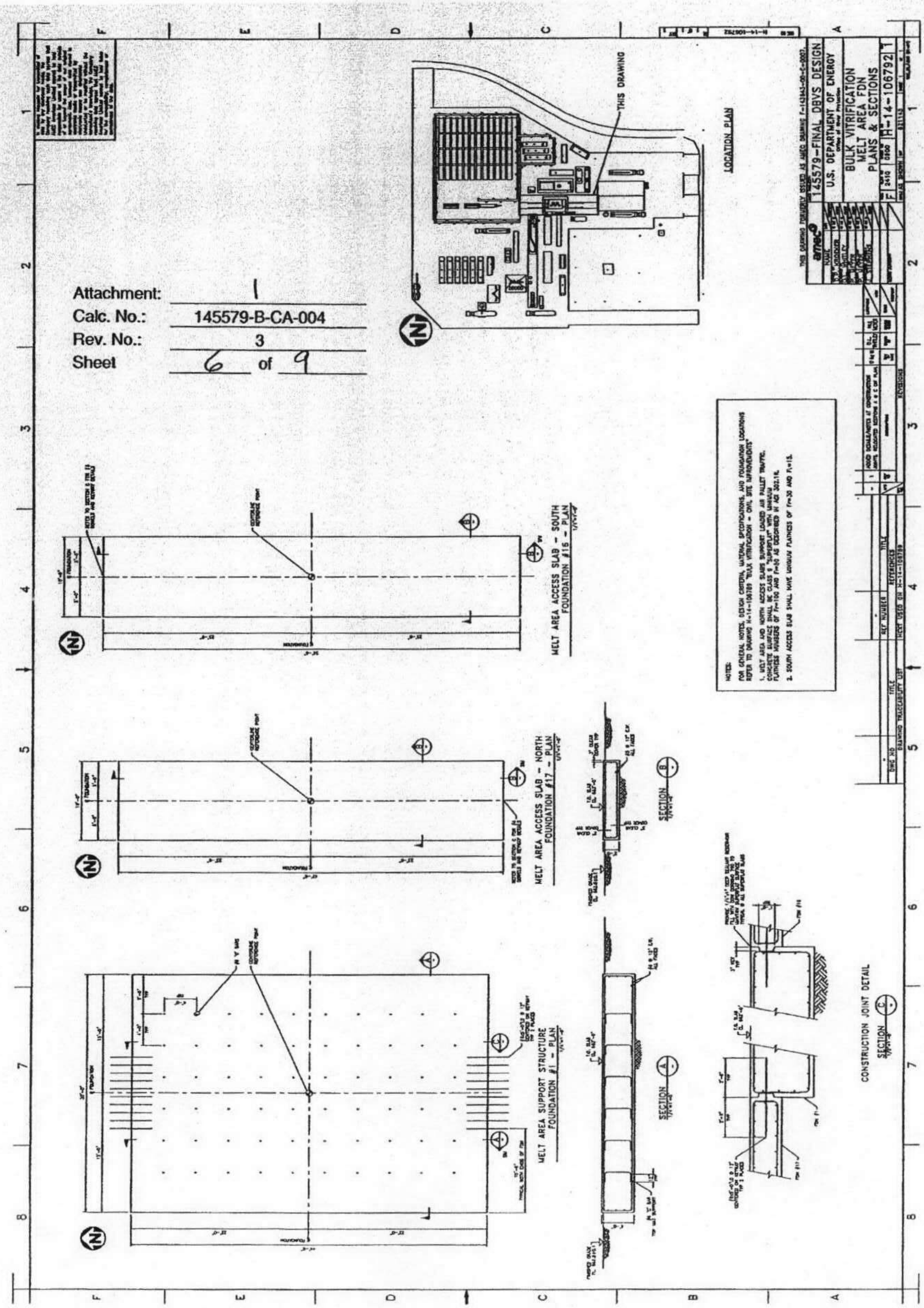

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CH2M HILL ENGINEERING CHANGE NOTICE CONTINUATION SHEET	1a. ECN 722340 R 0
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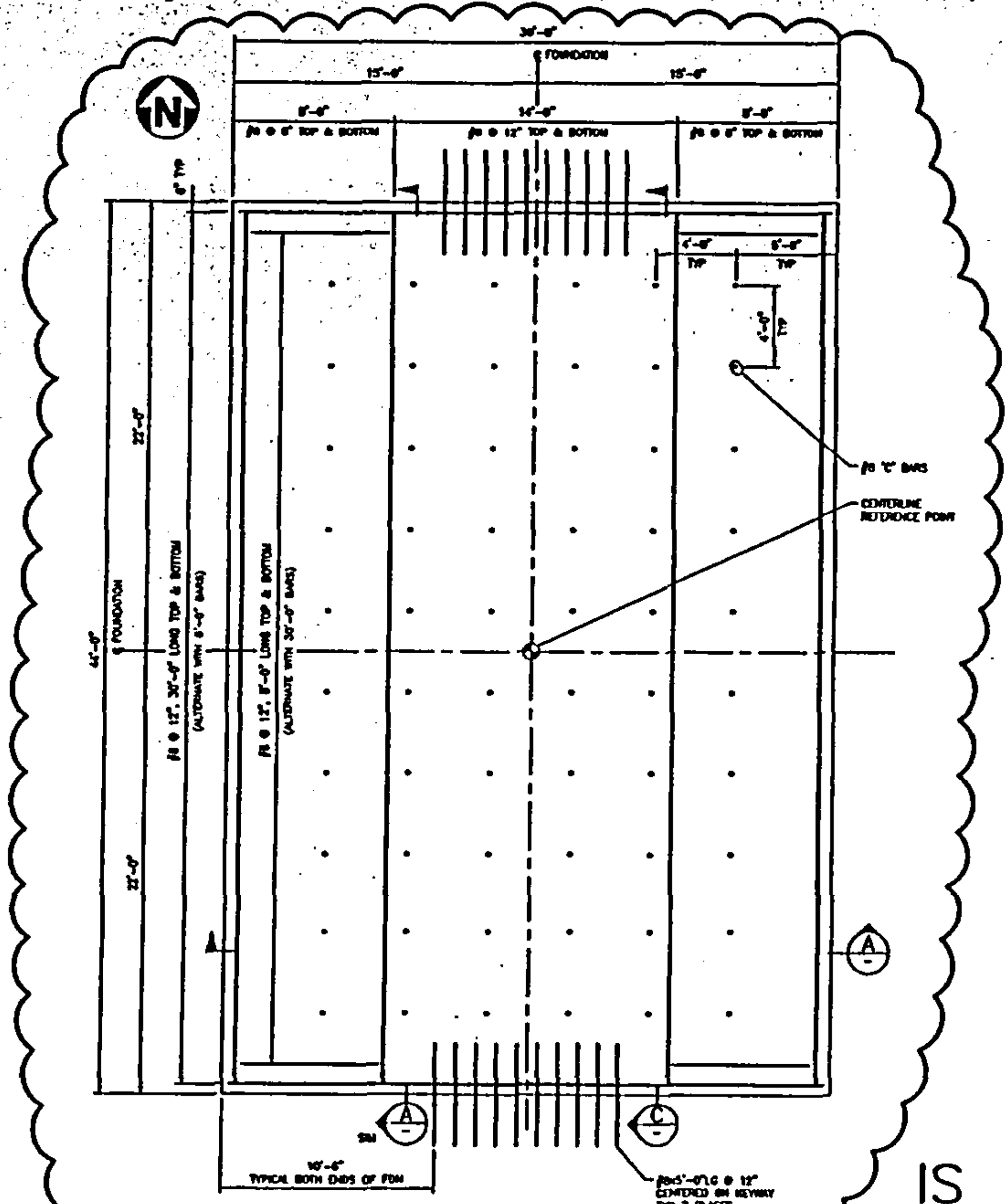
Document/Drawing No. H-14-106792 Sheet 1 Revision 1



MELT AREA SUPPORT STRUCTURE
FOUNDATION #1 – PLAN
1/4"=1'-0"

IS

REVISE TO ADD REBAR INFORMATION AS SNOWN

Attachment: 1
Calc. No.: 145579-B-CA-004
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Sheet 7 of 9

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		DATE 01-06-05		
		DRAWING NO H-14-106792	SH 1	REV 1

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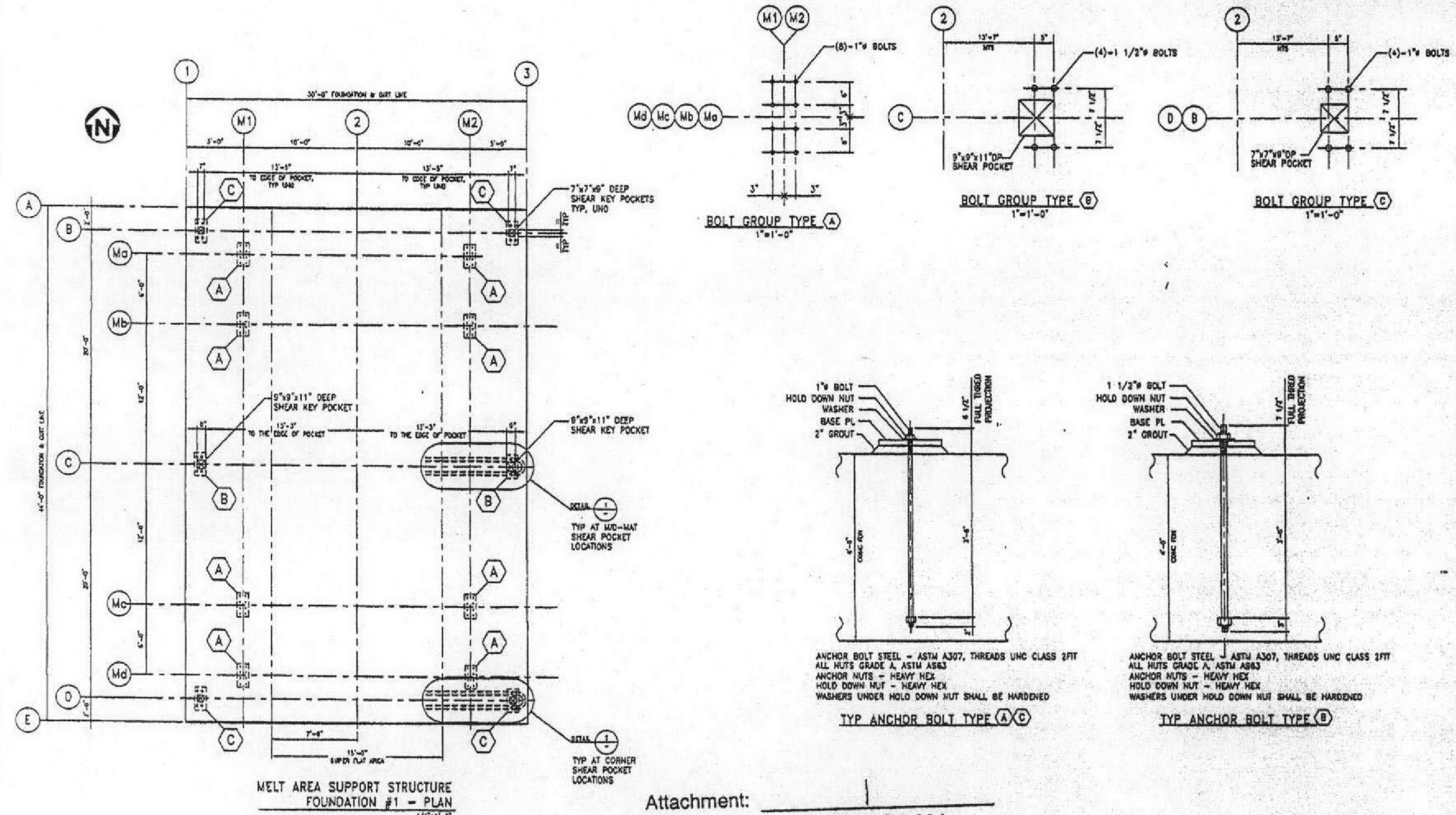
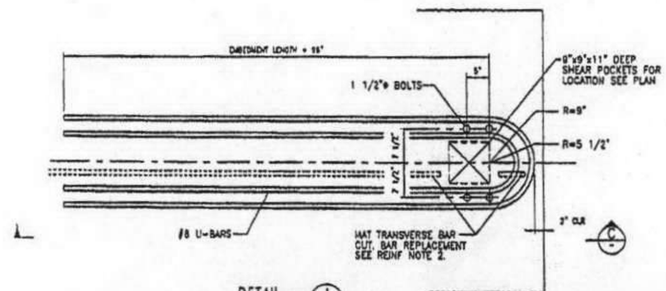


Attachment: 1
Calc. No.: 145579-B-CA-004
Rev. No.: 3
Sheet 8 of 9

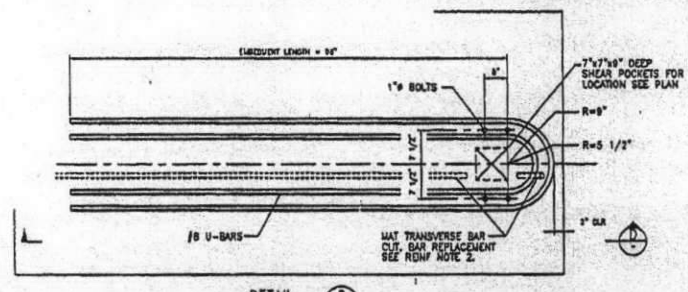
ENGINEERING CHANGE NOTICE CONTINUATION SHEET	PAGE 5 OF 6	ECN 722567 R0
		DATE 01-06-05

DRAWING NO	SH	REV
H-14-106792	1	1

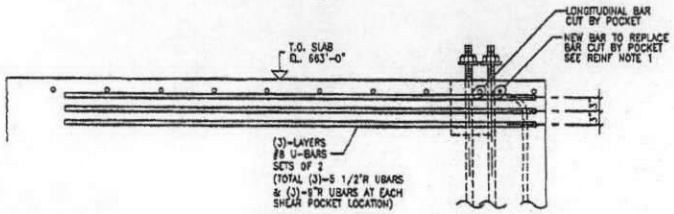
"ADD"



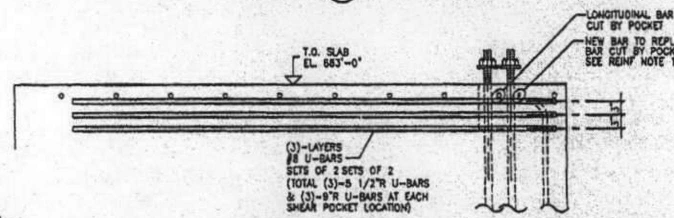
DETAIL 1
1"=1'-0"



DETAIL 2
1"=1'-0"



SECTION C SEE NOTE BELOW
1"=1'-0"

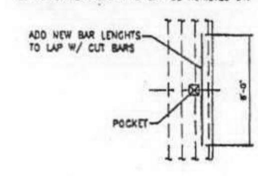


SECTION D SEE NOTE BELOW
1"=1'-0"

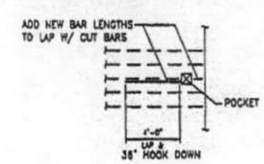
NOTE:
SECTIONS 'C' & 'D' ARE DRAWN AS IF LONGITUDINAL BARS ARE NEAREST TO TOP SURFACE OF CONCRETE. U-BARS ARE LOCATED ACCORDINGLY.
IF TRANSVERSE BARS ARE NEAREST THE TOP SURFACE, U-BARS MUST BE MOVED UP ACCORDINGLY. i.e. TRANSVERSE U-BARS LAY IN SAME PLANE AS TRANSVERSE MAT BARS

GENERAL REINF NOTES

1. LONGITUDINAL REBAR FOR FOOTING WHICH INTERFERES WITH THE LOCATION OF THE SHEAR KEY POCKET OR ANCHOR BOLTS SHALL BE MOVED TO CLEAR, WHILE MAINTAINING THE SAME EFFECTIVE AREA OF THE LONGITUDINAL STEEL. THIS CAN BE ACHIEVED BY:



2. TRANSVERSE REBAR FOR FOOTING WHICH INTERFERES WITH THE LOCATION OF THE SHEAR KEY POCKET OR ANCHOR BOLTS SHALL BE MOVED SIDEWAYS TO CLEAR OR CUT TO CLEAR AND NEW BARS ADDED TO THE SIDE AND LAP LENGTH TO EXISTING:



Attachment: 1
Calc. No.: 145579-B-CA-004
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Sheet 9 of 9

145579-B-CA-004

Attachment 2

ICV™ Box Support Curbs Type 'C' and 'D' and 'E' Detailed Calculations

DESIGN MEMORANDUM

Client: GeoMelt | Sheet 1 of 50
Project: Final Design | Date: 2006 Mar 22
Data For: Steel Curbs Check C,D,E | Work Order: 149774
Prepared By: PMeyer | Checked By: DWhitley | File No: 145579-B-CA-004 REV 3.

Note: This form must be used for project calculations and original filed in project files

ATTACHMENT 2

CURBS C, D, E - FABRICATED FROM ASTM A992 STEEL BEAMS ($F_y = 50$ ksi) AND ASTM A36 ($F_y = 36$ ksi) PLATE, ON EXISTING CONCRETE FOUNDATIONS.

1) DETERMINE NPH LOADS ON CURBS.

2) COMBINE LOADS PER UBC-97 AS LOADS CAN APPLY TO EACH TYPE OF CURB. DERIVE FORCES ON ANCHORS.

3) DETERMINE PROPERTIES OF CURBS (GEOMETRIC) AND DERIVE LOAD RESISTANCES (ALLOWABLE STRESSES) AS WELL AS ANCHORAGE CAPACITIES

4) COMPARE LOADS EFFECTS TO ALLOWABLE. VERIFY ALL EFFECTS ARE LESS THAN ALLOWABLE.

NOTE TO CALCULATIONS: NUMBERS HAVE BEEN ROUNDED TO AVOID "FALSE PRECISION" THAT CAN ARISE WHEN WORKING WITH INPUT DATA WITH SMALL NUMBERS OF SIGNIFICANT DIGITS. IN GENERAL, RESULTS WILL NOT HAVE MORE SIGNIFICANT DIGITS THAN INPUTS. ROUNDING IS DONE IN THE DIRECTION OF A MORE CONSERVATIVE RESULT, RATHER THAN THE "NEAREST" METHOD.

DESIGN MEMORANDUM

amec

Client: GEO MEET — Sheet 2 of 50
Project: FINAL DBVS DESIGN — Date: 2006. MAR 22
Data For: STEEL CURBS CHECK CDE — Work Order: 149774
Prepared By: P. Nyjitr — Checked By: D. Whitley — File No: 145579-B-CA-004 REV3

Note: This form must be used for project calculations and original filed in project files

ATTACHMENT 2

DEAD LOAD

DEAD LOAD IS CURBS SELF-WEIGHT

W_{DC} = SELF WEIGHT CURB TYPE 'C'

W_{DD} = SELF WEIGHT CURB TYPE "D"

W_{DE} = SELF WEIGHT CURB TYPE E

$W_{DC} \approx W_{DD}$ (only ≈ 12" DIFFERENCE)

W_{DC} ⇒ 25 ft of W21X62 BEAM
PLUS 13 PAIRS STIFFENERS PLUS GUIDE RAIL

STIFFENERS: $20" \times \frac{3}{8}" \times 4" \times 0.2836$ LB/cu in
= 8.50 LB each
26 STIFFENERS: $8.5 \times 26 = 221$ LB

W21X62 BEAM: 25 ft × 62 LB/ft
= 1550 LB

GUIDE RAIL ⇒ TOTAL SIZE OF RAIL + STIFFENER
≈ $2(4") \times \frac{1}{2}" \times 25\,ft \times 12"/ft \times 0.2836$ LB/in³
= 340 LB

TOTAL W_{DC} = 221 + 1550 + 340 LB
= 2111 LB
W_{DC} = 2100 LB rounded

$W_{DD} \approx W_{DC}$ + 62 LB (longer section) + 14 LB (guiderails)
= 2100 + 62 + 14 = 2176 LB
W_{DD} ≈ 2200 LB rounded

DESIGN MEMORANDUM amec

Client: GeoMelt | Sheet 3 of 50
Project: Final DBVS Design | Date: 2006 MAR 22
Data For: Steel Curbs Check CDE | Work Order: 149774
Prepared By: PMejia Checked By: DWhitley | File No: 145579-B-CA-004 REV3

Note: This form must be used for project calculations and original filed in project files

ATTACHMENT 2

W_{DE} = All W21X62 sections + 19 stiffeners

Total length of W21X62 = 1 @ 26'
1 @ 24'-8" (24.66 ft)
7 @ 1'-6" (1.5 ft) (webs = 24" 2 flanges 16")

Length of W21X62 = 26 + 24.66 + 7(1.5)
= 61.16 ft ≈ 62 ft

Section wt = 62 ft x 62 lb/ft = 3844 lb

From previous page stiffeners = 8.50 lb each
∴ 19 stiffeners = 19 x 8.5 = 161.5 lb

W_{DE} = 3844 lb + 161.5 lb = 4005 lb

W_{DE} = 4000 lb

Note: Self wt of curb does not actually "load" curb as it is fully supported on concrete

As seen below live load due to ICV™ box is 240000 lb or > 60 times curb weight.

Curb dead load provides minimal stability in lateral load condition. If W_D assumed = Ø the effect is conservative

∴ Can ignore self wt of curbs for design check.

DESIGN MEMORANDUM

Client: GEO MELT | Sheet 4 of 50

Project: FINAL DBVS DESIGN | Date: 2006.MAR.22

Data For: STEEL CURBS CHECK C, D, E | Work Order: 149774

Prepared By: PMEYER | Checked By: DWhitley | File No: 145579-B-CA-004 REV 3

Note: This form must be used for project calculations and original filed in project files

ATTACHMENT 2

LIVE LOAD

1) ICV™ BOX – BOX HAS DIFFERENT WEIGHT WHEN PLACED ON EACH CURB TYPE

TYPE C – FULL BOX – MAY BE GROUTED = 217582 LB — ATTACHMENT 6

TYPE D – BOX IN PROC BLDG – 105401 LB — ATTACHMENT 6

TYPE E – FULL BOX – NOT GROUTED IN MELT AREA = 209302 LB — ATTACHMENT 6

FOR DESIGN OF CURBS.

- IN CASE OF GRAVITY + SEISMIC LOADS HEAVIER = WORSE
  ∴ CONSERVATIVELY SET $W_{BOX\ FULL} = 240000$ LB

- IN CASE OF WIND LOADS. LIGHTER = WORSE (LESS SELF-STABILITY)
  ∴ CONSERVATIVELY SET $W_{BOX\ EMPTY} = 100\,000$ LB

ONLY CURB TYPE "C" IS EXPOSED TO WIND, AND, IN THEORY, BOX WILL ALWAYS BE FULL (BUT NOT NECESSARILY GROUTED) BEFORE IT IS PLACED ON TYPE "C" CURBS. CONSERVATIVELY, ASSUME BOX IS 100000 LB FOR WIND DESIGN, NOT 209000 LB.

2) IMPACT LOAD

LATERAL LOAD DUE TO IMPACT per ASCE-7 - passenger cars = 6000 LB @ 16" HEIGHT (ASCE 4.4.2)

DOESN'T REALLY APPLY TO CURBS.

DESIGN MEMORANDUM

amec

Client: GEOMELT Sheet 5 of 50
Project: FINAL DBVS DESIGN Date: 2006-MAR 22
Data For: STEEL CURBS CHECK C,D,E Work Order: 149774
Prepared By: P.MEYER Checked By: D.Whitley File No: 145579-B-CA-004 REV 3
Note: This form must be used for project calculations and original filed in project files ATTACHMENT 2

WHAT IS A RATIONAL METHOD OF DEVELOPING AN IMPACT LOAD?

IMPACT OCCURS WHEN A FULLY LOADED BOX + TRANSPORTER HITS A CURB
WHAT IS MAGNITUDE OF FORCE?

CONSIDER: MASS OF BOX + TRANSPORTER ATTACHMENT 3 (VENDOR)
= 240000 LB + 32000 LB
= 272000 LB

VELOCITY OF BOX + TRANSPORTER ATTACHMENT 3 (VENDOR)
= 37 ft/min = 0.6166 ft/sec

IN PREVIOUS CORRESPONDENCE, TRANSPORTER VELOCITY PROPOSED ≈ 40 fpm ATTACHMENT 3 (email)

∴ Assume 40 fpm (conservative)
= 0.666 ft/sec

KINETIC ENERGY IN IMPACT = E_{K_1}

$$E_{K_1} = \tfrac{1}{2}mv^2 = 0.5(272000\ \text{LB})(0.666\ \text{ft/sec})^2$$
$$= 60{,}444\ \text{LB}\cdot\text{ft}^2/\text{sec}^2$$

COMPARE PASSENGER VEHICLE IMPACT ENERGY

"TYPICAL" VEHICLE ≈ 3500 LB
(CHRYSLER 300 ≈ 3700 LB, HONDA ACCORD ≈ 3500 LB) MFR'S LITERATURE ONLINE
BARRIERS MUST WITHSTAND 5 mph IMPACT IN TYPICAL BUILDING APPLICATION
5 mph = 7.33 ft/second

DESIGN MEMORANDUM amec

Client: GeoMelt | Sheet 6 of 50
Project: Final DBVS Design | Date: 2006 MAR 22
Data For: Steel Curbs Chall C, D, E | Work Order: 149774
Prepared By: P Meyer | Checked By: D Whitley | File No: 145579-B-CA-004 REV3

Note: This form must be used for project calculations and original filed in project files

ATTACHMENT 2

Consider a typical passenger car (3500 LB) impacting a barrier @ 5 mph

$E_{K_2} = 0.5 (3500 LB)(7.33 ft/sec)^2$

$= 94,111 \ LB \cdot ft^2/sec^2$

Ratio = ICV™ energy / Passenger car energy

$= E_{K_1} / E_{K_2}$

$= 60444 / 94111$

$= 0.64 \approx 2/3$

1 Moving transporter with fully loaded ICV™ box has about 2/3 the kinetic energy of a typical passenger car @ 5 mph.

Since ASCE-7 design load of 6000 LB is based on "typical" vehicle, seems reasonable to us 2/3 of 6000 LB or 4000 LB as design impact load of ICV box on transporter.

Set impact load $V_I = 4000$ LB horizontal

Note: As indicated by vendor during preliminary design phase, transporter drives have ≈ 4000 LB force so this seems a reasonable design value — Attach 3 E-mail

DESIGN MEMORANDUM

Client:	GeoMelt	Sheet	7 of 50
Project:	Final DBVS Design	Date:	2006.MAR.22
Data For:	Steel Curbs Check C,D,E	Work Order:	149774
Prepared By: P.Meyer	Checked By: D.Whitley	File No:	145579-B-CA-004 REV.3

amec

Note: This form must be used for project calculations and original filed in project files

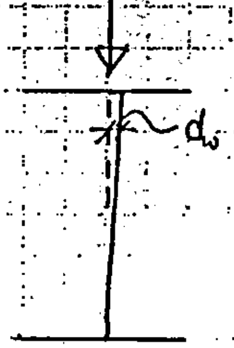
ATTACHMENT 2

APPLICATION OF LIVE LOADS

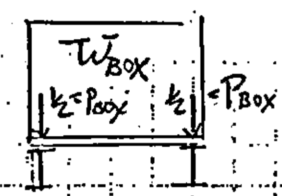
1) ICV BOX $W_{BOX\,FULL}$ OR $W_{BOX\,EMPTY}$

IS APPLIED TO TOP OF CURB. 50% EACH CURB

BOX ITSELF IS EXTREMELY STIFF (± 8' DEEP) COMPARED TO TOP FLANGE OF CURBS SO THERE IS NO TENDENCY FOR THE BOX TO ROTATE THE FLANGE.



BOXES ARE LOCATED ON TYPE 'D' & 'E' CURBS USING LOCATOR PINS AND ON TYPE C CURBS BY TRANSPORTER GUIDE WHEELS. THEREFORE LOAD CAN BE MODELLED AS UDL ON TOP FLANGE.



TO ALLOW FOR SLIGHT OFFSET IN WEB VERTICALITY, ASSUME CURB IS AT MAXIMUM OUT-OF-PLUMB PER INSTALLATION SPEC = 3/16"

DRAWING F-145579-00-B-0025

$\therefore d_w = 3/16"$ (0.3125")

APPLY SLIGHT OVERTURNING MOMENT ($0.5W_{BOX} \times 0.3125"$) IN DIRECTION OF LATERAL LOADS WHEN COMBINING LOADS.

W_{BOX} ON SINGLE CURB = $\frac{1}{2}$ W_{BOX} ON TWO CURBS = P_{BOX} ∴

$P_{BOX\,FULL(1)} = 120{,}000$ LB, $P_{BOX\,EMPTY(1)} = 50{,}000$ LB

DESIGN MEMORANDUM

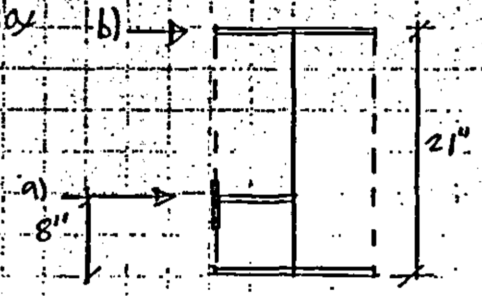
Client: GeoMelt | Sheet 8 of 50
Project: FINAL DBVS DESIGN | Date: 2006-MAR-22
Data For: STEEL CURBS CHECK C,D,E | Work Order: 149774
Prepared By: P Meyer Checked By: D Whitley | File No: 145579-B-CA-004 REV 3

Note: This form must be used for project calculations and original filed in project files

ATTACHMENT 2

2) IMPACT LOAD V_I

TWO POSSIBLE HEIGHTS TO USE FOR IMPACTING TRANSPORTER/BOX COMBINATION WITH CURB



a) GUIDE WHEELS ON TRANSPORTER HIT GUIDE PLATE ON CURB

b) TRANSPORTER IS CARRYING BOX SLIGHTLY LOW, BOX ITSELF HITS TOP FLANGE OF CURB BEAM SECTION.

BY INSPECTION, IT IS OBVIOUS "B" IS MOST CRITICAL LOAD CASE; MORE TENDENCY TO OVERTURN THE CURBS.

FOR CURB TYPE "D" = (INSIDE ICV™ BOX ASSEMBLY BUILDING) THE IMPACT LOAD REALLY IS UNLIKELY, BUT SINCE TYPE "D" AND TYPE "C" CURBS ARE NEARLY IDENTICAL, AND ARE ANCHORED IN AN IDENTICAL FASHION, IF TYPE "C" CURBS OK, THEN TYPE "D" CURBS OK.

FOR CURB TYPE "E" THE SITE GEOMETRY (F-145579-00-B-0022 IN ATTACHMENT 1) REALLY PREVENTS A LATERAL IMPACT AT SPEED (BOX CAN ONLY TRAVEL NORTH-SOUTH) BUT IMPACT WILL BE CHECKED ANYWAY.

DESIGN MEMORANDUM

Client: GEO MELT | Sheet 9 of 50

Project: FINAL DBVS DESIGN | Date: 2006 MAR 22

Data For: STEEL CURBS CHECK CDE | Work Order: 149774

Prepared By: P.Meyer | Checked By: DWhitley | File No: 145579-B-CA-004-Rev 3

Note: This form must be used for project calculations and original filed in project files

ATTACHMENT 2

WIND LOAD - APPLIED TO TYPE "C" CURBS - USE PC-1

PER TFC-ENG-STD-06 TABLE 3

FOR PC-1 SSC's WIND VELOCITY = 85 mph

IMPORTANCE FACTOR I = 1.0

EXPOSURE CATEGORY = C

PER ASCE-7

		(ASCE 7)
GUST FACTOR FOR RIGID STRUCTURES	$G = 0.85$	(6.5.8.1)
VELOCITY PRESSURE EXPOSURE COEFFICIENT (≤15')	$K_z = 0.85$	(TABLE 6-3)
TOPOGRAPHIC FACTOR (FLAT)	$K_{zt} = 1.0$	(FIG 6-4)
DIRECTIONALITY FACTOR (SQUARE TANK)	$K_d = 0.9$	(TABLE 6-4)
ENCLOSURE CLASSIFICATION -	FULLY ENCLOSED	(no openings)

$$q_z = 0.00256\, K_z K_{zt} K_d V^2 I \qquad \text{EQ 6-15}$$

$$q_z = 0.00256(0.85)(1.0)(0.9)(85\,\text{mph})^2(1.0)$$

$$q_z = 14.15\ \text{psf}$$

TRANSVERSE WIND (BLOWING AT WIDE SIDE OF BOX) CONTROLS

A_f = Area normal to wind

$$A_f = (24'\text{-}8\tfrac{3}{8}")(9'\text{-}9" + 21") \qquad \text{REFERENCE 4}$$

$$= (24.7')(11.5')$$

$$A_f = 284\ \text{ft}^2$$

C_f = pressure coefficient = 1.3 $(h/d \approx 1.0)$ ASCE-7 FIGURE 6-19 TANKS, etc

DESIGN MEMORANDUM

Client: GEO MELT — Sheet 10 of 50

Project: FINAL DBVS DESIGN — Date: 2006 MAR 22

Data For: STEEL CURBS CHECK CDE — Work Order: 149774

Prepared By: P.Lloyd — Checked By: D.Whitley — File No: 145579-B-CA-004 Rev 3

Note: This form must be used for project calculations and original filed in project files — ATTACHMENT 2

STRUCTURE IS RIGID TANK OR "OTHER STRUCTURE" (CLEARLY NOT A FLEXIBLE BUILDING) — ASCE 7 6.5.13

THUS $F_{WIND} = q_z G C_f A_f$

$F_{WIND} = (14.15\,psf)(0.85)(1.3)(284\,ft^2)$

$F_{WIND} = 4440\ lb$

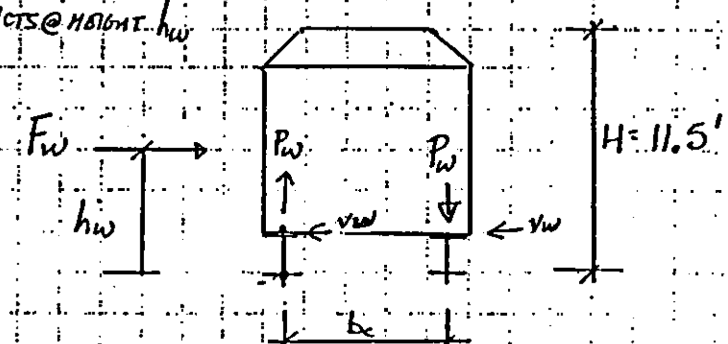
THIS FORCE ACTS PERPENDICULAR TO LONG AXIS OF CURBS AND ICV™ BOX.

BY GEOMETRY, THIS IS CLEARLY THE MOST CRITICAL CASE; WIND BLOWING AT SHORT SIDE WILL HAVE LESS TOTAL FORCE, CURBS NOT VULNERABLE TO OVERTURNING END OVER END.

F_{WIND} OVERTURNING ⟹ ACTS @ HEIGHT h_w

$h_w = \frac{1}{2}H$

$h_w = 5.75' = 69"$



SPACING OF CURBS = b_c

$b_c = 7'\text{-}0\tfrac{1}{4}" = 84.25"$

b_c from CURB DWGS (ATTACH #1)

P_w = vertical load on curb due to wind

V_w = wind load on each curb.

DESIGN MEMORANDUM amec

Client: GEO MELT Sheet 11 of 50

Project: FINAL DBVS DESIGN Date: 2006 Mar 22

Data For: STEEL CURBS CHECK CDE Work Order: 149774

Prepared By: [signature] Checked By: DWhitley File No: 145579-B-CA-004 Rev 3

Note: This form must be used for project calculations and original filed in project files ATTACHMENT 2

$P_w = F_w \times h_w / b_c$ ΣM_o

$= 4440\text{ LB} \times (69\text{ in})/(84.25\text{ in})$

$P_w = 3636\text{ LB}$ UP OR DOWN ↕ $P_w = 3700\text{ LB}$ rounded

P_w UP IS FAR LESS THAN ICV BOX SELF-WT
THEREFORE UPLIFT NOT AN ISSUE.

$V_w = \frac{1}{2} F_w = 4440\text{ LB}/2$

$V_w = 2220\text{ LB}$

rounded $V_w = 2300\text{ LB}$ per curb @ top flange ↔

* AS NOTED PREVIOUSLY, BOX IS PC-2 IN MELT AREA ONLY
ELSEWHERE PC-1 ANALYSIS IS ACCEPTABLE.
NO WIND IN MELT AREA, AND AS WILL BE
SEEN ON FOLLOWING PAGES, SEISMIC LATERAL LOAD
IS MUCH HIGHER IN MELT AREA THAN WIND ELSEWHERE.

DESIGN MEMORANDUM amec

Client: GEOMELT Sheet 12 of 50
Project: FINAL DBVS DESIGN Date: 2006 MARCH 22
Data For: STEEL CURBS CHECK - C, D, E Work Order: 149774
Prepared By: P Meyer Checked By: D Whitley File No: 145579-B-CA-004 REV3
Note: This form must be used for project calculations and original filed in project files ATTACHMENT 2

SEISMIC LOAD

SEISMIC LOAD APPLIES TO BOX IN MELT AREA (ATTACH 4)
WHERE IT IS PC-2.
SEISMIC LOAD CALCULATED PER UBC-97
USING STATIC FORCE PROCEDURE

NOTES: CURBS ARE A "NON-BUILDING STRUCTURE" SUPPORTING THE ICV™ BOX — UBC-97 SEC 1634
ALTHOUGH THE BOX IS "MOVABLE" AND THEREFORE A LIVE LOAD, FOR PURPOSES OF SEISMIC LOAD THE VALUE OF W WILL BE TAKEN AS 240,000 LB ie $W_{BOX FULL}$
THIS IS ≈ 15% (30,700 LB) ABOVE THE BOX WEIGHT CALCULATED IN 145579-D-CA-010 REV.F, AND IS CONSERVATIVE.
CURB SELF WT. (W_{DE}) OF ≈ 4000 LB EACH IS INCLUDED IN THE 240,000 LB W AND LATERAL FORCE APPLIED TO CURBS FROM WHOLE W IS APPLIED AT ICV™ BOX/CURB INTERFACE ie TOP OF CURB. THIS IS CONSERVATIVE.

1) IS CURB STRUCTURE RIGID?

$T = C_t (h_n)^{3/4}$ (seconds) — UBC EQN 30-8

$h_n = 21'' = 1.75\ ft$

$C_t = 0.020$ "other" structure — UBC PAGE 2-14

DESIGN MEMORANDUM amec

Client: GEO MELT Sheet 13 of 50
Project: FINAL DBVS DESIGN Date: 2006 MAR 22
Data For: STEEL CURBS CHECK CDE Work Order: 149774
Prepared By: PAsfar Checked By: DWhitley File No: 145579-B-CA-004 Rev 3
Note: This form must be used for project calculations and original filed in project files ATTACHMENT 2

$\therefore T = 0.020(1.75)^{3/4} = 0.0304 = 0.03$ sec

$T \leq 0.06$ sec $\therefore$ RIGID UBC 1634.3

$\therefore V = 0.7 C_a I W$ UBC EQ'N 34-1

SEISMIC ZONE = 2B REFERENCE 5 (STD06)
SOIL PROFILE TYPE = S_C REFERENCE 9 (GEOTECH)

SEISMIC ZONE FACTOR $Z = 0.2$ UBC TABLE 16-I

SEISMIC IMPORTANCE FACTOR = I UBC TABLE 16-K

DISCUSSION: TFC-ENG-STD-06 NOTES ON PAGE 7 of 42
THAT "PC-2 SSCs SHALL COMPLY WITH
THE UBC SEISMIC ZONE 2B FOR ESSENTIAL
FACILITIES."
FOR TABLE 16-K OF UBC, THE
VALUE OF "I" IS 1.25 AND THE
VALUE OF I_p IS 1.5.
EQUATION 34-1 USES "I" NOT "I_p"
BUT ON PAGE 5 OF 42 IT NOTES REF. 5
THAT "ANCHORAGE FOR NEW PC-1 AND P5/42
PC-2 SYSTEMS ... SHALL BE DESIGNED
USING THE METHODS (AND THE IMPORTANCE
FACTOR OF 1.5) IN THE UBC FOR
LIFE-SAFETY SYSTEMS."
THE UBC ALSO NOTES (NOTE 3 TO TABLE 16-K)
"ANCHORAGE OF MACHINERY AND EQUIPMENT
REQUIRED FOR LIFE SAFETY SYSTEMS, THE
VALUE OF I_p SHALL BE TAKEN AS 1.5"

THIS SUGGESTS $I = 1.25$ IS ACCEPTABLE, $I_p = 1.50$

DESIGN MEMORANDUM

Client: GEO MELT | Sheet 14 of 50
Project: FINAL DBVS DESIGN | Date: 2006 MAR 22
Data For: STEEL CURBS CHECK CDE | Work Order: 149774
Prepared By: PMoon | Checked By: DWhitley | File No: 145579-B-CA-004 Rev 3

Note: This form must be used for project calculations and original filed in project files

ATTACHMENT 2

HOWEVER, IT IS CONSERVATIVE TO USE A VALUE OF $I = 1.5$ IN FORMULA 34-1 AS THIS INCREASES THE DESIGN LATERAL FORCE. GIVEN THE UNUSUAL NATURE OF THE ICV™ BOX, A CONSERVATIVE ANALYSIS SEEMS WARRANTED

$\therefore$ USE $I = 1.5$

$C_a = 0.24$ IF $Z = 0.2$ AND $S_{OIL} = 2C$ — UBC TABLE 16-Q

$\therefore C_a = 0.24$

V = TOTAL DESIGN LATERAL FORCE DUE TO SEISMIC

$V = 0.7(0.24)(1.5)(240{,}000\ LB)$

$= 0.252(240{,}000)\ LB$

$= 60{,}480\ LB = 60.5\ kips$

$V = 60.5\ kips$

V_e = DESIGN FORCE PER CURB SEISMIC

$V_e = 0.5(60.5\ kips) = 30.25\ kips$

$V_e = 30.3\ kips$ rounded

V_e CAN ACT PERPENDICULAR TO CURBS, TENDING TO TOPPLE OVER (EAST-WEST) OR V CAN ACT PARALLEL TO CURBS, TENDING TO MAKE THEM SLIDE NORTH OR SOUTH.

DESIGN MEMORANDUM

Client: Geo Melt Sheet 15 of 50

Project: Final DBVS Design Date: 2006 MAR 22

Data For: Steel Curbs Check CDE Work Order: 149774

Prepared By: P.Moyer Checked By: DWhitley File No: 145579-B-CA-004 Rev 3

Note: This form must be used for project calculations and original filed in project files

amec

ATTACHMENT 2

VERTICAL FORCE DUE TO SEISMIC = P_E

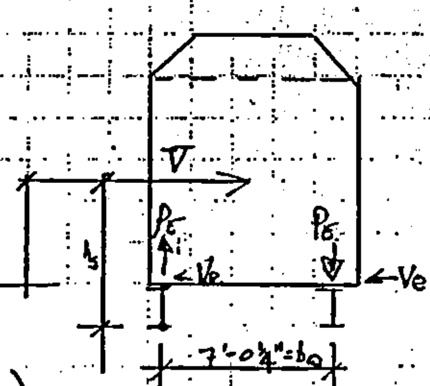
P_E APPLIES UP OR DOWN TO A CURB

V ACTS THROUGH CENTER OF GRAVITY OF FILLED (BUT NOT GROUTED) BOX

h_g = height of C.G. from bottom of box

h_s = height of C.G. from bottom of curbs

h_g IS CALCULATED IN 145579-D-CO-010 REV F (REFERENCE 9)



$h_g = 4'-7\frac{3}{16}"$

(LABELLED ON DRAWING F-145579-35-D-004 REV 1 (IN REFERENCE 4) AS P 2/8 ATT 11)

$h_s = 4'-7\frac{3}{16}" + 21" = 76.2$ inches

b_c = 84.25 inches CURB SPACING DRAWING F-145579-00-B-0025 ATTACHED IN ATT #1

$P_E = V \cdot \frac{76.2\,in}{84.25\,in}$

$P_E = 60.5$ kips $\times 0.90 = 54.45$

$P_E = 54.5$ kips UP OR DOWN.

SINCE $P_E \ll P_{BOX\ FULL}$ UPLIFT NOT AN ISSUE.

Ve = LATERAL FORCE DUE TO EARTHQUAKE ON EACH CURB

PER UBC 1630.1.1 $\rho = 1.0$ E_v taken as Ø (Allowable Stress)

∴ Ve as from base shear $= \frac{1}{2}V = 0.5(60.5\text{ kips}) = 30.3$ kips

(CONFIRMING Ve for LOAD COMBINATIONS)

DESIGN MEMORANDUM

Client: GEO MELT
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Note: This form must be used for project calculations and original filed in project files

ATTACHMENT 2

LOAD COMBINATIONS

EACH CURB IS SUBJECT TO DIFFERENT POTENTIAL LOADS.

FOR THE PURPOSE OF THE UBC-97 LOAD COMBINATIONS THE CASE OF DEAD LOAD ALONE IS OBVIOUSLY TRIVIAL (CURB ON CONCRETE, NO BOX)

∴ FOR UBC COMBINATIONS

"D" = EFFECT OF ICV BOX WEIGHT

L = IMPACT LOAD - CONSIDERED WITHOUT BOX ON CURBS "L" ACTS ALONE

W = WIND LOAD AND ASSOCIATED VERTICAL AND HORIZONTAL FORCES ACTING ON CURBS

E = EARTHQUAKE LOAD AND ASSOCIATED VERTICAL AND HORIZONTAL FORCES ACTING ON CURBS

FOR THE CURBS SUPPORTING THE BOX, IN ALL CASES THE EFFECT OF LATERAL LOAD DUE TO WIND OR SEISMIC WILL BE TO INCREASE THE DOWNWARD VERTICAL FORCE ON ONE CURB AND DECREASE THE DOWNWARD FORCE ON THE OTHER. WHEN CHECKING THE CURBS, THE "DOWNWIND" CURB IS CRITICAL; WHEN CHECKING ANCHORAGE IT IS THE "UPWIND" CURB THAT WILL BE CRITICAL

DESIGN MEMORANDUM

amec

Client: GEO MELT Sheet 17 of 50
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Note: This form must be used for project calculations and original filed in project files ATTACHMENT 2

- FOR THE PURPOSE OF EARTHQUAKE DESIGN, THE "DOWNWIND" CURB SHALL REFER TO THE CURB WHICH RECEIVES A GREATER VERTICAL LOAD DUE TO SEISMIC AND THE "UPWIND" CURB IS THE CURB WITH THE REDUCED VERTICAL FORCE.
- BECAUSE THE CURBS AND ICV™ BOX ARE SYMMETRIC ABOUT THE BOX LONGITUDINAL AXIS, AND ALL CRITICAL LATERAL LOADS ARE TRANSVERSE THIS APPROACH IS VALID AND SIMPLIFIES THE NUMBER OF LOAD COMBINATIONS THAT NEED BE CONSIDERED.

- THE ADDITIONAL OVERTURNING MOMENT DUE TO THE 3/16" (ASSUMED) OUT-OF-PLUMB OF THE CURB BEAM SECTION WEB WILL ALWAYS ACT IN THE SAME DIRECTION AS THE LATERAL FORCE. THE TOTAL VERTICAL FORCE (GRAVITY PLUS WIND OR SEISMIC) TIMES THE 3/16" WILL BE A CONSISTENT ADDITIONAL EFFECT.

DESIGN MEMORANDUM

Client: GEO MELT Sheet 18 of 50
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Note: This form must be used for project calculations and original filed in project files ATTACHMENT 2

LOAD COMBINATIONS

CURB TYPE C

1) D + W on both curbs UBC EQN 12-9
2) L (IMPACT ONLY) UBC EQN 12-8

WIND LOAD COMBINED WITH ICV™ BOX WEIGHT WILL BE CRITICAL FOR BOTH UPWIND AND DOWNWIND CURBS, AND EXCEED EFFECT OF ICV™ BOX WEIGHT ALONE

D = "FULL" FOR DOWNWIND D = EMPTY FOR UPWIND

CURB TYPE D

1) D (ICV™ BOX WEIGHT) ON CURB UBC EQN 12-7
2) L (IMPACT) UBC EQN 12-8

NEITHER WIND NOR SEISMIC APPLY INSIDE THE ICV™ BOX ASSEMBLY BUILDING

D = "FULL" FOR BOTH CURBS

CURB TYPE E

1) D + E/1.4 FOR DOWNWIND CURB UBC EQN 12-9
2) 0.9D − E/1.4 FOR UPWIND CURB UBC EQN 12-10
3) L (IMPACT)
4) D AT ELEVATED TEMPERATURE

AS LATERAL FORCE DUE TO SEISMIC IS DISTRIBUTED EQUALLY TO BOTH CURBS, THE UPWIND CURB ANCHORS ARE MOST STRESSED WITH THE LIGHTEST VALUE OF "D" ∴ 0.9 APPLIES

DESIGN MEMORANDUM

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Note: This form must be used for project calculations and original filed in project files ATTACHMENT 2

TYPE C CURBS

PROPERTIES - note all values of S_{web} + I_{web} etc. (section modulus and moment of inertia) are in the transverse direction ie. resisting lateral loads perpendicular to the long axis of the curbs, unless noted otherwise.

ALL DIMENSIONS FROM F-145579-00-B-0018 AND AISC ASD pp 1-20, 1-21.

LENGTH OF WEB = 25'-0" = 300 in

THICKNESS OF WEB = 0.400 inch

$$S_{web} = \frac{(300\text{ in})(0.400\text{ in})^2}{6} = 8\text{ in}^3$$

$$I_{web} = \frac{(300\text{ in})(0.400\text{ in})^3}{12} = 1.6\text{ in}^4$$

STIFFENERS - each = 8 in X 0.375 in

$$S_{STIFF} = \frac{(0.375\text{ in})(8\text{ in})^2}{6} = 4.0\text{ in}^3 \text{ each pair}$$

$$I_{STIFF} = \frac{(0.375\text{ in})(8\text{ in})^3}{12} = 16\text{ in}^4 \text{ each pair}$$

TOTAL 13 pairs per curb C (IGNORE ONE-SIDED PL NORTH END)

$$S_{CURB\,C} = (8\text{ in}^3) + 13(4\text{ in}^3) = 60\text{ in}^3$$

$$I_{CURB\,C} = (1.6\text{ in}^4) + 13(16\text{ in}^4) = 209.6\text{ in}^4$$

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Client: GEO MELT Sheet 20 of 50

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Note: This form must be used for project calculations and original filed in project files ATTACHMENT 2

$A_{rea\,web}$ = 300 inches x 0.400 inches
= 120 in²

$A_{rea\,stiffr}$ = 8 in x 0.375 in per pair
= 3 in² per pair

$A_{rea\,curb_C}$ = (120 in²) + 13(3 in²)

$A_{curb} = 159\,in^2$

WEB WITH STIFFENERS ACTS AS UNIT TO RESIST THE VERTICAL AND LATERAL LOADS. STIFFENERS ARE SPACED AT ≈ 1.15 d. STIFFENERS PROVIDE ADDITIONAL RESISTANCE TO WEB CRIPPLING WHICH MAY BE NECESSARY TO RESIST VERTICAL LOAD

1. FIRST: VERIFY THAT COMPRESSIVE STRESS IN WEB ALONE (WITHOUT STIFFENERS) IS ≤ 0.66 f_y — AISC ASD K.1.3

CHECK DOWNWIND CURB

TOTAL VERTICAL LOAD = $P_{boxfill} + P_{wind}$

= 120,000 LB + 3700 LB

$P_{TOTAL\,C}$ = 123,700 LB

TOTAL LATERAL LOAD: V_w = 2300 LB

DESIGN MEMORANDUM

Client: GEO MELT — Sheet 21 of 50 — amec

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Data For: STEEL CURBS CHECK CDE — Work Order: 149774

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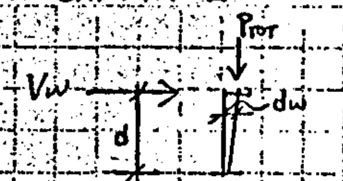
Note: This form must be used for project calculations and original filed in project files — ATTACHMENT 2

OVERTURNING MOMENT = M_o



$M_o = V_w d + P_{TOTAL_C} d_w$

d = depth of section = 21 in (conservative to top of fillet)
d_w = offset/out of plumb of web = 3/16 in = 0.1875 in (p7)

M_{o_c} = (2300 LB)(21 in) + (123700 LB)(0.1875 in)

= 48,300 LBin + 23200 LBin

M_{o_c} = 71,500 LBin

ARE STIFFENERS NEEDED? — AISC ASD K-1-2

VERTICAL COMPRESSIVE STRESS = $f_{a_{web}}$ (web only) — $f_a < 0.66 F_y$

$f_{a_{web}} = P_{TOTAL_C} / A_{web}$

= 123700 LB / 120 in²

$f_{a_{web}}$ = 1030 psi

F_y = 50000 psi BEAMS ASTM A992 STEEL
F_y = 36000 psi STIFFENERS ASTM A36 STEEL

$0.66 F_{y_{web}}$ = 0.66 (50000 psi) = 33 000 ksi WEBS OF BEAM

$f_{a_{web}} \ll 0.66 F_y$ ∴ Stiffeners not req'd for web crippling

DESIGN MEMORANDUM

amec

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Data For: STEEL CURBS CHECK CDE Work Order: 149774
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Note: This form must be used for project calculations and original filed in project files ATTACHMENT 2

VERTICAL COMPRESSIVE STRESS = $f_{a\,curb_C}$ (whole curb)

$f_{a\,curb_C} = P_{TOTAL} / A_{curb_C}$

$= 123700\ LB / 159\ in^2$

$f_{a\,curb_C} = 778\ psi$

FLEXURAL STRESS DUE TO BENDING (whole curb) = $f_{b\,curb_C}$

$f_{b\,curb_C} = \frac{M_o}{S_{curb}} = \frac{71500\ LB\cdot in}{60\ in^3}$

$f_{b\,curb_C} = 1192\ psi$

STIFFENERS BY DEFINITION ARE NON-COMPACT AISC-ASD TABLE B5.1

IS $b/t \le 95/\sqrt{F_y}$

Use $F_y = 36\ ksi$ for stiffeners (conservative)

$b = 4\ in \quad t = 0.375\ in$

IS $4/0.375 \le 95/\sqrt{36\ ksi}$ TABLE B5.1

$10.66 \le 15.83$ OK

$\therefore F_b = 0.60\ F_y$

$F_b = 0.60\,(36{,}000\ psi) = 21{,}600\ psi$ AISC ASD EQN F1-5

For simplicity.. use $F_a = 0.60 F_y$ not $0.66 F_y$ EQN K-1-3

DESIGN MEMORANDUM

amec

Client: GEO MELT Sheet 23 of 50
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Note: This form must be used for project calculations and original filed in project files ATTACHMENT 2

CHECK COMBINED STRESSES CURB C (DOWNWIND)

IS $\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \leq 1.0$? AISC ASD EQN. H1-3

$f_{by} = 0$ (no bending north/south)
$f_a/F_a < 0.15$ EQN. H-1-3 USED.

∴ IS $\frac{778\ psi}{21600\ psi} + \frac{1192\ psi}{21600\ psi} \leq 1.0$?

$0.036 + 0.055 < 1.0$

$0.091 \leq 1.0$ YES

∴ CURB C DOWNWIND OK MAX. STRESS ≈ 9.1 % ALLOWABLE

CHECK BEARING PRESSURE ON CONCRETE

BEARING PRESSURE ON CONCRETE = $B_{C\,CURB\,C}$

W/ AREA OF BOTTOM FLANGE = A_{BFC}

SECTION MODULUS OF BOTTOM FLANGE = S_{BFC}

$B_{C\,CURB\,C} = \frac{P_{TOTAL\,C}}{A_{BFC}} \pm \frac{M_{OC}}{S_{BFC}}$

DESIGN MEMORANDUM

amec

Client: GEO MELT Sheet 24 of 50
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Note: This form must be used for project calculations and original filed in project files

ATTACHMENT 2

$A_{BF_c} = (300\text{ inch})(8.24\text{ in})$

$A_{BF_c} = 2472\text{ in}^2$

$S_{BF_c} = \frac{(300\text{ in})(8.24\text{ in})^2}{6}$

$S_{BF_c} = 3395\text{ in}^3$

$B_{P\,CURBC} = \frac{123700\text{ LB}}{2472\text{ in}^2} \pm \frac{71500\text{ LB in}}{3395\text{ in}^3}$

$= 50.0 \pm 21.1\text{ psi}$

$B_{P\,CURBC} = 71.1\text{ psi or } +28.9\text{ psi}$ both compressive

BEARING CAPACITY OF 4000 psi CONCRETE CLEARLY >> 71.1 psi ∴ OK

FURTHER INFORMATION ON CONCRETE CAN BE SEEN IN CALCULATION 145579-C-CA-013.

DESIGN MEMORANDUM

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Client: Geo Melt — Sheet 25 of 50
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Note: This form must be used for project calculations and original filed in project files — ATTACHMENT 2

CURB C CHECK UPWIND CURB

$P_{TOT} = P_{BOX\,EMPTY} - P_{WIND}$

$= 50000\ LB - 3700\ LB$

$P_{TOT} = 46300\ LB$

M_{O_C} = OVERTURNING MOMENT - UPWIND CURB

$M_{O_C} = V_W d + P_{TOT}\, d_W$

$= (2300\ LB)(21\ in) + (46300\ LB)(0.1875\ in)$

$= (48300\ LB\,in) + 8680\ LB\,in$

$M_{O_C} = 56980\ LB\,in \approx 57000\ LB\,in$

STRESSES IN CURB OBVIOUSLY LESS THAN DOWNWIND CURB UNDER BOX FULL LOAD.
∴ OK

CHECK IF UPLIFT ON ANCHORS ie IS BEARING PRESSURE ON CONCRETE EVER NEGATIVE? $BP_{CURB\,C} = \frac{P_{TOT}}{A_{BFC}} \pm \frac{M_{O_C}}{S_{BFC}}$

$BP_{CONC\ UPWIND} = \frac{46300\ LB}{24.72\ in^2} \pm \frac{57000\ LB\,in}{3395\ in^3}$

$= 18.73\ psi \pm 16.78\ psi$

$= +35.5$ or $+1.95$ always compressive

∴ No uplift on anchors due to wind + dead load — OK

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Note: This form must be used for project calculations and original filed in project files

ATTACHMENT 2

CURB C
CHECK DEFLECTION OF CURB UNDER WIND $\Delta_{LATWIND}$

$$\Delta_{LATWIND} = \frac{(V_{WIND})d^3}{3EI_{CURBC}}$$

FIXED BASE CANTILEVER POINT LOAD

AISC ASD p. 2-303 adapted for this application

$$\Delta_{LATWIND} = \frac{(2300LB)(21in^3)}{3(30\times10^6 psi)(209.6 in^4)}$$

$\Delta_{LATWIND} = 0.0011$ in (0.03 mm)

AS MIGHT BE EXPECTED, LATERAL DRIFT OF CURB UNDER WIND + GRAVITY LOAD IS EFFECTIVELY ZERO.

CURB C
CHECK IMPACT LOAD

$V_I = 4000$ LB

1) IMPACT PARALLEL TO CURB (IE HITS END OF CURB)
- THIS CAUSES CURB TO WANT TO SLIDE NORTH OR SOUTH.
- AXIAL LOAD ON CURB SECTION OBVIOUSLY NOT AN ISSUE.
- SLIDING RESISTED BY THE SIX ANCHORS NEAR MIDDLE OF CURB IN ROUND HOLES.

DRAWING F-145579-00-B-011B

ANCHORS ARE HILTI HDA-TR 12mm

DESIGN MEMORANDUM

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Prepared By: P. [signature] Checked By: D Whitley
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Note: This form must be used for project calculations and original filed in project files

ATTACHMENT 2

AS LISTED IN ICBO 5608 AND HILTI CALCULATOR — ATTACHMENT 7

V_t = ALLOWABLE SERVICE SHEAR LOAD

V_t = 5113 LB (ICBO ES-5608) HDA-T — TABLE 4

ICBO PUBLISHED VALUE IS LOWER THAN MANUFACTURER'S PUBLISHED VALUES FOR HDA-T, HDA-TR, HDA-TF THEREFORE ASSUMED VALID FOR HDA-TR (STAINLESS)

ANCHOR SPACING = $\sqrt{6in^2 + 5in^2}$ = 7.81 in (GEOMETRY)

SPACING IS GREATER THAN MINIMUM (4.92in) — ICBO 5608
SPACING IS LESS THAN CRITICAL (14.76in) — ICBO 5608

CONSERVATIVELY USE FULL 13% REDUCTION — ICBO 5608 NOTE 7 p3/5

$V_{t\,allow}$ = 5113 × 0.87 = 4448 LB

V_I = 4000 LB

AS $V_{t\,allow}$ IS GREATER THAN IMPACT LOAD, ONE ANCHOR CAN RESIST SLIDING. OK

CAPACITY = 6 × 4448 = 26690

STRESS RATIO = $\frac{4000\ LB}{26690\ LB}$ = 0.15

IMPACT LOAD N-5 IS 15% OF ALLOWABLE. OK

DESIGN MEMORANDUM

Client: GEO MELT — Sheet 28 of 50

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Prepared By: P. Meier — Checked By: DWhitley — File No: 145579-B-CA-004 Rev 3

Note: This form must be used for project calculations and original filed in project files — ATTACHMENT 2

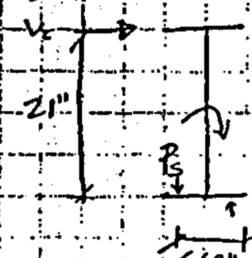
CHECK IMPACT LOAD: CURB C

2) IMPACT PERPENDICULAR TO CURB

OVERTURNING MOMENT ON STEEL SECTION = M_I

$M_I = 4000\ LB \times 21\ in$

$M_I = 84000\ LB{\cdot}in$



a) STEEL CURB: SECTION MODULUS = S_{CURBC}

$S_{CURBC} = 60\ in^3$ — page 19

$f_b = \dfrac{84000\ LB\cdot in}{60\ in^3} = 1400\ psi$

$F_b = 0.60\,F_y = 21600\ psi$ — page 22
(STIFFENERS A36 STEEL)

$f_b / F_b = 1400\ psi / 21600\ psi = 0.065$

BENDING STRESS IN STEEL = 6.5% ALLOWABLE — OK

b) CHECK TENSION ON ANCHORS

LEVER ARM FOR TENSILE ANCHORS = 6.62" (F-145579-00-B-0018)

$P_S = (V_I \times 21\ in) / (6.62\ in)$ — USE "P_S" AS PER ICBO STANDARD

$= (84000\ LB\cdot in) / (6.62\ in)$

$P_S = 12688\ LB.$

DESIGN MEMORANDUM

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MINIMUM # OF ANCHORS ON TENSILE SIDE IS 8 ANCHORS

P_S per ANCHOR = 12688 LB / 8

P_S = 1586 LB

TENSILE CAPACITY OF HDI-TR 1/2 — ICBO ER 5608

P_t = 3988 LB — "SPECIAL INSPECTED" AS LISTED ON DRAWING F-145579-00-B-0018

$P_S / P_t = \frac{1586 \text{ LB}}{3988 \text{ LB}} = 0.3977$

TENSILE FORCE ON ANCHORS IS 40% OF ALLOWABLE. OK

c) CHECK SHEAR ON ANCHORS
CONSERVATIVELY, ASSUME 100% SHEAR IS RESISTED BY ANCHORS ON COMPRESSION SIDE OF CURB BOTTOM FLANGE

MINIMUM 8 ANCHORS ON COMPRESSION SIDE

$V_S = V_I / 8 = 4000 \text{ LB} / 8 = 500 \text{ LB}$ per anchor

$V_{t_{allow}}$ = 4448 LB each (p.27)

$V_S / V_{t_{allow}} = 500 \text{ LB} / 4448 \text{ LB} = 0.112$

SHEAR LOAD (TRANSVERSE) ON ANCHORS IS 11% OF ALLOWABLE OK

DESIGN MEMORANDUM

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Client: GEO MELT
Project: FINAL DBVS DESIGN
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Prepared By: P. Meyer
Checked By: D. Whitley
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Note: This form must be used for project calculations and original filed in project files

ATTACHMENT 2

TYPE 'D' CURBS

PROPERTIES - SEE NOTE P.19 RE ORIENTATION OF SECTION MODULUS, etc

LENGTH OF WEB = 26'-0" = 312 inches
THICKNESS OF WEB = 0.400 inch

$S_{web} = (312 in)(0.400 in)^2/6 = 8.32 in^3$

$I_{web} = (312 in)(0.400 in)^3/12 = 1.66 in^4$

STIFFENERS each 8 in x 0.375 in

$S_{STIFFENER} = (0.375 in)(8 in)^2/6 = 4.0 in^3$ per pair

$I_{STIFFENER} = (0.375 in)(8 in)^3/12 = 16.0 in^4$ per pair

TOTAL 13 STIFFENER PAIRS (IGNORE SINGLE-SIDED STIFFENERS @ ENDS)

$S_{CURB D} = (8.32 in^3) + 13(4.0 in^3) = 60.32 in^3$

$I_{CURB D} = (1.66 in^4) + 13(16 in^4) = 209.66 in^4$

$A_{web D} = (312 in)(0.40 in) = 124.8 in^2$

$A_{STIFFS} = (8 in)(0.375 in) = 3 in^2$ each

$A_{CURB D} = (124.8 in^2) + 13(3 in^2) = 163.8 in^2$

DESIGN MEMORANDUM

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Client: GEO MELT | Sheet 31 of 50
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Prepared By: P Meyer | Checked By: D Whitley | File No: 145579-B-CA-004 Rev 3

Note: This form must be used for project calculations and original filed in project files

ATTACHMENT 2

TYPE D CURB

INDOOR CURB - NPH LOAD IS GRAVITY ONLY

VERTICAL LOAD PER CURB = $P_{BOX\,FULL}$ = 120,000 LB = $P_{TOTAL\,D}$

CHECK - $f_{y\,web} \le 0.6 F_y$? AISC-ASD K1.3

$$f_{y\,web} = \frac{P_{TOTAL\,D}}{A_{web}} = \frac{120000\ LB}{124.8\ in^2}$$

$$f_{y\,web} = 961\ psi$$

$0.66 F_y$ - (web of beam) $0.66(50\ ksi) = 33\ ksi$

$f_{y\,web} << 0.66 F_y$ ∴ Stiffeners optional

CHECK OVERTURNING MOMENT (OUT OF PLUMB) M_{OD}

$M_{O_D} = P_{TOTAL} \times d_w$

$M_{O_D} = 120000\ LB \times 0.1875\ in$ (d_w from page 7)

$M_{OD} = 22,500\ LB{\cdot}in$

f_b = BENDING STRESS IN STIFFENED WEB

$$f_b = \frac{M_{OD}}{S_{curb\,D}} = \frac{22500\ LB\,in}{60.32\ in^3} = 373\ psi$$

$F_b = 0.60 F_y$ $F_y = 36\ ksi$ (STIFFENERS) AISC-ASD EQN F1-5

$F_b = 0.60 F_y = 0.60(36\ ksi) = 21600\ psi$

DESIGN MEMORANDUM

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Client: GEO MELT　Sheet 32 of 50
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Prepared By: PMeyer　Checked By: DWhitley　File No: 14557[illegible]-B-CA-004 Rev 3
Note: This form must be used for project calculations and original filed in project files　ATTACHMENT 2

TYPE D

CHECK VERTICAL COMPRESSIVE STRESS

$f_{a\,curb_D} = P_{TOTAL_D} / A_{CURB_D}$

$f_{a\,curb_D} = 120{,}000\ LB / 163.8\ in^2$

$f_{a\,curb_D} = 733\ psi$

$F_a = 0.60\ F_y$ – as with curb C use $0.6\ F_y$ instead of $0.66\ F_y$ for simplicity.　AISC-ASD K-1-3

CHECK COMBINED STRESSES　AISCASD H-1-3

IS $\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \le 1.0$?　$f_{by} = \emptyset$　NO WEAK AXIS BENDING N-S

$\frac{733\ psi}{21600\ psi} + \frac{373\ psi}{21600\ psi} = 0.034 + 0.017 = 0.051 \ll 1.0$

YES

∴ CURB D STEEL OK – MAX STRESS = 5.1% ALLOWABLE

CHECK IMPACT

CURB TYPE D IS VERY SIMILAR TO TYPE C.
- 12" LONGER AS BOTH ENDS HAVE TAPERED SECTION
- ONE ADDITIONAL ANCHOR PER SIDE AT SOUTH END – RESIST OVERTURN
- SAME SIX ANCHORS NEAR MIDDLE – RESIST LONGITUDINAL LOAD

(AS NOTED IN "LOADS" A FULLY LOADED ICV™ BOX IS UNLIKELY TO BE IMPACTING THE TYPE 'D' CURBS IN THE ASSEMBLY BUILDING)

DESIGN MEMORANDUM amec

Client: Geo Melt Sheet 33 of 50
Project: Final DBVS Design Date: 2006 MAR 22
Data For: Steel Curbs Check CDE Work Order: 149774
Prepared By: P.Moyer Checked By: D.Whitley File No: 145579-B-CA-004 Rev 3
Note: This form must be used for project calculations and original filed in project files ATTACHMENT 2

TYPE D

CHECK FOR 4000 LB IMPACT ANYWAY (CONSERVATIVE)

1) IMPACT PARALLEL TO CURB - SHEAR ON ANCHORS
AS WITH CURB C - 6 ANCHORS HDA-TR RM
AS PAGE 27 LOAD IS 15% of ALLOWABLE -OK

2) IMPACT PERPENDICULAR TO CURB
a) OVERTURNING + BENDING STRESS IN STEEL
i) SIMILAR TO CURB "C" EXCEPT
$S_{CURB D} = 60.32 \text{ in}^3$ while $S_{CURB C} = 60 \text{ in}^3$ ref p 28
EFFECTIVELY IDENTICAL (< ½% VARIANCE)

BENDING STRESS IN STEEL = 6.5% of ALLOWABLE

b) OVERTURNING MOMENT - TENSION ON ANCHORS
SIMILAR TO CURB C EXCEPT MINIMUM
9 ANCHORS INSTEAD OF 8 ANCHORS

$\therefore P_S = 12688 \text{ LB} / 9 = 1410 \text{ LB}$ per anchor ref p.29

TENSILE CAPACITY = P_t = 3988 LB

$P_S / P_t = 1410/3988 = 0.36$

TENSILE FORCE IS 36% of ALLOWABLE

c) SHEAR ON ANCHORS - TRANSVERSE LOAD
AGAIN - SAME AS CURB C BUT MINIMUM
9 ANCHORS ON COMPRESSION SIDE VERSUS 8 ref page 29
SHEAR LOAD PER ANCHOR $V_S = 4000 \text{ LB}/9 = 445 \text{ LB}$
$V_{t_{allow}} = 4448 \text{ LB}$ $\therefore V_S / V_{t_{allow}} = 445/4448 = 0.10$

SHEAR LOAD (TRANSVERSE) ON ANCHORS IS 10% OF ALLOWABLE OK

DESIGN MEMORANDUM

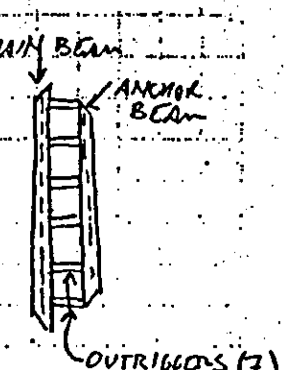
Client: GeoMat — Sheet 34 of 50
Project: Final DBVS Design — Date: 2006 MAR 22
Data For: Steel Curbs Check CDE — Work Order: 149774
Prepared By: PAnyon — Checked By: DWhitley — File No: 145579-B-CD-004 REV 3

Note: This form must be used for project calculations and original filed in project files — ATTACHMENT 2

TYPE E CURBS

PROPERTIES - CURB SECTION PROPERTIES S_x, I_x etc ARE GIVEN WITH RESPECT TO THE TRANSVERSE DIRECTION, i.e. RESISTING THE EFFECTS OF LATERAL LOADS PERPENDICULAR TO THE LONG AXIS OF THE CURBS UNLESS OTHERWISE NOTED.

"OUTRIGGER" BEAMS ON THE EXTERIOR ARE TAKEN INTO ACCOUNT FOR OVERTURNING STABILITY, BUT CONSERVATIVELY IGNORED (EXCEPT THE PORTIONS THAT ARE DIRECTLY UNDER THE TOP FLANGE OF THE MAIN W21X62 CURB SECTION) FOR RESISTING VERTICAL LOADS.



EAST CURB

1) AREA RESISTING VERTICAL LOADS

a) A_{web_E} = LENGTH OF WEB X WEB THICKNESS

LENGTH OF WEB = 26 feet = 312 in — F-145579-00-B-0025
WEB THICKNESS = 0.400 in — AISC-ASD TABLES

$A_{web_E} = 312\,in \times 0.400\,in = 124.8\,in^2$

b) $A_{STIFFENERS}$ - CONSIDER THE PORTION OF WEBS OF OUTRIGGERS UNDER THE TOP FLANGE ONLY. CONSERVATIVELY USE 0.375 IN FOR ALL PLATES, RATHER THAN 0.400 FOR OUTRIGGER WEBS.

$A_{STIFF} = 8\,in \times 0.375\,in = 3.0\,in^2$ each

DESIGN MEMORANDUM

Client: GEO MELT Sheet 35 of 50

Project: FINAL DBVS DESIGN Date: 2006 MAR 22

Data For: STEEL CURBS CHECK CDE Work Order: 149774

Prepared By: P.Meyer Checked By: D.Whitley File No: 145579-B-CA-004 Rev 3

Note: This form must be used for project calculations and original filed in project files ATTACHMENT 2

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TOTAL 13 STIFFENERS (IGNORE 2 END PLATES THAT OCCUR ON SINGLE SIDE ONLY, CONSERVATIVE)

$\therefore A_{CURBE} = (124.8\ in^2) + 13(3.0\ in^2)$

$A_{curbE} = 163.8\ in^2$

2) SECTION MODULUS OF CURB E

- OUTRIGGERS ARE ATTACHED TO MAIN CURB SECTION WITH 100% MOMENT CONNECTIONS AND ARE ATTACHED TO ANCHOR BEAM WITH SHEAR CONNECTIONS.
  THE MAIN CURB RESISTS BENDING IN THE EAST-WEST DIRECTION BY THE COMBINED FLEXURAL STRENGTHS OF ITS OWN STIFFENED WEB AND THE FLEXURAL STRENGTH OF THE SEVEN OUTRIGGERS. CONSERVATIVELY THE BENDING RESISTANCE OF THE WEB STIFFENERS CAN BE IGNORED.

$S_{webE} = (312\ in)(0.400\ in)^2/6 = 8.32\ in^3$

$S_{OUTRIGGER} = S_{OF\ W21\times62} = 127\ in^3$ each AISC ASD TABLES

$S_{CURBE} = (8.32\ in^3) + 7(127\ in^3) = 8.32 + 889\ in^3$

$S_{CURBE} = 897\ in^3$

OUTRIGGERS PROVIDE ≈ 99% OF STRENGTH, SO IGNORING STIFFENERS IS NOT EXCESSIVELY CONSERVATIVE

DESIGN MEMORANDUM

amec

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Note: This form must be used for project calculations and original filed in project files ATTACHMENT 2

3) MOMENT OF INERTIA –
SIMILAR TO SECTION MODULUS, USE
CURB WEB AND 7 OUTRIGGERS ONLY

$I_{web_E} = (312\,in)(0.400\,in)^3/12 = 1.66\,in^4$

$I_{OUTRIGGER} = I_{W21X62} = 1330\,in^4$ — AISC-ASD TABLES

$I_{CURB_E} = (1.66\,in^4) + 7(1330\,in^4)$

$I_{CURB_E} = (1.66\,in^4) + (9310\,in^4)$

$I_{CURB_E} = 9310\,in^4$ (ie web makes no difference)

CHECK "DOWNWIND" CURB
(IE: WHERE SEISMIC INCREASES THE VERTICAL DOWNWARD FORCES ON THE CURB)

$P_{TOTAL_E} = P_{BOX\,FULL} + P_E/1.4$ — UBC EQN 12-9

$P_{TOTAL_E} = 120000\,LB + 54500/1.4$ — pages 7+15
$= 158928\,LB$

$P_{TOTAL_E} = 160000\,LB$ (rounded)

1) ARE STIFFENERS REQUIRED? — AISC ASD K-1.3
IS STRESS IN WEB > $0.66F_y$
$F_y = 50\,ksi$ … $0.66F_y = 33\,ksi$ — ASTM A992 STEEL

$f_a = P_{TOTAL_E}/A_{web_E} = (160000\,LB)/(124.8\,in^2)$

$f_a = 1282\,psi \ll 33000\,psi$

∴ WEB STIFFENERS NOT REQUIRED.

DESIGN MEMORANDUM

amec

Client: GEO MELT Sheet 37 of 50
Project: FINAL DBVS DESIGN Date: 2006 MAR 22
Data For: STEEL CURBS CHECK CDE Work Order: 149774
Prepared By: P Mayer Checked By: D Whitley File No: 145579-B-CA-004 Rev 3
Note: This form must be used for project calculations and original filed in project files ATTACHMENT 2

FULL CAPACITY OF STIFFENERS MAY BE ASSUMED TO RESIST LOADS, NOT STABILIZE WEB.
HAVE ALREADY ESTABLISHED (p22 THIS CALC) THAT STIFFENERS ARE NON COMPACT FOR AXIAL (VERTICAL) LOADING ASD TABLE B.5.1
USE $F_y = 36000$ psi, TO ACCOUNT FOR STIFFENERS, EVEN THOUGH WEBS OF W21X62 ARE $F_y = 50{,}000$ psi
THIS IS CONSERVATIVE
ALSO USE $F_a = 0.60 F_y$ BASED ON STIFFENERS, RATHER THAN $F_a = 0.66 F_y$ FOR WEBS OF BEAM SECTIONS. ALSO CONSERVATIVE

CHECK VERTICAL STRESS

$$f_a = P_{TOTAL} / A_{CURBE}$$

$$f_a = (160{,}000\ LB)/(163.81\ in^2)$$

$$\underline{f_a = 977\ psi}$$

$$F_a = 0.6(36000\ psi) = 21{,}600\ psi$$

CHECK OVERTURNING STRESS

$$M_{OE} = (P_{TOTAL E})(d_w) + \frac{(V_E)(d)}{1.4}$$ UBC EQ'N 12-9

$$M_{OE} = (160000\ LB)(0.1875\ in) + \frac{(30300\ LB)(21\ in)}{1.4}$$

$$M_{OE} = (30{,}000\ LB\cdot in) + 454{,}500\ LB\cdot in$$

$$\underline{M_{OE} = 484{,}500\ LB\cdot in}$$

DESIGN MEMORANDUM

Client: GEO MELT — Sheet 38 of 50

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Data For: STEEL CURBS CHECK CDE — Work Order: 149774

Prepared By: PMajor — Checked By: DWhitley — File No: 145579-B-CA-004 Rev 3

Note: This form must be used for project calculations and original filed in project files — ATTACHMENT 2

$f_b = M_{OE} / S_{CURB\ E}$ BENDING STRESS

$f_b = \dfrac{484{,}500\ \text{LB·in}}{897\ \text{in}^3}$

$f_b = 540\ \text{psi}$

$F_b = 0.66\ F_y$ W21X62 IN STRONG-AXIS BENDING — AISC ASD F-1-1

$F_y = 50000\ \text{psi}$ APPLIES TO W21X62 ONLY — ASTM A992 STEEL

$\therefore F_b = 0.66\ F_y = 0.66\ (50000\ \text{psi})$

$F_b = 33{,}000\ \text{psi}$

CHECK COMBINED STRESSES - CURB E

IS $\dfrac{f_a}{F_a} + \dfrac{f_{bx}}{F_{bx}} + \dfrac{f_{by}}{F_{by}} \leq 1.0$? — AISC ASD H-1-3

$f_{by} = \emptyset$ no out of plane bending N-S

$\therefore$ IS $\dfrac{977\ \text{psi}}{21600\ \text{psi}} + \dfrac{540\ \text{psi}}{33000\ \text{psi}} \leq 1.0$

$0.045 + 0.016 = 0.061 < 1.0$ OK

CURB E DOWNWIND OK — MAXIMUM STRESS = 6.1% of ALLOWABLE

DESIGN MEMORANDUM amec

Client: GEO MELT
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Date: 2006 MAR 22
Data For: STEEL CURBS CHECK CDE
Work Order: 149774
Prepared By: PMeyer Checked By: DWitley
File No: 14557-B-CA-004 Rev 3

Note: This form must be used for project calculations and original filed in project files

ATTACHMENT 2

CHECK AGAINST ELEVATED TEMPERATURE

- AS REQUESTED IN A PREVIOUS REVIEW, CURB E STRENGTH TO BE CHECKED AT ELEVATED TEMPERATURE.

TEMPERATURE USED IN ICV™ BOX STRUCTURAL ANALYSIS IS 1058°F AS SEEN IN ATTACHMENT 8 AND REFERENCE 8. CALC 14557-D-CA-011

AS LISTED IN THAT CALCULATION F_y OF STRUCTURAL STEEL AT 1058°F IS APPROXIMATELY 0.55 (55%) OF THE F_y AT AMBIENT TEMPERATURES.

IF CURBS WERE TO REACH 1058°F THEN THE EFFECT WOULD BE TO CHANGE THE DENOMINATORS IN THE "COMBINED STRESS CHECK" BY A FACTOR OF 0.55 AISC ASD EQN H-1-3

THIS INCREASES THE COMBINED STRESS RATIOS BY 1/0.55 OR 1.81

f_a/F_a increases from 0.045 to 0.082 STILL ≤ 0.15
f_b/F_b increases from 0.016 to 0.029

∴ COMBINED STRESS RATIO = 0.082 + 0.029 = 0.111

CURB "E" DOWNWIND OK UNDER COMBINED GRAVITY AND SEISMIC LOADING AT ELEVATED TEMPERATURE

MAXIMUM STRESS @ 1058°F IS 11.1% OF ALLOWABLE

DESIGN MEMORANDUM

Client: GEO MELT | Sheet 40 of 50

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Data For: STEEL CURBS CHECK CDE | Work Order: 149774

Prepared By: P. Meyer | Checked By: D Whitley | File No: 145579-B-CA-004 Rev 3

Note: This form must be used for project calculations and original filed in project files

ATTACHMENT 2

CURB 6

CHECK BEARING PRESSURE ON CONCRETE

FOR SIMPLICITY, CONSERVATIVELY ASSUME MAIN BEAM SUPPORTS ALL VERTICAL LOAD AND ANCHOR BEAM RESISTS ALL OVERTURNING MOMENT EFFECT. THIS IGNORES THE BENEFICIAL EFFECT OF BEARING OF THE OUTRIGGERS ON THE CONCRETE FOUNDATION.

Bearing Pressure Main Curb = $B_{c\,CURBE}$
Area Bottom Flange Main Curb = A_{BFE} =
Area Bottom Flange Anchor Beam = A_{BANC}
Bearing Pressure Anchor Curb = B_{cANC}

$A_{BFE} = 312\text{ in} \times 8.24\text{ in}$ — F145579-00-B-002S
$= 2570\text{ in}^2$

Use 2500 in² to account for trimmed corners

$A_{BANC} = 296\text{ in} \times 8.24\text{ in}$ — F-145579-00-B-002S
$= 2440\text{ in}^2$

Use 2400 in² to account for trimmed corners

$B_{c\,CURBE} = P_{TOTAL} / A_{BFE} = (160{,}000\text{ LB})/(2500\text{ in}^2)$

$B_{c\,CURBE} = 64\text{ psi}$ — OBVIOUSLY OK ON CONCRETE

$B_{cANC} = \left(\frac{M_0}{24\text{ in}}\right) / A_{BANC}$ — 24 in Lever arm

$= \left(\frac{484500\text{ LB}\cdot\text{in}}{24\text{ in}}\right) / 2400\text{ in}^2 = 8.4\text{ psi}$ — OK ON CONCRETE

DESIGN MEMORANDUM amec

Client: GEO MELT Sheet 41 of 50

Project: FINAL DBYS DESIGN Date: 2006 MAR 22

Data For: STEEL CURB CHECK CDE Work Order: 149774

Prepared By: [signature] Checked By: DWhitley File No: 145579-B-CA-004 Rev 3

Note: This form must be used for project calculations and original filed in project files ATTACHMENT 2

CURB E CHECK UPWIND CURB

$P_{TOTAL_{UP}} = 0.9(P_{BOX FULL}) - P_E/1.4$ UBC EQN 12-10

$P_{TOTAL_{UP}} = 0.9(120000\,LB) - (54500\,LB)/1.4$

$P_{TOTAL_{UP}} = 108{,}000\,LB - 38930\,LB$

$P_{TOTAL_{UP}} = 69{,}070\,LB$

$P_{TOTAL_{UP}}$ 69000 LB ROUNDED

LIGHTER LOAD MORE LIKELY TO CAUSE UPLIFT

M_{OUP} = OVERTURNING MOMENT ON UPWIND CURB

$M_{OUP} = \frac{V_E\,d}{1.4} + P_{TOTAL_{UP}}\,d_W$ UBC EQ 12-10

$M_{OUP} = \frac{(30300\,LBS)(21\,IN)}{1.4} + (69000\,LB)(0.1875\,IN)$

$= 454{,}500\,LB\cdot in + 12938\,LB\cdot in$

$M_{OUP} = 467438\,LB\cdot in$

$M_{OUP} = 467500\,LB\cdot in$ rounded.

CONSERVATIVELY, ASSIGN ALL UPLIFT RESISTANCE TO ANCHORS LOCATED IN THE ANCHOR CURB. BECAUSE OF THEIR LONGER LEVER ARMS, THEY WILL BE MOST EFFECTIVE ANCHORS. IGNORING WEIGHT OF ANCHOR BEAM IS CONSERVATIVE.

DESIGN MEMORANDUM

Client: GEO MELT — Sheet 42 of 50

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Data For: STEEL CURBS CHECK CDE — Work Order: 149774

Prepared By: P. Meyer — Checked By: D Whitley — File No: 145579-B-CA-004 Rev 3

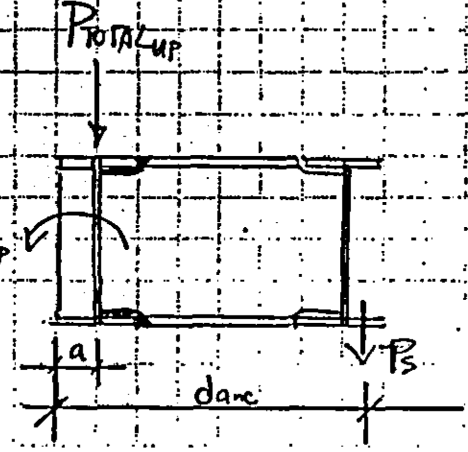
Note: This form must be used for project calculations and original filed in project files

ATTACHMENT 2

OFFSET OF $P_{TOTAL_{UP}}$ ALREADY CONSIDERED IN DEVELOPMENT M_o

$P_{TOTAL_{UP}}$ = VERTICAL LOAD ON CURB

M_{OUP} = OVERTURNING DUE TO COMBINED SEISMIC AND OFFSET LOAD



a = LEVER ARM OF VERTICAL LOAD ABOUT TOE OF MAIN CURB BEAM
(use 4.00 in instead of 4.12 in - conservative)

d_{anc} = LEVER ARM OF ANCHORS IN ANCHOR BEAM ABOUT TOE OF MAIN CURB BEAM

d_{anc} = 4 in + 24 in + 2.5 in = 30.5 in
(145579-00-B-0025)

P_S = TENSION IN ANCHORS (12 ANCHORS TOTAL)

$$P_S = \frac{M_{OUP} - (P_{TOT})(a)}{d_{anc}}$$

$$= \frac{(467500\ \text{LB}\cdot\text{in}) - (69000\ \text{LB})(4.0\ \text{in})}{30.5\ \text{in}}$$

P_S = 6279 LB per 12 anchors

P_S = 6279 LB / 12 = 524 LB each

P_t of HDA-TR 12M = 3988 LB — ICBO ES 5608 SPECIAL INSPECTED

P_S/P_t = 524 LB / 3988 LB = 0.131

TENSILE FORCE ON ANCHORS IS 13.1% OF ALLOWABLE

DESIGN MEMORANDUM

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Client: GEO MELT | Sheet 43 of 50
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Data For: STEEL CURBS CHECK CDE | Work Order: 149774
Prepared By: [signature] Checked By: DWhitley | File No: 145579-B-CA-004 Rev 3
Note: This form must be used for project calculations and original filed in project files ATTACHMENT 2

CURB C

CHECK SHEAR ON ANCHORS - SEISMIC

SEISMIC LOAD IN ANY DIRECTION: V_E = 30,300 LB = V_S for anchor

WORST CASE IS N-S WHERE ONLY THE 6 CENTRAL ANCHORS RESIST FORCE

V_E OF HDA-TR 16M = 9200 LB each — ICBO ES 5608
FOR SPACING 22.44 in — TABLE 4

MINIMUM SPACING = 7.48 inches — ICBO ES 5608 TABLE 2

ACTUAL SPACING: $\sqrt{(6\,in)^2 + (5\,in)^2}$ = 7.81 in

FOR SPACING @ MINIMUM REDUCE SHEAR CAPACITY BY 13% — ICBO ES 5608 Note 1 p3/5

∴ $V_{E\,allow}$ = 0.87 (9200 LB)

$V_{E\,allow}$ = 8004 LB = 8000 LB (rounded)

6 anchors ⇒ = 6 (8000 LB) = 48000 LB

RATIO → $\frac{30300}{48000}$ = 0.63

WORST CASE SHEAR FORCE ON ANCHORS IS 63% ALLOWABLE.

DESIGN MEMORANDUM

Client: GEO MELT
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Project: FINAL DBVS DESIGN
Date: 2006 MAR 22

Data For: STEEL CURBS CHECK CDF
Work Order: 149774

Prepared By: [signature] Checked By: D Whitley File No: 145579-B-CA-004 Rev 3

Note: This form must be used for project calculations and original filed in project files ATTACHMENT 2

IMPACT LOAD - CURB E

AS CAN BE SEEN ON PLAN F-145579-00-B-0022 (ATTACH 1) THE TRANSPORTER/ICV BOX COMBINATION IS GUIDED INTO THE MELT AREA AND IMPACT WITH THE TYPE E CURBS IS DIFFICULT TO ACHIEVE.

HOWEVER:

1) N-S IMPACT ON MAIN CURB BEAM WILL BE RESISTED BY SHEAR CAPACITY OF CENTRAL 6 ANCHORS.
AS ON PAGE 43, CAPACITY OF EACH ANCHOR IS 8000 LB.

$V_I = 4000$ LB

$V_t = 6(8000\text{ LB}) = 48000$ LB

$V_I / V_t = 4000/48000 = 0.083$

IMPACT N/S ON ANCHORS IS 8.3% OF ALLOWABLE

2) E-W "IMPACT" WOULD CONSIST OF OPERATOR DRIVING THE ICV™ BOX/TRANSPORTER COMBINATION SIDEWAYS AT THE TYPE E CURB. DIFFICULT TO ACTUALLY HIT THE CURB, BUT WILL CONSIDER EFFECT OF 4000 LB LATERAL LOAD APPLIED TRANSVERSELY TO TOP FLANGE OF MAIN CURB BEAM.

DESIGN MEMORANDUM

Client: GEO MELT
Project: FINAL DBVS DESIGN
Data For: STEEL CURBS CHECK CDE
Prepared By: P/Aror
Checked By: DWhitley
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Note: This form must be used for project calculations and original filed in project files

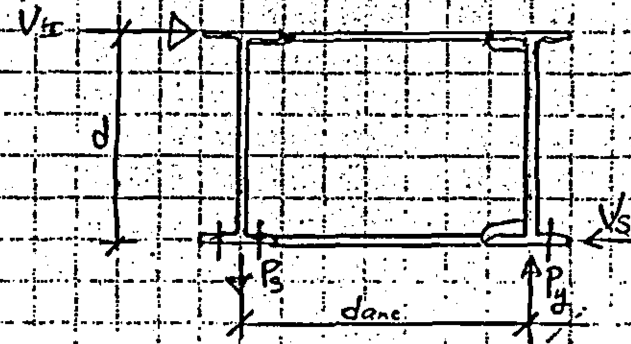
ATTACHMENT 2

V_I = 4000 LB impact force

V_S = SHEAR RESISTANCE OF 12 ANCHORS IN ANCHOR BEAM

P_S = TENSION (UPLIFT) ON 20 ANCHORS IN MAIN CURB BEAM

P_y = ADDITIONAL VERTICAL LOAD ON ANCHOR BEAM



d = DEPTH OF BEAM W21X62 = 21 in

danc = LEVER ARM FOR TENSION ANCHORS (CONSERVATIVELY TAKE AS BEAM-BEAM DISTANCE) = 24 inches

a) CHECK UPLIFT

$$P_S = \frac{V_I\, d}{d_{anc}} = \frac{(4000\ LB)(21\ in)}{(24\ in)} = 3500\ LB$$

P_t of HDA TR 12M = 3988 LB EACH AND THERE ARE 14 OF THEM, IN ADDITION TO 6 HDA TR 16M WITH TENSILE CAPACITIES OF (0.83)(7155 LB) = 5938 LB EACH.

CLEARLY ANCHORS ARE ADEQUATE TO RESIST ANY UPLIFT CAUSED BY IMPACT LOAD.

P_y = P_S = 4000 LB. CLEARLY, THIS IS A MINOR LOAD AND CAN BE SUPPORTED ON THE CONCRETE BASE.

DESIGN MEMORANDUM

Client: GEO MELT   Sheet 46 of 50   amec
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Data For: STEEL CURBS CHECK CDE   Work Order: 149774
Prepared By: P Meyer   Checked By: DWhitley   File No: 145579-B-CA-004 Rev 3
Note: This form must be used for project calculations and original filed in project files   ATTACHMENT 2

b) CHECK SHEAR E-W

$V_S = V_I = 4000$ LB

V_t = SHEAR CAPACITY OF HDA-TR ANCHORS
= 12 (5113 LB) = 61356 LB

V_S/V_t = 4000 LB / 61356 LB

RATIO = 0.065

LATERAL FORCE ON ANCHOR BEAM ANCHORS IN SHEAR IS 6.5% OF ALLOWABLE.

c) CHECK BENDING

M_{OI} = OVERTURNING DUE TO IMPACT

M_{OI} = 4000 LB × 21 in
M_{OI} = 84000 LB·in

STRESS IN CURB DUE TO LATERAL IMPACT = f_{bI}

$f_{bI} = \frac{M_{OI}}{S_{CURBE}} = \frac{84000 \text{ LB·in}}{897 \text{ in}^3}$ S_{curbe} from page 35

f_{bI} = 93.6 psi = 94 psi rounded

$F_b = 0.66 F_y = 0.66 (50000 \text{ psi})$ ASTM A992 STEEL FOR BEAMS
F_b = 33000 psi

NO VERTICAL LOAD OR OUT OF PLANE BENDING $f_a = 0$ $f_{by} = 0$

$\therefore \quad \frac{f_b}{F_b} = \frac{94 \text{ psi}}{33000 \text{ psi}} = 0.0028$

STRESS IN CURB DUE TO IMPACT LOAD IS 0.3% OF ALLOWABLE.

DESIGN MEMORANDUM

Client: GEO MELT — Sheet 47 of 50
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Data For: STEEL CURBS CHECK C,D,E — Work Order: 149774
Prepared By: P/Meyer — Checked By: DWhitley — File No: 145579-B-CA-004 Rev 3
Note: This form must be used for project calculations and original filed in project files — ATTACHMENT 2

CHECK CURB DEFLECTION CURB E

CONSIDER HOW FAR TOP OF CURB CAN DEFLECT DUE TO LATERAL LOAD
(NOTE POSSIBLE MOVEMENT OF ICV™ BOX ITSELF IS CONSIDERED IN ATTACHMENT 9.

TWO LATERAL LOADS = IMPACT + SEISMIC

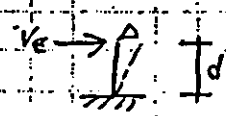
V_I = 4000 LB IMPACT

V_E = 30,300 LB SEISMIC PER CURB. * CONTROLS

BY INSPECTION, ANY DEFLECTION WILL BE IN THE EAST-WEST DIRECTION. (BENDING) AS DEFLECTION NORTH SOUTH WOULD REQUIRE SHEAR DEFLECTION OF THE STIFFENED MAIN CURB BEAM WEB.

DEFLECTION DUE TO SEISMIC = Δ_E

BASE OF CURB FIXED TO CONCRETE, CANTILEVERED FROM BASE



$$\therefore \Delta_E = \frac{(V_E)(d)^3}{3\,E\,I_{curbE}}$$

$$\Delta_E = \frac{(30{,}300\text{ LB})(21\text{ in})^3}{3(30\times10^6\text{ psi})(9310\text{ in}^4)} = 0.0003\text{ in} \quad (0.0085\text{ mm})$$

(i.e. ZERO)

DEFLECTION OF THE CURB UNDER SEISMIC LOAD WITH RESPECT TO BASE CONCRETE = Ø.

DESIGN MEMORANDUM

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Client: GEO MELT Sheet 48 of 50
Project: FINAL DBVS DESIGN Date: 2006 MAR 22
Data For: STEEL CURBS CHECK CDE Work Order: 149774
Prepared By: P. [signature] Checked By: DWhitley File No: 145579-B-CA-004 Rev 3

Note: This form must be used for project calculations and original filed in project files ATTACHMENT 2

THERMAL EXPANSION - ALL CURBS

AS NOTED IN "ASSUMPTIONS" THE TEMPERATURE OF THE BASE CONCRETE FOUNDATION MUST REMAIN ≤ 212°F TO ENSURE CONCRETE DURABILITY.

ALL THREE CURB TYPES WILL EXPAND AND CONTRACT IN USE. SLOTTED HOLES ARE PROVIDED TO ALLOW THIS EXPANSION/CONTRACTION TO OCCUR.

AS SEEN ON THE DETAIL DRAWINGS, PROVISION IS MADE FOR 1/4" OF CONTRACTION AND 7/8" OF EXPANSION. — F-145579-00-B-0018 + F-145579-00-B-0025 DETAILS 1+2

THE HILTI HDA-TR 12M ANCHORS ARE INSTALLED SNUG TIGHT ONLY AND WILL NOT CREATE SIGNIFICANT FRICTION THAT MIGHT RESIST EXPANSION/CONTRACTION OF CURBS. — SAME DWGS NOTE 6

HDA-TR ANCHORS DO NOT REQUIRE NUT TORQUE TO HOLD SET. — ATTACH 7, p8

CHECK POTENTIAL TEMPERATURE CHANGE THAT CAN BE ACCOMODATED BY SLOTTED HOLES

ALLOWABLE CONTRACTION = Δ_C = 0.25in

ALLOWABLE EXPANSION = Δ_E = 0.875in

DESIGN MEMORANDUM

Client: GEO MELT | Sheet 49 of 50
Project: FINAL DBVS DESIGN | Date: 2006 MAR 22
Data For: STEEL CURBS CHECK CDE | Work Order: 149774
Prepared By: P Major | Checked By: D Whitley | File No: 145579-B-CA-004 Rev 3
Note: This form must be used for project calculations and original filed in project files

amec

ATTACHMENT 2

ΔT_C = ALLOWABLE TEMPERATURE DROP FROM INSTALLATION TEMPERATURE

ΔT_E = ALLOWABLE TEMPERATURE RISE FROM INSTALLATION TEMPERATURE

CONSERVATIVELY, NO ALLOWANCE WILL BE MADE FOR CONTRACTION OR EXPANSION OF THE CONCRETE ITSELF.

COEFFICIENT OF THERMAL EXPANSION FOR STRUCT STEEL = $\epsilon = 6.5 \times 10^{-6}$ /°F — AISC-ASD PAGE 6-6

LENGTH OF STEEL = L = DISTANCE FROM ℄ STEEL CURB TO FURTHEST SLOTTED HOLE = 12'-6" = 130 in — F-145579-00-B-001B + F-145579-00-B-002S

$\Delta_C = (\epsilon)(\Delta T_C)(L) = 0.25\text{ in}$

$\therefore \Delta T_C = \frac{0.25\text{ in}}{(6.5\times10^{-6}/°F)(130\text{ in})} = 295°F$ change ↓

SIMILARLY $\Delta T_E = \frac{0.875\text{ in}}{(6.5\times10^{-6}/°F)(130\text{ in})} = 1035°F$ change ↑

∴ IF CURBS INSTALLED AT THE SITE MAX DESIGN TEMP OF 115°F, THEY COULD ACCOMODATE CONTRACTION TO A TEMPERATURE OF MINUS 180°F. THIS IS CLEARLY ACCEPTABLE.

DESIGN MEMORANDUM amec

Client: GeoMelt Sheet 50 of 50
Project: Final DBVS Design Date: 2006-MR
Data For: Steel Curbs Check C, D, E Work Order: 149774
Prepared By: PMeyer Checked By: DWhitley File No: 145579-B-CA-004 REV3
Note: This form must be used for project calculations and original filed in project files ATTACHMENT 2

IF CURBS INSTALLED AT A SITE AMBIENT TEMPERATURE OF 20°F (COLDEST TEMP WORK IS LIKELY TO PROCEED) THEY COULD ACCOMODATE EXPANSION TO A TEMPERATURE OF 1055°F AS THIS IS BASICALLY THE SAME TEMPERATURE (1058°F) USED AS THE UPSET CONDITION FOR THE ICV™ BOX ITSELF IT REPRESENTS A BOUNDING CONDITION. CLEARLY EXPANSION OF THE CURBS WILL NOT BE LIMITED BY THE SLOTTED HOLES, AND THIS IS ACCEPTABLE.

145579-D-CA-011
REFERENCE 8

"NOTE: CONCRETE TEMPERATURE MUST STILL BE MAINTAINED TO NO HIGHER THAN 212°F. IN ORDER TO RETAIN ITS FULL STRENGTH."

145579-B-CA-004

Attachment 3

Travel Speed Data from ICV™ Box Transporter Manufacturer – AeroGo

AeroGo, Inc.
1170 Andover Park W. ■ Seattle, WA 98188-3909
206/575-3344 ■ Fax: 206/575-3505 ■ 800/426-4757

PROJECT AMEC
JOB NO. AG-40608
PREPARED BY ARA DATE 1/30/06
SHEET NO. 1 OF

A. DETERMINE TRACTION DRIVE SIZE

LOAD = 240,000 LBS (BOX)
D.L. = 32,000 LBS (TRANSPORTER)
TOTAL = 272,000 LB

DRAWBAR REQ'D TO MOVE TRANSPORTER ON WHEELS

$F_1 = 32,000 (.075) = 2400$ LBS.

WIND PRESSURE, $P = 0.00256 V^2 \left(\frac{H}{30}\right)^{2/7} C_f G_f$
(COMPRESSOR SIDE)

$= 0.00256 (10)^2 \left(\frac{6.8}{30}\right)^{2/7} (1.6)(1.3)$

$P = .35$ LBS/FT²

$F_{WIND/COMPRESSOR} = \frac{145 \times 99.5}{144} (.35)$

$= 35$ LBS.

WIND PRESSURE, $P = .00256 (10)^2 \left(\frac{.83}{30}\right)^{2/7} (1.6)(1.3)$
(TRANSPORTER SIDE)

$P = .19$ LBS/FT²

$F_{WIND/TRANSPORTER} = \frac{20 \times 393.6}{144} (.19)$

$= 11$ LBS

TOTAL DRAWBAR REQ'D TO MOVE TRANSPORTER

EMPTY ON WHEELS = 2400 + 35 + 11 = 2446 LBS.

Attachment: 3
Calc. No.: 145579-B-CA-004
Rev. No.: 3
Sheet 1 of 3

AeroGo, Inc.
1170 Andover Park W. ■ Seattle, WA 98188-3909
206/575-3344 ■ Fax: 206/575-3505 ■ 800/426-4757

PROJECT AMEC
JOB NO. AG-40608
PREPARED BY ARA DATE 1/30/06
SHEET NO. 2 OF

DRAWBAR REQ'D TO MOVE BOX + TRANSPORTER ON AEROCASTERS

$F_2 = 272{,}000(.015) = 4080$ LBS.

WIND PRESSURE (BOX + TRANSPORTER)

$p = 0.00256(10)^2\left(\frac{5.76}{30}\right)^{2/7}(1.6)(1.3)$

$p = .33$ PSF

$F_{WIND} = \frac{139 \times 454}{144}(.33) = 145$ LBS

TOTAL DRAWBAR REQ'D = 4080 + 145 = 4225 LBS.

USE (2) AEROGO DRIVE AG4500JR REF. DWG. 47610

AVERAGE DRAWBAR PER DRIVE = 4300 LBS

AIR REQUIREMENT PER DRIVE:

TRACTION MOTOR - PSI± DV4-190-05 - 125 SCFM

STEERING MOTOR - GAST 6AM-NRV-11A - 70 SCFM

AVERAGE DRIVE SPEED = 37 FPM = .62 FPS

Attachment: 3
Calc. No.: 145579-B-CA-004
Rev. No.: 3
Sheet 2 of 3

amec

RECORD OF DISCUSSION

Date/Time:	4 October 2004 / 4.15 pm.	Project/File No:	145579 / 35.4.9.2
Between:	Tom Wilson	of:	AMEC (Trail Office)
and	John Massenburg	of:	AeroGo
Subject:	Area 35 / ICV Box : Air Pallet Data.		
Distribution:	Frank Sweet, Glyn Jones, Paul Meyer, Billy Merry, Michael Paul, Victor Lourenco.		

1. Changing the ICV Box weight from 95 tonnes to 100 tonnes will not change the size of the Air Pallet presently proposed.

2. The maximum total lateral force imposed by the air pallet is 4,000 lb (generated by 2 drive units).

Tom Wilson

Attachment:	3
Calc. No.:	145579-B-CA-004
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Sheet	3 of 3

AMEC Americas Limited
1385 Cedar Avenue
Trail, BC V1R 4C3
Tel (250) 368-2400
Fax (250) 368-2401
www.amec.com

145579-B-CA-004

Attachment 4

E-mail Containing Design Authority Ruling on ICV™ Box Curbs Performance Category

Paul Meyer (Trail)

Subject: FW: PC-1M

From: Leonard, Michael W
Sent: Thursday, March 24, 2005 5:09 PM
To: 'Luey, Ja-Kael'
Cc: Shuford, David H (Dave); Janicek, George P
Subject: FW: PC-1M

Ja-Kael,

As detailed below we have a concern that B-CA-004 is treating the box as PC-1M in the melt station (i.e., when it's on a Type D curb) and therefore neglecting the seismic response of a "Design Feature" for the release of dried waste and of toxic off-gas accidents while in the melt station.

Our DA recommends that the box and box support curbs be analyzed to PC-2 while in the melt area.

Please incorporate this comment into the ICV System design package RCRs and forward to the Trail guys ASAP.

Thanks,
ML

From: Janicek, George P
Sent: Monday, March 21, 2005 10:46 AM
To: Leonard, Michael W
Cc: Shuford, David H (Dave); Haq, Mian A
Subject: RE: PC-1M

Mike,

First of all, the PC-1M designation is only allowable for use for in-tank-farm retrieval project activities/facilities. This categorization was negotiated with ORP specifically for these projects. It currently is not available to the DBVS facilities under discussion.

That being said, I believe the curbs should be categorized as PC-0. That is, NPHs are not an issue.

However, in this same calculation the statement is made that the ICV box itself has the same categorization (PC-1M) as the curbs. This cannot be. If the box were sitting out on the storage pad, containing a monolithic block of immobilized waste (glass), then I believe we could successfully argue that it was PC-0, like the curbs. But, the box initially is acting as secondary containment for the dried waste being added to it during the melt process; for the molten glass itself; and, for the gases being generated (NOX) during melting. The PDSA credits the ICV box as a "design feature", meaning that it is not specifically Safety-Significant (SS), which would drive a PC-2 categorization, but is at least General-Service (GS), which would drive a, minimum, PC-1 categorization. But, as you should recall, we made a conservative call for the project and said that we would design all waste containing structures to a minimum PC-2. In keeping with this conservative approach, we should make the ICV box PC-2.

Mian, what structural qualification do you think is required for the ICV box during the fill/melt processing?

George

From: Leonard, Michael W
Sent: Friday, March 18, 2005 4:19 PM

Attachment	4
Calc. No.:	145579-B-CA-004
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Sheet	1 of 2

To: Janicek, George P
Cc: Shuford, David H (Dave)
Subject: PC-1M

George,

Can you please look at and comment on AMEC's use of PC-1M as the design criteria for the support curbs (pg. 2 of attached calc).

AMEC has used the logic that the boxes are inherently moveable (both within the DBVS site and off-site--i.e., transport to IDF) and are not *tied-down/anchored*; therefore, we do not *need* to design the box *storage area* & melt area curbs & foundations to withstand seismic.

Thanks,
ML

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06/02/2005

145579-B-CA-004

Attachment 5

Friction Coefficient Reference – from the AISC Manual of Steel Construction Load and Resistance Factor Design 3rd Edition 2001

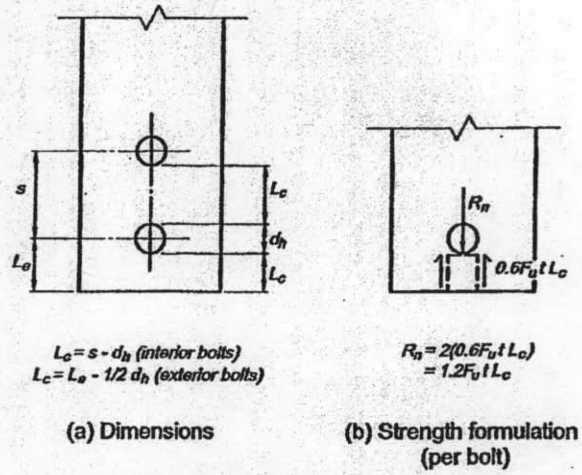

Figure. C-5.1. Bearing strength formulation.

5.4

When long slotted holes are oriented with the long dimension perpendicular to the direction of load, the bending component of the deformation in the material between adjacent holes or between the hole and the edge of the plate is increased. The nominal bearing strength is limited to $2dtF_u$, which [illegible] provides a bearing strength limit state that is attainable at reasonable deform[illegible]. The design bearing strength has been expressed as that of a single [illegible] although it is really that of the connected material that is immediately adj[illegible] the bolt. In calculating the design bearing strength of a connected part, the [illegible] bearing strength of the connected part can be taken as the sum of the [illegible] strengths of the individual bolts.

5.4. Design Slip Resistance

5.4.1. At the Factored-Load Level: The design slip resistance is ϕR_n, where ϕ is [illegible] defined below and:

$$R_n = \mu D_u T_m N_b \left(1 - \frac{T_u}{D_u T_m N_b}\right) \qquad \text{(Equation [illegible])}$$

where

ϕ = 1.0 for standard holes
= 0.85 for oversized and short-slotted holes
= 0.70 for long-slotted holes perpendicular to the direction [illegible]
= 0.60 for long-slotted holes parallel to the direction of load

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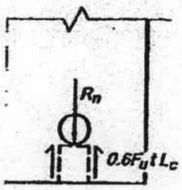

$R_n = 2(0.6F_u t L_c)$
$= 1.2F_u t L_c$

trength formulation
(per bolt)

formulation.

:esistance is ϕR_n, where

(Equa

ted holes
ndicular to the directio
el to the direction of lo

or A490 Bolts, June 23,
L CONNECTIONS

R_n	=	*nominal strength* (slip resistance) of a slip plane, kips;
μ	=	*mean slip coefficient* for Class A, B or C *faying surfaces*, as applicable, or as established by testing in accordance with Appendix A (see Section 3.2.2(b))
	=	0.33 for Class A *faying surfaces* (uncoated clean mill scale steel surfaces or surfaces with Class A coatings on blast-cleaned steel)
	=	0.50 for Class B surfaces (uncoated blast-cleaned steel surfaces or surfaces with Class B coatings on blast-cleaned steel
	=	0.35 for Class C surfaces (roughened hot-dip galvanized surfaces);
D_u	=	1.13, a multiplier that reflects the ratio of the mean installed bolt pretension to the specified minimum bolt pretension T_m; the use of other values of D_u shall be approved by the *Engineer of Record;*
T_m	=	specified minimum bolt pretension (for *pretensioned joints* as specified in Table 8.1), kips;
N_b	=	number of bolts in the *joint*; and
T_u	=	*required strength* in tension (tensile component of applied factored load for combined shear and tension loading), kips
	=	zero if the *joint* is subject to shear only

5.4.2. At the Service-Load Level: The service-load slip resistance is ϕR_s, where ϕ is as defined in Section 5.4.1 and:

$$R_s = \mu D T_m N_b \left(1 - \frac{T}{D T_m N_b}\right) \qquad \text{(Equation 5.7)}$$

where

D	=	0.80, a slip probability factor that reflects the distribution of actual slip coefficient values about the mean, the ratio of mean installed bolt pretension to the specified minimum bolt pretension, T_m, and a slip probability level; the use of other values of D must be approved by the *Engineer of Record*
T	=	applied service load in tension (tensile component of applied service load for combined shear and tension loading), kips
	=	zero if the *joint* is subject to shear only

and all other variables are as defined for Equation 5.6.

Commentary

The design check for slip resistance can be made either at the factored-load level (Section 5.4.1) or at the service-load level (Section 5.4.2). These alternatives are based upon different design philosophies, which are discussed below. They have been calibrated to produce results that are essentially the same. The factored-load level approach is provided for the expedience of only working with factored loads. Irrespective of the approach, the limit state is based upon the prevention of slip at service-load levels.

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Attachment 6

ICV™ Box Weight Summary from Calculation 145579-D-CA-010 Box Weight Calculations Revision F

CALCULATION SHEET

amec

CALC. NO.: ~~145579-D-CA-010~~ ~~REV.: F~~ ~~DATE: 20-Oct-05~~

CALC. TITLE: ICV™ Box Weight Calculations

PROJECT NO.: 145579 PROJECT TITLE: Final DBVS Design

f) Bottom Plate Stiffeners (transverse) – HSS 6"x6"x1/2"

3) Components for the lid (F-145579-35-D-0006):

a) Stiffeners – HSS 4"x2"x1/4"
b) Stiffeners – HSS 4"x2"x5/16"
c) Stiffeners – HSS 3"x3"x1/4"
d) Plate Throughout – 5/16"
e) 1 5/8" x 1 5/8" Unistrut
f) Stiffener Bar - 4" x 3/8"
g) Gussets - 30

Attachment: 6
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The weight break-down for each component is shown below:

Component	SolidWorks Model		Attachment 1	
Box Components	19486	lb	-	lb
Bolts	-	lb	50	lb
Steel in Box (Base)	-	lb	19069	lb
Welds	-	lb	198	lb
Lid	5120	lb	4737	lb
Electrodes	1268	lb	1273	lb
Insulation	189	lb	171	lb
Support Ribs & Bricks	6419	lb	6467	lb
Refractory	49824	lb	46748	lb
Sand	23095	lb	24424	lb
Solid Glass	93917	lb	93917	lb
Top-Off Soil (>10 in)	9984	lb	10547	lb
Melt Station Weight	209302	lb	207601	lb

Melt Station Weight	209302	lb
Grout (≈ 6 in)	8280	lb (calculated)
Storage Pad Weight	217582	lb

WT empty
= 217582 100% full
− 93917 glass
123665
− 8280 grout
115385
− 9984 top off
105401 net "empty"

P/Neym
2006·MAR·01

b) Starter Path:

The starter path is absorbed by the molten glass and therefore its weight

Typed names/dates in this box indicate the calculation has been signed off/approved and the originals have been placed in the Project files.

ORIGINATOR:	DATE:	CHECKER:	DATE:
Ryan Burrows	20-Oct-05	[signature]	20-Oct-05

M:\Demonstration Bulk VIT\Fiscal Year 2005 Work\Calculations DM.MACA-010 (ICV Box Weight)\Rev. F\145579-D-CA-010 Cover (Weight) Rev F.1.doc ~~Page 8 of 9~~

145579-B-CA-004

Attachment 7

ICC-ES Legacy Report 5608 - Hilti HDA Metric Self-Undercutting Concrete Anchors, and Manufacturer's Data

ES LEGACY REPORT

ER-5608*

Reissued February 1, 2004

ICC Evaluation Service, Inc.
www.icc-es.org

Business/Regional Office ▪ 5360 Workman Mill Road, Whittier, California 90601 ▪ (562) 699-0543
Regional Office ▪ 900 Montclair Road, Suite A, Birmingham, Alabama 35213 ▪ (205) 599-9800
Regional Office ▪ 4051 West Flossmoor Road, Country Club Hills, Illinois 60478 ▪ (708) 799-2305

Legacy report on the 1997 *Uniform Building Code™*

DIVISION: 03—CONCRETE
Section: 03151—Concrete Anchoring

HILTI HDA METRIC SELF-UNDERCUTTING CONCRETE ANCHORS

HILTI, INC.
5400 SOUTH 122ND EAST AVENUE
TULSA, OKLAHOMA 74146

1.0 SUBJECT

Hilti HDA Metric Self-undercutting Concrete Anchors.

2.0 DESCRIPTION

2.1 General:

The HDA is a self-undercutting-type concrete anchor. The anchor is available in pre-set (HDA-P) and through-set (HDA-T) configurations and is fabricated from carbon steel. Figures 1 and 2 illustrate available configurations. All carbon steel parts are electroplated with a 5μm-thick zinc coating in accordance with DIN 50961. Both configurations include a cone bolt, sleeve, washer and hex nut. Specifications for the anchors are provided in Table 1.

2.2 Components:

2.2.1 Cone Bolt: Produced from carbon steel conforming to DIN 931, Grade 8.8, the cone bolt is cold-formed with rolled threads on one end and a cone on the other end. Within the threaded part of the bolt there is a small area without thread. This area without thread carries the setting mark (expansion control) of the anchor rod. The rod end is covered by a plastic cap to protect the thread during the setting process. On the tip of the rod, above the bolt end, a code letter is stamped, which permits establishing the total embedded length of the anchor, as described in Table 1.

2.2.2 Expansion Sleeve: The sleeve is machined carbon steel conforming to AISI 4130. The expansion area of the sleeve is subdivided into six sections by means of longitudinal slots. Two of these expansion sections have brazed tungsten carbide tips for undercutting. In the joint where the expansion sections transition to the body of the sleeve, there is a retention ring of plastic.

2.2.3 Washer: The washer is formed from carbon steel conforming to DIN 6796.

2.2.4 Hex Nut: The hex nut is formed from carbon steel conforming to DIN 934, Grade 8.

2.2.5 Concrete: Normal-weight concrete must conform to Sections 1903 and 1905 of the 1997 *Uniform Building Code™* (UBC), with compressive strength in compliance with this report at the time of anchor installation.

2.3 Design:

2.3.1 Service Loads: Allowable service (allowable stress design) static shear and tension loads are described in Tables 3 and 4.

Service loads for anchors subjected to combined shear and tension forces are determined by the following equation:

$$(P_s/P_t)^{5/3} + (V_s/V_t)^{5/3} \leq 1$$

where:

P_s = Applied service tension load.

P_t = Allowable service tension load.

V_s = Applied service shear load.

V_t = Allowable service shear load.

For anchors installed at edge distances less than critical edge distance, c_{cr}, and/or anchor spacing less than critical spacing, s_{cr}, the load capacity is reduced in accordance with reduction factors in Table 2.

2.3.2 Strength Design: Strength design static shear and tension loads are determined in accordance with Sections 1923.2, 1923.3.2, 1923.3.3 and 1923.4 of the UBC. For the purposes of design, A_b in Section 1923.3.2 of the UBC shall be taken as A_t in Table 1, and f_u in Section 1923.3.2 of the UBC shall be taken as f_{ub} in Table 1. The limiting deflections used to determine the ultimate load in shear or tension are as follows:

M10: 0.39 inch (10 mm)

M12: 0.47 inch (12 mm)

M16: 0.63 inch (16 mm)

The design steel strength of the HDA-T in shear [pounds (N)] shall be calculated as follows:

$$V_{ss} = 0.60\, A_t\, f_{ub} + 0.40\, A_s\, f_{us}$$

where:

A_t = Area of bolt as given in Table 1 (in²/mm²).

f_{ub} = Ultimate tensile strength of the bolt as given in Table 1 (psi/MPa).

*Corrected April 2004

Attachment: 7
Calc. No.: 145579-B-CA-004
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Sheet 1 of 8

A_{sl} = Cross-sectional area of the sleeve as given in Table 1 (in²/mm²).

$f_{u,sl}$ = Ultimate tensile strength of the sleeve as given in Table 1 (psi/MPa).

2.4 **Installation:**

Installation details for the HDA pre-set and through-set anchors are described in Tables 1 and 2 and in Figures 3, 4, 5 and 6. Stepped drill bits are supplied by Hilti, Inc., and are described in Table 1.

2.5 **Special Inspection:**

Where special inspection is required, compliance with Section 1701.5.2 of the UBC is necessary. The special inspector shall verify anchor type, anchor dimensions, concrete type, concrete compressive strength, hole dimensions, anchor spacing, edge distances, slab thickness, anchor embedment and anchor installation procedures (including the undercutting process and position of red setting mark).

2.6 **Identification:**

The label on packages of anchors includes the manufacturer's name (Hilti, Inc.) and address, the anchor name, the anchor size, the evaluation report number (ER-5608), and the name of the quality control agency (Underwriters Laboratories Inc.). Each anchor has the letters HDA-P or HDA-T, the anchor rod size, and the maximum fastened thickness embossed on the sleeve. As described in Section 2.2.1, on the tip of the rod, above the bolt end, a code letter is stamped, which permits establishing the total length of the anchor set in concrete.

3.0 EVIDENCE SUBMITTED

Reports of tension, shear and seismic load tests and mechanical properties tests; calculations; and quality control manual.

4.0 FINDINGS

That the Hilti HDA anchor system described in this report complies with the 1997 *Uniform Building Code*™ (UBC), subject to the following conditions:

4.1 Anchor sizes, dimensions and minimum embedment depths are as set forth in the tables of this report.

4.2 Loads applied to the anchors are adjusted in accordance with Sections 1909.2 and 1923.2 of the code for strength design and 1612.3 of the UBC for service design.

4.3 The anchors are installed in accordance with the manufacturer's instructions and this report.

4.4 Prior to installation, calculations and details demonstrating compliance with this report shall be submitted to the local building official for approval.

4.5 Design loads are as set forth in Section 2.3 of this report.

4.6 Special inspection is provided in accordance with Section 2.5 of this report.

4.7 Fire-resistive construction: Anchors are not permitted for use in conjunction with fire-resistive construction. Exceptions would be:

- **Anchors resist wind or seismic loading only.**
- **For other than wind or seismic loading, special consideration is given to fire exposure conditions.**

4.8 Fatigue and shock loading: Since an ICC-ES acceptance criteria for evaluating data to determine the performance of expansion anchors subjected to fatigue or shock loading is unavailable at this time, the use of these anchors under these conditions is beyond the scope of this report.

4.9 Cracked concrete or masonry: Since an ICC-ES acceptance criteria for evaluating the performance of anchors in cracked concrete or masonry is unavailable at this time, the use of anchors is limited to installation in uncracked concrete or masonry. Cracking occurs when $f_t > f_r$ due to service loads or deformations.

4.10 Use of the anchors is limited to dry, interior exposure.

4.11 Use of anchors in resisting earthquake or wind loads is permitted within the scope of this report. Section 4.2 references adjustments to the applied loads.

4.12 HDA self-undercutting anchors are manufactured by Hilti at their facilities in Schaan, Liechtenstein, with quality control inspections by Underwriters Laboratories Inc. (AA-637).

This report is subject to re-examination in two years.

TABLE 1—SPECIFICATION TABLE

ANCHOR SIZE	HDA-T/HDA-P	M10 x 100/20	M12 x 125/30	M12 x 125/50	M16 x 190/40	M16 x 190/60
Stop drill bit for HDA-T		TEC-HDA-B 20 x 120	TEC-HDA-B 22 x 155	TEC-HDA-B 22 x 175	TEY-HDA-B 30 x 230	TEY-HDA-B 30 x 250
Stop drill bit for HDA-P		TEC-HDA-B 20 x 120	TEC-HDA-B 22 x 125	TEC-HDA-B 22 x 125	TEY-HDA-B 30 x 190	TEY-HDA-B 30 x 190
Setting tool		TEC-HDA-ST 20-M10	TEC-HDA-ST 22-M12	TEC-HDA-ST 22-M12	TEY-HDA-ST 30-M16	TEY-HDA-ST 30-M16
h: Thickness of base material, min.[1]	mm (in.)	150 (6)	188 ($7^{3}/_{8}$)	188 ($7^{3}/_{8}$)	285 ($11^{1}/_{4}$)	285 ($11^{1}/_{4}$)
l: Total anchor length	mm (in.)	150 (5.90)	190 (7.48)	210 (8.27)	275 (10.83)	295 (11.61)
Length I.D. code[2]	letter	I	L	N	R	S
t_{fix}: Fastening thickness HDA-T, min.[3] HDA-T, max. HDA-P, max.	 mm (in.) mm (in.) mm (in.)	 10 (0.39) 20 (0.79) 20 (0.79)	 10 (0.39) 30 (1.18) 30 (1.18)	 10 (0.39) 50 (1.97) 50 (1.97)	 15 (0.59) 40 (1.58) 40 (1.58)	 15 (0.59) 60 (2.36) 60 (2.36)
d_{o}: Nom. dia. of drill bit[4]	mm (in.)	20 (0.787)	22 (0.866)	22 (0.866)	30 (1.181)	30 (1.181)
h_1: Min. depth of drill hole	mm (in.)	107 (4.21)	134.5 (5.30)	134.5 (5.30)	203 (7.99)	203 (7.99)
h_{ef}: Effective anchoring depth	mm (in.)	100 (3.94)	125 (4.92)	125 (4.92)	190 (7.48)	190 (7.48)

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TABLE 1—SPECIFICATION TABLE (Continued)

ANCHOR SIZE	HDA-T/HDA-P	M10 x 100/20	M12 x 125/30	M12 x 125/50	M16 x 190/40	M16 x 190/60
d_f: Recommended clearance hole (min.)						
HDA-T	mm (in.)	21 (13/16)	23 (7/8)	23 (7/8)	32 (1 1/4)	32 (1 1/4)
HDA-P	mm (in.)	12 (1/2)	14 (9/16)	14 (9/16)	18 (11/16)	18 (11/16)
d_o: Anchor diameter						
HDA-T	mm (in.)	19 (0.748)	21 (0.827)	21 (0.827)	29 (1.142)	29 (1.142)
HDA-P	mm (in.)	10 (0.394)	12 (0.472)	12 (0.472)	16 (0.630)	16 (0.630)
d_w: Washer diameter	mm (in.)	27.5 (1.08)	33.5 (1.32)	33.5 (1.32)	45.5 (1.79)	45.5 (1.79)
S_w: Width across flats of the nut	mm (in.)	17 (0.669)	19 (0.748)	19 (0.748)	24 (0.945)	24 (0.945)
T_{max}: Max. tightening torque[5]	N-m (ft.-lb.)	50 (37)	80 (59)	80 (59)	120 (88)	120 (88)
Sleeve properties						
A_s: Cross sectional area	mm² (in.²)	196 (0.304)	223 (0.346)	223 (0.346)	445 (0.690)	445 (0.690)
S_s: Elastic section modulus	mm³ (in.³)	596 (0.0364)	779 (0.0475)	779 (0.0475)	2110 (0.1288)	2110 (0.1288)
Bolt properties						
A_b: Bolt nominal area	mm² (in.²)	78.5 (0.122)	113 (0.175)	113 (0.175)	201 (0.312)	201 (0.312)
A_t: Bolt tension area	mm² (in.²)	58 (0.090)	84.3 (0.131)	84.3 (0.131)	157 (0.243)	157 (0.243)
S_b: Elastic section modulus	mm³ (in.³)	67 (0.0041)	117 (0.0071)	117 (0.0071)	293 (0.0179)	293 (0.0179)
A_{brg}: Undercut bearing area[6]	mm² (in.²)	234.1 (0.363)	291.6 (0.452)	291.6 (0.452)	496.9 (0.770)	496.9 (0.770)
$f_{u,s}$: Sleeve ultimate tensile strength	MPa (psi)	850 (123,250)	850 (123,250)	850 (123,250)	700 (101,500)	700 (101,500)
$f_{u,b}$: Bolt ultimate tensile strength	MPa (psi)	800 (116,000)	800 (116,000)	800 (116,000)	800 (116,000)	800 (116,000)

[1]Minimum concrete base material thickness as required to avoid splitting of concrete.
[2]Length code correlating to total anchor length, ℓ.
[3]Minimum thickness of fastened part as required to ensure engagement of full sleeve cross section in shear.
[4]Metric drill bit supplied by Hilti must be used.
[5]Torque tightening of the anchor is not required for proper set. Torque tightening may reduce initial slip under load.
[6]Bearing area conforms to Section 1923.3.1 of the code.

HILTI RECOMMENDED HAMMER DRILLS FOR SETTING						
Anchor Size	HDA-T/HDA-P	M10 x 100/20	M12 x 125/30	M12 x 125/50	M16 x 190/40	M16 x 190/60
Drilling system for anchor setting		TE24, TE25 first gear			TE75 max. hammering power	
Single impact energy	Joules (ft.-lb.)	3.7 - 4.7 (2.7 - 3.5)			7.0 - 9.0 (5.2 - 6.6)	
Speed under load	rpm	250 - 500			150 - 350	

Setting Details

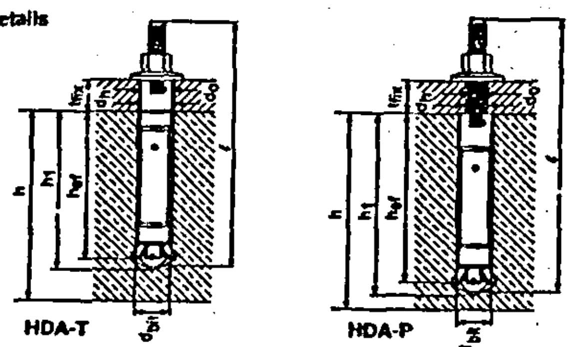

TABLE 2—HDA-P AND HDA-T ANCHOR SPACING AND EDGE DISTANCE GUIDELINES

GUIDELINE TYPE	LOAD CONDITION (Style)	CRITICAL (inches)			MINIMUM (inches)		
		M10	M12	M16	M10	M12	M16
Spacing (S)	Tension and shear	$3.0 \times h_{ef} = 11.81$	$3.0 \times h_{ef} = 14.76$	$3.0 \times h_{ef} = 22.44$	$1.0 \times h_{ef} = 3.94$	$1.0 \times h_{ef} = 4.92$	$1.0 \times h_{ef} = 7.48$
Edge (C)	Tension for HDA-P and HDA-T and shear for HDA-P	$1.5 \times h_{ef} = 5.91$	$1.5 \times h_{ef} = 7.38$	$1.5 \times h_{ef} = 11.22$	$0.8 \times h_{ef} = 3.15$	$0.8 \times h_{ef} = 3.94$	$0.8 \times h_{ef} = 5.98$
Edge (C)	Shear for HDA-T	$2.0 \times h_{ef} = 7.87$	$2.0 \times h_{ef}$ 9.84	$2.0 \times h_{ef} = 14.95$	$0.8 \times h_{ef} = 3.15$	$0.8 \times h_{ef} = 3.94$	$0.8 \times h_{ef} = 5.98$

For SI: 1 inch = 25.4 mm.

Notes:
1. When using minimum spacing and the load condition is either tension or shear, reduce the allowable service load by 13%.
2. When using minimum edge distance and the load condition is tension for HDA-P and HDA-T or shear for the HDA-P, reduce the allowable service load by 9%.
3. When using minimum edge distance and the load condition is shear for the HDA-T, reduce the allowable service load by 74%.

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TABLE 3—HDA-P AND HDA-T METRIC ALLOWABLE SERVICE TENSION LOAD VALUES FOR NORMAL-WEIGHT CONCRETE (pounds)

ANCHOR SIZE (mm)	EMBEDMENT DEPTH (inches)	$f'_c \geq 2,500$ psi		MAXIMUM DEFLECTION (inch)
		Special Inspection	Without Special Inspection	
M10	4	2,640	1,320	0.043
M12	5	3,988	1,994	0.052
M16	7.5	7,155	3,578	0.055

For SI: 1 inch = 25.4 mm, 1 psi = 6.895 × 10⁻³ MPa, 1 lbf = 4.45 N.

Notes:
1. The tabulated shear and tension loads are for anchors installed in structural normal-weight concrete having the tabulated ultimate compressive strength at the time of anchor installation.
2. Special inspection is provided in accordance with Section 2.5 of this report.
3. Minimum concrete thickness, *h*, must be in accordance with Table 1.

TABLE 4—HDA METRIC ALLOWABLE SERVICE SHEAR LOAD VALUES FOR NORMAL-WEIGHT CONCRETE (pounds)

ANCHOR SIZE (mm)	EMBEDMENT DEPTH (inches)	$f'_c \geq 2,500$ psi		MAXIMUM DEFLECTION (inch)
		HDA-P	HDA-T	
M10	4	1,630	4,688	0.071
M12	5	2,378	5,113	0.071
M16	7.5	4,233	9,200	0.087

For SI: 1 inch = 25.4 mm, 1 psi = 6.895 × 10⁻³ MPa, 1 lbf = 4.45 N.

Notes:
1. The tabulated shear and tension loads are for anchors installed in normal-weight concrete having the tabulated ultimate compressive strength at the time of anchor installation.
2. Special inspection is provided in accordance with Section 2.5 of this report.
3. Minimum concrete thickness, *h*, must be in accordance with Table 1.

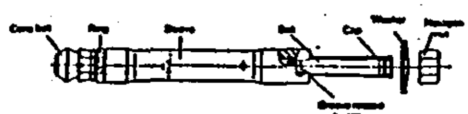

FIGURE 1—"PRE-SET"

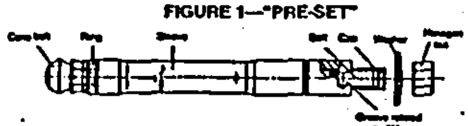

FIGURE 2—"THROUGH-SET"

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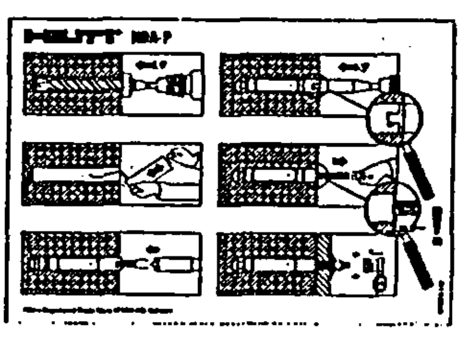

FIGURE 3—INSTALLATION INSTRUCTIONS FOR HDA-P

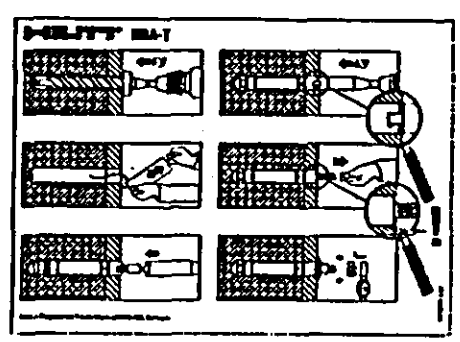

FIGURE 4—INSTALLATION INSTRUCTIONS FOR HDA-T

Description of the setting procedure for the HDA-P (pre-setting) and HDA-T (through-fastening) anchors.

Pictogram 1:
With a stop drill bit assigned to the anchor (tables 2 and 5), a hole with defined depth is produced.

Pictogram 2:
The hole has to be cleaned with a pump.

Pictogram 3:
The anchor is placed in the hole, so that the cone sits on the bottom of the bore hole. Then the setting tool assigned to the anchor (tables 2 and 6) is attached to the rotary hammer drill, which has been used for drilling the hole. The setting tool is guided over the anchor rod, so that the noses on the end of the setting tool catch the groove in the sleeve.

Pictogram 4:
The anchor is set rotating and hammering analogously to the drilling procedure. During the setting procedure, the sleeve shifts axially to the anchor rod and at the same time the undercut is made in the concrete. On the setting tool, there is a red ring as a first setting mark. This mark can give the user a clue, how far the setting procedure has progressed. If this marking is flush with the concrete surface for the pre-setting style and with the connected part for the through-fastening, the setting procedure should be finished soon.

Pictogram 5:
Mandatory for a correct setting procedure is the setting marking on the anchor rod. The anchor is set and the undercut is completely produced, as soon as the red setting marking on the anchor bolt is visible above the top edge of the sleeve.

Pictogram 6:
The part to be fastened is secured by tightening the torque.

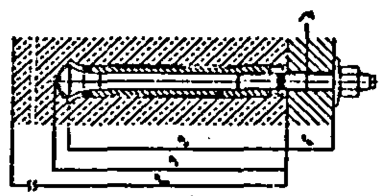

FIGURE 5—PRE-SETTING ANCHOR HDA-P (PREPOSITIONING)

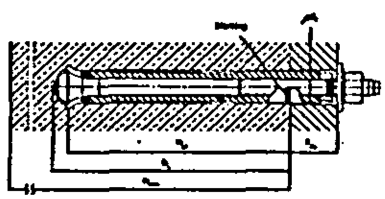

FIGURE 6—THROUGH-SETTING ANCHOR HDA-T (POSTPOSITIONING)

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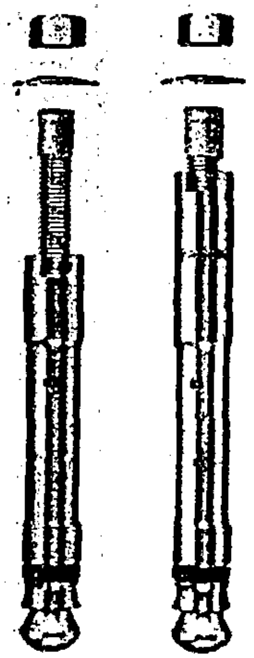


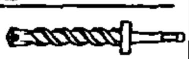
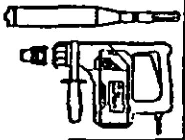
HDA-P
Heavy-Duty Undercut Anchor (Pre-Set Type)

HDA-T
Heavy-Duty Undercut Anchor (Through-Set Type)

Listings/Approvals

ICC-ES (International Code Council) ER-5608
COLA (City of Los Angeles) Research Report No. 25422
European Technical Approval ETA-99/0009

Components

- Stop Drill Bit 
- Setting Tool 
- Rotary Hammer Drill 

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4.3.1.1 Product Description

The Hilti HDA Undercut Anchor is a heavy duty mechanical undercut anchor whose undercut segments incorporate carbide tips so as to perform a self-undercutting process designed to develop a ductile steel failure. The HDA system includes either preset (HDA-P) or through-set (HDA-T) style anchors, stop drill bits, setting tool, and roto-hammer drill for four metric bolt sizes: M10 (3/8"), M12 (1/2"), M16 (5/8") and M20 (3/4"). The HDA is available in a sherardized and 316 stainless steel versions for outdoor environments. Each size/style is offered in two lengths to accommodate various material thicknesses to be fastened (except M10).

Product Features

- Undercut segments provide cast-in-place like performance with limited expansion stresses
- Ductile high strength anchor for safety related, heavy duty fastenings/predictable failure modes
- Self-undercutting wedges provide an easy, fast and reliable anchor installation
- Excellent performance in cracked concrete (tension zones, earthquake-resisting structures)
- Undercut keying load transfer allows for reduced edge distances and anchor spacings
- Through-set style provides increased shear capacity
- Fully removable
- Sherardized (53 μm zinc) and 316 stainless steel for corrosive environments
- Sherardized zinc coating has equivalent corrosion resistance to hot dipped galvanizing

Guide Specifications

Undercut Anchors Undercut anchors shall be of an undercut style with brazed tungsten carbides on the embedded end that perform the self-undercutting process. Undercut portion of anchor shall have a minimum projected bearing area equal to or greater than 2.5 times the nominal bolt area. The bolt shall conform to ISO 898 class 8.8 strength requirements. Anchors dimensioned and supplied by Hilti.

Installation Refer to 4.3.1.3 and 4.3.1.4.

4.3.1.2 Material specifications

	Mechanical Properties	
	f_y ksi (MPa)	min. f_u ksi (MPa)
HDA-T/-TF/-P/-PF carbon steel cone bolt; M10, M12, M16 and M20 meets strength requirements of ISO 898, class 8.8	92.8 (640)	116 (800)
HDA-T/-TF/-P/-PF carbon steel sleeve; M10 & M12 conforms to European Standard No. 25CrMoS4	–	123.3 (850)
HDA-T/-TF/-P/-PF carbon steel sleeve; M16 conforms to European Standard No. 25CrMoS4	–	101.5 (700)
HDA-T/-TF/-P/-PF carbon steel sleeve; M20 conforms to European Standard No. 25CrMoS4	–	79.8 (550)
HDA-TR/-PR stainless steel cone bolt; M10, M12 and M16 conforms to AISI 316 or 316 Ti	87 (600)	116 (800)
HDA-TR/-PR stainless steel sleeve; M10 and M12 conforms to AISI 316 or 316 Ti	–	123.3 (850)
HDA-TR/-PR stainless steel sleeve; M16 conforms to AISI 316 or 316 Ti	–	101.5 (700)
HDA-T/-TF/-P/-PF nut conforms to DIN 934, grade 8		
HDA-TR/-PR nut conforms to DIN 934, grade A4-80		
HDA-T/-TF/-TR/-P/-PF/-PR washer conforms to DIN 6796		
HDA-T/-P components are electroplated min. 5 mm zinc		
HDA-TF/-PF sherardized components have average 53 mm zinc		

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4.3.1.3.2.3 Allowable Stress Design

Combined Shear and Tension Loading

$$\left(\frac{N_d}{N_{rec}}\right)^{5/3} + \left(\frac{V_d}{V_{rec}}\right)^{5/3} \leq 1.0$$

HDA, HDA-R and HDA-F Undercut Anchor Allowable Tension Loads in Normal Weight Concrete

Anchor Size, mm	Concrete Capacity[2] Embedment Depth, mm (in.)	$f_c \geq$ 17.4 MPa (2,500 psi) Tension, kN (lb)	Steel Capacity[1] Tension, kN (lb)
M10	100 (4)	15.4 (3,466)	20.7 (4,660)
M12	125 (5)	23.3 (5,235)	29.8 (6,710)
M16	190 (7.5)	40.9 (9,187)	53 (11,930)
M20	250 (9.8)	68 (15,287)	83 (18,645)

HDA, HDA-R and HDA-F Undercut Anchor Ultimate Tension Loads in Normal Weight Concrete[3]

Anchor Size, mm	Concrete Capacity[2] Embedment Depth, mm (in.)	$f_c \geq$ 17.4 MPa (2,500 psi) Tension, kN (lb)
M10	100 (4)	47 (10,560)
M12	125 (5)	71 (15,954)
M16	190 (7.5)	127 (28,621)
M20	250 (9.8)	204 (45,744)

1 Provided the anchor is placed at or greater than critical edge and spacing distances, the steel capacity can be used. Steel capacity is based on the minimum mechanical properties, and calculated per AISC equation: 0.33AgFu.

2 When edge or spacing influence factors are involved, apply them to concrete capacity values.

3 All ultimate load values represent the average values obtained in testing.

HDA, HDA-R and HDA-F Undercut Anchor Allowable[2] Shear Loads in Concrete

Anchor Size, mm	Embedment Depth, mm (in.)	$f_c \geq$ 17.4 MPa (2,500 psi) Shear, kN (lb)	
		HDA-P	HDA-T
M10	100 (4)	4.6 (1,027)	28.7 (6,453)
M12	125 (5)	12.2 (2,750)	31.2 (7,005)
M16	190 (7.5)	23.3 (5,240)	52.6 (11,835)
M20	250 (9.8)	33.2 (7,460)	81.0 (18,210)

HDA, HDA-R and HDA-F Undercut Anchor Ultimate Shear Loads in Concrete[1]

Anchor Size, mm	Embedment Depth, mm (in.)	$f_c \geq$ 17.4 MPa (2,500 psi) Shear, kN (lb)	
		HDA-P	HDA-T
M10	100 (4)	29 (6,516)	96 (21,640)
M12	125 (5)	42 (9,510)	130 (29,140)
M16	190 (7.5)	75 (16,930)	221 (49,700)
M20	250 (9.8)	120.6 (27,100)	313 (70,400)

1 All ultimate loads represent the average values obtained in testing

2 Allowable loads determined by 5% fractile. See Section 2.2.3.

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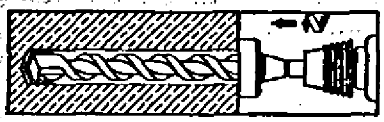
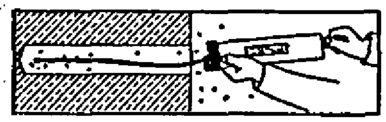
4.3.1.4 Installation Instructions

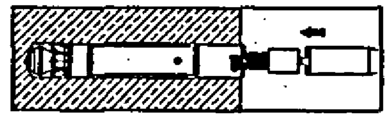
Setting Operation HDA-P/-PR/-PF (Pre-Set Style)



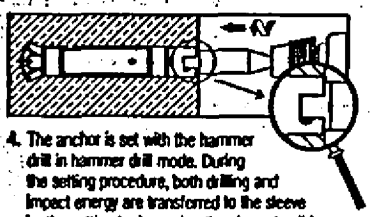
1. Drill a hole to the required depth using a stop drill bit matched to the anchor, (refer to specification table and ordering info.). If rebar is encountered, use a Hilti metric matched tolerance diamond core bit to drill through the rebar. Remove the concrete core and finish drilling the hole with the stop drill bit.



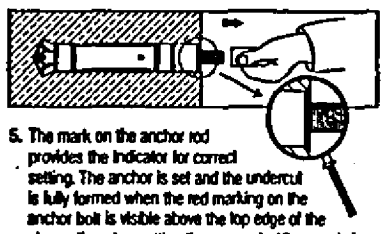
2. Clean hole with compressed air or a hand air pump such that drilling debris is evacuated.



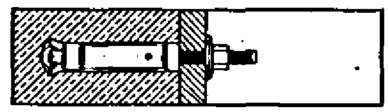
3. The anchor is inserted in the hole, so that the cone sits on the bottom of the drilled hole. Do not remove the plastic cap which protects the threaded rod. Using the assigned setting tool and Hilti Hammer Drill (Refer to spec. Table and Ordering Info.), the setting tool is guided over the anchor rod and engages the grooves in the sleeve. It is critical to use the specified Hilti hammer drills.



4. The anchor is set with the hammer drill in hammer drill mode. During the setting procedure, both drilling and impact energy are transferred to the sleeve by the setting tool, causing the sleeve to slide over the conical end of the anchor bolt while forming the undercut in the base material. On the setting tool, the red ring indicates the progress of the setting operation.

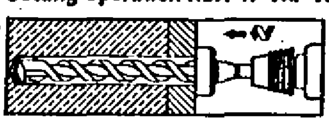


5. The mark on the anchor rod provides the indicator for correct setting. The anchor is set and the undercut is fully formed when the red marking on the anchor bolt is visible above the top edge of the sleeve. If anchor setting time exceeds 40 seconds for M10 or M12 anchors or 60 seconds for M16 or M20 anchors, remove the anchor (see HDA removal tool instructions). Install a new HDA anchor.

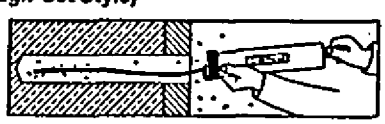


6. Remove the plastic thread protector cap. Secure the part to be fastened by using the conical spring washer and nut provided. Apply a torque not to exceed the ~~maximum values given in the Specification Table.~~ Torque is not required to set the anchor.

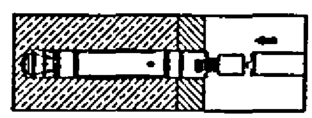
Setting Operation HDA-T/-TR/-TF (Through-Set Style)



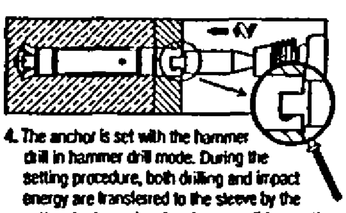
1. Drill a hole to the required depth using a stop drill bit matched to the anchor, (refer to specification table and ordering info.). If rebar is encountered, use a Hilti metric matched tolerance diamond core bit to drill through the rebar. Remove the concrete core and finish drilling the hole with the stop drill bit.



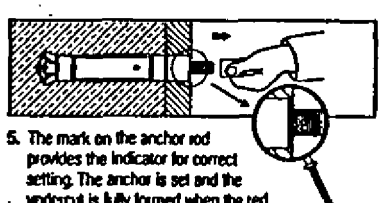
2. Clean hole with compressed air or a hand air pump such that drilling debris is evacuated.



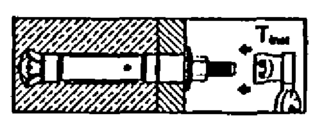
3. The anchor is inserted in the hole, so that the cone sits on the bottom of the drilled hole. Do not remove the plastic cap which protects the threaded rod. Using the assigned setting tool and Hilti Hammer Drill (Refer to spec. Table and Ordering Info.), the setting tool is guided over the anchor rod and engages the grooves in the sleeve. It is critical to use the specified Hilti hammer drills.



4. The anchor is set with the hammer drill in hammer drill mode. During the setting procedure, both drilling and impact energy are transferred to the sleeve by the setting tool, causing the sleeve to slide over the conical end of the anchor bolt while forming the undercut in the base material. On the setting tool, the red ring indicates the progress of the setting operation. When this marking is flush with the connected part, check the anchor for proper setting (refer to step 5).



5. The mark on the anchor rod provides the indicator for correct setting. The anchor is set and the undercut is fully formed when the red marking on the anchor bolt is visible above the top edge of the sleeve. If anchor setting time exceeds 40 seconds for M10 or M12 anchors or 60 seconds for M16 or M20 anchors, remove the anchor (see HDA Removal Tool instructions). Install a new HDA anchor.



6. Remove the plastic thread protector cap. Secure the part to be fastened by using the conical spring washer and nut provided. Apply a torque not to exceed the ~~maximum values given in the Specification Table.~~ Torque is not required to set the anchor.

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Rev. No.: 3
Sheet 8 of 8

145579-B-CA-004

Attachment 8

Effect of Heat on Structural Steel and Box Design Temperature References from ASD Design Manual and ICV Box Structural Analysis (Calculation 145579-D-CA-011 Rev. 1)

CALCULATION SHEET amec

CALC. NO.: ~~145579-D-CA-011~~	~~REV:~~ ~~1~~	~~DATE: January 24, 2006~~	
CALC. TITLE: ~~ICV™ Box Structural Analysis~~			
PROJECT NO.: 145579	PROJECT TITLE: Final DBVS Design		

1 INTRODUCTION

1.1 PURPOSE

The purpose of this calculation is to verify adequate strength of all members in the ICV™ Box and lid design for the projected load conditions they will be subjected to. The plate thickness and stiffeners are examined for stress at two temperatures, 662°F (350°C) and 1058°F (570°C). This calculation provides a breakdown for each section of the box (i.e. lid, sides, ends and floor) and, if areas of concern are identified, will specify modifications to the material selection and spacing of structural members for the current design of the ICV™ Box. An analysis of the lifting points is completed and the results stated.

1.2 SCOPE

The scope of this calculation is the analysis of the structural integrity of the ICV™ Box for the following conditions:

- Lifting of the box when empty.
- Box at melt station (analyzed at two ICV™ box surface temperatures).
- Lifting of the box when filled with material (refractory, glass, top-off soil, and void space filler).

Additional discussion of each condition is provided in the body of the calculation and in the Results and Conclusions section.

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Calc. No.: 145579-B-CA-004
Rev. No.: 3
Sheet 1 of 3

2 BASIS

2.1 DESIGN INPUTS

1. Box surface temperatures = 662°F (350°C) and 1058°F (570°C). Box surface temperature of 662°F is an anticipated upper value during normal operating conditions. A higher value of 1058°F represents point at which the yield strength of steel is significantly diminished. Note that this upper value also bounds the results from calculation 145579-D-CA-001, which determined the box skin temperature for normal and upset conditions.
2. Specific Gravity of glass = 2.65. Specific gravity of top-off soil = 1.43. From F-145579-00-A-0021, Rev. 0J, *Full DBVS Feed Preparation & Melt Process Flow Diagram.*

Typed names/dates in this box indicate the calculation has been signed off/approved and the originals have been placed in the Project files.

ORIGINATOR:	DATE:	CHECKER:	DATE:
[signature]	1/24/06	[signature]	1-24-06

amec	CALCULATION SHEET	Project Number: 145579
~~Calculation No. 145579-B-CA-011~~ ~~Attachment No. 1~~ ~~Calculation Title: ICV™ Box Structural Analysis~~ ~~Rev. No. 1~~		Originator: ~~James Van Corbach~~ JVC ~~Date: January 24, 2006~~ Checker: ~~Mike Custer~~ MCC Date: 1/24/06 ~~Page 2 of 10~~

Determine Heat effects on the ICV Box Steel

Analysis of ICV Box will be at two temperatures as indicated below.

$T_1 := 662°F$

$T_2 := 1058°F$

As listed in *AISC ASD* page 6-3, the yield strength of ratios for carbon steel at elevated temperatures are approximately 0.77 at 800°F, 0.63 at 1000°F and 0.37 at 1200°F. Use straight line interpolation to determine the yield strength ratio of steel for the temperatures as listed above. Using the yield strength ratio of 1.0 at an assumed ambient temperature of 60°F, results in the following yield strength reductions:

$$\delta_1 := \frac{662°F - 60°F}{\frac{800°F - 60°F}{0.77 - 1.0}} + 1.0 \qquad \delta_1 = 0.81$$

Reduction of yield strength as a result of the lower bounding temperature.

$$\delta_2 := \frac{1058°F - 1000°F}{\frac{1200°F - 1000°F}{0.37 - 0.63}} + 0.630 \qquad \boxed{\delta_2 = 0.55}$$

Reduction of yield strength as a result of the higher bounding temperature.

The modulus of elasticity will change with temperature but AISC does not give any guidance on the values to use at elevated temperatures. Use *ASME B&PV Code IID*, to determine the values at the temperatures as listed above. The modulus of elasticity of Carbon steel is $26.5x10^6$ at 600°F, $25.5x10^6$ at 700°F, $20.4x10^6$ at 1000°F, and $18.0x10^6$ at 1100°F. Use straight line interpolation to determine the value.

$E := 29000psi$

Modulus of Elasticity at ambient temperatures, *AISC ASD, page 6-30.*

$$E_1 := \frac{662°F - 600°F}{\frac{700°F - 600°F}{25500ksi - 25600ksi}} + 25600ksi \qquad E_1 = 25538\,ksi$$

Modulus of elasticity of steel at 662°F, *ASME B&PV Code Section II Part D Subpart 2*, see Attachment 2, page 2.

$$E_2 := \frac{1058°F - 1000°F}{\frac{1100°F - 1000°F}{18000ksi - 20400ksi}} + 20400ksi \qquad E_2 = 19008\,ksi$$

Modulus of elasticity of steel at 1058°F, *ASME B&PV Code Section II Part D Subpart 2*, see Attachment 2, page 2.

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GAGES
s of an inch

... Standard Gage for Uncoated ...t & Cold ...ed Sheets[a]	Galvanized Sheet Gage for Hot-Dipped Zinc Coated Sheets[b]	USA Steel Wire Gage
.0897	.0934	.092*
.0747	.0785	.080
.0673	.0710	.072
.0598	.0635	.062*
.0538	.0575	.054
.0478	.0516	.048*
.0418	.0456	.041
.0359	.0396	.035*
.0329	.0366	—
0299	.0336	—
0269	.0306	—
0239	.0276	—
0209	.0247	—
0179	.0217	—
0164	.0202	—
0149	.0187	—
—	.0172	—
—	.0157	—

STM A510 "General Require-
r". Sizes originally quoted to 4
al places in accordance with
29.
duct is commonly specified to

URE FOR
TEEL

1.)

Over 8 To 12	Over 12 To 48	Over 48
Plate	Plate	Plate
Strip	Sheet	Plate
Strip	Sheet	Plate
Strip	Sheet	Sheet

sheet and strip not generally
these widths and thicknesses

EFFECT OF HEAT ON STRUCTURAL STEEL

Short-time elevated-temperature tensile tests on the constructional steels permitted by the AISC Specification indicate that the ratios of the elevated-temperature yield and tensile strengths to their respective room-temperature strength values are reasonably similar at any particular temperature for the various steels in the 300 to 700° F. range, except for variations due to strain aging. (The tensile strength ratio may increase to a value greater than unity in the 300 to 700° F. range when strain aging occurs.) Above this range, the ratio of elevated-temperature to room-temperature strength decreases as the temperature increases.

The composition of the steels is usually such that the carbon steels exhibit strain aging with attendant reduced notch toughness. The high-strength low-alloy and heat-treated constructional alloy steels exhibit less-pronounced or little strain aging.

As examples of the decreased ratio levels obtained at elevated temperature, the yield strength ratios for carbon and high-strength low-alloy steels are approximately 0.77 at 800° F., 0.63 at 1000° F., and 0.37 at 1200° F.

FIRE-RESISTANT CONSTRUCTION

ASTM Specification E119, *Standard Methods of Fire Tests of Building Construction and Materials*, outlines the procedures of fire testing of structural elements located inside a building and exposed to fire within the compartment or room in which they are located. The temperature criterion used requires that the average of the temperature readings not exceed 1000° F. for columns and 1100° F. for beams. An individual temperature reading may not exceed 1100° F. for columns and 1200° F. for beams.

Steel buildings whose condition of exterior exposure and whose combustible contents under fire hazards will not produce a steel temperature greater than the foregoing criteria may therefore be considered fire-resistive without the provision of insulating protection for the steel.

A fire exposure of severity and duration sufficient to raise the temperature of the steel much above the fire test criteria temperature will seriously impair its ability to sustain loads at the unit stresses or plasticity load factors permitted by the AISC Specification. In such cases, the members upon which the stability of the structure depends should be insulated by fire-resistive materials or construction capable of holding the average temperature of the steel to not more than that specified for the fire test standard.

Under the E119 specification, each tested assembly is subjected to a standard fire of controlled extent and severity. The fire resistance rating is expressed as the time, in hours, that the assembly is able to withstand the fire exposure before the first critical point in its behavior is reached. These tests indicate the minimum period of time during which structural members, such as columns and beams, are capable of maintaining their strength and rigidity when subjected to the standard fire. They also establish the minimum period of time during which floors, roofs, walls or partitions will prevent fire spread by protecting against the passage of flame, hot gases and excessive heat.

Tables of fire resistance ratings for various insulating materials and constructions applied to structural elements are published in the AISI booklets *Fire Resistant Steel Frame Construction, Designing Fire Protection for Steel Columns* and *Designing Fire Protection for Steel Trusses*. Ratings may also be found in publications of the Underwriters' Laboratories, Inc.

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Attachment 9

Estimated Displacement of ICV™ Box Due to Seismic Event

DESIGN MEMORANDUM

amec

Client: GeoMelt
Sheet 1 of 14
Project: FINAL DBVS DESIGN
Date: MARCH 15 2006
Data For: ESTIMATED BOX MOVEMENT - SEISMIC
Work Order: 149774
Prepared By: P. Meyer
Checked By:
File No: 145579-B-CA-004 REV 3

Note: This form must be used for project calculations and original filed in project files

ATTACHMENT #9

AS DEMONSTRATED IN THE DOCUMENT:

"GENERIC ASSESSMENT OF UNSECURED III/I AND I/I ITEMS" (HANFORD ENGINEERING DEVELOPMENT LABORATORY DTRF NO A-3886, S.E. WAGNER 1980)
(follows in this attachment)

AN UNSECURED OBJECT SUBJECTED TO SEISMIC LOAD CONDITION
1) FALL OVER
2) SLIDE
3) REMAIN IN PLACE.

VARIABLES

a = horizontal dist from origin to CG — DWG F-145579-35-D-004 (follows)
= ½ BOX WIDTH
= 49.2" (49.1875")

b = vertical dist from origin to CG — DWG F-145579-35-D-004 (follows)
= 55.2" (55.1875")

μ = coefficient of friction steel/steel — Attachment 5
= 0.33

H = 0.215g — e-mail T. Mackay (follows)
V = 0.157g

W = 240,000 lb — DESIGN LOAD

DESIGN MEMORANDUM amec

Client: GeoMelt Sheet 2 of 14
Project: Final DBVS Design Date: March 15 2006
Data For: Estimated Box Movement - Seismic Work Order: 149774
Prepared By: P Meyer Checked By: File No: 145579-B-CA-004 REV. 3

Note: This form must be used for project calculations and original filed in project files ATTACHMENT #9

1) Check if box falls over

Is $\mu \geq a/b$?

$a/b = \frac{49.2''}{55.2''} = 0.89$

$\mu = 0.33$

$\therefore \mu \not\geq a/b$ ∴ Box does not tip over

2) Check if box slides

Is $\mu < \frac{H}{1 \pm V}$?

$H/1+V = \frac{0.215}{1+0.157} = 0.1858 = 0.19$

$H/1-V = \frac{0.215}{1-0.157} = 0.255$

$\mu \not< \frac{H}{1 \pm V}$ ∴ Box does not slide

Consider: ICV(TM) Box is PC-2

∴ Seismic Importance Factor = 1.5 Reference 5

DESIGN MEMORANDUM

amec

Client: GeoMelt — Sheet 3 of 14
Project: Final DBVS Design — Date: 2006 Mar 15
Data For: Estimated Box Movement - Seismic — Work Order: 149774
Prepared By: P. Meyer — Checked By: — File No: 145579-B-CA-004 REV 3

Note: This form must be used for project calculations and original filed in project files

ATTACHMENT #9

ALTHOUGH NOT DEALT WITH IN THE HEDL GENERIC ASSESSMENT, CONSIDER EFFECT OF USING I=1.5 ON BOTH H+V (CONSERVATIVE)

$H_{1.5} = 0.215g \times 1.5 = 0.3225g$

$V_{1.5} = 0.157g \times 1.5 = 0.2355$

CHECK IF BOX SLIDES

$$H_{1.5}/1-V_{1.5} = \frac{0.3225g}{1-0.2355g} = 0.422$$

$\therefore \mu < \frac{H}{1 \pm V} \therefore$ BOX SLIDES

DETERMINE MAXIMUM SLIDING DISTANCE FOR 10 CYCLES OF SEISMIC EFFECT (DBE)

$$X_{TOTAL} = \frac{5gH^2}{4\pi^2 f^2 \mu (1-V)}$$

WAGNER, FOLLOWS

f = fundamental "building" frequency (Hz)

CURBS ARE THE "BUILDING" THE BOX RESTS UPON. ICV(TM) BOX SUPPORT CURBS HAVE A FUNDAMENTAL FREQUENCY THAT MAY BE APPROXIMATED AS SHOWN IN THE UNIFORM BUILDING CODE 1997

$T = C_T (h_n)^{3/4}$ — UBC EQ'N 30-8

T = PERIOD (seconds)

DESIGN MEMORANDUM amec

Client: GeoMelt Sheet 4 of 14
Project: Final DBVS Design Date: 2006-March-15
Data For: Estimated Box Movement - Seismic Work Order: 149774
Prepared By: PM Checked By: File No: 145579-B-CA-004
Note: This form must be used for project calculations and original filed in project files Attachment #9

$C = 0.020$ "other" UBC p 2-14
$h_n = 1.75'$ $(21" = 1.75')$

$\therefore T = 0.020\,(1.75\,ft)^{3/4}$

$= 0.020\,(1.5215) = 0.0304\,s$

$f = 1/T = 32.8\ Hz$ (units s^{-1})

g = gravity acceleration = $32\ ft/s^2$ (Newton)

$= 384\ inches/s^2$

$$\therefore X_{TOTAL} = \frac{5\,(384\ in/s^2)(0.3225)^2}{4\pi^2\,(32.8\ Hz)^2\,(0.33)\,(1-0.2355)} = 0.0186"$$

$\approx 0.02"$

$X_{TOTAL} = 0.02"$

Total estimated box displacement = 0.02" (≈ 0.5 mm)

This is acceptable. Box sliding, if it occurs at all is below the tolerance of the box fabrication itself.

CH2MHILL FAX

Tel
Fax

To: Paul Mayer
Company: AMEC
Fax No.: 250-368-2455
Voice No.: 250-368-2407

From: Tom Mickey
Date: 2/23/06
Total Pages: Cover + 6 pages (#14-18 #1)

Message: Please call my cell @ 509-438-9521 if you do not have all pages. Use this reference as "Hanford Engineering Development Laboratory" (HEDL) DTRF NO. A-3886, S.F. Wagner. 1980

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Please call if pages are missing or illegible or if you receive this fax in error.

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1 of 1				A-3886	

TO: Hanford Engineering Development Laboratory — Westinghouse Hanford Company, A Subsidiary of Westinghouse Electric Corporation, P. O. Box 1970 Richland, Wa. 99352

ATTN:

FROM: PLANT ANALYSIS

SELLER'S CODE NO.: —

CONTROLLING SDD NO.	MAJOR ASSY. DWG. NO.	EQ. PIECE NO.	HEDL COG. ENGINEER	HEDL COG. ENG. CODE
			S. E. Wagner	92180

ORIGINATOR'S REMARKS:

HEDL REMARKS:

ORIGINATOR QUALITY ASSURANCE APPROVAL IF APPLICABLE: — DATE:

ORIGINATOR APPROVAL: S E Wagner (signature) — DATE: 1/16/80

DATA TRANSMITTED

ITEM NO.	DATA OR DRAWING NO.	SHEET NO.	REVISION	SPEC. ADDENDUM OR REVISION NO.	TITLE OR DESCRIPTION	NEXT ASSEMBLY DRAWING NUMBER	A DATA TYPE	B REFERENCE ECP NUMBER	C SUBJECT CODE	D REQUESTED DISPOSITION	E1 REVIEWER'S DISPOSITION	E2 HEDL ENG. DISPOSITION	F FFTF-PO DISPOSITION
1					Generic Assessment of Unsecured III/I and I/I items.					1			

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APPROVAL NAME AND CODE NO.	RESPONSE TO COL. E2				SIGNATURE / DATE	REVIEW NAME AND CODE NO.	R A R		SIGNATURE / DATE
						MANUFACTURING			
						STRESS ANALYSIS AND CODES: L. K. Severud	A		(signature)
SAFETY ANALYSIS: J. W. Hagan	A	X			(signature) 1-17-80	MATERIALS			
QUALITY ASSURANCE: R. A. Humphrey	A	X			(signature) 1/17/80	SYSTEMS ENGINEERING			
PROJECT CONTROL						R. P. Warrick	I		
COGNIZANT ENGINEER: S. E. Wagner	A	X			(signature) 1/16/80	W. M. Gajewski	I		
RESPONSIBLE ENGINEERING MGR.: G. D. Summers	A	X			(signature) 1-16-80				

REQUESTED DISPOSITION BY ORIGINATOR (COL "D")
1. APPROVAL.
2. HEDL POST REVIEW SUBSEQUENT TO ORIGINATOR RELEASE.
3. INFORMATION SUBMITTAL. RECEIPT ACKNOWLEDGEMENT REQUESTED.
4. IN PROCESS REVIEW.

HEDL DISPOSITION CODES (USE FOR COL "E1" OR "E2")
1. APPROVED WITHOUT COMMENT.
2. APPROVED SUBJECT TO ATTACHED COMMENTS.
3. DISAPPROVED — COMMENTS ATTACHED.
4. REVIEWED — NO COMMENTS.
5. REVIEWED — COMMENTS ATTACHED.
6. RECEIPT OF SUBMITTAL ACKNOWLEDGED.

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13. DISAPPROVED — COMMENTS ATTACHED.
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15. REVIEWED — COMMENTS ATTACHED.

ABBREVIATIONS USED ABOVE:
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CON — CONCUR; C/WC — CONCUR WITH COMMENT; NC/WC — NON CONCUR WITH COMMENT
A — APPROVE; R — REVIEW; I — INFORMATION

CHANGE CONTROL BOARD — APPROVED — DISPOSITION

24-7660-110 (11-79)

ENGINEERING RELEASE ORDER

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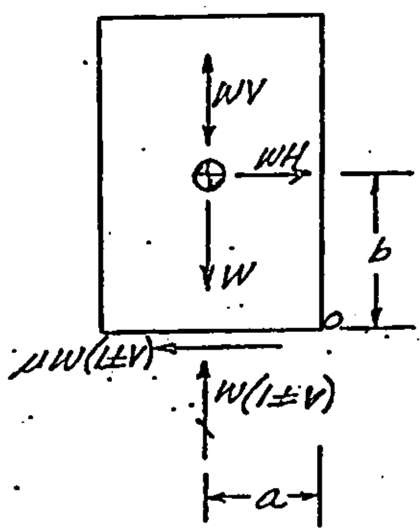
S.P. Wiedmer
11/11/80

DERIVATION OF EQUATIONS

CONSIDER AN OBJECT RESTING ON THE FLOOR AND NOT TIED DOWN. IF AN EARTHQUAKE (DBE) OCCURS THE OBJECT COULD

1. FALL OVER
2. SLIDE
3. REMAIN IN PLACE

CONSIDER A FREE BODY OF THE OBJECT



W = WEIGHT, LB.

H = HORIZONTAL RESPONSE, g

V = VERTICAL RESPONSE, g

μ = COEFFICIENT OF FRICTION

a = HORIZONTAL DISTANCE FROM PT O TO CG, IN

b = VERTICAL DISTANCE FROM PT O TO CG, IN

FOR THE OBJECT TO FALL OVER THE FOLLOWING CONDITIONS MUST BE MET. TAKING MOMENTS ABOUT PT O,

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2

S FINAGNER 1/11/50

$$WH(b) \geq W(1 \pm V)(a) \quad (1)$$

AND SUMMING HORIZONTAL FORCES

$$WH \leq \mu W(1 + V) \quad (2)$$

SUBSTITUTING FOR $W(1 \pm V)$ FROM (1) INTO (2)

$$WH \leq \mu \, WH\left(\frac{b}{a}\right)$$

OR

$$\mu \geq \frac{a}{b} \quad (3)$$

FOR SLIDING TO OCCUR THE HORIZONTAL FORCE DUE TO ACCELERATION MUST OVERCOME THE FRICTION FORCE OR

$$WH > \mu W(1 \pm V)$$

OR

$$\mu < \frac{H}{1 \pm V} \quad (4)$$

IF SLIDING CAN OCCUR THE QUESTION ARISES HOW FAR WILL THE OBJECT SLIDE? BY DEFINITION (PAGE 4, JABE-WADCO-02) A DBE PRODUCES 10 CYCLES OF MAXIMUM RESPONSE. IN THE FOLLOW ANALYSIS THE CONSERVATIVE ASSUMPTIONS MADE ARE

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S.E. WAGNER
1/15/00

1. H IS CONSTANT IN DIRECTION FOR A GIVEN CYCLE AND ACTS IN THE SAME DIRECTION FOR ALL 10 CYCLES
2. V ALWAYS ACTS UPWARD. THIS GIVES THE LOWEST FRICTION FORCE AND THE MAXIMUM SLIDING DISTANCE

ASSUME THE FORCING FUNCTION IS SINUSOIDAL

THEN

$$\dot{X}_m = \frac{gH}{2\pi f} \quad (5)$$

f = FUNDAMENTAL BUILDING FREQUENCY (Hz)

AND THE KINETIC ENERGY

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$$KE = \frac{1}{2}\left(\frac{W}{g}\right)\left(\dot{X}_m\right)^2$$
$$= \frac{1}{2}\left(\frac{W}{g}\right)\left(\frac{g^2H^2}{4\pi^2f^2}\right)$$
$$= \frac{WgH^2}{8\pi^2f^2} \quad (6)$$

THE ENERGY IN MOVING THE OBJECT AGAINST FRICTION

$$PE = \mu W(1-V)X \quad (7)$$

SETTING (7) EQUAL TO (6) FIND THE MAXIMUM SLIDE FOR ONE CYCLE

$$\mu W(1-V)X_m = \frac{WgH^2}{8\pi^2f^2}$$

$$X_m = \frac{gH^2}{8\pi^2f^2\mu(1-V)} \quad (8)$$

16

SG WAGNER
1/15/80

THEN FOR 10 CYCLES

$$X_{TOT} = \frac{5 g H^2}{4\pi^2 f^2 \mu (1-V)}$$

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5

SEHMAUR
11/14/80

IN THE FOLLOWING CALCULATIONS THE OBJECT UNDER CONSIDERATION IS ASSUMED TO BE RIGID. H AND V ARE TAKEN AS THE ZPA VALUES FROM HWS-1386 RESPONSE CURVES FOR A GIVEN LOCATION. THE BUILDING FREQUENCY, f, IS TAKEN AS THE LOWEST FREQUENCY OF THE PEAK OF THE RESPONSE CURVE. *

TABLE 1 GIVES VALUES OF H, V AND f FOR A NUMBER OF LOCATIONS. TABLES 2 AND 3 GIVE VALUES OF SLIDING DISTANCE AND SPECIFIC ENERGY FOR THESE LOCATIONS AND FOR VARIOUS VALUES OF COEFFICIENT OF FRICTION. THE SLIDING DISTANCE IS PLOTTED IN FIGURE 1

* EXCEPT FOR CONTAINMENT MEZZANINE - SEE TABLE 1

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Meyer, Paul (Trail)

From: Meyer, Paul (Trail)
Sent: February 28, 2006 9:54 AM
To: 'Mackey, Thomas C'
Cc: Shuford, David H (Dave); Stephens, John D (Trail); Leonard, Michael W; Sweet, Frank
Subject: RE: Calculation of possible ICV Box movement

Tracking:

Recipient	Read
'Mackey, Thomas C'	
Shuford, David H (Dave)	
Stephens, John D (Trail)	
Leonard, Michael W	
Sweet, Frank	Read: 28/02/2006 10:19 AM

I will use H=0.215g and V=0.157g in my check of the possible box movement.

Thanks.

The quick version: with importance factor 1.0, the seismic forces cannot overcome friction and initiate sliding using the equations from HEDL.

With an importance factor of 1.5 applied to the seismic loads, both vertically and horizontally, the box may overcome friction and would move 0.018 inches (~0.5 mm) after 10 earthquake cycles. This is acceptable.
-Paul

From: Mackey, Thomas C [mailto:Thomas_C_Mackey@RL.gov]
Sent: February 27, 2006 3:12 PM
To: Meyer, Paul (Trail)
Cc: Shuford, David H (Dave); Stephens, John D (Trail); Mackey, Thomas C; Leonard, Michael W
Subject: RE: Calculation of possible ICV Box movement

Paul

We have been having similar discussions here regarding PGA and ZPA. The old FFTF spectra is a little higher than our new site specific response spectra. The following is extracted from another discussion on this subject:

PGA, and ZPA are essentially synonymous terms. The peaks of the horizontal and vertical design spectra provided by Geomatrix are 0.588g and 0.346g.

These are not peak ground accelerations, but rather peak spectral accelerations. The PGA's (ZPA's) of the horizontal and vertical surface design spectra for the tank farms as provided by Geomatrix are 0.215g, and 0.157g, respectively.

Tom

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03/02/2006

From: Meyer, Paul (Trail) [mailto:paul.meyer@amec.com]
Sent: Monday, February 27, 2006 2:56 PM
To: Mackey, Thomas C
Cc: Shuford, David H (Dave); Stephens, John D (Trail)
Subject: Calculation of possible ICV Box movement

Thanks.

Question: to do the calculation, I'll need the "H" and "V" values for our site. On page 5 of the fax (page 18 of the calc) it says the "H and V values are taken from HWS-1386 response curves for a given location." Are those response curves available for the 200W site? I did a search for HWS-1386 on the Internet and the single hit was a document called "FFTF Final Safety Analysis Report (WHC-TI-75002)" for the Fast Flux Text Facility. According to that document, the full title of HWS-1386 is "FFTF Structure Response Curves for Seismic Design of FFTF Equipment." Report 75002 references HWS-1386, but does not give any of the response values.

Are the tables 1 2 and 3 mentioned on page 5 (page 18 of the calculation) available? It looks as if they have typical values of sliding distance for various locations and various coefficients of friction, perhaps a result is already available.

I assume the value of "f" is the fundamental frequency in Hz (which is the reciprocal of the period) The curbs have a period "T" (per UBC) of 0.03 seconds, or a natural frequency of ~33 Hz. Definitely rigid!

My assumption is that "H" probably corresponds to Ca in the UBC-97.
If I take H as 0.24g and V as 50% of H or 0.12g, then:
Calculation (4) suggests sliding cannot occur. 0.33 > (0.24)/(1-0.12) 0.33>0.27
Assuming it does occur anyway,
If H= 0.24g, V= 0.12g, "mu" = 0.33 and f = 33 Hz and g= 32 ft/sec^2 or 384 in/sec^2
then the movement of the box would be
Xm = 0.000885 inches per cycle, or 0.009 inches in 10 cycles. This is acceptable.

IF the assumed values of H and V are both increased by an importance factor of 1.5, then sliding <u>will</u> occur as the value of H/(1-V) = 1.5(0.24)/(1-(1.5*0.12)) = 0.5 which is greater than he coefficient of friction. In that scenario, the total movement would be 0.0024 inches per cycle, or 0.024 inches (0.6 mm) in 10 cycles. Still acceptable.

This is subject to confirmation of the correct values to use for H and V.

-Paul

From: Mackey, Thomas C [mailto:Thomas_C_Mackey@RL.gov]
Sent: February 27, 2006 8:05 AM
To: Meyer, Paul (Trail)
Cc: Shuford, David H (Dave); Mackey, Thomas C
Subject: FW: Attached is the file you requested.

Paul

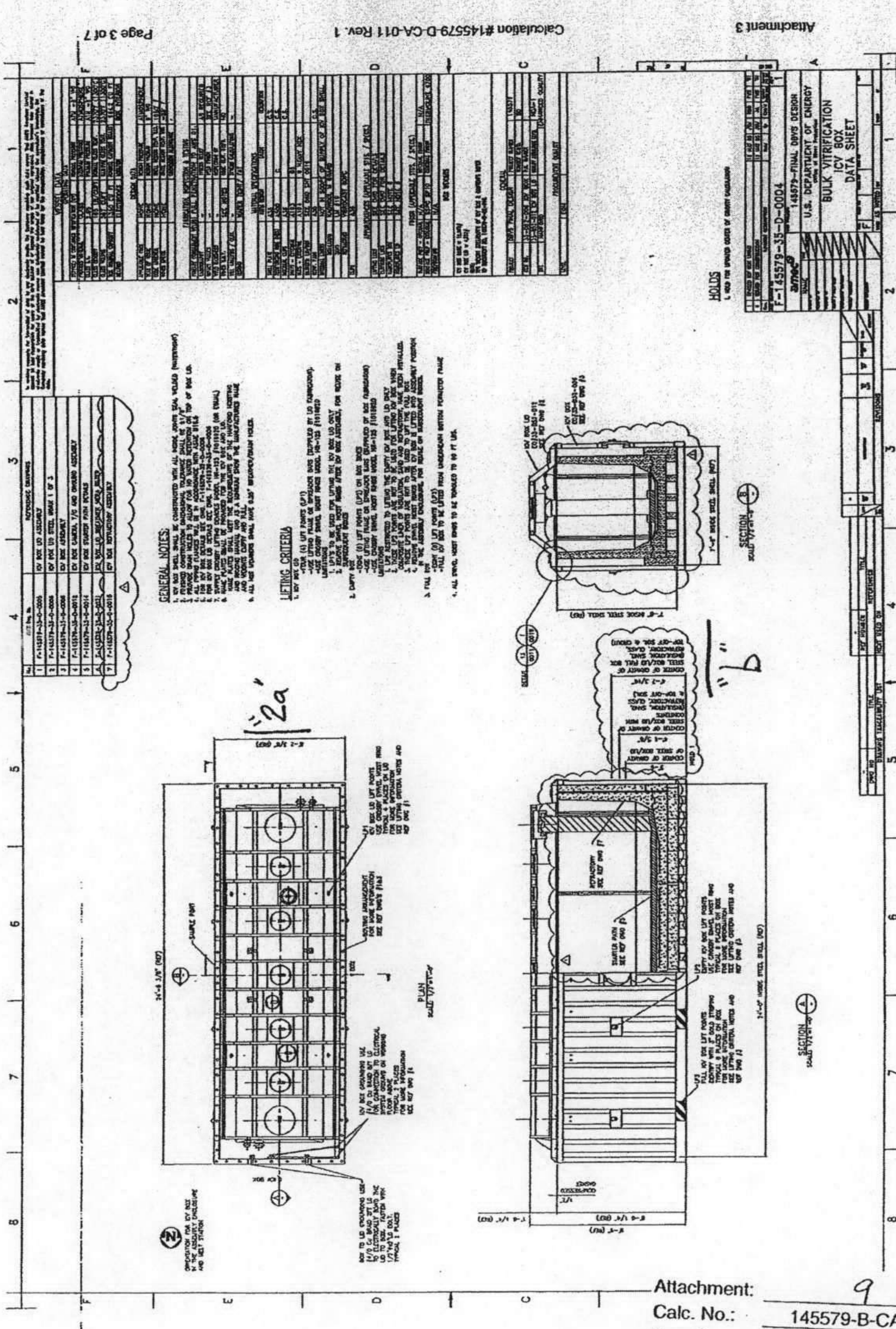
Here is the PDF.

Tom

From: Lenz, Kelli S
Sent: Monday, February 27, 2006 8:05 AM
To: Mackey, Thomas C
Subject: Attached is the file you requested.

Attachment: 9
Calc. No.: 145579-B-CA-004
Rev. No.: 3
Sheet 13 of 14

03/02/2006



Attachment:	9
Calc. No.:	145579-B-CA-004
Rev. No.:	3
Sheet	14 of 14

Calculation Reviewed: 145579-B-CA-004 REV 3

Scope of Review: COMPLETE DOC.
(e.g., document section or portion of calculation)

Engineer/Analyst: Paul Meyer Date: 2006.MAR.22

Organizational Mgr: Paul Meyer Date: 2006.MAR.22

This document consists of 11 pages and the following attachments (if applicable):
ATTACHMENTS 1-9 AS LISTED ON CALCULATION

Yes	No	NA*		
[X]	[ ]	[ ]	1.	Analytical and technical approaches and results are reasonable and appropriate.
[X]	[ ]	[ ]	2.	Necessary assumptions are reasonable, explicitly stated, and supported.
[ ]	[ ]	[X]	3.	Ensure calculations that use software include a paper printout, microfiche, CD ROM, or other electronic file of the input data and identification to the computer codes and versions used, or provide alternate documentation to uniquely and clearly identify the exact coding and execution process. No SOFTWARE
[X]	[ ]	[ ]	4.	Input data were checked for consistency with original source information.
[X]	[ ]	[ ]	5.	For both qualitative and quantitative data, uncertainties are recognized and discussed.
[X]	[ ]	[ ]	6.	Mathematical derivations were checked including dimensional consistency of results.
[X]	[ ]	[ ]	7.	Calculations are sufficiently detailed such that a technically qualified person can understand the analysis without requiring outside information.
[ ]	[ ]	[X]	8.	Software verification and validation are addressed adequately. No SOFTWARE
[X]	[ ]	[ ]	9.	Limits/criteria/guidelines applied to the analysis results are appropriate and referenced. Limits/criteria/guidelines were checked against references.
[X]	[ ]	[ ]	10.	Conclusions are consistent with analytical results and applicable limits.
[X]	[ ]	[ ]	11.	Results and conclusions address all points in the purpose.
[X]	[ ]	[ ]	12.	Referenced documents are retrievable or otherwise available.
[X]	[ ]	[ ]	13.	The version or revision of each reference is cited.
[X]	[ ]	[ ]	14.	The document was prepared in accordance with Attachment A, "Calculation Format and Preparation Instructions."
[X]	[ ]	[ ]	15.	All checker comments have been dispositioned and the design media matches the calculations.

Diana Whitley — March 22/06
Checker (Printed Name and Signature) — Date

* If No or NA is chosen, an explanation must be provided on or attached to this form.

Subcontractor Calculation Review Checklist.

Page 1 of 1

Subject: ICV™ Box Support Curbs Type 'C' and 'D' and 'E'

The subject document has been reviewed by the undersigned.
The checker reviewed and verified the following items as applicable.

Documents Reviewed: 145579-B-CA-004, Rev. 3

Analysis Performed By: AMEC

- * Design Input
- Basic Assumptions
- Approach/Design Methodology
- Consistency with item or document supported by the calculation
- Conclusion/Results Interpretation
- Impact on existing requirements
- ______________________________

Checker (printed name, signature, and date): M. W. Leonard M.W. Leonard 4/3/06

Organizational Manager (printed name, signature and date): D. H. Shuford DH Shuford 4/5/06

* Clarification on p.4 of 11, Impact Load. Worst case impact load on curbs is a fully loaded ICV™ box transporter hitting an empty curb. Note that this is the case because a full container can either be on the transporter or curb when the box is in the melt area.
[see e-mail from T. Mackey to M. Leonard, 4/3/06 "FW: Today's discussion of Calculation 145579-B-CA-003, Rev.3]

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145579-D-CA-001

CALCULATION SHEET

amec

CALC. NO.: 145579-D-CA-001 REV: 2 DATE: March 22, 2006

CALC. TITLE: Area 35 – Transient Heat Transfer Calculations of ICV™ Box

PROJECT NO.: 145579 PROJECT TITLE: Final DBVS Design

Design Verification Required: ☐ Yes ☒ No

Calculation Type: ☐ Scoping ☐ Preliminary ☒ Final

Superseded by Calculation No.: ______ ☐ Voided

ORIGINAL AND REVISED CALCULATIONS/ANALYSIS APPROVAL

REV.	ORIGINATOR:	DATE:	CHECKED:	DATE:	APPROVED	DATE
0	Victor Lourenco	09-Mar-05	Tom Wilson	09-Mar-05	Frank Sweet, P. Eng	10-Mar-05
1	Ja-Kael Luey	22-Dec-05	Kurt McCracken	22-Dec-05	Kurt McCracken	22-Dec-05
2	Ja-Kael Luey	3/23/06	Kurt McCracken	3/23/06	[signature]	3/23/06
	[signature]					

AFFECTED DOCUMENTS

DOCUMENT NUMBER:	TITLE:	REV. NO.:	DISC. LEAD INITIALS

RECORD OF REVISION

REV. NO.	REASON FOR REVISION:
1	Evaluate ICV™ Box Design for Various Heat Transfer Boundary Conditions
2	ICV Box drawings updated. DBVS ICV Box Thermal Analysis Updated.

ATTACHMENTS

DOCUMENT NUMBER/ID:	TITLE:	TOTAL PAGES
Attachment 1	Calculation 0509206.01-M-001: DBVS ICV Box Thermal Analysis	98
Attachment 2	Bulk Vitrification Design Drawings	8
	TOTAL PAGE COUNT	112

Typed names/dates in this box indicate the calculation has been signed off/approved and the originals have been placed in the Project files.

ORIGINATOR:	DATE:	CHECKER:	DATE:
[signature]	3/23/06	[signature]	3/23/06

CALCULATION SHEET

amec

CALC. NO.:	145579-D-CA-001	REV:	2	DATE:	March 22, 2006
CALC. TITLE:	Area 35 – Transient Heat Transfer Calculations of ICV™ Box				
PROJECT NO.:	145579	PROJECT TITLE:	Final DBVS Design		

1 INTRODUCTION

Full-scale testing with non-radioactive simulant in a prototypical ICV™ Box has led to evolution of the design for the refractory and insulating layers of the ICV™ Box. Heat transfer calculations modeling multiple configuration options were performed to guide the design evolution (see References 1 and 2). The resultant ICV™ Box refractory and sand configuration (see F-145579-35-D-0004, -0016, and -0017, attached) has been successfully tested at full-scale with non-radioactive simulant. Preliminary test results from Test 38A-1 correlate well with the heat transfer calculations documented in References 1 and 2.

This calculation utilizes the heat transfer model developed and used in References 1 & 2 and applies it to postulated conditions at the DBVS, as depicted in the attached drawings (see F-145579-00-D-0041, -00-B-0020 and -00-B-0025).

1.1 PURPOSE

The purpose of this calculation is to bound the ICV™ Box skin temperature by approximating worst case conditions seen in the DBVS. This calculation also verifies that, in the event molten glass leaks from the 60PC castable refractory in the ICV™ Box, leaking glass will not contact the steel ICV™ Box skin and appropriately "freeze" in the sand. The conditions modelled herein represent deviations from those expected during normal operating conditions at DBVS.

1.2 SCOPE

This calculation determines the ICV Box temperature profile from the inside refractory layer to the outer box skin for varying critical melt parameters and conditions external to the box (e.g., melt temperature, air temperature external to the box, properties of insulating sand, and external convection coefficient) using the heat transfer model developed in References 1 & 2. ICV box bottom and sidewall skin temperatures and the location of the isotherm at which leaking glass will "freeze" in the sand is reported for postulated conditions of glass "leaks" from the 60PC castable refractory. These cases are compared to the baseline case where no glass leaks from the castable refractory. The external environment used in the calculations for the DBVS ICV Box is based on bounding worst estimates of conditions in the DBVS melt area. The ICV Box lid temperature and heat transfer from the ICV box through the melt area supports, or curbs, (see drawing F-145579-00-B-0025) to the melt area concrete are treated in separate calculations.

Typed names/dates in this box indicate the calculation has been signed off/approved and the originals have been placed in the Project files.

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[signature]	3/23/06	[signature]	3/23/06

CALCULATION SHEET

amec

CALC. NO.:	145579-D-CA-001	REV: 2	DATE: March 22, 2006
CALC. TITLE:	Area 35 – Transient Heat Transfer Calculations of ICV™ Box		
PROJECT NO.:	145579	PROJECT TITLE:	Final DBVS Design

2 BASIS

2.1 DESIGN INPUTS

1. Configurations modelled (based on design drawings F-145579-35-D-0004 and -0016, see Attachment 2).
   a. Side wall: 6" 60PC castable refractory , 6" Sand, box skin
   b. Bottom: 6" 60 PC castable refractory, 8" Sand and 8" Refractory Brick (same layer in alternating columns on bottom), box skin, 6"x 6" HSS member. [Note that the HSS is not modelled in Attachment #1, which is conservative for heat transfer away from the box surface.]
   c. Tube steel vertical stiffeners and box bottom stiffeners are not included in the analysis. References 1 and 2 show that worst case box skin temperatures are calculated when the tube steel exoskeleton is not included in the model.
   d. Shield walls around the melt area (see Drawing F-145579-00-B-0020). Melt area concrete slab (see Drawing F-145579-00-D-0041). These are included in the model as surfaces that can radiate back to the ICV box and also form, with the steel support structure shown on Drawing F-145579-00-D-0041, a confined area that limits natural convection.
2. Heat transfer model input specifics are discussed in Attachment 1.

2.2 ASSUMPTIONS

Glass properties used in this analysis are for Low Activity Waste glass simulants developed for Hanford Tank Waste and are believed to be representative of the properties for the DBVS glass product. As data for the DBVS glass product become available, the properties can be compared to those used in this analysis to determine if the analysis is bounding.

The concrete surface temperature used in the analysis is an estimated worst case and not based on the results from a separate analysis. This analysis uses the same concrete surface temperature for the concrete slab and the shield walls. The impact from this assumption is a condition external to the ICV box that is estimated to be more insulating than conditions expected at the DBVS Site for the given design.

Typed names/dates in this box indicate the calculation has been signed off/approved and the originals have been placed in the Project files.

ORIGINATOR:	DATE: 3/23/06	CHECKER:	DATE: 3/23/06

CALCULATION SHEET

amec

CALC. NO.:	145579-D-CA-001	REV: 2	DATE: March 22, 2006
CALC. TITLE:	Area 35 – Transient Heat Transfer Calculations of ICV™ Box		
PROJECT NO.:	145579	PROJECT TITLE:	Final DBVS Design

3 CRITERIA

1. The "freeze point" isotherm (defined in this analysis as 826°C) does not contact the box skin.

4 REFERENCES

1. Calculation No. 0513206.01-M-001 AMEC BulkVit 1D Thermal Analysis of the ICV™ Box Refractory Liner. ARES Corporation. 2005.

2. Calculation No. 0513206.01-M-002 AMEC BulkVit 2D Thermal Analysis of the ICV™ Box Refractory Liner and "Leaking Glass" Configuration. ARES Corporation. 2005.

5 METHODS

Calculation methods are discussed in Attachment 1.

6 RESULTS AND CONCLUSIONS

Table 5-1 from Attachment 1, Results for the ICV Box Sidewall Heat Transfer Simulations, is reproduced below. As shown in the table, the criteria for the freeze point isotherm is not exceeded for any of the cases run (the X_{826} represents the distance of the freeze point isotherm from the box skin). The nominal operating cases without leaking glass are shown as Case 3.1 (60PC castable refractory with 110PC castable refractory backing) and Case 3.2(60PC castable refractory with sand backing); both of which show skin temperatures more than 250°C below the calculated worst case (Case 3.3.4) skin temperature in the leaking glass scenario.

As shown in Table 5-1, the melt temperature and the box convective/radiated heat transfer coefficient are varied to determine the sensitivity of leaking glass penetration and box skin temperature to these parameters. The results indicate (see Case 3.3.4) that if glass leaks and the model's side wall heat transfer coefficient is high by a factor of 2 for the DBVS box sidewall configuration and the nominal melt temperature is exceeded by 400°C (~ 30%) in extreme environmental conditions for DBVS, the leaking glass does not contact the box skin. These results can also be used to bound the conditions for DBVS operation.

Typed names/dates in this box indicate the calculation has been signed off/approved and the originals have been placed in the Project files.

ORIGINATOR:	DATE: 3/23/06	CHECKER:	DATE: 3/23/06

CALCULATION SHEET

amec

CALC. NO.:	145579-D-CA-001	REV:	2	DATE:	March 22, 2006
CALC. TITLE:	Area 35 – Transient Heat Transfer Calculations of ICV™ Box				
PROJECT NO.:	145579	PROJECT TITLE:	Final DBVS Design		

Table 5-1. Results for the ICV™ Box Sidewall Heat Transfer Simulations

Case	T_{melt} [°C]	T_{∞} [°C]	Heat Transfer Coefficient Multiplier	"Leaking Glass" Condition	X_{826}	T_{skin} [°C]
3.1(1)	1300	100	1x	No	5⅛"	281
3.2(2)	"	"	"	No	3¾"	232
3.3.1	"	"	"	Yes	2⅛"	286
3.3.2	1500	"	"	"	1¼"	342
3.3.3	1700	"	"	"	⅝"	421
3.3.4	"	"	½x	"	½"	557
3.3.5	"	"	2x	"	⅞"	313

Notes (1) Sidewall model through 110C vertical castable refractory rib backing
(2) Sidewall model through sand backing

Table 5-2 from Attachment 1, Results for the ICV Box Bottom Heat Transfer Simulations, is reproduced below. The results for the box bottom analysis also show that the criterion for the freeze point isotherm is not exceeded for any of the cases run. The nominal operating case without leaking glass is shown as Case 4.1 (60PC castable refractory with 110PC castable refractory and sand "backing"). As with the sidewall analysis, the nominal case skin temperature was more than 250°C below the calculated worst case (Case 4.2.4) skin temperature in the leaking glass scenario.

As shown in Table 5-2, the melt temperature and the box convective/radiated heat transfer coefficient are varied to determine the sensitivity of leaking glass penetration and box skin temperature to these parameters. The results indicate (see Case 4.2.4) that if glass leaks and the model's box bottom heat transfer coefficient is high by a factor of 2 for the DBVS box bottom configuration and the nominal melt temperature is exceeded by 400°C (~ 30%) in extreme environmental conditions for DBVS, the leaking glass freezes more than 1" from the box bottom skin. These results can also be used to bound the conditions for DBVS operation.

Typed names/dates in this box indicate the calculation has been signed off/approved and the originals have been placed in the Project files.

ORIGINATOR:	DATE: 3/23/06	CHECKER:	DATE: 3/23/06

amec

CALCULATION SHEET

CALC. NO.: 145579-D-CA-001 **REV:** 2 **DATE:** March 22, 2006

CALC. TITLE: Area 35 – Transient Heat Transfer Calculations of ICV™ Box

PROJECT NO.: 145579 **PROJECT TITLE:** Final DBVS Design

Table 5-2. Results for the ICV™ Box Bottom Heat Transfer Simulations

Case	T_{melt} [°C]	T_{∞} [°C]	Heat Transfer Coefficient Multiplier	"Leaking Glass" Condition	x_{828}	T_{skin} [°C]
4.1	1300	100	1x	No	5⅝"	252
4.2.1	"	"	"	Yes	3⅞"	254
4.2.2	1500	"	"	"	2⅜"	340
4.2.3	1700	"	"	"	1⅝"	391
4.2.4	"	"	½x	"	1⅛"	517
4.2.5	"	"	2x	"	1⅝"	299

CALCULATION SHEET

amec

CALC. NO.:	145579-D-CA-001	REV: 2	DATE: March 22, 2006
CALC. TITLE:	Area 35 – Transient Heat Transfer Calculations of ICV™ Box		
PROJECT NO.:	145579	PROJECT TITLE:	Final DBVS Design

Attachment 1
DBVS ICV Box Thermal Analysis: 0509206.01-M-001 Revision 1
(98 pages including Attachment Cover)

ARES CORPORATION	CALCULATION COVER SHEET	Page No. 1 of 97 / Calculation No: 0509206.01-M-001
Project No. 0509206.01	Project Title: AMEC Demonstration Bulk Vitrification System (DBVS) Project Support	Client: AMEC/DMJMH&N

Title:
DBVS ICV™ Box Thermal Analysis

Purpose and Objective:

A series of computational simulations was performed previously to determine the thermal response of a number of candidate designs for the refractory liner system used in Horn Rapids Test Site (HRTS) In-Container Vitrification (ICV™) BulkVit containers. The results of those simulations are presented in references 1 & 2. The simulations performed in this calculation build upon the results and methodologies developed in references 1 & 2 for the purpose of assessing the maximum box surface temperature for the Demonstration BulkVit System (DBVS) ICV™ containers. The maximum box skin temperatures predicted in the calculations presented herein will be factored into the thermal stress considerations of the ICV™ box structural design. In addition, the refractory liner materials must be designed and configured to "stop" any glass that may leak through seams, cracks, or other openings developed in the castable refractory materials during processing from contacting the steel surfaces of the ICV™ box. The calculations presented herein are intended to demonstrate that these design constraints will not be violated under a number of normal and off-normal operation scenarios. The configurations, material choices, and other parameters used in these models were guided by the results obtained from the spectrum of cases considered in the previous calculations (ref. 1 & 2) performed for a similar assessment of the HRTS ICV™ box design.

Rev. No.	Total Pages	Revision Description (Add Continuation Sheet If Required)	Prepared By Name/Date	Checked By Name/Date	PM/TL Approval/Date
0	98	Original	P.S. Lowery	J. A. Debban	S.R. Pierce
1	97	Revised to incorporate CHG comments	P.S. Lowery [signature] 3/21/06	S.R. Pierce [signature] 3/21/06	S.R. Pierce [signature] 3/21/06

Calculation Cover Sheet QAP 3.1, Rev. 6 (11-15-05)

ARES CORPORATION	CALCULATION REVIEW CHECKLIST

Project No.	Calculation No.	Rev.	Page No.
0509206.01	0509206.01-M-001	1	2 of 97

Items Checked	Accept Y	Accept N	Accept N/A	Initial/Date
1. Cover sheets properly completed.	✓			SRP 3/21/06
2. Calc sheet headers complete with calc no, rev, etc.	✓			
3. Calc sheet contents complete per format.	✓			
4. Listed attachments included.	✓			
5. Calc objective clearly described.	✓			
6. Criteria are suitable and properly referenced to task specific documents.	✓			
7. Assumptions and input data described and attached or referenced to task documents.	✓			
8. Calc method identified and appropriate for the design activity.	✓			
9. Calc results reasonable and correctly described in results and conclusions.	✓			
10. Computer program identified with version and revision.	✓			
11. Computer input/output provided or referenced.	✓			
12. Computer run traceable to calculation (file #, etc.).	✓			
13. Computer input data within permissible design input range.	✓			
14. Computer program validation/verification addressed.	✓			

Discrepancies / Comments:

Checker (Print Name ~~and Sign~~)	Date:
P.S. Lowery [signature]	3/21/06
Originator (Print Name and Sign)	Date:
S.R. Pierce [signature]	3/21/06

Signatures obtained only after discrepancies are corrected and comments are resolved.

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 3 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

Table of Contents

APPENDICES

Figures

Tables

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 5 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

Acronyms

DBVS	Demonstration Bulk Vitrification System
FEM	Finite Element Model
GUI	Graphical User Interface
HRTS	Horn Rapids Test Site
ICV™	In Container Vitrification
LAW	Low Activity Waste
PNNL	Pacific Northwest National Laboratory

1.0 INTRODUCTION

A series of computational simulations was performed previously to determine the thermal response of a number of candidate designs for the refractory liner system used in Horn Rapids Test Site (HRTS) In-Container Vitrification (ICV™) BulkVit containers. The results of those simulations are presented in references 1 & 2. The simulations performed in this calculation build upon the results and methodologies developed in references 1 & 2 for the purpose of assessing the maximum box surface temperature for the Demonstration BulkVit System (DBVS) ICV™ containers. The maximum box skin temperatures predicted in the calculations presented herein will be factored into the thermal stress considerations of the ICV™ box structural design. In addition, the refractory liner materials must be designed and configured to "stop" any glass that may leak through seams, cracks, or other openings developed in the castable refractory materials during processing from contacting the steel surfaces of the ICV™ box. The calculations presented herein are intended to demonstrate that these design constraints will not be violated under a number of normal and off-normal operation scenarios. The configurations, material choices, and other parameters used in these models were guided by the results obtained from the spectrum of cases considered in the previous calculations (ref. 1 & 2) performed for a similar assessment of the HRTS ICV™ box design.

While the ICV™ box refractory liner system employed at the DBVS is the same as was developed for the HRTS ICV™ box design, there are differences in the box surroundings that require additional analysis to determine the adequacy of the design for the DBVS application. In particular, at the HRTS, vertical sidewalls of the ICV™ boxes were exposed to ambient air conditions. Because the materials being processed at the DBVS will contain radioactive constituents, the ICV™ boxes will be surrounded by concrete shielding walls on two sides. As a consequence, the heat losses off the DBVS ICV™ box sidewalls will be somewhat restricted by the reflection of radiant heat energy back to the box. Figure 1-1 provides an illustration of the ICV™ box supporting arrangement as deployed at the HRTS. The configuration to be deployed at the DBVS will be similar, however. The drawing provided in reference 3 provides plan, elevation, and section views of the proposed DBVS ICV™ container and its associated support system. The concrete ecology blocks utilized for the HRTS arrangement (illustrated beneath the ICV™ box in Figure 1-1) will be replaced with a steel I-beam rail arrangement. The box and support rail assembly will be surrounded on two sides by concrete shielding walls. The drawing identified in reference 14 provides plan and detailed views of the ICV™ box and shield wall arrangement.

In addition, one of the initial BulkVit tests performed at the HRTS experienced some leaking glass that propagated through gaps developed in the castable castable refractory liner materials present in the box. This glass eroded the sand material between the outboard face of the castable refractory and the steel ICV™ box, forming slabs of essentially pure glass on the outboard face of the castable. Descriptions and illustrations depicting these results are provided in reference 4. The presence of this glass and its direct communication with the glass batch being processed tends to elevate the temperature of the steel ICV™ box surfaces. The glass will propagate through the sand liner material until the thermal energy conducted to it from the batch melt body is balanced by losses off the surfaces of the leaking glass. Work performed by Pacific Northwest National Laboratory (PNNL) has determined that the glass will propagate until its surface reaches a temperature of 826°C (ref. 5). A number of the simulations presented herein are intended to assess the extent of propagation of this leaking glass in the vicinity of the ICV™ box vertical and bottom walls of the castable refractory liner materials during these off-normal conditions.

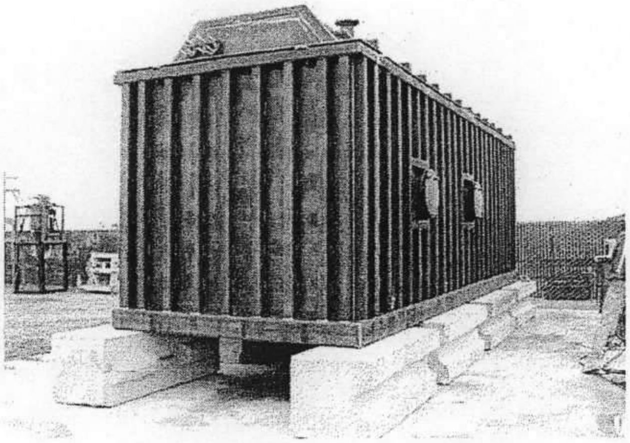

Figure 1-1. HRTS ICV™ Box and Support System.

The simulations are grouped into two categories in this calculation – those associated with heat loss and glass propagation through the ICV™ box vertical side walls, and those associated with heat loss and glass propagation through the ICV™ box bottom wall. Results for the sidewall simulations are presented in Section 3.0. Results for the ICV™ box bottom wall simulations are presented in Section 4.0. Finally, a summary of the findings and some conclusions are presented in Section 5.0.

2.0 ANSYS® MODEL DEVELOPMENT AND ANALYSIS METHODOLOGY

A finite element model (FEM) incorporating all significant elements of the DBVS ICV™ Box Sidewall and Bottom was developed with the ANSYS® program (Reference 12), using available design data. The scope for examining the box sidewall and bottom was to translate the model and analysis results generated for the thermal response of the HRTS ICV™ box (refs. 1 & 2) to the DBVS set-up and configuration, and to determine what affect the "leaking glass" had on the temperature profile in the DBVS ICV™ box refractory liner system.

The geometry sections of the box sidewall and bottom refractory was modeled in ANSYS® using a combination of commands and an interactive menu system called the Graphical User Interface (GUI). The GUI feature of ANSYS® provides the capability to automatically generate complex finite element models. The solid modeling from the bottom up is defined in terms of keypoints, lines, areas, and elements. The modeling process is initiated by defining the lowest-order solid model entities; the keypoints. Keypoints are defined within the currently active coordinate system and are important/key coordinate points to start the modeling.

The members of the assembly are then defined by lines that are defined by connecting these keypoints. Element types, material properties, and geometrical properties are assigned to the generated lines and areas. The ANSYS® meshing module automatically maps selected geometric components (e.g. – lines and areas) to indicated elements. The boundary conditions and loading are assigned after model meshing is complete.

ARES CORPORATION

CALCULATION SHEET

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2.1 Selection of Element Types

The ICV™ Box Sidewall and Bottom consists of the following primary elements:

1. 60PC Castable Refractory,
2. 110C Castable Refractory,
3. Sand,
4. ¼" Steel Lining,
5. "leaking glass" (where applicable), and
6. Combined free convection and radiation heat transfer coefficients.

Tables 2-1 and 2-2 summarize the element types and the material properties of these various components. These tables are utilized during the generation of the ICV™ Box Sidewall and Bottom finite element model. The PLANE 55 element type, 2-D Thermal Solid, is used as a plane element or a plane element with a 2-D thermal conduction capability. The element has four nodes with a single degree of freedom, temperature, at each node.

Table 2-1. ANSYS® Finite Element Types Used in ICV™ Box Sidewall and Bottom Models.

Element Type	Name	Element Description
1	PLANE55	2-D THERMAL SOLID

The material numbers used in this analysis are for conduction through the medium and the convection off of the liner. Material numbers vary depending on case number.

Table 2-2. Material Types Used in ICV™ Box Sidewall and Bottom Models.

Material Number	Description	k (Thermal Conductivity) / h (Convection/Radiation Heat Transfer Coefficient)
1	60PC Castable Refractory	See Appendices
2	110C Castable Refractory	See Appendices
3	Steel Lining	See Appendices
4,8	Air Conductivity	See Appendices
2,5	Sand data	See Appendices
3,9	"Leaking Glass" Thermal Conductivity	See Appendices
6	Horizontal Convection	See Appendices
4,7	Vertical Convection	See Appendices

2.2 Geometry and Modeling Approach

The FEM generation of the ICV™ Box Sidewall and Bottom was started by defining the coordinates of keypoints at various locations. The lines were defined from these keypoints. The element type, material properties, and geometrical properties were assigned to the generated lines. The ANSYS® meshing module automatically meshed areas into PLANE 55 elements. The boundary conditions and loading were assigned after model meshing.

2.3 ANSYS® Verification & Validation

The FEM of the ICV™ Box Sidewall and Bottom was used to determine the temperature change across the refractory using the ANSYS® computer program. The ANSYS® program has been thoroughly benchmarked with a set of over 200 verification problems that are provided with the program documentation and verified by ARES Corporation, as documented in Verification No. VV-05-02-010, *ANSYS® Version 10.0 Verification* (Reference 13). For the calculations presented herein, the program was executed on a Dell OptiPlex GX280 computer having Service Tag Number 7VB3W61and ARES ID RL_C0104.

3.0 ICV™ BOX SIDEWALL THERMAL ANALYSES

The refractory liner system for the ICV™ box sidewalls is composed of a castable refractory liner, backed by a layer of sand materials. The system is contained in a steel box. The box has an exoskeleton of 3½" x 3½" x ¼" steel tubing running vertically up the sides of the box, spaced at approximately 12" intervals. The castable refractory liner material is nominally 6" thick and is constructed of RESCO Vibrocast 60PC. A data sheet for this material is presented in the Appendices. The vertical walls of the castable refractory liner materials are backed-up by sand. Representative data for this material are also presented in the Appendices. To support the castable refractory liner sidewalls during construction of the box, columns of RESCO Rescocast110C castable refractory are staged at periodic intervals between the outboard surfaces of the 60PC castable and the steel ICV™ box walls (Data sheets for this material are included in the Appendices). The sand is then backfilled into the void space between the 60PC castable refractory liner walls, the 110C refractory vertical ribs, and the ICV™ box steel walls. The exterior surface of the ICV™ box is painted flat black using a product called Thermaline 4700 manufactured by Carboline. Emissivity data for this paint is provided in the Appendices. The emissivity data presented is for Carboline 4674. Per Mr. Mike Beckman of Carboline, this is the same product as the 4700, just an updated product number. A nominal emissivity of 0.6 was assumed for all concrete surfaces modeled (ref. 6). Correlations for free convection heat transfer were included in the formulation of the net heat transfer coefficient on the exterior surface of the ICV™ box (ref. 6). The correlation used for combined free convection and radiative heat transfer are provided in the Appendices for both vertically- and horizontally-oriented surfaces of the ICV™ box.

The ICV™ box sidewall thermal analyses performed for the HRTS simulations (references 1 & 2) indicated that the worst-case box skin temperatures were obtained when the heat fin effect of the tube steel exoskeleton is not included in the model. Consequently, they are not explicitly included in the simulations presented herein.

For the "leaking glass" cases considered, temperature-dependent thermal conductivity data for representative glass was included in the model. Presently there is no data for the glasses to be generated by the BulkVit process. Consequently, a "hybrid" glass data set was generated using thermal conductivity for a LAW glass in the low-temperature region (reference 7) and data obtained from PNL-4800 (ref. 11) for Hanford soils.

The end walls of the DBVS ICV™ box refractory liner system will involve 60PC backed by refractory M-board (to accommodate thermal growth during processing) and sand. This configuration is not explicitly modeled herein as the M-board will reduce the gradient through the outboard materials and, consequently result in lower box skin temperatures. In the "leaking glass" scenarios, the M-board will not hinder the growth and progression of the "leaking glass". Therefore the results obtained with the configurations involving 60PC castable backed by sand will be representative of the results that could be expected for a "leak" in the end wall regions of the melt refractory liner system.

Figure 3-1 presents a schematic of the ICV™ box sidewall for the case when the 60PC castable is backed by 110C castable; Figure 3-2 presents the configuration when it is backed by sand. Both configurations are analyzed to determine the ICV™ box sidewall temperatures during normal conditions. The leaking glass scenario can only occur in regions wherein the 60PC is backed by sand, however.

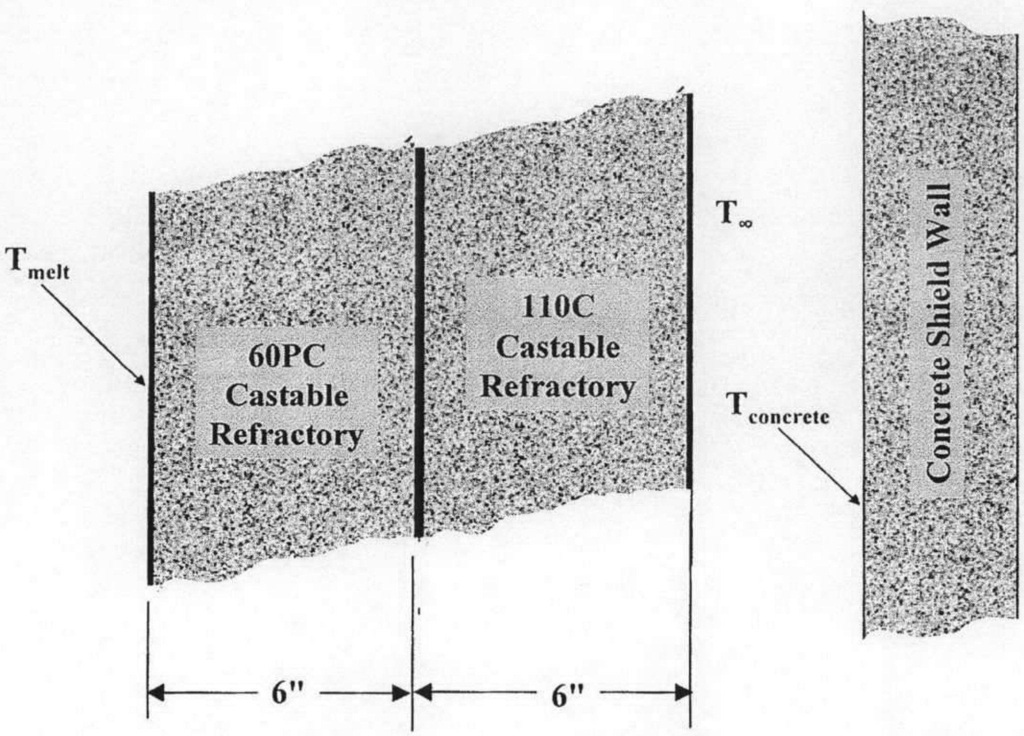

Figure 3-1. DBVS ICV™ Box Side Wall Model Schematic – in the Vicinity of the 110C Vertical Ribs.

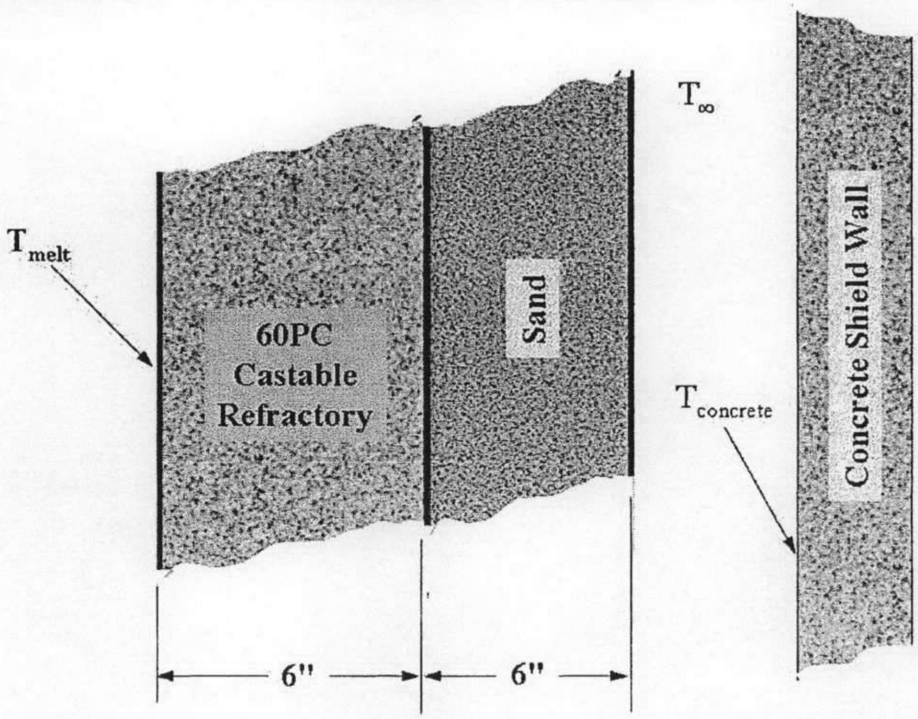

Figure 3-2. DBVS ICV™ Box Side Wall Model Schematic – in the Vicinity of the Sand Backing.

Figure 3-3 presents an illustration of the sidewall configuration modeled in the "leaking glass" scenarios. In these scenarios, it is postulated that a horizontally-oriented 1" seam opens-up in the 60PC castable refractory sidewall, allowing glass to flow into the region occupied by the sand material. The glass "flows" out toward the ICV™ box sidewall and up the outboard face of the 60PC castable refractory until the leading face of the "leaking glass" cools to the "freeze point" temperature of the glass, 826°C (as specified by PNNL for this glass composition, ref. 5). The ultimate position of this leading face is determined by the assumed melt, ambient, and concrete temperatures, the thermal properties of the materials involved in the process, and the convective and radiative heat losses off the exterior surface of the ICV™ box sidewall. This configuration is intended to mimic the conditions experienced during the HRTS BulkVit Test 38A and identified n the post-test sampling and evaluation of the apparatus (ref. 4).

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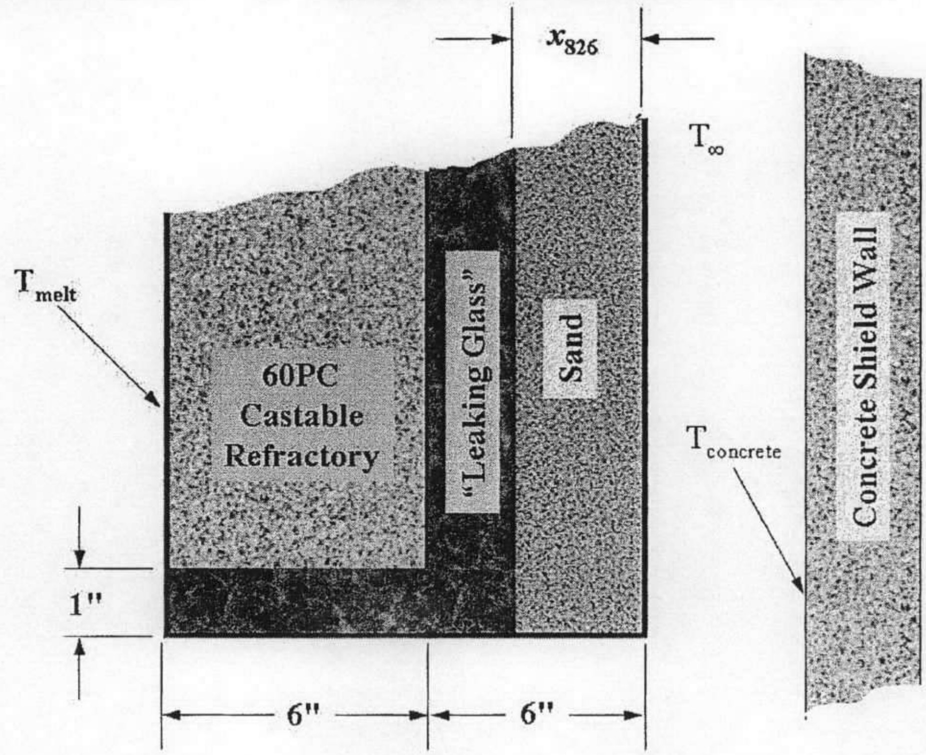

Figure 3-3. DBVS ICV™ Box Side Wall "Leaking Glass" Model Schematic.

Seven cases were considered to assess the impact of the "leaking glass" scenario on the maximum temperature realized on the ICV™ box surface and the proximity of the leading edge of the "leaking glass" to the box steel sidewall. The following sections describe the assumptions and corresponding results for each of these cases.

3.1 Base Case Conditions – 110C Castable Refractory Backing

The configuration modeled for this case is depicted in Figure 3-1. Temperature-dependent thermal conductivity data for each material was included in the model and is presented in the Appendices. Combined free convection and radiation heat transfer was modeled off the outside surface of the ICV™ box sidewall. The radiation heat transfer component assumed an emissivity of 0.8 for the ICV™ box steel and 0.6 for the concrete shield wall. A temperature of 1300°C was assumed for the melt/60PC interface. This temperature reflects a conservatively high, but reasonable, estimate of the melt temperature in this region during normal operating conditions. A conservative, upper-bound temperature of 100°C was assumed for the ambient and concrete surface temperatures outboard of the ICV™ box. In summary, the conditions modeled for this case were:

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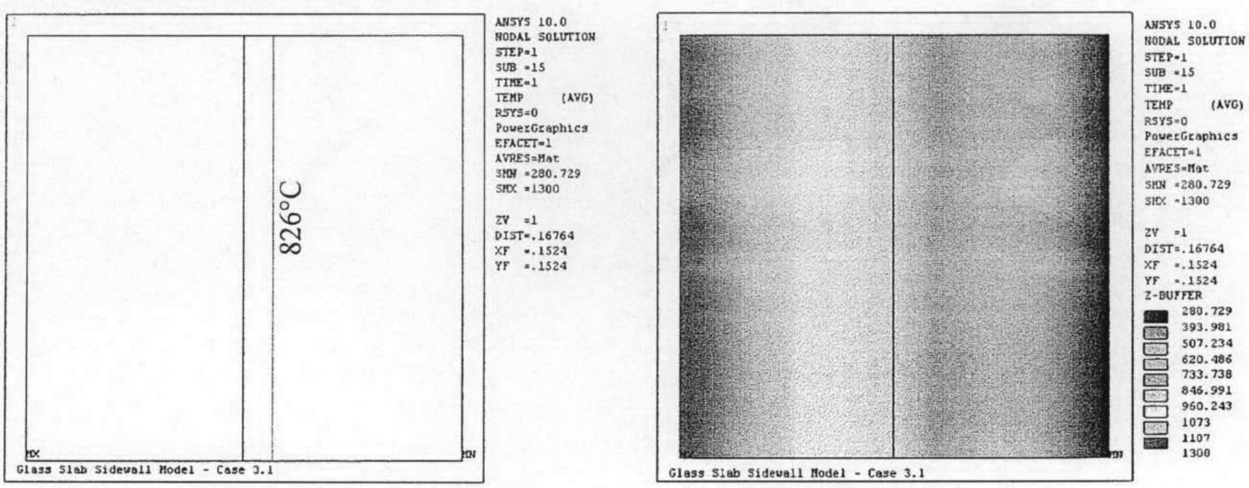
- 2D Model of Box sidewall – Base Case Configuration, No leaking glass
  - 1300°C temperature at melt/60PC interface
  - 6" thick 60PC castable refractory
  - 6" thick 110C castable refractory vertical ribs
  - Hybrid LAW/PNL-4800 glass thermal conductivity properties
  - Nominal natural convection & radiation on outside box wall – with effect of concrete shield wall included
    - $\varepsilon_{box} = 0.8$
    - $\varepsilon_{concrete} = 0.6$
  - 100°C ambient for both air and concrete surfaces

The ANSYS® v10.0 computer code was used to compute the temperature distribution in the ICV™ box refractory liner system under these conditions. Figure 3-4(a) provides an illustration of the location of the 826°C isotherm for this model; a color map of the full-field temperature distribution is presented in Figure 3-4(b). As the results indicate, the results for the key metrics were:

- Location of the 826°C isotherm ~ 5⅛" from box skin
- Maximum Box skin temperature ~ 281°C



(a) (b)

Figure 3-4. Temperature Distribution for the ICV™ Box Sidewall Configuration – 110C Refractory Backing.

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3.2 Base Case Conditions – Sand Backing

The configuration modeled for this case is depicted in Figure 3-2. Temperature-dependent thermal conductivity data for each material was included in the model and is presented in the Appendices. Combined free convection and radiation heat transfer was modeled off the outside surface of the ICV™ box sidewall. The radiation heat transfer component assumed an emissivity of 0.8 for the ICV™ box steel and 0.6 for the concrete shield wall. A temperature of 1300°C was assumed for the melt/60PC interface. This temperature reflects a conservatively high, but reasonable, estimate of the melt temperature in this region during normal operating conditions. A conservative, upper-bound temperature of 100°C was assumed for the ambient and concrete surface temperatures outboard of the ICV™ box. In summary, the conditions modeled for this case were:

- 2D Model of Box sidewall – Base Case Configuration, No leaking glass
  - 1300°C temperature at melt/60PC interface
  - 6" thick 60PC castable refractory
  - 6" thick sand
  - Hybrid LAW/PNL-4800 glass thermal conductivity properties
  - Nominal natural convection & radiation on outside box wall – with effect of concrete shield wall included
    - $\varepsilon_{box} = 0.8$
    - $\varepsilon_{concrete} = 0.6$
  - 100°C ambient for both air and concrete surfaces

The ANSYS® v10.0 computer code was used to compute the temperature distribution in the ICV™ box refractory liner system under these conditions. Figure 3-5(a) provides an illustration of the location of the 826°C isotherm for this model; a color map of the full-field temperature distribution is presented in Figure 3-5(b). As the results indicate, the results for the key metrics were:

- Location of the 826°C isotherm ~ 3¾" from box skin
- Maximum Box skin temperature ~ 232°C

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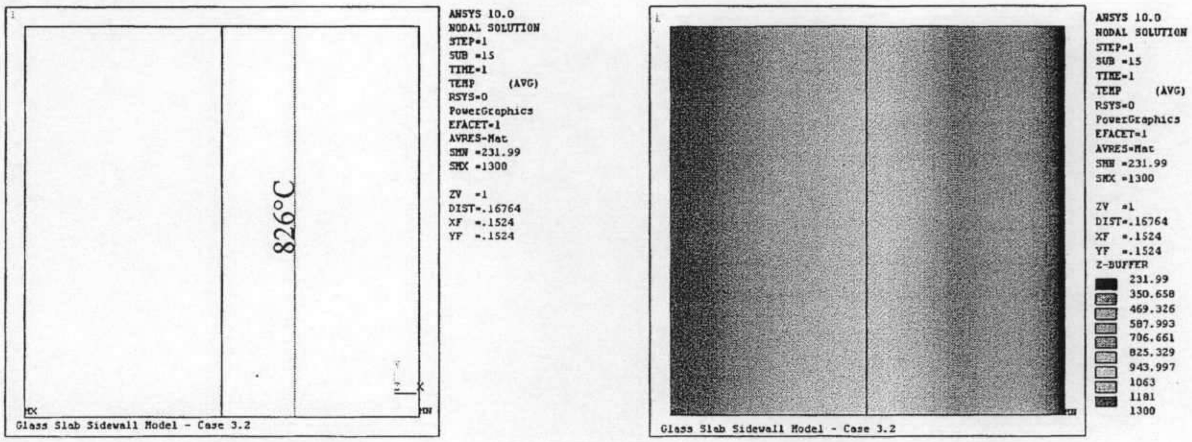

(a) (b)

Figure 3-5. Temperature Distribution for the ICV™ Box Sidewall Configuration – Sand Backing.

3.3 "Leaking Glass" Scenarios

As discussed in section 3.0, a number of cases were considered to assess the consequences of a horizontal seam opening in the 60PC refractory allowing a slab of "leaking glass" to flow and form on the outboard face of the 60PC castable refractory. The configuration modeled is depicted in Figure 3-3. The leading face of the "leaking glass" region was adjusted in the model until it coincided with the location of the 826°C isotherm. The results obtained from a number of conditions are presented in this section. These results reflect variations in the assumption of the temperature of the melt at the melt/60PC interface, and modifying the combined heat transfer coefficient on the surface of the ICV™ box by factors of ½ and 2.

3.3.1 1300°C Melt/60PC Interface Conditions

The configuration modeled for this case is depicted in Figure 3-3. The conditions modeled were:

- 2D Model of Box sidewall – "Leaking Glass" Scenario
    - 1300°C temperature at melt/60PC interface
    - 6" thick 60PC castable refractory
    - 6" thick sand
    - Hybrid LAW/PNL-4800 glass thermal conductivity properties
    - Nominal natural convection & radiation on outside box wall – with effect of concrete shield wall included
        - $\varepsilon_{box} = 0.8$
        - $\varepsilon_{concrete} = 0.6$
    - 100°C ambient for both air and concrete surfaces

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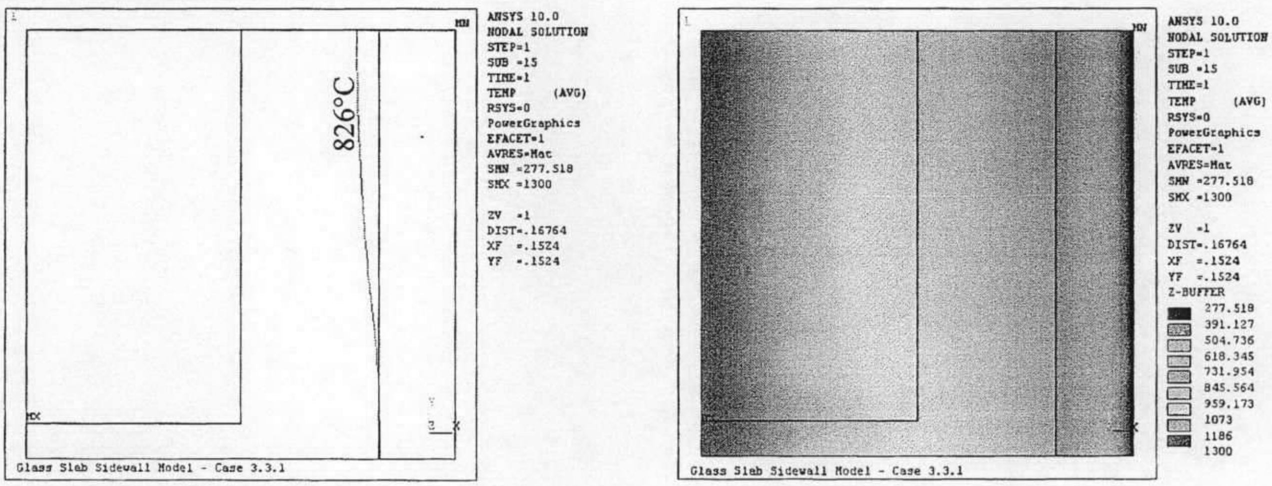
The ANSYS® v10.0 computer code was used to compute the temperature distribution in the ICV™ box refractory liner system under these conditions. Figure 3-6(a) provides an illustration of the location of the 826°C isotherm for this model; a color map of the full-field temperature distribution is presented in Figure 3-6(b). As the results indicate, the results for the key metrics were:

- Location of the 826°C isotherm ~ 2⅛" " from box skin
- Maximum Box skin temperature ~ 286°C



(a) (b)

Figure 3-6. Temperature Distribution for the ICV™ Box Sidewall Configuration – 1300°C "Leaking Glass".

3.3.2 1500°C Melt/60PC Interface Conditions

The configuration modeled for this case is depicted in Figure 3-3. The conditions modeled were:

- 2D Model of Box sidewall – "Leaking Glass" Scenario
  - 1500°C temperature at melt/60PC interface
  - 6" thick 60PC castable refractory
  - 6" thick sand
  - Hybrid LAW/PNL-4800 glass thermal conductivity properties
  - Nominal natural convection & radiation on outside box wall – with effect of concrete shield wall included
    - $\varepsilon_{box} = 0.8$
    - $\varepsilon_{concrete} = 0.6$
  - 100°C ambient for both air and concrete surfaces

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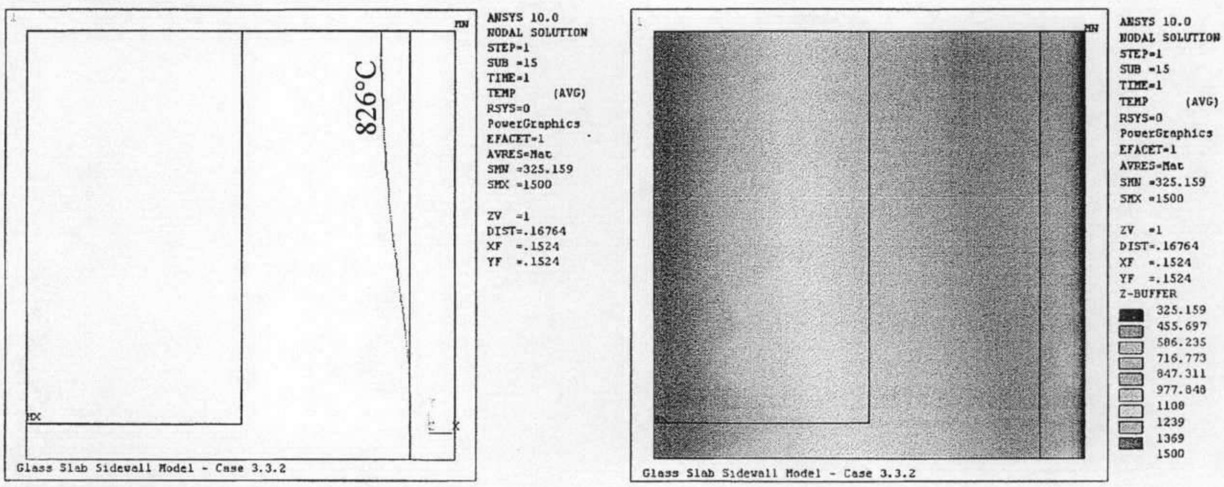
The ANSYS® v10.0 computer code was used to compute the temperature distribution in the ICV™ box refractory liner system under these conditions. Figure 3-7(a) provides an illustration of the location of the 826°C isotherm for this model; a color map of the full-field temperature distribution is presented in Figure 3-7(b). As the results indicate, the results for the key metrics were:

- Location of the 826°C isotherm ~ 1¼" " from box skin
- Maximum Box skin temperature ~ 342°C



(a) (b)

Figure 3-7. Temperature Distribution for the ICV™ Box Sidewall Configuration – 1500°C "Leaking Glass".

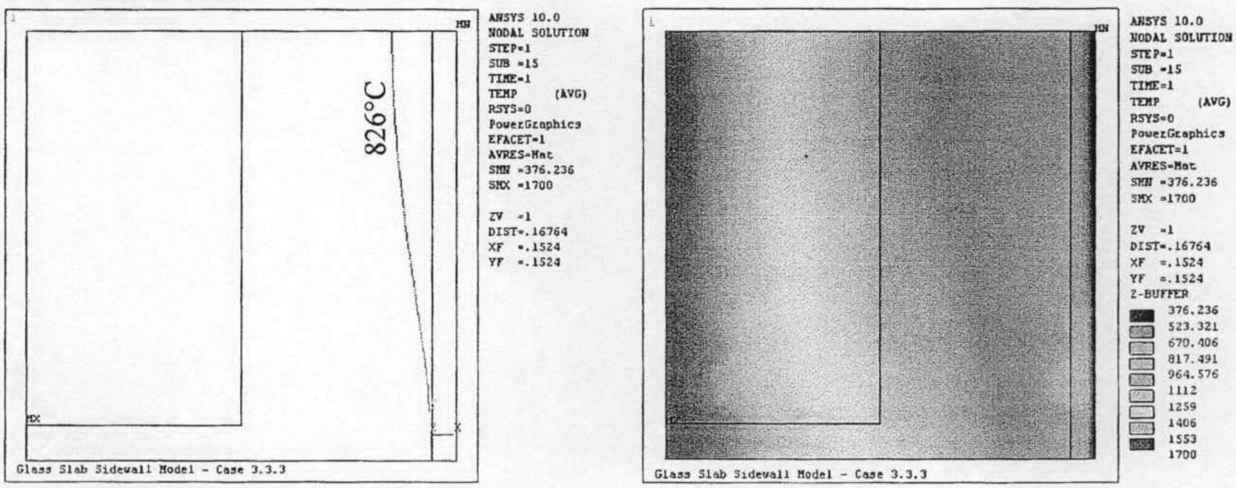
3.3.3 1700°C Melt/60PC Interface Conditions

The configuration modeled for this case is depicted in Figure 3-3. The conditions modeled were:

- 2D Model of Box sidewall – "Leaking Glass" Scenario
  - 1700°C temperature at melt/60PC interface
  - 6" thick 60PC castable refractory
  - 6" thick sand
  - Hybrid LAW/PNL-4800 glass thermal conductivity properties
  - Nominal natural convection & radiation on outside box wall – with effect of concrete shield wall included
    - $\varepsilon_{box} = 0.8$
    - $\varepsilon_{concrete} = 0.6$
  - 100°C ambient for both air and concrete surfaces

The ANSYS® v10.0 computer code was used to compute the temperature distribution in the ICV™ box refractory liner system under these conditions. Figure 3-8(a) provides an illustration of the location of the 826°C isotherm for this model; a color map of the full-field temperature distribution is presented in Figure 3-8(b). As the results indicate, the results for the key metrics were:

- Location of the 826°C isotherm ~ ⅝" from box skin
- Maximum Box skin temperature ~ 421°C



(a) (b)

Figure 3-8. Temperature Distribution for the ICV™ Box Sidewall Configuration – 1700°C "Leaking Glass".

3.3.4 1700°C Melt/60PC Interface Conditions; Reduced surface heat transfer coefficient

The configuration modeled for this case is depicted in Figure 3-3. The configuration is similar to the one presented in Section 3.3.3. In this case however, the net heat transfer coefficient used to compute the combined convective and radiative heat losses off the ICV™ box external sidewall was reduced by a factor of 2 to assess the sensitivity of the results to variations in this parameter. The conditions modeled were:

- 2D Model of Box sidewall – "Leaking Glass" Scenario
  - 1700°C temperature at melt/60PC interface
  - 6" thick 60PC castable refractory
  - 6" thick sand
  - Hybrid LAW/PNL-4800 glass thermal conductivity properties
  - ½ x nominal natural convection & radiation on outside box wall – with effect of concrete shield wall included
    - $\varepsilon_{box} = 0.8$
    - $\varepsilon_{concrete} = 0.6$
  - 100°C ambient for both air and concrete surfaces

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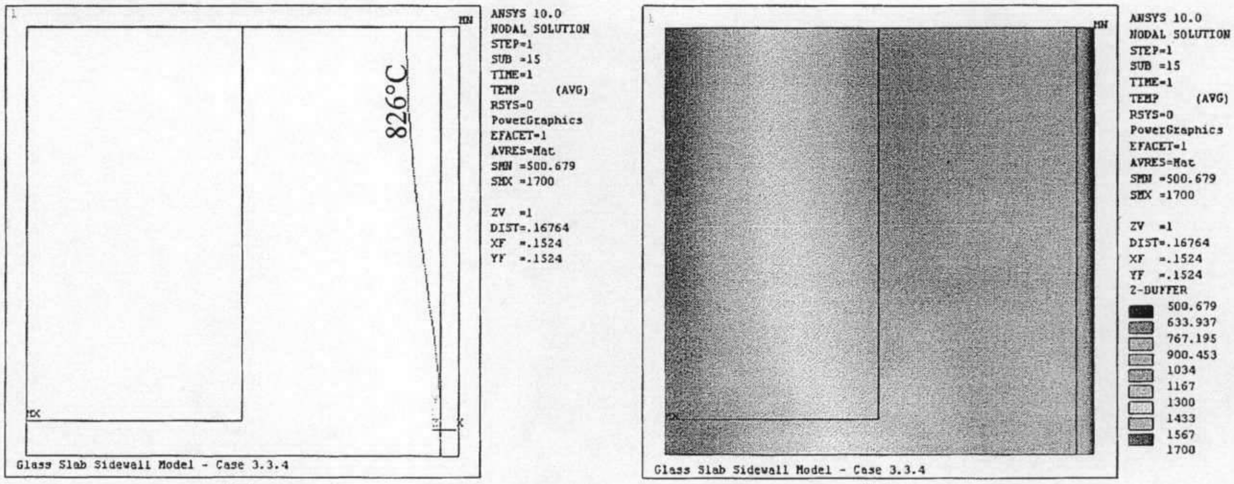
The ANSYS® v10.0 computer code was used to compute the temperature distribution in the ICV™ box refractory liner system under these conditions. Figure 3-9(a) provides an illustration of the location of the 826°C isotherm for this model; a color map of the full-field temperature distribution is presented in Figure 3-9(b). As the results indicate, the results for the key metrics were:

- Location of the 826°C isotherm ~ ½" from box skin
- Maximum Box skin temperature ~ 557°C



(a) (b)

Figure 3-9. Temperature Distribution for the ICV™ Box Sidewall Configuration – 1700°C "Leaking Glass"; Reduced ICV™ Box Surface Heat Transfer Coefficient.

3.3.5 1700°C Melt/60PC Interface Conditions; Increased surface heat transfer coefficient

The configuration modeled for this case is depicted in Figure 3-3. The configuration is similar to the one presented in Section 3.3.3. In this case however, the net heat transfer coefficient used to compute the combined convective and radiative heat losses off the ICV™ box external sidewall was increased by a factor of 2 to assess the sensitivity of the results to variations in this parameter. The conditions modeled were:

- 2D Model of Box sidewall – "Leaking Glass" Scenario
  - 1700°C temperature at melt/60PC interface
  - 6" thick 60PC castable refractory
  - 6" thick sand
  - Hybrid LAW/PNL-4800 glass thermal conductivity properties
  - 2 x nominal natural convection & radiation on outside box wall – with effect of concrete shield wall included
    - $\varepsilon_{box} = 0.8$
    - $\varepsilon_{concrete} = 0.6$
  - 100°C ambient for both air and concrete surfaces

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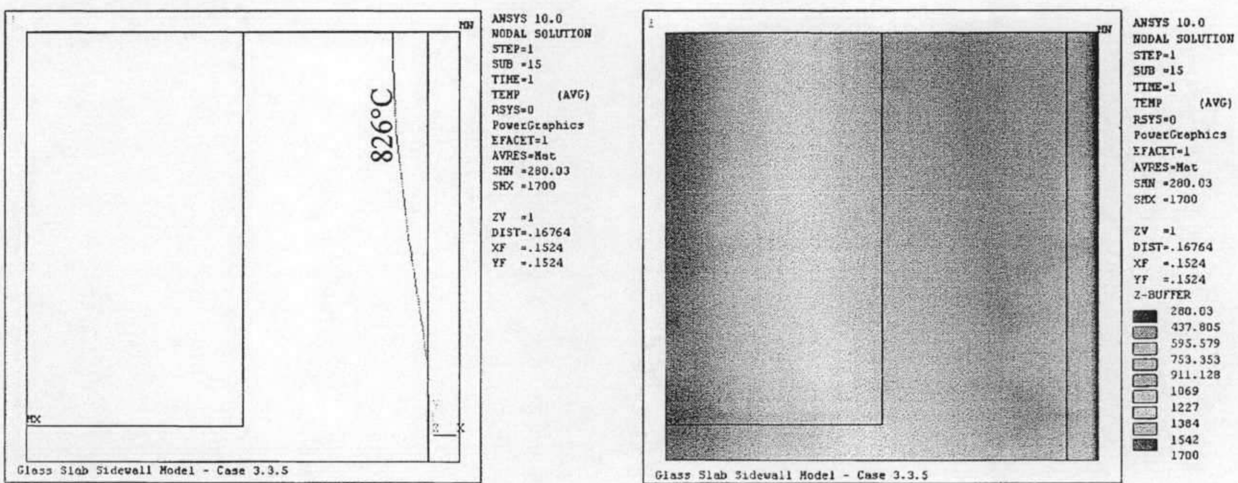
The ANSYS® v10.0 computer code was used to compute the temperature distribution in the ICV™ box refractory liner system under these conditions. Figure 3-10(a) provides an illustration of the location of the 826°C isotherm for this model; a color map of the full-field temperature distribution is presented in Figure 3-10(b). As the results indicate, the results for the key metrics were:

- Location of the 826°C isotherm ~ ⅞" from box skin
- Maximum Box skin temperature ~ 313°C



(a) (b)

Figure 3-10. Temperature Distribution for the ICV™ Box Sidewall Configuration – 1700°C "Leaking Glass"; Increased ICV™ Box Surface Heat Transfer Coefficient.

4.0 ICV™ BOX BOTTOM THERMAL ANALYSES

Similar to the ICV™ box sidewalls, the ICV™ box bottom refractory liner region is composed of an array of castable refractory floor slabs, resting on a composite layer of castable refractory support blocks. The region between refractory support blocks is filled with sand. The floor slabs make-up the bottom of the melt castable refractory liner, and are composed of 6" thick RESCO Vibrocast 60PC slabs that are joined with a half-lap seam between slabs. The joints in each seam are slathered with a layer of refractory "mud" during construction to cement them together and seal any gaps. The refractory support blocks are 5" wide by 8" tall, and are composed of RESCO Rescocast 110C. The data sheets containing compositional and property data for both of these RESCO products is provided in the Appendices. The regions occupied by sand are 9" wide by 8" tall. The bottom surfaces of the 110C support blocks and sand rests on the ICV™ steel box bottom. The outer surface of the box bottom is ribbed with 6" x 6" x ½" tube steel, spaced approximately 12" on-centers. The tubes run across the 8' width of the box. The outer surface of the ICV™ box bottom is painted with the Carboline Thermoline 4700 flat black product. Again, all the property data relevant to the thermal analyses performed for this calculation is presented in the Appendices. The correlations and associated numerical data

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used to model convective and radiative heat transfer off the ICV™ box bottom is also presented in the Appendices.

As for the sidewall analyses, for the box bottom "leaking glass" cases considered, temperature-dependent thermal conductivity data for representative glass was included in the model. The "hybrid" glass data generated for the sidewall analyses was also used in these cases. This data is presented in the Appendices.

The ICV™ box bottom thermal analyses performed for the HRTS simulations (references 1 & 2) indicated that the worst-case box skin temperatures were obtained when the heat fin effect of the tube steel exoskeleton is not included in the model. Consequently, they are not explicitly included in the simulations presented herein.

Figure 4-1 presents a schematic diagram of the ICV™ box bottom model used in these analyses.

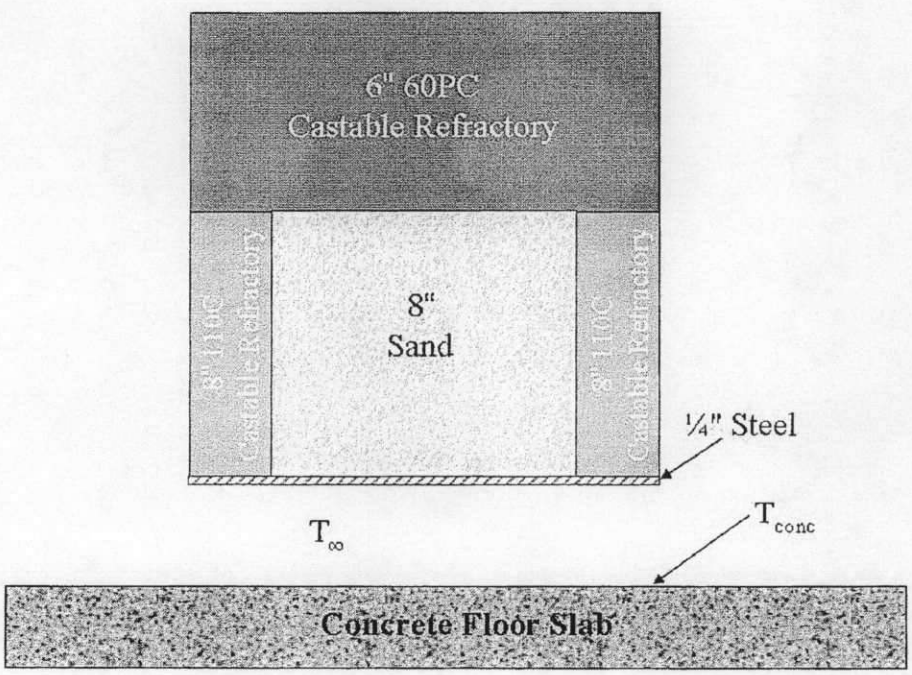


Figure 4-1. ICV™ Box Bottom Model Schematic.

For the ICV™ box bottom "leaking glass" scenarios, the configuration modeled is as depicted in Figure 4-2. As with the "leaking glass" model used for the ICV™ sidewall analyses, a 1" wide seam was assumed to open-up in the 60PC floor slabs to allow direct communication between the melt and the sand region below. The thickness of the "leaking glass" region in the refractory slab was determined by the assumed temperatures for the melt at the melt/60PC interface, the thermal properties of the various materials present in the ICV™ box bottom region, and the heat transfer coefficients used to represent convective and radiative heat losses from the exterior steel surface of the ICV™ box bottom and its surrounding environment. The "leaking glass" will propagate into the sand until the leading edge of the slab coincides with the location of the 826°C isotherm in that region. As indicated in Figure 4-2, x_{826} represents the distance between exterior surface of the ICV™ box bottom and the leading edge of the "leaking glass" slab.

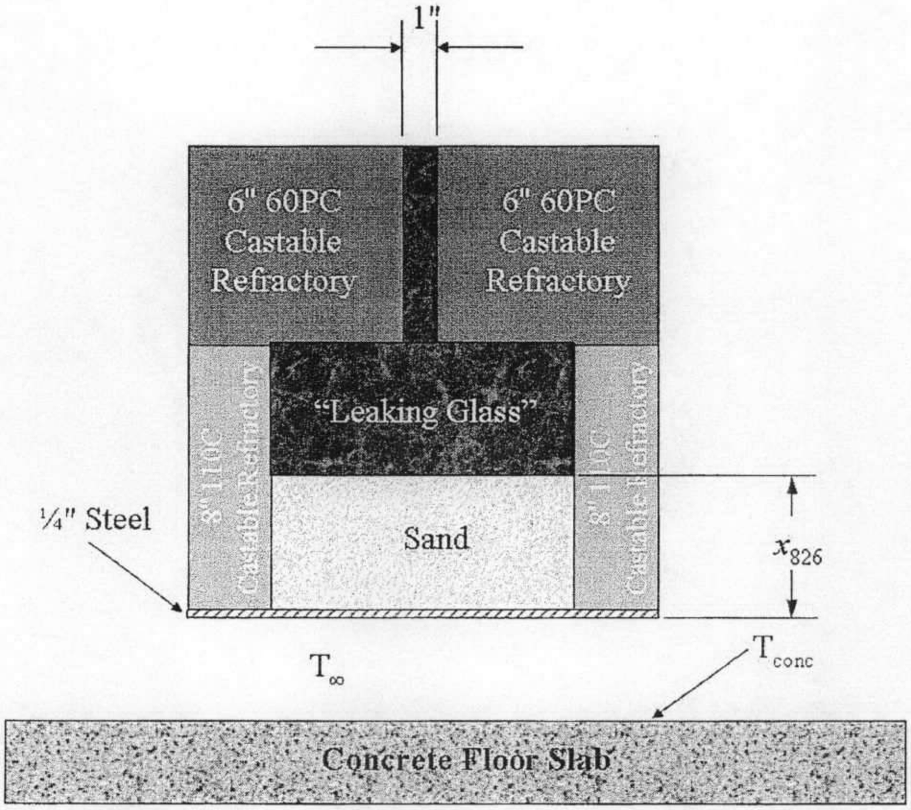


Figure 4-2. ICV™ Box Bottom Model Schematic – "Leaking Glass" Scenario.

Six cases were considered to assess the impact of the "leaking glass" scenario on the maximum temperature realized on the ICV™ box bottom surface and the proximity of the "leaking glass" to the box bottom steel. The following sections describe the assumptions and corresponding results for each of these cases.

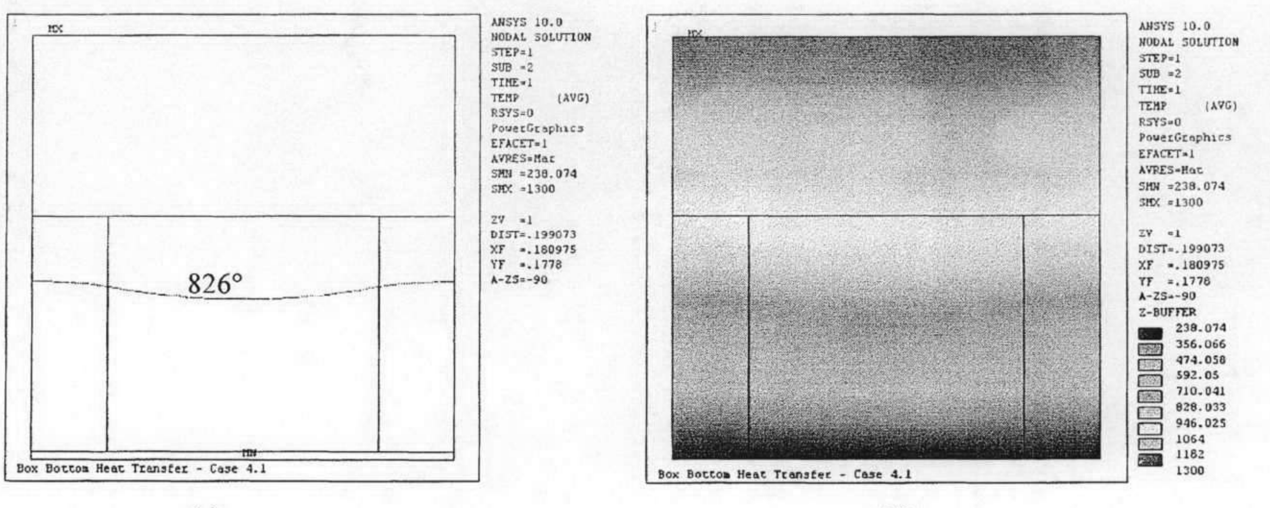
4.1 Base Case Conditions

The configuration modeled for this case is depicted in Figure 4-1. Temperature-dependent thermal conductivity data for each material was included in the model and is presented in the Appendices. Combined free convection and radiation heat transfer was modeled off the outside surface of the ICV™ box bottom. The radiation heat transfer component assumed an emissivity of 0.8 for the ICV™ box steel and 0.6 for the concrete floor. A temperature of 1300°C was assumed for the melt/60PC interface. This temperature reflects a conservatively high, but reasonable, estimate of the melt temperature in this region during normal operating conditions. A conservative, upper-bound temperature of 100°C was assumed for the ambient and concrete surface temperatures outboard of the ICV™ box. In summary then, the conditions modeled for this case were:

- 2D Model of Box bottom – Base Case Configuration, No Leak
  - 1300°C temperature at melt/60PC interface
  - 6" thick 60PC castable refractory
  - 8" tall by 9" wide sand; 8" tall by 5" wide 110C castable refractory supports (split to center the sand region on the model's vertical centerline)
  - Nominal natural convection & radiation on bottom box wall – with effect of concrete floor included
    - $\varepsilon_{box} = 0.8$
    - $\varepsilon_{concrete} = 0.6$
  - 100°C ambient for both air and concrete surfaces

The ANSYS® v10.0 computer code was used to compute the temperature distribution in the ICV™ box refractory liner system under these conditions. Figure 4-3(a) provides an illustration of the location of the 826°C isotherm for this model; a color map of the full-field temperature distribution is presented in Figure 4-3(b). As the results indicate, the results for the key metrics were:

- Location of the 826°C isotherm ~ 5⅝" from box bottom
- Maximum Box skin temperature ~ 252°C



(a) (b)

Figure 4-3. Temperature Distribution for the ICV™ Box Bottom Configuration.

4.2 "Leaking Glass" Scenarios

A series of five cases were considered to assess the impact of the "leaking glass" scenario on the maximum box skin temperature and the proximity of the leading edge of the "leaking glass" slab to the ICV™ box bottom steel wall. The configuration modeled in these cases is depicted in the model schematic presented in Figure 4-2. The cases considered variations on the assumed temperature at the melt/60PC interface and the sensitivity to the heat transfer coefficient used to model convective and radiative losses off the bottom of the ICV™ box. As was done for the ICV™ box sidewall cases, the combined surface heat transfer coefficient was modified by factors of ½ and 2 in this sensitivity study.

4.2.1 1300°C Melt/60PC Interface Conditions

The conditions modeled for this case were as follows:

- 2D Model of Box bottom
  - 1300°C temperature at melt/60PC interface
  - 6" thick 60PC castable refractory
  - 8" thick sand; 8" 110C castable refractory supports
  - Hybrid LAW/PNL-4800 glass thermal conductivity properties
  - Nominal natural convection & radiation on bottom box wall – with effect of concrete floor included
    - $\varepsilon_{box} = 0.8$
    - $\varepsilon_{concrete} = 0.6$
  - 100°C ambient for both air and concrete surfaces

The ANSYS® v10.0 computer code was used to compute the temperature distribution in the ICV™ box refractory liner system under these conditions. Figure 4-4(a) provides an illustration of the location of the 826°C isotherm for this model; a color map of the full-field temperature distribution is presented in Figure 4-4(b). As the results indicate, the results for the key metrics were:

- Location of the 826°C isotherm ~3⅞" from box bottom
- Maximum box skin temperature ~254°C

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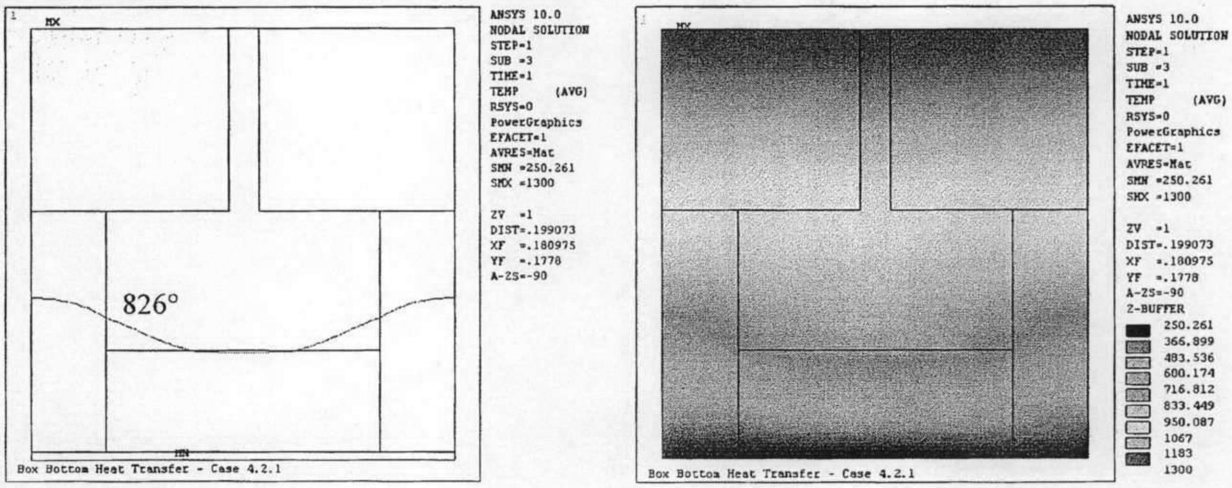

(a) (b)

Figure 4-4. Temperature Distribution for the ICV™ Box Bottom Configuration – 1300°C "Leaking Glass".

4.2.2 1500°C Melt/60PC Interface Conditions

The conditions modeled for this case were as follows:

- 2D Model of Box bottom
  - 1500°C temperature at melt/60PC interface
  - 6" thick 60PC castable refractory
  - 8" thick sand; 8" 110C castable refractory supports
  - Hybrid LAW/PNL-4800 glass thermal conductivity properties
  - Nominal natural convection & radiation on bottom box wall – with effect of concrete floor included
    - $\varepsilon_{box} = 0.8$
    - $\varepsilon_{concrete} = 0.6$
  - 100°C ambient for both air and concrete surfaces

The ANSYS® v10.0 computer code was used to compute the temperature distribution in the ICV™ box refractory liner system under these conditions. Figure 4-5(a) provides an illustration of the location of the 826°C isotherm for this model; a color map of the full-field temperature distribution is presented in Figure 4-5(b). As the results indicate, the results for the key metrics were:

- Location of the 826°C isotherm ~ 2⅜" from box bottom
- Maximum box skin temperature ~ 340°C

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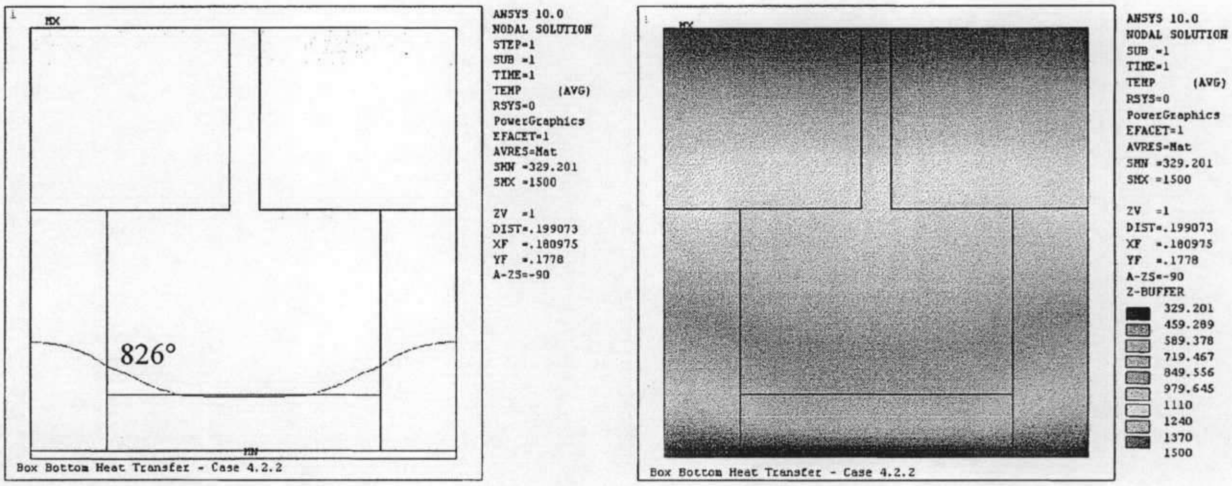

(a) (b)

Figure 4-5. Temperature Distribution for the ICV™ Box Bottom Configuration – 1500°C "Leaking Glass".

4.2.3 1700°C Melt/60PC Interface Conditions

The conditions modeled for this case were as follows:

- 2D Model of Box bottom
  - 1700°C temperature at melt/60PC interface
  - 6" thick 60PC castable refractory
  - 8" thick sand; 8" 110C castable refractory supports
  - Hybrid LAW/PNL-4800 glass thermal conductivity properties
  - Nominal natural convection & radiation on bottom box wall – with effect of concrete floor included
    - $\varepsilon_{box} = 0.8$
    - $\varepsilon_{concrete} = 0.6$
  - 100°C ambient for both air and concrete surfaces

The ANSYS® v10.0 computer code was used to compute the temperature distribution in the ICV™ box refractory liner system under these conditions. Figure 4-6(a) provides an illustration of the location of the 826°C isotherm for this model; a color map of the full-field temperature distribution is presented in Figure 4-6(b). As the results indicate, the results for the key metrics were:

- Location of the 826°C isotherm ~ 1⅝" from box bottom
- Maximum box skin temperature ~ 391°C

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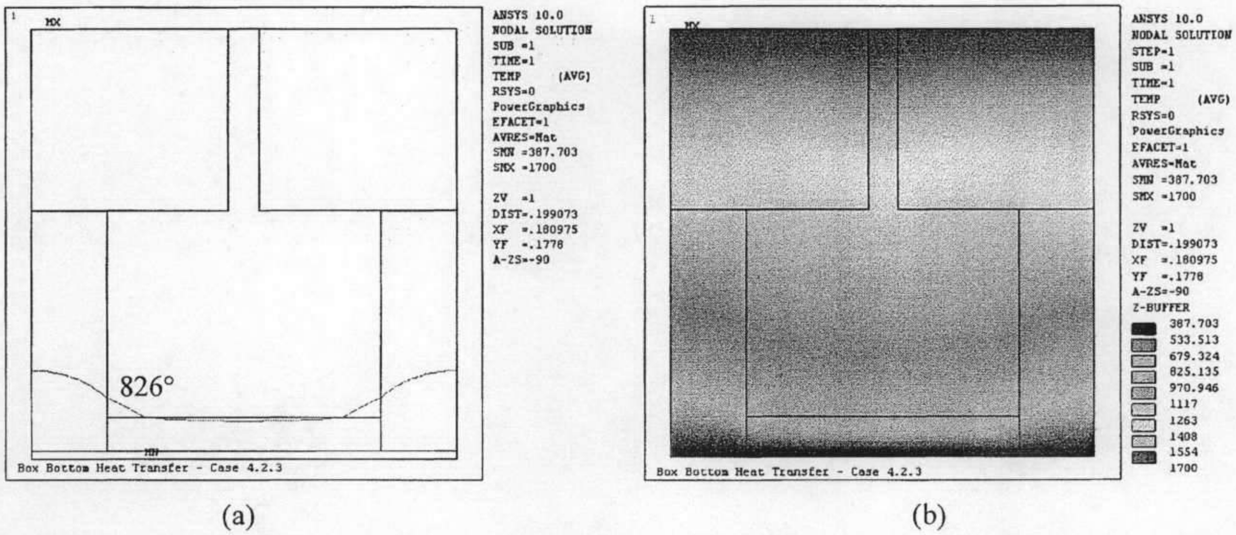

Figure 4-6. Temperature Distribution for the ICV™ Box Bottom Configuration – 1700°C "Leaking Glass".

4.2.4 1700°C Melt/60PC Interface Conditions; Reduced surface heat transfer coefficients

The conditions modeled for this case were as follows:

- 2D Model of Box bottom
  - 1700°C temperature at melt/60PC interface
  - 6" thick 60PC castable refractory
  - 8" thick sand; 8" 110C castable refractory supports
  - Hybrid LAW/PNL-4800 glass thermal conductivity properties
  - ½ x nominal natural convection & radiation on bottom box wall – with effect of concrete floor included
    - $\varepsilon_{box} = 0.8$
    - $\varepsilon_{concrete} = 0.6$
  - 100°C ambient for both air and concrete surfaces

The ANSYS® v10.0 computer code was used to compute the temperature distribution in the ICV™ box refractory liner system under these conditions. Figure 4-7(a) provides an illustration of the location of the 826°C isotherm for this model; a color map of the full-field temperature distribution is presented in Figure 4-7(b). As the results indicate, the results for the key metrics were:

- Location of the 826°C isotherm ~ 1⅛" from box bottom
- Maximum box skin temperature ~ 517°C

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Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

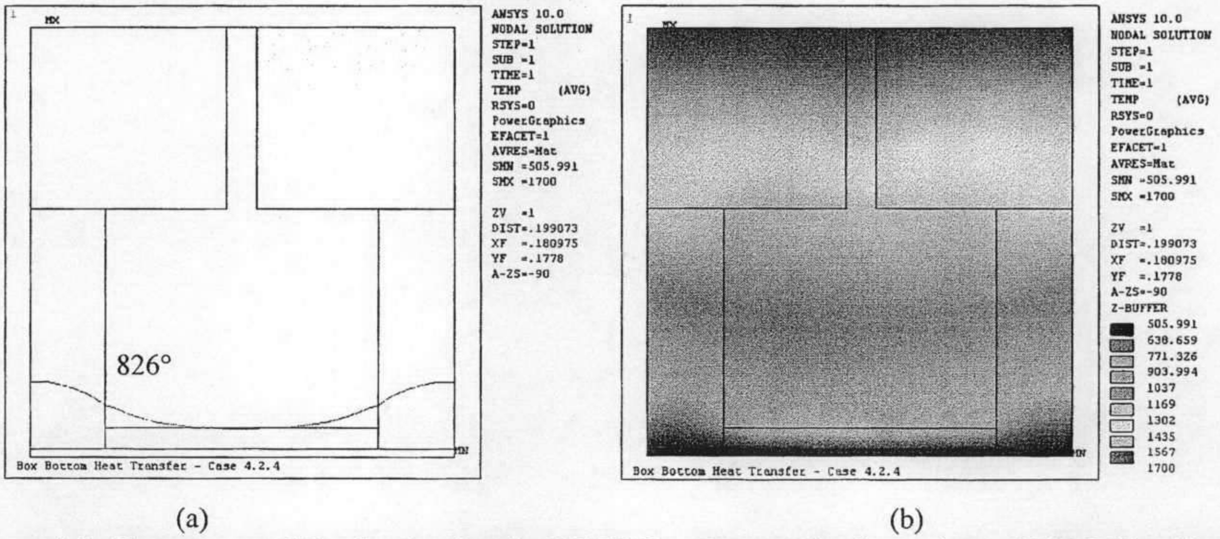

Figure 4-7. Temperature Distribution for the ICV™ Box Bottom Configuration – 1700°C "Leaking Glass"; Reduced ICV™ Box Surface Heat Transfer Coefficient.

4.2.5 1700°C Melt/60PC Interface Conditions; Increased surface heat transfer coefficients

The conditions modeled for this case were as follows:

- 2D Model of Box bottom
  - 1700°C temperature at melt/60PC interface
  - 6" thick 60PC castable refractory
  - 8" thick sand; 8" 110C castable refractory supports
  - Hybrid LAW/PNL-4800 glass thermal conductivity properties
  - 2 x nominal natural convection & radiation on bottom box wall – with effect of concrete floor included
    - $\varepsilon_{box} = 0.8$
    - $\varepsilon_{concrete} = 0.6$
  - 100°C ambient for both air and concrete surfaces

The ANSYS® v10.0 computer code was used to compute the temperature distribution in the ICV™ box refractory liner system under these conditions. Figure 4-8(a) provides an illustration of the location of the 826°C isotherm for this model; a color map of the full-field temperature distribution is presented in Figure 4-8(b). As the results indicate, the results for the key metrics were:

- Location of the 826°C isotherm ~ 1⅝" from box bottom
- Maximum box skin temperature ~ 299°C

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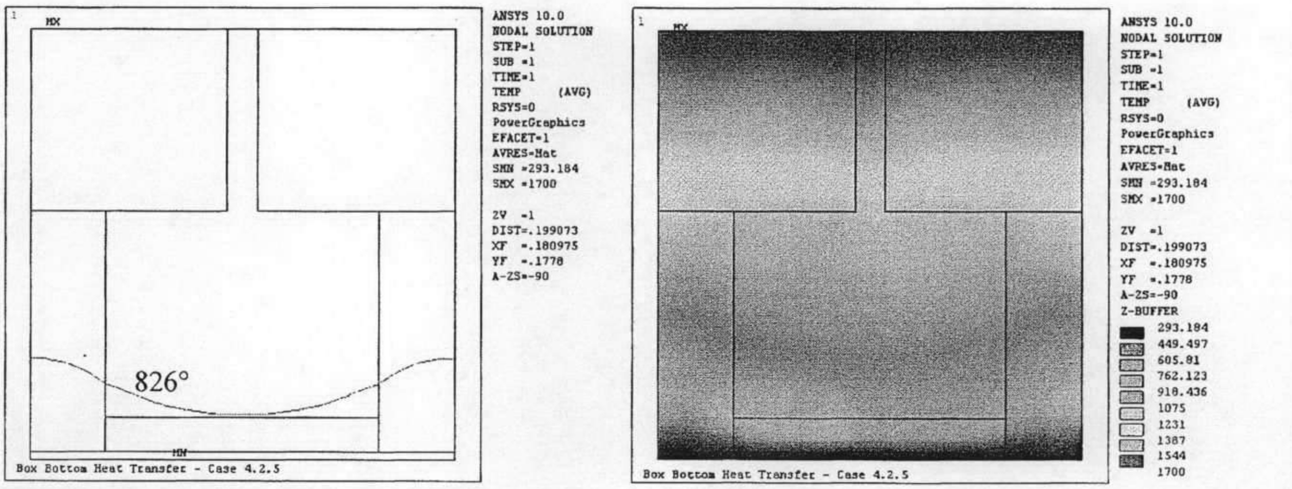

(a) (b)

Figure 4-8. Temperature Distribution for the ICV™ Box Bottom Configuration – 1700°C "Leaking Glass"; Increased ICV™ Box Surface Heat Transfer Coefficient.

5.0 CONCLUSIONS

A series of simulations were performed to evaluate the thermal performance of the ICV™ box side and bottom regions under base case and "leaking glass" scenarios. The simulations considered the sensitivity of the maximum box skin temperature and proximity of the "leaking glass" front to the box surface to variations in assumed melt temperature at the melt/60PC interface and the heat transfer coefficient used to model convective and radiative heat losses from the ICV™ box surface to the surroundings. The results are summarized in Table 5-1 for the ICV™ box sidewall simulations and Table 5-2 for the ICV™ box bottom simulations.

These results indicate that, under normal operating conditions, a maximum ICV™ box sidewall skin temperature of approximately 280°C would occur in the vicinity of the vertical castable refractory ribs. Under off-normal conditions, when a seam has opened in the 60PC castable refractory slabs allowing molten glass to propagate into the sand layer between the 60PC melt castable refractory liner and the ICV™ box sidewall, the peak ICV™ box skin temperature would be approximately 286°C, and the "leaking glass" front would propagate through the sand layer and approach to within 2⅛" of the ICV™ box skin. In the extremely off-normal condition of a melt/60PC interface temperature of 1700°C, the maximum box skin temperature increases to 421°C and the leading edge of the "leaking glass" approaches to within ⅝" of the ICV™ box steel skin. Even under these extremely severe assumptions, the molten material is still contained within the sand layer. As an indication of the conservatism imposed in the analysis, if the heat transfer coefficients are reduced by a factor of two, the ICV™ box sidewall temperature increases to 557°C. Under these conditions, the "leaking glass" front approaches to within ½" of the ICV™ box steel skin. These conditions are still within the design limits of the box.

A.R.E.S CORPORATION

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The results obtained from simulations of the ICV™ box bottom region indicate a maximum surface temperature of approximately 250°C under normal operating conditions (assuming a melt/60PC interface temperature of 1300°C). In the assumed off-normal condition wherein a seam opens-up in the 60PC castable refractory floor slabs of the melt castable refractory liner, the maximum box surface temperature increases slightly to approximately 255°C. The leading edge of the "leaking glass" melt slab propagates through the sand layer beneath the 60PC floor slabs to within 3⅞" of the ICV™ box steel skin. In the extremely off-normal condition of a melt/60PC interface temperature of 1700°C, the ICV™ box bottom temperature increases to 391°C and the leading edge of the "leaking glass" approaches to within 1⅝" of the ICV™ steel box skin. Even under these extremely severe assumptions, the molten material is still contained within the sand layer. As an indication of the conservatism imposed in the analysis, if the heat transfer coefficients are reduced by a factor of two, the ICV™ box bottom temperature increases to 517°C and the leading edge of the "leaking glass" approaches to within 1⅛" of the ICV™ steel box bottom. These conditions are still within the design limits of the box.

In summary then, these results indicate that a melt castable refractory liner composed of 6" thick RESCO VIBROCAST 60PC, backed-up by 6" of sand and/or 6" thick vertical support ribs composed of RESCO RESCOCAST 110C is sufficient to contain the melt, even under off-normal "leaking glass" conditions in which a 1" wide seam opens-up in the sidewalls of the 60PC castable refractory liner. Similarly, the 6" thick RESCO VIBROCAST 60PC material used to form the floor of the melt castable refractory liner, backed-up by an 8" thick layer of either RESCO RESCOCAST 110C support blocks or 8" of sand is sufficient to contain the melt, even under off-normal "leaking glass" conditions in which a 1" wide seam opens-up in the floor of the 60PC-lined melt castable refractory liner.

Table 5-1. Results for the ICV™ Box Sidewall Heat Transfer Simulations

Case	T_{melt} [°C]	T_{∞} [°C]	Heat Transfer Coefficient Multiplier	"Leaking Glass" Condition	x_{826}	T_{skin} [°C]
3.1[(1)]	1300	100	1x	No	5⅛"	281
3.2[(2)]	"	"	"	No	3¾"	232
3.3.1	"	"	"	Yes	2⅛"	286
3.3.2	1500	"	"	"	1¼"	342
3.3.3	1700	"	"	"	⅝"	421
3.3.4	"	"	½x	"	½"	557
3.3.5	"	"	2x	"	⅞"	313

Notes: (1) Sidewall model through 110C vertical castable refractory rib backing
(2) Sidewall model through sand backing

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Table 5-2. Results for the ICV™ Box Bottom Heat Transfer Simulations

Case	T_{melt} [°C]	T_{∞} [°C]	Heat Transfer Coefficient Multiplier	"Leaking Glass" Condition	x_{826}	T_{skin} [°C]
4.1	1300	100	1x	No	5⅝"	252
4.2.1	"	"	"	Yes	3⅞"	254
4.2.2	1500	"	"	"	2⅜"	340
4.2.3	1700	"	"	"	1⅝"	391
4.2.4	"	"	½x	"	1⅛"	517
4.2.5	"	"	2x	"	1⅝"	299

6.0 REFERENCES

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2. ARES Calculation No. 0513206.01-M-002, *AMEC Bulk Vitrification 2D Thermal Analysis of the ICV™ Box Refractory Liner and "Leaking Glass" Configuration*, Rev. 3. ARES Corporation, Richland, WA.

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APPENDIX A

CONVECTION RADIATION HEAT TRANSFER CORRELATIONS

COMBINED FREE CONVECTION & RADIATION HEAT TRANSFER COEFFICIENT CORRELATION – HORIZONTAL SURFACE

$$h_H = C_0\left[T_B - T_\infty\right]^n + \frac{\sigma\left[T_B^4 - T_{conc}^4\right]}{\left\{\left(\frac{1-\varepsilon_B}{\varepsilon_B}\right) + 1 + \left(\frac{1-\varepsilon_{conc}}{\varepsilon_{conc}}\right)\right\}(T_B - T_\infty)}$$

where: $C_0 = 0.691$

$n = \frac{1}{3}$

T_B = Box Surface Temperature, °K

T_∞ = Ambient Air Temperature, °K

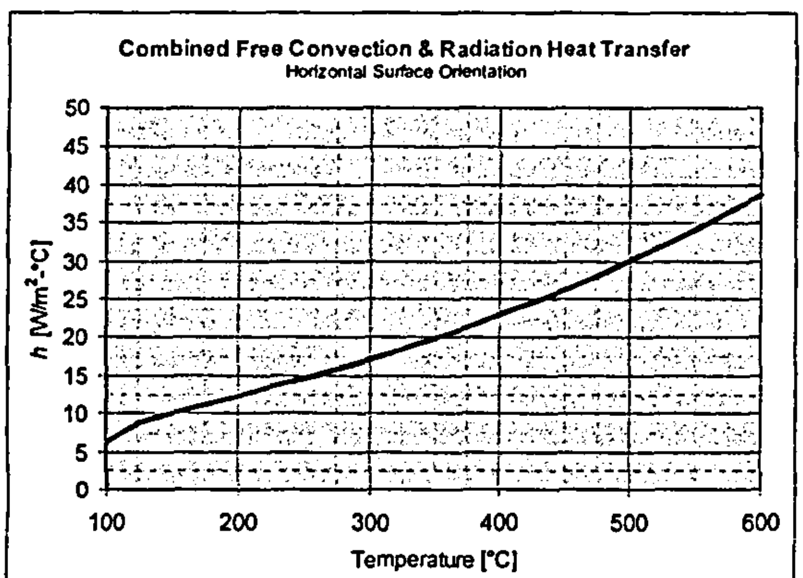
T_{conc} = Concrete Surface Temperature, °K

σ = Stefan-Boltzmann Constant, 5.67×10^{-8} W/m²-°K⁴

ε_B = Emissivity of the painted ICV™ box surface, 0.8

ε_{conc} = Emissivity of the concrete surface, 0.6

With $T_{conc} = T_\infty = 100$°C, this yields:



T_B [°C]	h [W/m²-°C]
100	6.1
125	8.8
150	10.0
175	11.2
200	12.3
225	13.4
250	14.6
275	15.8
300	17.1
325	18.5
350	19.9
375	21.4
400	23.0
425	24.6
450	26.3
475	28.2
500	30.1
525	32.1
550	34.2
575	36.4
600	38.7

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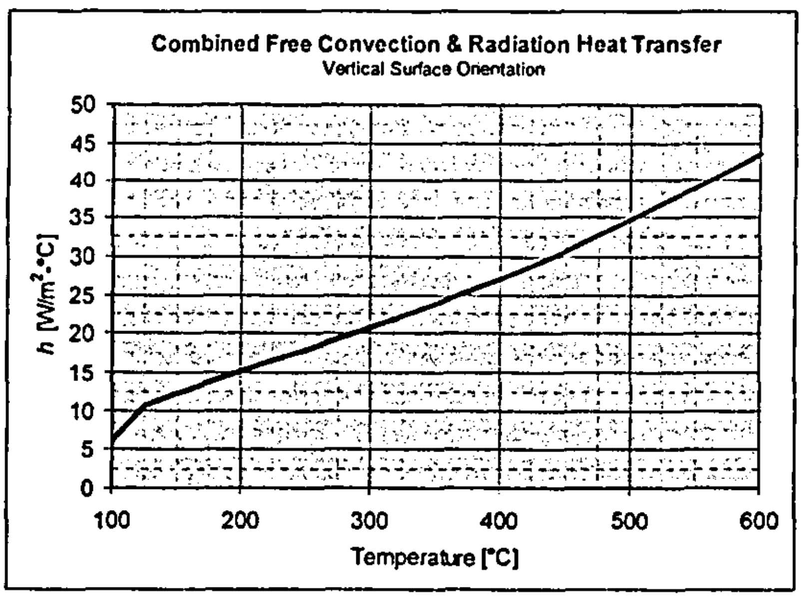
COMBINED FREE CONVECTION & RADIATION HEAT TRANSFER COEFFICIENT CORRELATION – VERTICAL SURFACE

$$h_V = C_0\left[T_B - T_\infty\right]^n + \frac{\sigma\left[T_B^4 - T_{conc}^4\right]}{\left\{\left(\frac{1-\varepsilon_B}{\varepsilon_B}\right) + 1 + \left(\frac{1-\varepsilon_{conc}}{\varepsilon_{conc}}\right)\right\}\left(T_B - T_\infty\right)}$$

where: $C_0 = 1.312$
$n = ⅓$
T_B = Box Surface Temperature, °K
T_∞ = Ambient Air Temperature, °K
T_{conc} = Concrete Surface Temperature, °K
σ = Stefan-Boltzmann Constant, 5.67×10^{-8} W/m^2-°K^4
ε_B = Emissivity of the painted ICV™ box surface, 0.8
ε_{conc} = Emissivity of the concrete surface, 0.6

With $T_{conc} = T_\infty = 100°C$, this yields:

T_B [°C]	h [W/m^2-°C]
100	6.1
125	10.6
150	12.3
175	13.8
200	15.2
225	16.5
250	17.9
275	19.3
300	20.8
325	22.3
350	23.8
375	25.4
400	27.1
425	28.9
450	30.7
475	32.6
500	34.7
525	36.8
550	39.0
575	41.3
600	43.7



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APPENDIX B

MATERIAL PROPERTY DATA SHEETS

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RESCO Products Inc. VIBROCAST 60 PC (Reference 8)

RESCO® PRODUCTS INC.

Vibratables

Product Data

VIBROCAST 60PC

VIBROCAST 60PC is a sixty percent alumina, mullite based, pumpable, 3100°, low-cement castable designed to provide minimum porosity and low linear change with maximum density and high fired strengths. This material will withstand severe high temperature corrosive and erosive environments.

Maximum Service Temperature:	3100°F (1700°C)
Bulk Density:	
220°F (105°C)	163 lb/ft³ (2608 kg/m³)
1500°F (815°C)	160 lb/ft³ (2560 kg/m³)
Porosity:	
1500°F (815°C)	17%
Cold Crushing Strength:	
1500°F (815°C)	10000-14000 psi (700-980 kg/cm²)
2500°F (1370°C)	11000-15000 psi (770-1050 kg/cm²)
2910°F (1600°C)	11000-15000 psi (770-1050 kg/cm²)
Modulus of Rupture:	
1500°F (815°C)	1400-2000 psi (98-140 kg/cm²)
2500°F (1370°C)	1500-2100 psi (105-147 kg/cm²)
2910°F (1600°C)	1500-2100 psi (105-147 kg/cm²)
Permanent Linear Change(%):	
1500°F (815°C)	-0.1 to -0.3
2500°F (1370°C)	0.0 to -0.3
2910°F (1600°C)	+0.4 to +0.8
Erosion Loss:	
1500°F (815°C)	Less than 9.0 cc (Typical Loss:4 - 6 cc)

Conductivity or "K" Factor:

Mean Temp.	BTU/ft²/HR/°F/in	W/mK
1000°F (540°C)	10.0	1.44
1500°F (815°C)	10.0	1.44
2000°F (1095°C)	10.0	1.44

Typical Chemical Analysis(%):

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	CaO	Other
60.8	34.5	1.0	1.8	1.6	0.3

Standard Packaging: 72-55 lb. bags per pallet

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RESCO Products Inc. RESCOCAST 110 C (Reference 8)

RESCO PRODUCTS INC.

Extreme Service Castables

Product Data

RESCOCAST 110C

RESCOCAST 110C is a casting grade refractory that combines strength and abrasion resistant qualities with low thermal conductivity. Rescocast 110C is the product of choice when both performance and insulation is desired in a single product

Maximum Service Temperature:	2400°F (1315°C)
Bulk Density:	
220°F (105°C)	117 lb/ft^3 (1870 kg/m^3)
1500°F (815°C)	110 lb/ft^3 (1760 kg/m^3)
Cold Crushing Strength:	
1500°F (815°C)	5000-9000 psi (350-630 kg/cm^2)
Modulus of Rupture:	
1500°F (815°C)	800-1200 psi (56-84 kg/cm^2)
Permanent Linear Change(%):	
1500°F (815°C)	0.0 to -0.3
Erosion Loss:	
1500°F (815°C)	Less than 12 cc
Typical	9-11 cc

Conductivity or "K" Factor:

Mean Temp.	BTU/ft^2/Hr/°F/in	W/mK
1000°F (540°C)	6.0	0.86
1500°F (815°C)	5.4	0.78

Typical Chemical Analysis(%):

Al_2O_3	SiO_2	Fe_2O_3	CaO	MgO	TiO_2	Alkalies
43.9	43.5	1.8	9.1	0.3	0.8	0.6

Standard Packaging: 72 - 55 lb. bags per pallet

CALCULATION SHEET

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Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

Steel Thermal Conductivity (Reference 9, Table A-19)

Temperature [°C]	k (Thermal Conductivity) [W/m-°K]
127	56.7
327	48
527	39.2
727	30

Representative Thermal Conductivity Data for Sand Liner Material

Temperature [°C]	k (Thermal Conductivity) [W/m-°K]
25	0.17
200	0.25
300	0.285
600	0.38
1000	0.55

A.R.E.S CORPORATION

CALCULATION SHEET

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Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

CARBOLINE PRODUCT DATA

product data carboline®

Thermaline®4700
& 4700 Aluminum

Selection & Specification Data

Generic Type
Single package silicone finish

Description
High-performance finish for areas exposed to extreme temperatures. Suitable for service from 400°F-1000°F (204°C-538°C) Color stability at maximum temperature will depend on color selected. Requires heat curing.

Features
- Resistant to severe thermal shock
- Provides outstanding long-term performance when applied over Carbozinc inorganic zinc primers
- Air-dries to touch (full film formation properties occurs after heat curing)

Color & Dry Temperature Resistance*
Available in the following stock colors:

Black (C900) 1000°F (538°C) Continuous
Aluminum (C901) 1000°F (538°C) Continuous
Black and Aluminum allow surges to 1200°F (649°C)
Gray (C705) 750°F (399°C)

All other colors are made to order and have temperature resistance in the 650-750°F (343°C-399°C) range.

Finish
Gloss - Initial (Flat after heat curing)

Primers
Inorganic zincs. None needed for stainless steel or aluminum.

Topcoats
Normally none

Dry Film Thickness
2 mils (50 microns), 4 wet mils (100 microns)
Do not exceed 2.0 mils in a single coat.

4700 Aluminum: 1.5 mils (40 microns)
Two coats are recommended over stainless steel and one or two coats over inorganic zincs.

Solids Content
By Volume: 48% ± 2
4700 Aluminum by volume: 30% ± 2

Theoretical Coverage Rate
770 mil/ft²/gal. (19 m²/l at 25 microns)
4700 Aluminum: 481 mil/ft²/gal.
(12 m²/l at 25 microns).

VOC Values
As Supplied 3.8 lbs./gal (456 g/l)
(sprayed un-thinned except in hot application)
Thinned:
12.8 oz/gal w/#235 (10%) 4.1 lbs./gal (492 g/l)

4700 Aluminum supplied: 5.04 lbs./gal (604 g/l)
Thinned:
8 oz/gal w/#10 (6%) 5.16 lbs./gal (618 g/l)
16 oz/gal w/#10 (12%) 5.27 lbs./gal (632 g/l)

Limitations
- Do not use for immersion service.
- Do not exceed thickness recommendation. Excessive film thickness may result in blistering and delamination when the temperature is increased.

Substrates & Surface Preparation

General
Surfaces must be clean and dry. Employ adequate methods to remove dirt, dust, oil and all other contaminants that could interfere with adhesion of the coating.

Steel
SSPC-SP 10 with a 0.5-1.0 mils (12-25 micron) surface profile. Prime with specific Carboline primers as recommended by your Carboline sales representative.

Stainless Steel
Sweep blast cleaning (SSPC-SP7) is recommended.

Aluminum
Sweep blast cleaning (SSPC-SP7) is recommended.

* The alignment of aluminum flakes in aluminum-filled finishes is very dependent on application conditions and techniques. Care must be taken to keep conditions as constant as possible to reduce variations in final appearance. It is also advisable to work from a single batch of material since variations can occur from batch to batch. For more information consult Carboline Technical Service Department.

November 2004 replaces August 2003 4700/4701

ARES CORPORATION

CALCULATION SHEET

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Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

CARBOLINE PRODUCT DATA

12/13/05 16:30 FAX 314 644 6883 CARBOLINE 001

FAX FROM CARBOLINE COMPANY

carboline.

350 Hanley Industrial Court • St. Louis, Missouri 63144

To: PAT LOWERY

Company: AREC

FAX #: 509-946-6016

From: Mike Beckman

Date: 12-13-05 Time:

# of Pages: Doc. #:

If you do not receive all the pages indicated please call: (314) 644-1000

REPLY TO	FAX NUMBER
Main Lobby	(314) 644-4617
Sales & Marketing	(314) 644-1088 Ext. 1-2394
Sales & Marketing	(314) 644-3353
Technical Service	(314) 644-6883
Customer Service	(314) 644-4684
Corporate Services	(314) 644-2246
Fireproofing/OEM Division	(314) 644-1080 Ext. 1-2344
Color Lab	(314) 644-1080 Ext. 1-2468
New Orleans	(504) 734-9120

TEST REPORT #08802

CC:

r03Cprt.p65

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CARBOLINE PRODUCT DATA

12/13/05 16:36 FAX 314 644 8883 CARBOLINE 003

9453507
ATTACHMENT
Page 1 of 3

M330.10L-9436

108802

Emittance of Five Test Coupons
for
Westinghouse Hanford Company

Westinghouse Purchase Order Number MRM-SVV-407026
TRW Sales Number 63458.4
May 1994

L.R. Kelley
Staff Engineer,
Thermal Research and
Development Center

TRW Space and Electronics Group
One Space Park
Redondo Beach, CA 90278

3

CALCULATION SHEET

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CARBOLINE PRODUCT DATA

12/13/01 10:30 FAX 314 644 6663 CARBOLINE 004

9453507
ATTACHMENT
Page 2 of 3

Emittance of Five Westinghouse Hanford Test Coupons

INTRODUCTION

Measurements have been performed at the TRW Thermophysics Laboratory to determine the emittance of five 3" x 3" stainless steel coupons coated with Carboline 4674-C900 black paint. These test coupons were assigned TRW laboratory sample numbers 115-94 through 119-94.

METHOD OF MEASUREMENT

Values of normal emittance were determined using a Gier-Dunkle Instruments Model DB100 Infrared Reflectometer[1,2]. This device measures the total normal reflectance, ρ_n, of a surface to a near-room temperature source. The samples are hemispherically illuminated and near-normally viewed by the instrument. The normal emittance, ε_n, is obtained using the relationship: $\varepsilon_n = 1 - \rho_n$.

The measurements were made in accordance with ASTM Standard E408, and were subject to the instrument errors described in Reference 2. The Gier-Dunkle Infrared Reflectometer has an accuracy better than ±0.02 emittance units.

Hemispherical emittance, ε_h, was calculated directly from normal emittance values using the theoretically and empirically derived correlation between hemispherical and normal emissivity as shown in figure 13-15 of reference 3.

RESULTS

Measurements were made in the approximate center of each test coupon. Results of these measurements are as follows:

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CALCULATION SHEET

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CARBOLINE PRODUCT DATA

12/13/05 10:31 FAX 314 644 8883 CARBOLINE 005

9453507
ATTACHMENT
Page 3 of 3

Emittance of Five Carboline 4674-C900 Black Paint Samples

Sample Description	Westinghouse Sample Number	TRW Sample Number	Normal Emittance*	Hemispherical Emittance*
Abrasive Blast 1 Coat 4674-C900 Black Baked to Cure	#1	115-94	0.87_5	0.83_0
Abrasive Blast 1 Coat 4674-C900 Black Baked to Cure	#2	116-94	0.87_5	0.83_0
Abrasive Blast 1 Coat 4674-C900 Black Baked to Cure	#3	117-94	0.87_5	0.83_0
Abrasive Blast 2 Coats 4674-C900 Black Baked to Cure	#4	118-94	0.88_2	0.83_5
Abrasive Blast 1 Coat Carbo Zinc 11 1 Coat 4674-C900 Black Baked to Cure	#5	119-94	0.83_3	0.79_5

*NOTE: Although the accuracy of the measuring instruments does not justify three significant figures the third digit is retained, subscripted, in order to indicate trends.

REFERENCES

1. K.E. Nelson, E.E. Luedke, and J.T. Bevans, "A Device for the Rapid Measurement of Total Emittance," J. Spacecraft Rockets 3:758-760 (1966).

2. R.P. Pettit, "Evaluation of Portable Optical Property Measurement Equipment for Solar Selective Surface," ASME Paper 77-WA/SOL-1, 1977.

3. E.R.G. Eckert, and R.N. Drake, Jr., Heat and Mass Transfer, 2nd Edition McGraw Hill Book Company, New York (1959).

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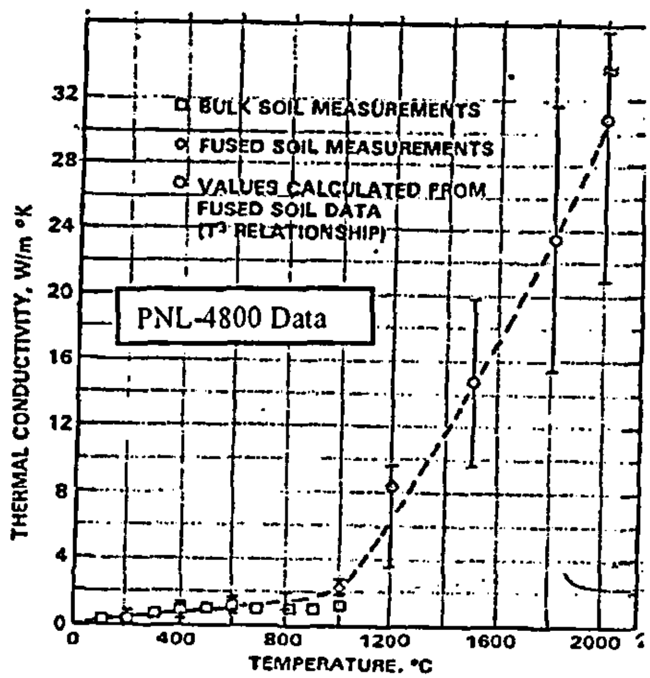
GLASS THERMAL CONDUCTIVITY DATA

Thermal Conductivity of a LAW Glass as a Function of Temperature (Ref. 7)

T [°C]	*K* [W/m -°C]
200	1.12
300	1.14
400	1.20
500	1.29
600	1.41
700	1.57
800	1.76
900	1.98
1000	2.24
1100	2.52
1200	2.85
1300	3.20
1400	3.58
1500	4.00

PNL-4800 Thermal Conductivity for Soil/Melt (Ref. 11)



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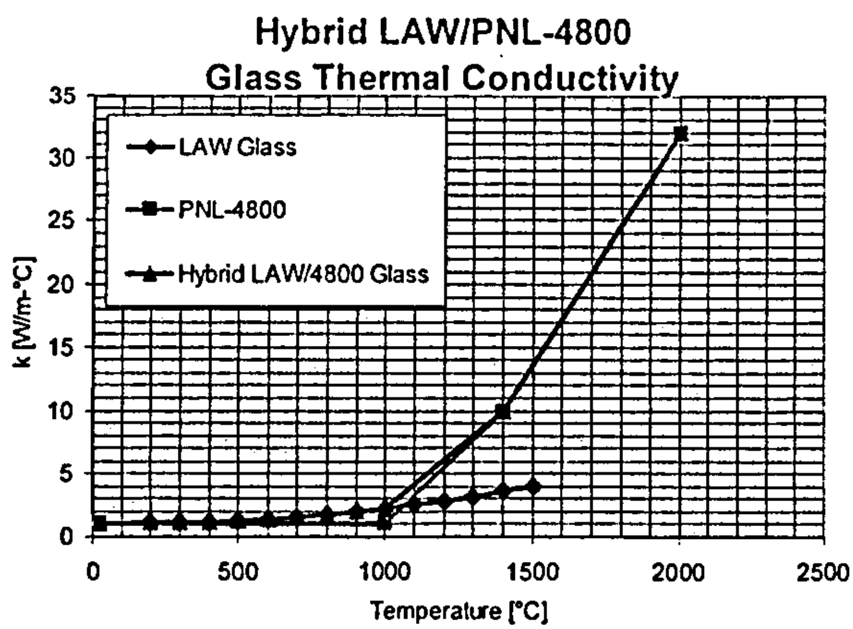
GLASS THERMAL CONDUCTIVITY DATA

HYBRID LAW/PNL-4800 GLASS PROPERTIES

Temperaure [°C]	Thermal Conductivity [W/m-°C]
25	1
200	1.12
300	1.14
400	1.2
500	1.29
600	1.41
700	1.57
800	1.76
900	1.98
1000	2.24
1400	10
2000	32



APPENDIX C

ANSYS® CASE INPUT LISTINGS

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Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

CASE 3.1: ICV™ BOX SIDEWALL BASE CASE CONDITIONS – 110C CASTABLE REFRACTORY BACKING

```
! 2D BulkVit SideWall Heat Trasnfer Simulation
! Leaking Glass (Pure Glass) Scenario - no leaking glass in this base case
! Modeled effect of side concrete shield wall
! e_box = 0.8 (painted with carboline 4700); e_conc = 0.6
! Modeled case of 60PC backed by 110C (no sand)

 FINISH
/cle
/prep7
/triad,rbot
/title, Glass Slab Sidewall Model - Case 3.1

!Set Element Types
ET,1, PLANE55          !Conduction Area
KEYOPT,1,1,1

ANTYPE,0

TOFFST,273             !Celsius
NSUBST,100
Tunif,100

!Set Material Properties
!Castable Refractory
MAT,1
MP,KXX,1,1.44

!8" Castable Refractory 110 C
Mat,2
MPTEMP
MPTEMP,1,25,540,815,1200,1500
MPDATA,Kxx,2,1,1,0.86,0.78,0.668,0.534

!Glass (Hybrid LAW/PNL-4800 Data)
Mat,3
MPTEMP
MPTEMP,1,25,200,300,400,500,600
MPDATA,Kxx,3,1,1,1.12,1.14,1.2,1.29,1.41
MPTEMP,7,700,800,900,1000,1400,2000
MPDATA,Kxx,3,7,1.57,1.76,1.98,2.24,10,32

! Combined Free & Radiation Heat Transfer Coefficieitn - Vertical Surface
! Models emissivity of box @ 0.8 & concrete shield walls @ 0.6
! Assumes Tinf = 100°C
MAT,4
MPTEMP
MPTEMP,1, 55, 65, 75, 85, 95, 100
MPDATA,hf,4,1,0.5, 1.0, 1.7, 2.6, 3.8, 6.1
MPTEMP,7, 125, 150, 175, 200, 225, 250
```

CALCULATION SHEET

A.R.E.S CORPORATION

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```
MPDATA,hf,4,7,10.6, 12.3, 13.8, 15.2, 16.5, 17.9
MPTEMP,13, 275, 300, 325, 350, 375, 400
MPDATA,hf,4,13,19.3, 20.8, 22.3, 23.8, 25.4, 27.1
MPTEMP,19, 425, 450, 475, 500, 525, 550
MPDATA,hf,4,19, 28.9, 30.7, 32.6, 34.7, 36.8, 39.0
MPTEMP,25, 575, 600
MPDATA,hf,4,25, 41.3, 43.7

!Generate Keypoints
k,1, 0,0
k,2, 0.2720,0
k,3, 0.3048,0
k,5, 0.1524,0
k,6, 0,0.3048
k,7, 0.1524,0.3048
k,8, 0.2720,0.3048
k,9, 0.3048,0.3048

!Create Lines
L,1,5,
L,5,2,
L,2,3,
L,3,9
L,8,9
L,7,8
L,6,7,
L,1,6
L,5,7
L,2,8

!Generate Areas
A,1,5,7,6
A,5,2,8,7
A,2,3,9,8

!Mesh Areas
type,1
esiz,0.00635
amesh,all

!Assign Materials to Areas
asel,,area,,1
esla
emod,all,mat,1

asel,,area,,2
esla
emod,all,mat,2
alls

asel,,area,,3
esla
emod,all,mat,2
```

CALCULATION SHEET

ARES CORPORATION

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Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
alls

NSEL,S,LOC,X,0.3048        ! right edge
SF,ALL,CONV,-4,100         ! apply convection and ambient 100C
NSEL,ALL

NSEL,S,LOC,X,0             ! select nodes on left side
D,ALL,TEMP,1300            ! apply fixed temp of 1300C
NSEL,ALL

fini
/solu
SOLVE
FINISH

/POST1
PRNSOL,TEMP          ! PRINT NODAL TEMPERATURES
prnsol,temp          ! List Temperatures at Nodes
```

A R E S CORPORATION	CALCULATION SHEET		
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Prepared By: P.S. Lowery Date: 3/20/06	Checked By: S.R. Pierce		Date: 3/20/06

CASE 3.2: ICV™ BOX SIDEWALL BASE CASE CONDITIONS – SAND BACKING

```
! 2D BulkVit SideWall Heat Transfer Simulation
! Leaking Glass (Pure Glass) Scenario - no leaking glass in this base case
! Modeled effect of side concrete shield wall
! e_box = 0.8 (painted with carboline 4700); e_conc = 0.6

FINISH
/cle
/prep7
/triad,rbot
/title, Glass Slab Sidewall Model - Case 3.2

!Set Element Types
ET,1, PLANE55          !Conduction Area
KEYOPT,1,1,1

ANTYPE,0

TOFFST,273             !Celsius
NSUBST,100
Tunif,100

!Set Material Properties
!Castable Refractory
MAT,1
MP,KXX,1,1.44

!Sand
Mat,2
MPTEMP,1,25,200,300,600,1000
MPDATA,Kxx,2,1,0.17,0.25,0.285,0.38,0.55

!Glass (Hybrid LAW/PNL-4800 Data)
Mat,3
MPTEMP
MPTEMP,1,25,200,300,400,500,600
MPDATA,Kxx,3,1,1,1.12,1.14,1.2,1.29,1.41
MPTEMP,7,700,800,900,1000,1400,2000
MPDATA,Kxx,3,7,1.57,1.76,1.98,2.24,10,32

! Combined Free & Radiation Heat Transfer Coefficieitn - Vertical Surface
! Models emissivity of box @ 0.8 & concrete shield walls @ 0.6
! Assumes Tinf = 100°C
MAT,4
MPTEMP
MPTEMP,1, 55, 65, 75, 85, 95, 100
MPDATA,hf,4,1,0.5, 1.0, 1.7, 2.6, 3.8, 6.1
MPTEMP,7, 125, 150, 175, 200, 225, 250
MPDATA,hf,4,7,10.6, 12.3, 13.8, 15.2, 16.5, 17.9
MPTEMP,13, 275, 300, 325, 350, 375, 400
```

CALCULATION SHEET

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```
MPDATA,hf,4,13,19.3, 20.8, 22.3, 23.8, 25.4, 27.1
MPTEMP,19, 425, 450, 475, 500, 525, 550
MPDATA,hf,4,19, 28.9, 30.7, 32.6, 34.7, 36.8, 39.0
MPTEMP,25, 575, 600
MPDATA,hf,4,25, 41.3, 43.7

!Generate Keypoints
k,1, 0,0
k,2, 0.2720,0
k,3, 0.3048,0
k,5, 0.1524,0
k,6, 0,0.3048
k,7, 0.1524,0.3048
k,8, 0.2720,0.3048
k,9, 0.3048,0.3048

!Create Lines
L,1,5,
L,5,2,
L,2,3,
L,3,9
L,8,9
L,7,8
L,6,7,
L,1,6
L,5,7
L,2,8

!Generate Areas
A,1,5,7,6
A,5,2,8,7
A,2,3,9,8

!Mesh Areas
type,1
esiz,0.00635
amesh,all

!Assign Materials to Areas
asel,,area,,1
esla
emod,all,mat,1

asel,,area,,2
esla
emod,all,mat,2
alls

asel,,area,,3
esla
emod,all,mat,2
alls
```

```
NSEL,S,LOC,X,0.3048          ! right edge
SF,ALL,CONV,-4,100           ! apply convection and ambient 100C
NSEL,ALL

NSEL,S,LOC,X,0                  ! select nodes on left side
D,ALL,TEMP,1300                 ! apply fixed temp of 1300C
NSEL,ALL

fini
/solu
SOLVE
FINISH

/POST1
PRNSOL,TEMP           ! PRINT NODAL TEMPERATURES
prnsol,temp         ! List Temperatures at Nodes
```

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 53 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

CASE 3.3.1: 1300°C MELT/60PC INTERFACE CONDITIONS

```
FINISH
/cle
/prep7
/triad,rbot
/title, Glass Slab Sidewall Model - Case 3.3.1

!Set Element Types
ET,1, PLANE55          !Conduction Area
KEYOPT,1,1,1

ANTYPE,0

TOFFST,273             !Celsius
NSUBST,100
Tunif,100

!Set Material Properties
!Castable Refractory
MAT,1
MP,KXX,1,1.44

!Sand
Mat,2
MPTEMP,1,25,200,300,600,1000
MPDATA,Kxx,2,1,0.17,0.25,0.285,0.38,0.55

!Glass (Hybrid LAW/PNL-4800 Data)
Mat,3
MPTEMP
MPTEMP,1,25,200,300,400,500,600
MPDATA,Kxx,3,1,1,1.12,1.14,1.2,1.29,1.41
MPTEMP,7,700,800,900,1000,1400,2000
MPDATA,Kxx,3,7,1.57,1.76,1.98,2.24,10,32

! Combined Free & Radiation Heat Transfer Coefficieitn - Vertical Surface
! Models emissivity of box @ 0.8 & concrete shield walls @ 0.6
! Assumes Tinf = 100°C
MAT,4
MPTEMP
MPTEMP,1, 55, 65, 75, 85, 95, 100
MPDATA,hf,4,1,0.5, 1.0, 1.7, 2.6, 3.8, 6.1
MPTEMP,7, 125, 150, 175, 200, 225, 250
MPDATA,hf,4,7,10.6, 12.3, 13.8, 15.2, 16.5, 17.9
MPTEMP,13, 275, 300, 325, 350, 375, 400
MPDATA,hf,4,13,19.3, 20.8, 22.3, 23.8, 25.4, 27.1
MPTEMP,19, 425, 450, 475, 500, 525, 550
MPDATA,hf,4,19, 28.9, 30.7, 32.6, 34.7, 36.8, 39.0
MPTEMP,25, 575, 600
MPDATA,hf,4,25, 41.3, 43.7
```

```
!Generate Keypoints
k,1, 0,0
k,2, 0.2500,0
k,3, 0.3048,0
k,4, 0,0.0254
k,5, 0.1524,0.0254
k,6, 0,0.3048
k,7, 0.1524,0.3048
k,8, 0.2500,0.3048
k,9, 0.3048,0.3048

!Create Lines
L,1,2,
L,2,3,
L,3,9
L,8,9
L,7,8
L,6,7,
L,4,6,
L,1,4
L,4,5
L,5,7
L,2,8

!Generate Areas
A,4,5,7,6
A,1,2,8,7,5,4
A,2,3,9,8

!Mesh Areas
type,1
esiz,0.00635
amesh,all

!Assign Materials to Areas
asel,,area,,1
esla
emod,all,mat,1

asel,,area,,2
esla
emod,all,mat,3
alls

asel,,area,,3
esla
emod,all,mat,2
alls


NSEL,S,LOC,X,0.3048          ! right edge
SF,ALL,CONV,-4,100           ! apply convection and ambient 100C
```

CALCULATION SHEET

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Title: DBVS ICV™ Box Thermal Analysis

Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
NSEL,ALL

NSEL,S,LOC,X,0              ! select nodes on left side
D,ALL,TEMP,1300             ! apply fixed temp of 1300C
NSEL,ALL

fini
/solu
SOLVE
FINISH

/POST1
PRNSOL,TEMP         ! PRINT NODAL TEMPERATURES
prnsol,temp         ! List Temperatures at Nodes
```

CASE 3.3.2: 1500°C MELT/60PC INTERFACE CONDITIONS

```
FINISH
/cle
/prep7
/triad,rbot
/title, Glass Slab Sidewall Model - Case 3.3.2

!Set Element Types
ET,1, PLANE55          !Conduction Area
KEYOPT,1,1,1

ANTYPE,0

TOFFST,273             !Celsius
NSUBST,100
Tunif,100

!Set Material Properties
!Castable Refractory
MAT,1
MP,KXX,1,1.44

!Sand
Mat,2
MPTEMP,1,25,200,300,600,1000
MPDATA,Kxx,2,1,0.17,0.25,0.285,0.38,0.55

!Glass (Hybrid LAW/PNL-4800 Data)
Mat,3
MPTEMP
MPTEMP,1,25,200,300,400,500,600
MPDATA,Kxx,3,1,1,1.12,1.14,1.2,1.29,1.41
MPTEMP,7,700,800,900,1000,1400,2000
MPDATA,Kxx,3,7,1.57,1.76,1.98,2.24,10,32

! Combined Free & Radiation Heat Transfer Coefficieitn - Vertical Surface
! Models emissivity of box @ 0.8 & concrete shield walls @ 0.6
! Assumes Tinf = 100°C
MAT,4
MPTEMP
MPTEMP,1, 55, 65, 75, 85, 95, 100
MPDATA,hf,4,1,0.5, 1.0, 1.7, 2.6, 3.8, 6.1
MPTEMP,7, 125, 150, 175, 200, 225, 250
MPDATA,hf,4,7,10.6, 12.3, 13.8, 15.2, 16.5, 17.9
MPTEMP,13, 275, 300, 325, 350, 375, 400
MPDATA,hf,4,13,19.3, 20.8, 22.3, 23.8, 25.4, 27.1
MPTEMP,19, 425, 450, 475, 500, 525, 550
MPDATA,hf,4,19, 28.9, 30.7, 32.6, 34.7, 36.8, 39.0
MPTEMP,25, 575, 600
MPDATA,hf,4,25, 41.3, 43.7
```

CALCULATION SHEET

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Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery, Date: 3/20/06	Checked By: S.R. Pierce, Date: 3/20/06		

```
!Generate Keypoints
k,1, 0,0
k,2, 0.2725,0
k,3, 0.3048,0
k,4, 0,0.0254
k,5, 0.1524,0.0254
k,6, 0,0.3048
k,7, 0.1524,0.3048
k,8, 0.2725,0.3048
k,9, 0.3048,0.3048

!Create Lines
L,1,2,
L,2,3,
L,3,9
L,8,9
L,7,8
L,6,7,
L,4,6,
L,1,4
L,4,5
L,5,7
L,2,8

!Generate Areas
A,4,5,7,6
A,1,2,8,7,5,4
A,2,3,9,8

!Mesh Areas
type,1
esiz,0.00635
amesh,all

!Assign Materials to Areas
asel,,area,,1
esla
emod,all,mat,1

asel,,area,,2
esla
emod,all,mat,3
alls

asel,,area,,3
esla
emod,all,mat,2
alls


NSEL,S,LOC,X,0.3048        ! right edge
SF,ALL,CONV,-4,100         ! apply convection and ambient 100C
NSEL,ALL
```

```
NSEL,S,LOC,X,0                 ! select nodes on left side
D,ALL,TEMP,1500                ! apply fixed temp of 1500C
NSEL,ALL

fini
/solu
SOLVE
FINISH

/POST1
PRNSOL,TEMP          ! PRINT NODAL TEMPERATURES
prnsol,temp         ! List Temperatures at Nodes
```

ARES CORPORATION	CALCULATION SHEET		
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Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

CASE 3.3.3: 1700°C MELT/60PC INTERFACE CONDITIONS

```
FINISH
/cle
/prep7
/triad,rbot
/title, Glass Slab Sidewall Model - Case 3.3.3


!Set Element Types
ET,1, PLANE55           !Conduction Area
KEYOPT,1,1,1

ANTYPE,0

TOFFST,273              !Celsius
NSUBST,100
Tunif,100

!Set Material Properties
!Castable Refractory
MAT,1
MP,KXX,1,1.44

!Sand
Mat,2
MPTEMP,1,25,200,300,600,1000
MPDATA,Kxx,2,1,0.17,0.25,0.285,0.38,0.55

!Glass (Hybrid LAW/PNL-4800 Data)
Mat,3
MPTEMP
MPTEMP,1,25,200,300,400,500,600
MPDATA,Kxx,3,1,1,1.12,1.14,1.2,1.29,1.41
MPTEMP,7,700,800,900,1000,1400,2000
MPDATA,Kxx,3,7,1.57,1.76,1.98,2.24,10,32

! Combined Free & Radiation Heat Transfer Coefficieitn - Vertical Surface
! Models emissivity of box @ 0.8 & concrete shield walls @ 0.6
! Assumes Tinf = 100°C
MAT,4
MPTEMP
MPTEMP,1, 55, 65, 75, 85, 95, 100
MPDATA,hf,4,1,0.5, 1.0, 1.7, 2.6, 3.8, 6.1
MPTEMP,7, 125, 150, 175, 200, 225, 250
MPDATA,hf,4,7,10.6, 12.3, 13.8, 15.2, 16.5, 17.9
MPTEMP,13, 275, 300, 325, 350, 375, 400
MPDATA,hf,4,13,19.3, 20.8, 22.3, 23.8, 25.4, 27.1
MPTEMP,19, 425, 450, 475, 500, 525, 550
MPDATA,hf,4,19, 28.9, 30.7, 32.6, 34.7, 36.8, 39.0
MPTEMP,25, 575, 600
```

ARES CORPORATION

CALCULATION SHEET

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Title: DBVS ICV™ Box Thermal Analysis

Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
MPDATA,hf,4,25, 41.3, 43.7

!Generate Keypoints
k,1, 0,0
k,2, 0.2875,0
k,3, 0.3048,0
k,4, 0,0.0254
k,5, 0.1524,0.0254
k,6, 0,0.3048
k,7, 0.1524,0.3048
k,8, 0.2875,0.3048
k,9, 0.3048,0.3048

!Create Lines
L,1,2,
L,2,3,
L,3,9
L,8,9
L,7,8
L,6,7,
L,4,6,
L,1,4
L,4,5
L,5,7
L,2,8

!Generate Areas
A,4,5,7,6
A,1,2,8,7,5,4
A,2,3,9,8

!Mesh Areas
type,1
esiz,0.00635
amesh,all

!Assign Materials to Areas
asel,,area,,1
esla
emod,all,mat,1

asel,,area,,2
esla
emod,all,mat,3
alls

asel,,area,,3
esla
emod,all,mat,2
alls

NSEL,S,LOC,X,0.3048          ! right edge
```

ARES CORPORATION

CALCULATION SHEET

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Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
SF,ALL,CONV,-4,100          ! apply convection and ambient 100C
NSEL,ALL

NSEL,S,LOC,X,0              ! select nodes on left side
D,ALL,TEMP,1700             ! apply fixed temp of 1700C
NSEL,ALL

fini
/solu
SOLVE
FINISH

/POST1
PRNSOL,TEMP          ! PRINT NODAL TEMPERATURES
prnsol,temp          ! List Temperatures at Nodes
```

CALCULATION SHEET

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Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

CASE 3.3.4: 1700°C MELT/60PC INTERFACE CONDITIONS; REDUCED SURFACE HEAT TRANSFER COEFFICIENTS

```
FINISH
/cle
/prep7
/triad,rbot
/title, Glass Slab Sidewall Model - Case 3.3.4


!Set Element Types
ET,1, PLANE55          !Conduction Area
KEYOPT,1,1,1

ANTYPE,0

TOFFST,273             !Celsius
NSUBST,100
Tunif,100

!Set Material Properties
!Castable Refractory
MAT,1
MP,KXX,1,1.44

!Sand
Mat,2
MPTEMP,1,25,200,300,600,1000
MPDATA,Kxx,2,1,0.17,0.25,0.285,0.38,0.55

!Glass (Hybrid LAW/PNL-4800 Data)
Mat,3
MPTEMP
MPTEMP,1,25,200,300,400,500,600
MPDATA,Kxx,3,1,1,1.12,1.14,1.2,1.29,1.41
MPTEMP,7,700,800,900,1000,1400,2000
MPDATA,Kxx,3,7,1.57,1.76,1.98,2.24,10,32

! Combined Free & Radiation Heat Transfer Coefficient - Vertical Surface
! ½x Nominal Values Case
! Models emissivity of box @ 0.8 & concrete shield walls @ 0.6
! Assumes Tinf = 100°C
MAT,4
MPTEMP
MPTEMP,1, 55, 65, 75, 85, 95, 100
MPDATA,hf,4,1,0.2, 0.5, 0.9, 1.3, 1.9, 3.1
MPTEMP,7, 125, 150, 175, 200, 225, 250
MPDATA,hf,4,7,5.3, 6.2, 6.9, 7.6, 8.3, 9.0
MPTEMP,13, 275, 300, 325, 350, 375, 400
MPDATA,hf,4,13,9.7, 10.4, 11.1, 11.9, 12.7, 13.6
MPTEMP,19, 425, 450, 475, 500, 525, 550
MPDATA,hf,4,19, 14.4, 15.4, 16.3, 17.3, 18.4, 19.5
```

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 63 of 97

Title: DBVS ICV™ Box Thermal Analysis

Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
MPTEMP,25, 575, 600
MPDATA,hf,4,25, 20.6, 21.8

!Generate Keypoints
k,1, 0,0
k,2, 0.2920,0
k,3, 0.3048,0
k,4, 0,0.0254
k,5, 0.1524,0.0254
k,6, 0,0.3048
k,7, 0.1524,0.3048
k,8, 0.2920,0.3048
k,9, 0.3048,0.3048

!Create Lines
L,1,2,
L,2,3,
L,3,9
L,8,9
L,7,8
L,6,7,
L,4,6,
L,1,4
L,4,5
L,5,7
L,2,8

!Generate Areas
A,4,5,7,6
A,1,2,8,7,5,4
A,2,3,9,8

!Mesh Areas
type,1
esiz,0.00635
amesh,all

!Assign Materials to Areas
asel,,area,,1
esla
emod,all,mat,1

asel,,area,,2
esla
emod,all,mat,3
alls

asel,,area,,3
esla
emod,all,mat,2
alls
```

```
NSEL,S,LOC,X,0.3048          ! right edge
SF,ALL,CONV,-4,100           ! apply convection and ambient 100C
NSEL,ALL

NSEL,S,LOC,X,0               ! select nodes on left side
D,ALL,TEMP,1700              ! apply fixed temp of 1700C
NSEL,ALL

fini
/solu
SOLVE
FINISH

/POST1
PRNSOL,TEMP          ! PRINT NODAL TEMPERATURES
prnsol,temp          ! List Temperatures at Nodes
```

ARES CORPORATION

CALCULATION SHEET

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Title: DBVS ICV™ Box Thermal Analysis

Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

CASE 3.3.5: 1700°C MELT/60PC INTERFACE CONDITIONS; INCREASED SURFACE HEAT TRANSFER COEFFICIENTS

```
FINISH
/cle
/prep7
/triad,rbot
/title, Glass Slab Sidewall Model - Case 3.3.5


!Set Element Types
ET,1, PLANE55          !Conduction Area
KEYOPT,1,1,1

ANTYPE,0

TOFFST,273             !Celsius
NSUBST,100
Tunif,100

!Set Material Properties
!Castable Refractory
MAT,1
MP,KXX,1,1.44

!Sand
Mat,2
MPTEMP,1,25,200,300,600,1000
MPDATA,Kxx,2,1,0.17,0.25,0.285,0.38,0.55

!Glass (Hybrid LAW/PNL-4800 Data)
Mat,3
MPTEMP
MPTEMP,1,25,200,300,400,500,600
MPDATA,Kxx,3,1,1,1.12,1.14,1.2,1.29,1.41
MPTEMP,7,700,800,900,1000,1400,2000
MPDATA,Kxx,3,7,1.57,1.76,1.98,2.24,10,32

! Combined Free & Radiation Heat Transfer Coefficient - Vertical Surface
!  2x Nominal Values Case
! Models emissivity of box @ 0.8 & concrete shield walls @ 0.6
! Assumes Tinf = 100°C
MAT,4
MPTEMP
MPTEMP,1, 55, 65, 75, 85, 95, 100
MPDATA,hf,4,1,0.9, 2.1, 3.4, 5.1, 7.6, 12.3
MPTEMP,7, 125, 150, 175, 200, 225, 250
MPDATA,hf,4,7,21.3, 24.7, 27.6, 30.4, 33.1, 35.8
MPTEMP,13, 275, 300, 325, 350, 375, 400
MPDATA,hf,4,13,38.6, 41.5, 44.5, 47.6, 50.9, 54.2
MPTEMP,19, 425, 450, 475, 500, 525, 550
MPDATA,hf,4,19, 57.8, 61.4, 65.3, 69.3, 73.5, 77.9
```

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Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
MPTEMP,25, 575, 600
MPDATA,hf,4,25, 82.5, 87.3

!Generate Keypoints
k,1, 0,0
k,2, 0.2825,0
k,3, 0.3048,0
k,4, 0,0.0254
k,5, 0.1524,0.0254
k,6, 0,0.3048
k,7, 0.1524,0.3048
k,8, 0.2825,0.3048
k,9, 0.3048,0.3048

!Create Lines
L,1,2,
L,2,3,
L,3,9
L,8,9
L,7,8
L,6,7,
L,4,6,
L,1,4
L,4,5
L,5,7
L,2,8

!Generate Areas
A,4,5,7,6
A,1,2,8,7,5,4
A,2,3,9,8

!Mesh Areas
type,1
esiz,0.00635
amesh,all

!Assign Materials to Areas
asel,,area,,1
esla
emod,all,mat,1

asel,,area,,2
esla
emod,all,mat,3
alls

asel,,area,,3
esla
emod,all,mat,2
alls
```

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 67 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
NSEL,S,LOC,X,0.3048        ! right edge
SF,ALL,CONV,-4,100         ! apply convection and ambient 100C
NSEL,ALL

NSEL,S,LOC,X,0             ! select nodes on left side
D,ALL,TEMP,1700            ! apply fixed temp of 1700C
NSEL,ALL

fini
/solu
SOLVE
FINISH

/POST1
PRNSOL,TEMP                ! PRINT NODAL TEMPERATURES
prnsol,temp                ! List Temperatures at Nodes
```

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 68 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

CASE 4.1: ICV™ BOX BOTTOM BASE CASE CONDITIONS

```
! 2D BulkVit Bottom Wall Heat Transfer Simulation
! Base Case for Leaking Glass (Pure Glass) Scenario - no Leak in this model
! Sand-centered case
! No Gap between box skin & tube steel


/title, Box Bottom Heat Transfer - Case 4.1

/prep7

antype, 0
toffst, 273
tunif,100

! Define element type
et,1, plane55
keyopt, 1,1,1

!Specify Material Properties

!6" Castable Refractory 60 PC
MAT,1
MP,KXX,1,1.44,

!8" Castable Refractory 110 C
Mat,2
MPTEMP
MPTEMP,1,25,540,815,1200,1500
MPDATA,Kxx,2,1,1,0.86,0.78,0.668,0.534

!Steel Lining/TS 6x6
Mat,3
MPTEMP
MPTEMP,1,27,127,327,527,727,
MPDATA,Kxx,3,1,60.5,56.7,48,39.2,30,

!Air Conductivity
Mat,4
MPTEMP
MPTEMP,1,27,127,327,527,727,
MPDATA,Kxx,4,1,0.0261,0.0331,0.0456,0.0569,0.0672,

!Sand
Mat,5
MPTEMP
MPTEMP,1,25,200,300,600,1000
MPDATA,Kxx,5,1,0.17,0.25,0.285,0.38,0.55

! Combined Free & Radiation Heat Transfer Coefficient - horizontal Surface
! Models emissivity of box @ 0.8 & concrete shield walls @ 0.6
! Assumes Tinf = 100°C
```

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 69 of 97
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Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
MAT,6
MPTEMP
MPTEMP,1, 25, 35, 45, 55, 65, 75
MPDATA,hf,6,1, 1.6, 1.9, 2.3, 2.7, 3.1, 3.5
MPTEMP,7,85, 95, 100, 125, 150, 175
MPDATA,hf,6,7, 4.1, 4.8, 6.1, 8.8, 10.0, 11.2
MPTEMP,13, 200, 225, 250, 275, 300, 325
MPDATA,hf,6,13, 12.3, 13.4, 14.6, 115.8, 17.1, 18.5
MPTEMP,19, 350, 375, 400, 425, 450, 475
MPDATA,hf,6,19, 19.9, 21.4, 23.0, 24.6, 26.3, 28.2
MPTEMP,25, 500, 525, 550, 575, 600
MPDATA,hf,6,25, 30.1, 32.1, 34.2, 36.4, 38.7

!Vertical Convection (Not used in this model)
MAT,7
MPTEMP
MPTEMP,1,100,105,110,115,120,125
MPDATA,hf,7,1,0.0,8.5,9.2,9.8,10.2,10.6
MPTEMP,7,150,175,200,225,250,300
MPDATA,hf,7,7,12.3,13.8,15.2,16.5,17.9,20.8

!Air Conductivity
Mat,8
MPTEMP
MPTEMP,1,27,127,327,527,727,
MPDATA,Kxx,8,1,0.0261,0.0331,0.0456,0.0569,0.0672,

!Glass (Hybrid LAW/PNL-4800 Data)
Mat,9
MPTEMP
MPTEMP,1,25,200,300,400,500,600
MPDATA,Kxx,9,1,1,1.12,1.14,1.2,1.29,1.41
MPTEMP,7,700,800,900,1000,1400,2000
MPDATA,Kxx,9,7,1.57,1.76,1.98,2.24,10,32

! keypoints - Sand-centered case

k, 1,      0, 0
k, 2, 0.15240, 0
k, 3, 0.35560, 0
k, 4, 0.36195, 0
k, 5, 0.15240, 0.0635
k, 6, 0.30798, 0.0635
k, 7, 0.35560, 0.0635
k,12,      0, 0.165100
k,13, 0.15240, 0.165100
k,14,      0, 0.190500
k,15, 0.15240, 0.190500
k,20, 0.15240, 0.2921
k,21, 0.30798, 0.2921
k,22, 0.35560, 0.2921
k,23,      0, 0.3556
k,24, 0.15240, 0.3556
```

CALCULATION SHEET

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Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
k,25, 0.35560, 0.3556
k,26, 0.36195, 0.3556

! lines - sand-centered case

l,1,2
l,2,5
l,5,13
l,13,12
l,12,1

l,13,15
l,15,14
l,14,12

l,15,20
l,20,24
l,24,23
l,23,14

l,2,3
l,3,7
l,7,6
l,6,5

l,6,21
l,21,20

l,7,22
l,22,21

l,22,25
l,25,24

l,3,4
l,4,26
l,26,25

! areas - sand-centered case

a,1,2,5,13,12        !A1
a,12,13,15,14        !A2
a,14,15,20,24,23     !A3
a,2,3,7,6,5          !A4
a,5,6,21,20,15,13    !A5
a,6,7,22,21          !A6
a,20,21,22,25,24     !A7
a,3,4,26,25,22,7     !A8

! Define mesh
type, 1
esize, 0.00635
amesh, all
```

```
!Assign Materials to Areas

asel,,area,,1
esla
emod,all,mat,1

asel,,area,,2
esla
emod,all,mat,1
alls

asel,,area,,3
esla
emod,all,mat,1
alls

asel,,area,,4
esla
emod,all,mat,2
alls

asel,,area,,5
esla
emod,all,mat,5
alls

asel,,area,,6
esla
emod,all,mat,5
alls

asel,,area,,7
esla
emod,all,mat,2
alls

asel,,area,,8
esla
emod,all,mat,3
alls

! Impose BCs - sand-centered case

LSEL,S,LINE,,24
NSLL,,1
SF,ALL,CONV,-6,100          ! apply horiz convection and ambient 100C

NSEL,S,LOC,X,0              ! select nodes on left side
D,ALL,TEMP,1300             ! apply fixed temp of 1300C
NSEL,ALL

! Finished set-up.  Now go to solver
```

CALCULATION SHEET

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Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
fini
/solu
solve
finish
```

ARES CORPORATION	CALCULATION SHEET		
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Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

CASE 4.2.1: ICV™ BOX BOTTOM 1300°C MELT/60PC INTERFACE CONDITIONS

```
! 2D BulkVit Bottom Wall Heat Trasnfer Simulation
! Leaking Glass (Pure Glass) Scenario
! Sand-centered case
! No Gap between box skin & tube steel


/title, Box Bottom Heat Transfer - Case 4.2.1

/prep7

antype, 0
toffst, 273
tunif,100

! Define element type
et,1, plane55
keyopt, 1,1,1

!Specify Material Properties

!6" Castable Refractory 60 PC
MAT,1
MP,KXX,1,1.44,

!8" Castable Refractory 110 C
Mat,2
MPTEMP
MPTEMP,1,25,540,815,1200,1500
MPDATA,Kxx,2,1,1,0.86,0.78,0.668,0.534

!Steel Lining/TS 6x6
Mat,3
MPTEMP
MPTEMP,1,27,127,327,527,727,
MPDATA,Kxx,3,1,60.5,56.7,48,39.2,30,

!Air Conductivity
Mat,4
MPTEMP
MPTEMP,1,27,127,327,527,727,
MPDATA,Kxx,4,1,0.0261,0.0331,0.0456,0.0569,0.0672,

!Sand
Mat,5
MPTEMP
MPTEMP,1,25,200,300,600,1000
MPDATA,Kxx,5,1,0.17,0.25,0.285,0.38,0.55

! Combined Free & Radiation Heat Transfer Coefficient - horizontal Surface
```

CALCULATION SHEET

ARES CORPORATION

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 74 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery, Date: 3/20/06	Checked By: S.R. Pierce, Date: 3/20/06		

```
! Models emissivity of box @ 0.8 & concrete shield walls @ 0.6
! Assumes Tinf = 100°C
MAT,6
MPTEMP
MPTEMP,1, 25, 35, 45, 55, 65, 75
MPDATA,hf,6,1, 1.6, 1.9, 2.3, 2.7, 3.1, 3.5
MPTEMP,7,85, 95, 100, 125, 150, 175
MPDATA,hf,6,7, 4.1, 4.8, 6.1, 8.8, 10.0, 11.2
MPTEMP,13, 200, 225, 250, 275, 300, 325
MPDATA,hf,6,13, 12.3, 13.4, 14.6, 115.8, 17.1, 18.5
MPTEMP,19, 350, 375, 400, 425, 450, 475
MPDATA,hf,6,19, 19.9, 21.4, 23.0, 24.6, 26.3, 28.2
MPTEMP,25, 500, 525, 550, 575, 600
MPDATA,hf,6,25, 30.1, 32.1, 34.2, 36.4, 38.7

!Vertical Convection (Not used in this model)
MAT,7
MPTEMP
MPTEMP,1,100,105,110,115,120,125
MPDATA,hf,7,1,0.0,8.5,9.2,9.8,10.2,10.6
MPTEMP,7,150,175,200,225,250,300
MPDATA,hf,7,7,12.3,13.8,15.2,16.5,17.9,20.8

!Air Conductivity
Mat,8
MPTEMP
MPTEMP,1,27,127,327,527,727,
MPDATA,Kxx,8,1,0.0261,0.0331,0.0456,0.0569,0.0672,

!Glass (Hybrid LAW/PNL-4800 Data)
Mat,9
MPTEMP
MPTEMP,1,25,200,300,400,500,600
MPDATA,Kxx,9,1,1,1.12,1.14,1.2,1.29,1.41
MPTEMP,7,700,800,900,1000,1400,2000
MPDATA,Kxx,9,7,1.57,1.76,1.98,2.24,10,32

! keypoints - Sand-centered case

k, 1,     0, 0
k, 2, 0.15240, 0
k, 3, 0.35560, 0
k, 4, 0.36195, 0
k, 5, 0.15240, 0.0635
k, 6, 0.27000, 0.0635
k, 7, 0.35560, 0.0635
k,12,     0, 0.165100
k,13, 0.15240, 0.165100
k,14,     0, 0.190500
k,15, 0.15240, 0.190500
k,20, 0.15240, 0.2921
k,21, 0.27000, 0.2921
k,22, 0.35560, 0.2921
```

```
k,23,      0, 0.3556
k,24, 0.15240, 0.3556
k,25, 0.35560, 0.3556
k,26, 0.36195, 0.3556

! lines - sand-centered case

l,1,2
l,2,5
l,5,13
l,13,12
l,12,1

l,13,15
l,15,14
l,14,12

l,15,20
l,20,24
l,24,23
l,23,14

l,2,3
l,3,7
l,7,6
l,6,5

l,6,21
l,21,20

l,7,22
l,22,21

l,22,25
l,25,24

l,3,4
l,4,26
l,26,25

! areas - sand-centered case

a,1,2,5,13,12        !A1
a,12,13,15,14        !A2
a,14,15,20,24,23     !A3
a,2,3,7,6,5          !A4
a,5,6,21,20,15,13    !A5
a,6,7,22,21          !A6
a,20,21,22,25,24     !A7
a,3,4,26,25,22,7     !A8

! Define mesh
type, 1
```

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 76 of 97

Title: DBVS ICV™ Box Thermal Analysis

Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
esize, 0.00635
amesh, all

!Assign Materials to Areas

asel,,area,,1
esla
emod,all,mat,1

asel,,area,,2
esla
emod,all,mat,9
alls

asel,,area,,3
esla
emod,all,mat,1
alls

asel,,area,,4
esla
emod,all,mat,2
alls

asel,,area,,5
esla
emod,all,mat,9
alls

asel,,area,,6
esla
emod,all,mat,5
alls

asel,,area,,7
esla
emod,all,mat,2
alls

asel,,area,,8
esla
emod,all,mat,3
alls

! Impose BCs - sand-centered case

LSEL,S,LINE,,24
NSLL,,1
SF,ALL,CONV,-6,100          ! apply horiz convection and ambient 100C

NSEL,S,LOC,X,0                 ! select nodes on left side
D,ALL,TEMP,1300                ! apply fixed temp of 1300C
NSEL,ALL
```

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 77 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
! Finished set-up.  Now go to solver

fini
/solu
solve
finish
```

CALCULATION SHEET

ARES CORPORATION

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 78 of 97

Title: DBVS ICV™ Box Thermal Analysis

Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

CASE 4.2.2: ICV™ BOX BOTTOM 1500°C MELT/60PC INTERFACE CONDITIONS

```
! 2D BulkVit Bottom Wall Heat Trasnfer Simulation
! Leaking Glass (Pure Glass) Scenario
! Sand-centered case
! No Gap between box skin & tube steel


/title, Box Bottom Heat Transfer - Case 4.2.2

/prep7

antype, 0
toffst, 273
tunif,100

! Define element type
et,1, plane55
keyopt, 1,1,1

!Specify Material Properties

!6" Castable Refractory 60 PC
MAT,1
MP,KXX,1,1.44,

!8" Castable Refractory 110 C
Mat,2
MPTEMP
MPTEMP,1,25,540,815,1200,1500
MPDATA,Kxx,2,1,1,0.86,0.78,0.668,0.534

!Steel Lining/TS 6x6
Mat,3
MPTEMP
MPTEMP,1,27,127,327,527,727,
MPDATA,Kxx,3,1,60.5,56.7,48,39.2,30,

!Air Conductivity
Mat,4
MPTEMP
MPTEMP,1,27,127,327,527,727,
MPDATA,Kxx,4,1,0.0261,0.0331,0.0456,0.0569,0.0672,

!Sand
Mat,5
MPTEMP
MPTEMP,1,25,200,300,600,1000
MPDATA,Kxx,5,1,0.17,0.25,0.285,0.38,0.55

! Combined Free & Radiation Heat Transfer Coefficient - horizontal Surface
! Models emissivity of box @ 0.8 & concrete shield walls @ 0.6
```

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 79 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06	

```
! Assumes Tinf = 100°C
MAT,6
MPTEMP
MPTEMP,1, 25, 35, 45, 55, 65, 75
MPDATA,hf,6,1, 1.6, 1.9, 2.3, 2.7, 3.1, 3.5
MPTEMP,7,85, 95, 100, 125, 150, 175
MPDATA,hf,6,7, 4.1, 4.8, 6.1, 8.8, 10.0, 11.2
MPTEMP,13, 200, 225, 250, 275, 300, 325
MPDATA,hf,6,13, 12.3, 13.4, 14.6, 115.8, 17.1, 18.5
MPTEMP,19, 350, 375, 400, 425, 450, 475
MPDATA,hf,6,19, 19.9, 21.4, 23.0, 24.6, 26.3, 28.2
MPTEMP,25, 500, 525, 550, 575, 600
MPDATA,hf,6,25, 30.1, 32.1, 34.2, 36.4, 38.7

!Vertical Convection (Not used in this model)
MAT,7
MPTEMP
MPTEMP,1,100,105,110,115,120,125
MPDATA,hf,7,1,0.0,8.5,9.2,9.8,10.2,10.6
MPTEMP,7,150,175,200,225,250,300
MPDATA,hf,7,7,12.3,13.8,15.2,16.5,17.9,20.8

!Air Conductivity
Mat,8
MPTEMP
MPTEMP,1,27,127,327,527,727,
MPDATA,Kxx,8,1,0.0261,0.0331,0.0456,0.0569,0.0672,

!Glass (Hybrid LAW/PNL-4800 Data)
Mat,9
MPTEMP
MPTEMP,1,25,200,300,400,500,600
MPDATA,Kxx,9,1,1,1.12,1.14,1.2,1.29,1.41
MPTEMP,7,700,800,900,1000,1400,2000
MPDATA,Kxx,9,7,1.57,1.76,1.98,2.24,10,32

! keypoints - Sand-centered case

k, 1,       0, 0
k, 2, 0.15240, 0
k, 3, 0.35560, 0
k, 4, 0.36195, 0
k, 5, 0.15240, 0.0635
k, 6, 0.30850, 0.0635
k, 7, 0.35560, 0.0635
k,12,       0, 0.165100
k,13, 0.15240, 0.165100
k,14,       0, 0.190500
k,15, 0.15240, 0.190500
k,20, 0.15240, 0.2921
k,21, 0.30850, 0.2921
k,22, 0.35560, 0.2921
k,23,       0, 0.3556
```

```
k,24, 0.15240, 0.3556
k,25, 0.35560, 0.3556
k,26, 0.36195, 0.3556

! lines - sand-centered case

l,1,2
l,2,5
l,5,13
l,13,12
l,12,1

l,13,15
l,15,14
l,14,12

l,15,20
l,20,24
l,24,23
l,23,14

l,2,3
l,3,7
l,7,6
l,6,5

l,6,21
l,21,20

l,7,22
l,22,21

l,22,25
l,25,24

l,3,4
l,4,26
l,26,25

! areas - sand-centered case

a,1,2,5,13,12        !A1
a,12,13,15,14        !A2
a,14,15,20,24,23     !A3
a,2,3,7,6,5          !A4
a,5,6,21,20,15,13    !A5
a,6,7,22,21          !A6
a,20,21,22,25,24     !A7
a,3,4,26,25,22,7     !A8

! Define mesh
type, 1
esize, 0.00635
```

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 81 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery Date: 3/20/06	Checked By: S.R. Pierce		Date: 3/20/06

```
amesh, all

!Assign Materials to Areas

asel,,area,,1
esla
emod,all,mat,1

asel,,area,,2
esla
emod,all,mat,9
alls

asel,,area,,3
esla
emod,all,mat,1
alls

asel,,area,,4
esla
emod,all,mat,2
alls

asel,,area,,5
esla
emod,all,mat,9
alls

asel,,area,,6
esla
emod,all,mat,5
alls

asel,,area,,7
esla
emod,all,mat,2
alls

asel,,area,,8
esla
emod,all,mat,3
alls

! Impose BCs - sand-centered case

LSEL,S,LINE,,24
NSLL,,1
SF,ALL,CONV,-6,100          ! apply horiz convection and ambient 100C

NSEL,S,LOC,X,0              ! select nodes on left side
D,ALL,TEMP,1500             ! apply fixed temp of 1500C
NSEL,ALL
```

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 82 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
! Finished set-up.  Now go to solver

fini
/solu
solve
finish
```

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 83 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

CASE 4.2.3: ICV™ BOX BOTTOM 1700°C MELT/60PC INTERFACE CONDITIONS

```
! 2D BulkVit Bottom Wall Heat Trasnfer Simulation
! Leaking Glass (Pure Glass) Scenario
! Sand-centered case
! No Gap between box skin & tube steel


/title, Box Bottom Heat Transfer - Case 4.2.3

/prep7

antype, 0
toffst, 273
tunif,100

! Define element type
et,1, plane55
keyopt, 1,1,1

!Specify Material Properties

!6" Castable Refractory 60 PC
MAT,1
MP,KXX,1,1.44,

!8" Castable Refractory 110 C
Mat,2
MPTEMP
MPTEMP,1,25,540,815,1200,1500
MPDATA,Kxx,2,1,1,0.86,0.78,0.668,0.534

!Steel Lining/TS 6x6
Mat,3
MPTEMP
MPTEMP,1,27,127,327,527,727,
MPDATA,Kxx,3,1,60.5,56.7,48,39.2,30,

!Air Conductivity
Mat,4
MPTEMP
MPTEMP,1,27,127,327,527,727,
MPDATA,Kxx,4,1,0.0261,0.0331,0.0456,0.0569,0.0672,

!Sand
Mat,5
MPTEMP
MPTEMP,1,25,200,300,600,1000
MPDATA,Kxx,5,1,0.17,0.25,0.285,0.38,0.55

! Combined Free & Radiation Heat Transfer Coefficient - horizontal Surface
! Models emissivity of box @ 0.8 & concrete shield walls @ 0.6
! Assumes Tinf = 100°C
```

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 84 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
MAT,6
MPTEMP
MPTEMP,1, 25, 35, 45, 55, 65, 75
MPDATA,hf,6,1, 1.6, 1.9, 2.3, 2.7, 3.1, 3.5
MPTEMP,7,85, 95, 100, 125, 150, 175
MPDATA,hf,6,7, 4.1, 4.8, 6.1, 8.8, 10.0, 11.2
MPTEMP,13, 200, 225, 250, 275, 300, 325
MPDATA,hf,6,13, 12.3, 13.4, 14.6, 115.8, 17.1, 18.5
MPTEMP,19, 350, 375, 400, 425, 450, 475
MPDATA,hf,6,19, 19.9, 21.4, 23.0, 24.6, 26.3, 28.2
MPTEMP,25, 500, 525, 550, 575, 600
MPDATA,hf,6,25, 30.1, 32.1, 34.2, 36.4, 38.7

!Vertical Convection (Not used in this model)
MAT,7
MPTEMP
MPTEMP,1,100,105,110,115,120,125
MPDATA,hf,7,1,0.0,8.5,9.2,9.8,10.2,10.6
MPTEMP,7,150,175,200,225,250,300
MPDATA,hf,7,7,12.3,13.8,15.2,16.5,17.9,20.8

!Air Conductivity
Mat,8
MPTEMP
MPTEMP,1,27,127,327,527,727,
MPDATA,Kxx,8,1,0.0261,0.0331,0.0456,0.0569,0.0672,

!Glass (Hybrid LAW/PNL-4800 Data)
Mat,9
MPTEMP
MPTEMP,1,25,200,300,400,500,600
MPDATA,Kxx,9,1,1,1.12,1.14,1.2,1.29,1.41
MPTEMP,7,700,800,900,1000,1400,2000
MPDATA,Kxx,9,7,1.57,1.76,1.98,2.24,10,32

! keypoints - Sand-centered case

k, 1,      0, 0
k, 2, 0.15240, 0
k, 3, 0.35560, 0
k, 4, 0.36195, 0
k, 5, 0.15240, 0.0635
k, 6, 0.32685, 0.0635
k, 7, 0.35560, 0.0635
k,12,      0, 0.165100
k,13, 0.15240, 0.165100
k,14,      0, 0.190500
k,15, 0.15240, 0.190500
k,20, 0.15240, 0.2921
k,21, 0.32685, 0.2921
k,22, 0.35560, 0.2921
k,23,      0, 0.3556
k,24, 0.15240, 0.3556
```

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 85 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
k,25, 0.35560, 0.3556
k,26, 0.36195, 0.3556

! lines - sand-centered case

l,1,2
l,2,5
l,5,13
l,13,12
l,12,1

l,13,15
l,15,14
l,14,12

l,15,20
l,20,24
l,24,23
l,23,14

l,2,3
l,3,7
l,7,6
l,6,5

l,6,21
l,21,20

l,7,22
l,22,21

l,22,25
l,25,24

l,3,4
l,4,26
l,26,25

! areas - sand-centered case

a,1,2,5,13,12        !A1
a,12,13,15,14        !A2
a,14,15,20,24,23     !A3
a,2,3,7,6,5          !A4
a,5,6,21,20,15,13    !A5
a,6,7,22,21          !A6
a,20,21,22,25,24     !A7
a,3,4,26,25,22,7     !A8

! Define mesh
type, 1
esize, 0.00635
amesh, all
```

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 86 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
!Assign Materials to Areas

asel,,area,,1
esla
emod,all,mat,1

asel,,area,,2
esla
emod,all,mat,9
alls

asel,,area,,3
esla
emod,all,mat,1
alls

asel,,area,,4
esla
emod,all,mat,2
alls

asel,,area,,5
esla
emod,all,mat,9
alls

asel,,area,,6
esla
emod,all,mat,5
alls

asel,,area,,7
esla
emod,all,mat,2
alls

asel,,area,,8
esla
emod,all,mat,3
alls

! Impose BCs - sand-centered case

LSEL,S,LINE,,24
NSLL,,1
SF,ALL,CONV,-6,100          ! apply horiz convection and ambient 100C

NSEL,S,LOC,X,0              ! select nodes on left side
D,ALL,TEMP,1700             ! apply fixed temp of 1700C
NSEL,ALL

! Finished set-up.  Now go to solver
```

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 87 of 97

Title: DBVS ICV™ Box Thermal Analysis

Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
fini
/solu
solve
finish
```

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 88 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

CASE 4.2.4: ICV™ BOX BOTTOM 1700°C MELT/60PC INTERFACE CONDITIONS; REDUCED SURFACE HEAT TRANSFER COEFFICIENTS

```
! 2D BulkVit Bottom Wall Heat Trasnfer Simulation
! Leaking Glass (Pure Glass) Scenario
! Sand-centered case
! No Gap between box skin & tube steel
! ½ x Bottom heat transfer coefficient


/title, Box Bottom Heat Transfer - Case 4.2.4

/prep7

antype, 0
toffst, 273
tunif,100

! Define element type
et,1, plane55
keyopt, 1,1,1

!Specify Material Properties

!6" Castable Refractory 60 PC
MAT,1
MP,KXX,1,1.44,

!8" Castable Refractory 110 C
Mat,2
MPTEMP
MPTEMP,1,25,540,815,1200,1500
MPDATA,Kxx,2,1,1,0.86,0.78,0.668,0.534

!Steel Lining/TS 6x6
Mat,3
MPTEMP
MPTEMP,1,27,127,327,527,727,
MPDATA,Kxx,3,1,60.5,56.7,48,39.2,30,

!Air Conductivity
Mat,4
MPTEMP
MPTEMP,1,27,127,327,527,727,
MPDATA,Kxx,4,1,0.0261,0.0331,0.0456,0.0569,0.0672,

!Sand
Mat,5
MPTEMP
MPTEMP,1,25,200,300,600,1000
MPDATA,Kxx,5,1,0.17,0.25,0.285,0.38,0.55
```

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 89 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
! ½ x Combined Free & Radiation Heat Transfer Coefficient - horizontal Surface
! Models emissivity of box @ 0.8 & concrete shield walls @ 0.6
! Assumes Tinf = 100°C
MAT,6
MPTEMP
MPTEMP,1, 25, 35, 45, 55, 65, 75
MPDATA,hf,6,1, 0.8, 1.0, 1.1, 1.3, 1.5, 1.8
MPTEMP,7,85, 95, 100, 125, 150, 175
MPDATA,hf,6,7, 2.0, 2.4, 3.1, 4.4, 5.0, 5.6
MPTEMP,13, 200, 225, 250, 275, 300, 325
MPDATA,hf,6,13, 6.1, 6.7, 7.3, 7.9, 8.6, 9.2
MPTEMP,19, 350, 375, 400, 425, 450, 475
MPDATA,hf,6,19, 10.0, 10.7, 11.5, 12.3, 13.2, 14.1
MPTEMP,25, 500, 525, 550, 575, 600
MPDATA,hf,6,25, 15.0, 16.0, 17.1, 18.2, 19.4

!Vertical Convection (Not used in this model)
MAT,7
MPTEMP
MPTEMP,1,100,105,110,115,120,125
MPDATA,hf,7,1,0.0,8.5,9.2,9.8,10.2,10.6
MPTEMP,7,150,175,200,225,250,300
MPDATA,hf,7,7,12.3,13.8,15.2,16.5,17.9,20.8

!Air Conductivity
Mat,8
MPTEMP
MPTEMP,1,27,127,327,527,727,
MPDATA,Kxx,8,1,0.0261,0.0331,0.0456,0.0569,0.0672,

!Glass (Hybrid LAW/PNL-4800 Data)
Mat,9
MPTEMP
MPTEMP,1,25,200,300,400,500,600
MPDATA,Kxx,9,1,1,1.12,1.14,1.2,1.29,1.41
MPTEMP,7,700,800,900,1000,1400,2000
MPDATA,Kxx,9,7,1.57,1.76,1.98,2.24,10,32

! keypoints - Sand-centered case

k, 1,       0, 0
k, 2, 0.15240, 0
k, 3, 0.35560, 0
k, 4, 0.36195, 0
k, 5, 0.15240, 0.0635
k, 6, 0.33750, 0.0635
k, 7, 0.35560, 0.0635
k,12,       0, 0.165100
k,13, 0.15240, 0.165100
k,14,       0, 0.190500
k,15, 0.15240, 0.190500
k,20, 0.15240, 0.2921
```

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 90 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
k,21, 0.33750, 0.2921
k,22, 0.35560, 0.2921
k,23,       0, 0.3556
k,24, 0.15240, 0.3556
k,25, 0.35560, 0.3556
k,26, 0.36195, 0.3556

! lines - sand-centered case

l,1,2
l,2,5
l,5,13
l,13,12
l,12,1

l,13,15
l,15,14
l,14,12

l,15,20
l,20,24
l,24,23
l,23,14

l,2,3
l,3,7
l,7,6
l,6,5

l,6,21
l,21,20

l,7,22
l,22,21

l,22,25
l,25,24

l,3,4
l,4,26
l,26,25

! areas - sand-centered case

a,1,2,5,13,12        !A1
a,12,13,15,14        !A2
a,14,15,20,24,23     !A3
a,2,3,7,6,5          !A4
a,5,6,21,20,15,13    !A5
a,6,7,22,21          !A6
a,20,21,22,25,24     !A7
a,3,4,26,25,22,7     !A8
```

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 91 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery, Date: 3/20/06	Checked By: S.R. Pierce, Date: 3/20/06		

```
! Define mesh
type, 1
esize, 0.00635
amesh, all

!Assign Materials to Areas

asel,,area,,1
esla
emod,all,mat,1

asel,,area,,2
esla
emod,all,mat,9
alls

asel,,area,,3
esla
emod,all,mat,1
alls

asel,,area,,4
esla
emod,all,mat,2
alls

asel,,area,,5
esla
emod,all,mat,9
alls

asel,,area,,6
esla
emod,all,mat,5
alls

asel,,area,,7
esla
emod,all,mat,2
alls

asel,,area,,8
esla
emod,all,mat,3
alls

! Impose BCs - sand-centered case

LSEL,S,LINE,,24
NSLL,,1
SF,ALL,CONV,-6,100          ! apply horiz convection and ambient 100C

NSEL,S,LOC,X,0                 ! select nodes on left side
```

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 92 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
D,ALL,TEMP,1700                    ! apply fixed temp of 1700C
NSEL,ALL

! Finished set-up.  Now go to solver

fini
/solu
solve
finish
```

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 93 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery, Date: 3/20/06	Checked By: S.R. Pierce, Date: 3/20/06		

CASE 4.2.5: ICV™ BOX BOTTOM 1700°C MELT/60PC INTERFACE CONDITIONS; INCREASED SURFACE HEAT TRANSFER COEFFICIENTS

```
! 2D BulkVit Bottom Wall Heat Trasnfer Simulation
! Leaking Glass (Pure Glass) Scenario
! Sand-centered case
! No Gap between box skin & tube steel
! 2x Bottom heat transfer coefficient


/title, Box Bottom Heat Transfer - Case 4.2.5

/prep7

antype, 0
toffst, 273
tunif,100

! Define element type
et,1, plane55
keyopt, 1,1,1

!Specify Material Properties

!6" Castable Refractory 60 PC
MAT,1
MP,KXX,1,1.44,

!8" Castable Refractory 110 C
Mat,2
MPTEMP
MPTEMP,1,25,540,815,1200,1500
MPDATA,Kxx,2,1,1,0.86,0.78,0.668,0.534

!Steel Lining/TS 6x6
Mat,3
MPTEMP
MPTEMP,1,27,127,327,527,727,
MPDATA,Kxx,3,1,60.5,56.7,48,39.2,30,

!Air Conductivity
Mat,4
MPTEMP
MPTEMP,1,27,127,327,527,727,
MPDATA,Kxx,4,1,0.0261,0.0331,0.0456,0.0569,0.0672,

!Sand
Mat,5
MPTEMP
MPTEMP,1,25,200,300,600,1000
MPDATA,Kxx,5,1,0.17,0.25,0.285,0.38,0.55
```

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 94 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
! 2 x Combined Free & Radiation Heat Transfer Coefficient - horizontal Surface
! Models emissivity of box @ 0.8 & concrete shield walls @ 0.6
! Assumes Tinf = 100°C
MAT,6
MPTEMP
MPTEMP,1, 25, 35, 45, 55, 65, 75
MPDATA,hf,6,1, 3.2, 3.9, 4.6, 5.3, 6.2, 7.1
MPTEMP,7,85, 95, 100, 125, 150, 175
MPDATA,hf,6,7, 8.2, 9.7, 12.3, 17.6, 20.1, 22.4
MPTEMP,13, 200, 225, 250, 275, 300, 325
MPDATA,hf,6,13, 24.6, 26.9, 29.2, 31.7, 34.3, 37.0
MPTEMP,19, 350, 375, 400, 425, 450, 475
MPDATA,hf,6,19, 39.8, 42.8, 45.9, 49.2, 52.7, 56.3
MPTEMP,25, 500, 525, 550, 575, 600
MPDATA,hf,6,25, 60.2, 64.2, 68.4, 72.8, 77.5

!Vertical Convection (Not used in this model)
MAT,7
MPTEMP
MPTEMP,1,100,105,110,115,120,125
MPDATA,hf,7,1,0.0,8.5,9.2,9.8,10.2,10.6
MPTEMP,7,150,175,200,225,250,300
MPDATA,hf,7,7,12.3,13.8,15.2,16.5,17.9,20.8

!Air Conductivity
Mat,8
MPTEMP
MPTEMP,1,27,127,327,527,727,
MPDATA,Kxx,8,1,0.0261,0.0331,0.0456,0.0569,0.0672,

!Glass (Hybrid LAW/PNL-4800 Data)
Mat,9
MPTEMP
MPTEMP,1,25,200,300,400,500,600
MPDATA,Kxx,9,1,1,1.12,1.14,1.2,1.29,1.41
MPTEMP,7,700,800,900,1000,1400,2000
MPDATA,Kxx,9,7,1.57,1.76,1.98,2.24,10,32

! keypoints - Sand-centered case

k, 1,      0, 0
k, 2, 0.15240, 0
k, 3, 0.35560, 0
k, 4, 0.36195, 0
k, 5, 0.15240, 0.0635
k, 6, 0.32650, 0.0635
k, 7, 0.35560, 0.0635
k,12,      0, 0.165100
k,13, 0.15240, 0.165100
k,14,      0, 0.190500
k,15, 0.15240, 0.190500
k,20, 0.15240, 0.2921
```

CALCULATION SHEET

ARES CORPORATION

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 95 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
k,21, 0.32650, 0.2921
k,22, 0.35560, 0.2921
k,23,       0, 0.3556
k,24, 0.15240, 0.3556
k,25, 0.35560, 0.3556
k,26, 0.36195, 0.3556

! lines - sand-centered case

l,1,2
l,2,5
l,5,13
l,13,12
l,12,1

l,13,15
l,15,14
l,14,12

l,15,20
l,20,24
l,24,23
l,23,14

l,2,3
l,3,7
l,7,6
l,6,5

l,6,21
l,21,20

l,7,22
l,22,21

l,22,25
l,25,24

l,3,4
l,4,26
l,26,25

! areas - sand-centered case

a,1,2,5,13,12        !A1
a,12,13,15,14        !A2
a,14,15,20,24,23     !A3
a,2,3,7,6,5          !A4
a,5,6,21,20,15,13    !A5
a,6,7,22,21          !A6
a,20,21,22,25,24     !A7
a,3,4,26,25,22,7     !A8
```

CALCULATION SHEET

ARES CORPORATION

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 96 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
! Define mesh
type, 1
esize, 0.00635
amesh, all

!Assign Materials to Areas

asel,,area,,1
esla
emod,all,mat,1

asel,,area,,2
esla
emod,all,mat,9
alls

asel,,area,,3
esla
emod,all,mat,1
alls

asel,,area,,4
esla
emod,all,mat,2
alls

asel,,area,,5
esla
emod,all,mat,9
alls

asel,,area,,6
esla
emod,all,mat,5
alls

asel,,area,,7
esla
emod,all,mat,2
alls

asel,,area,,8
esla
emod,all,mat,3
alls

! Impose BCs - sand-centered case

LSEL,S,LINE,,24
NSLL,,1
SF,ALL,CONV,-6,100          ! apply horiz convection and ambient 100C

NSEL,S,LOC,X,0                 ! select nodes on left side
```

ARES CORPORATION

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-001	Rev. No. 1	Page No. 97 of 97
Title: DBVS ICV™ Box Thermal Analysis			
Prepared By: P.S. Lowery	Date: 3/20/06	Checked By: S.R. Pierce	Date: 3/20/06

```
D,ALL,TEMP,1700                ! apply fixed temp of 1700C
NSEL,ALL

! Finished set-up.  Now go to solver

fini
/solu
solve
finish
```

CALCULATION SHEET

amec

CALC. NO.: 145579-D-CA-001 REV: 2 DATE: March 22, 2006

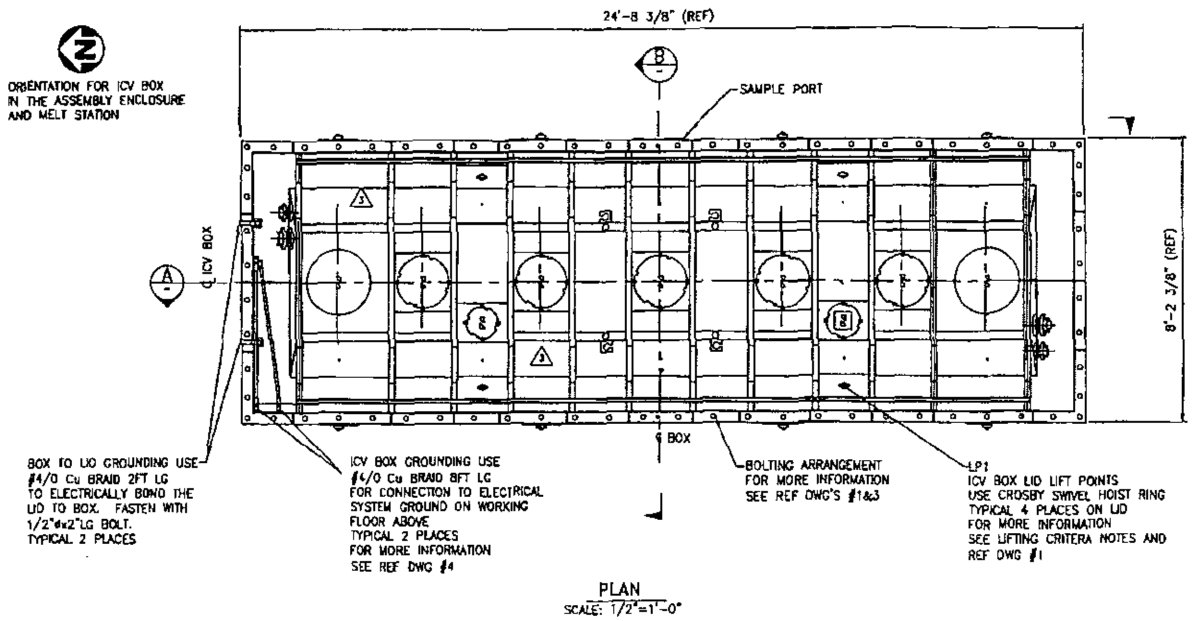
CALC. TITLE: Area 35 – Transient Heat Transfer Calculations of ICV™ Box

PROJECT NO.: 145579 PROJECT TITLE: Final DBVS Design

Attachment 2
Bulk Vitrification Design Drawings
(8 pages including Attachment Cover)

Drawing Number	Title	Revision	Pages
F-145579-35-D-0004	Bulk Vitrification ICV Box Data Sheet	4	1
F-145579-35-D-0008	Bulk Vitrification ICV Box Plan & Sections	1	1
F-145579-35-D-0016	Bulk Vitrification ICV Box Refractory Assembly	K	1
F-145579-35-D-0017	Bulk Vitrification ICV Box Refractory Details	K	1
F-145579-00-D-0041	Bulk Vitrification Melt Area G.A. Elevations North and West	F	1
F-145579-00-B-0020	Bulk Vitrification Shielding Walls General Arrangement	K	1
F-145579-00-B-0025	Bulk Vitrification Melt Area Steel Curbs	F	1
	Total Number of Drawing Pages		7

No.	AMEC Dwg. No.	REFERENCE DRAWINGS
1	F-145579-35-0-0005	ICV BOX LID ASSEMBLY
2	F-145579-35-0-0006	ICV BOX LID STEEL WORK 1 OF 3
3	F-145579-35-0-0008	ICV BOX ASSEMBLY
4	F-145579-35-0-0012	ICV BOX CAMERA, T/C AND GROUND ASSEMBLY
5	F-145579-35-0-0014	ICV BOX STARTER PATH DETAILS
6	F-145579-35-0-0021	ICV BOX LID BREATHER HEPA FILTER
7	F-145579-35-0-0016	ICV BOX REFRACTORY ASSEMBLY



PLAN
SCALE: 1/2"=1'-0"

GENERAL NOTES:

1. ICV BOX SHELL SHALL BE CONSTRUCTED WITH ALL INSIDE JOINTS SEAL WELDED (WATERTIGHT)
2. FINISHED CONSTRUCTION DIMENSIONAL TOLERANCE SHALL BE ±1/8"
3. PROVIDE DRAIN HOLES TO ALLOW FOR NO WATER RETENTION ON TOP OF BOX LID.
4. ALL PIPING FLANGES WILL BE IN ACCORDANCE WITH ASME B16.5
5. FOR ICV BOX DETAILS SEE DWG. F-145579-35-D-0008
6. FOR ICV BOX LID DETAILS SEE DWG. F-145579-35-D-0006
7. SUPPLY CROSBY LIFTING DEVICES MODEL HR-125 #1016920 (OR EQUAL)
8. NAME PLATES SHALL BE PROVIDED FOR THE ICV BOX AND LID. NAME PLATES SHALL MEET THE REQUIREMENTS OF THE HANFORD HOISTING AND RIGGING MANUAL AND AS A MINIMUM SHOW THE MANUFACTURES NAME AND WEIGHTS EMPTY AND FULL.
9. ALL HSS MEMBERS SHALL HAVE 0.25" BREATHER/DRAIN HOLES.
10. FOR CENTER OF GRAVITY DIMENSIONS SEE 145579-D-CA-028.

LIFTING CRITERIA

1. ICV BOX LID
   - FOUR (4) LIFT POINTS (LP1)
   - USE LIFTING FRAME OR SPREADER BARS (SUPPLIED BY LID FABRICATOR).
   - USE CROSBY SWIVEL HOIST RINGS MODEL HR-125 #1016920

   LIMITATIONS
   1. LP1'S TO BE USED FOR LIFTING THE ICV BOX LID ONLY
   2. REMOVE SWIVEL HOIST RINGS AFTER ICV BOX ASSEMBLY, FOR REUSE ON SUBSEQUENT BOXES
2. EMPTY BOX
   - EIGHT (8) LIFT POINTS (LP2) ON BOX SIDES
   - USE LIFTING FRAME OR SPREADER BARS (SUPPLIED BY BOX FABRICATOR)
   - USE CROSBY SWIVEL HOIST RINGS MODEL HR-125 #1016920

   LIMITATIONS
   1. LP2 RESTRICTED TO LIFTING THE EMPTY ICV BOX AND LID ONLY
   2. THESE LP2 POINTS ARE NOT TO BE USED FOR LIFTING ICV BOX WHEN COMPOSITE LINER OF INSULATION, SAND AND REFRACTORY, HAVE BEEN INSTALLED.
   3. THESE LP2 POINTS ARE NOT TO BE USED TO LIFT THE FULL BOX
   4. REMOVE SWIVEL HOIST RINGS AFTER ICV BOX IS LIFTED INTO ASSEMBLY POSITION IN THE ASSEMBLY ENCLOSURE, FOR REUSE ON SUBSEQUENT BOXES.
3. FULL BOX
   - EIGHT (8) LIFT POINTS (LP3)
   - FULL ICV BOX TO BE LIFTED FROM UNDERNEATH BOTTOM PERIMETER FRAME
4. ALL SWIVEL HOIST RINGS TO BE TORQUED TO 60 FT LBS.

VESSEL DATA

FABRICATION, INSPECTION & TESTING

PRIMARY CONTAINMENT WELDS	FULL PENETRATION TO AWS D1.1		
RADIOGRAPHY	–	STRESS RELIEF	AS REQUIRED
IMPACT VALUES	–	WELD FINISH	SEE REF #3
WELD HARDNESS	–	INSPECTION BY	MANUFACTURER
OTHER N.D.T.	SEE NOTES	CODE CERT. REQ'D.	NO
MILL ANALYSIS / CERT.	–	STRESS CALCULATIONS	–
TESTING	WATER TIGHT/ FAT		

MATERIAL SPECIFICATIONS

	ASTM DESIGN	GRADE	DESCRIPTION
SHELL PLATE	A36		C.S.
REINFORCING RIBS (HSS)	A500	C	C.S.
INTERNAL CLIPS	A36		C.S.
BOLTS - EXTERNAL	A193	B7	C.S.
NUTS - EXTERNAL	A194	7 HEAVY HEX	C.S.
GASKETS: LID/BOX	SEE DWG SHT 0019		
REINF. PADS	A36		C.S.
INTERNAL LINERS	NOT IN SCOPE OF SUPPLY OF ICV BOX SHELL		
INSULATION	KAOWOOL M BOARD		
SAND			
REFRACTORY	VIBROCAST 60PC		
CLIPS	A36		

APPURTENANCES (APPLICABLE STDS. / SPECS.)

LIFTING LUGS	SEE DWG FOR DETAILS
EARTHING LUGS	SEE DWG FOR DETAILS
NAMEPLATES BOX	SEE NOTE 8
NAMEPLATES LID	SEE NOTE 8

FINISH (APPLICABLE STDS. / SPECS.)

SURFACE PREP - INTERNAL	N/A	INTERNAL FINISH	N/A
SURFACE PREP - EXTERNAL	SSPC SP10	EXTERNAL FINISH	THERMOLINE 4700
FIREPROOFING	N/A		

BOX WEIGHTS

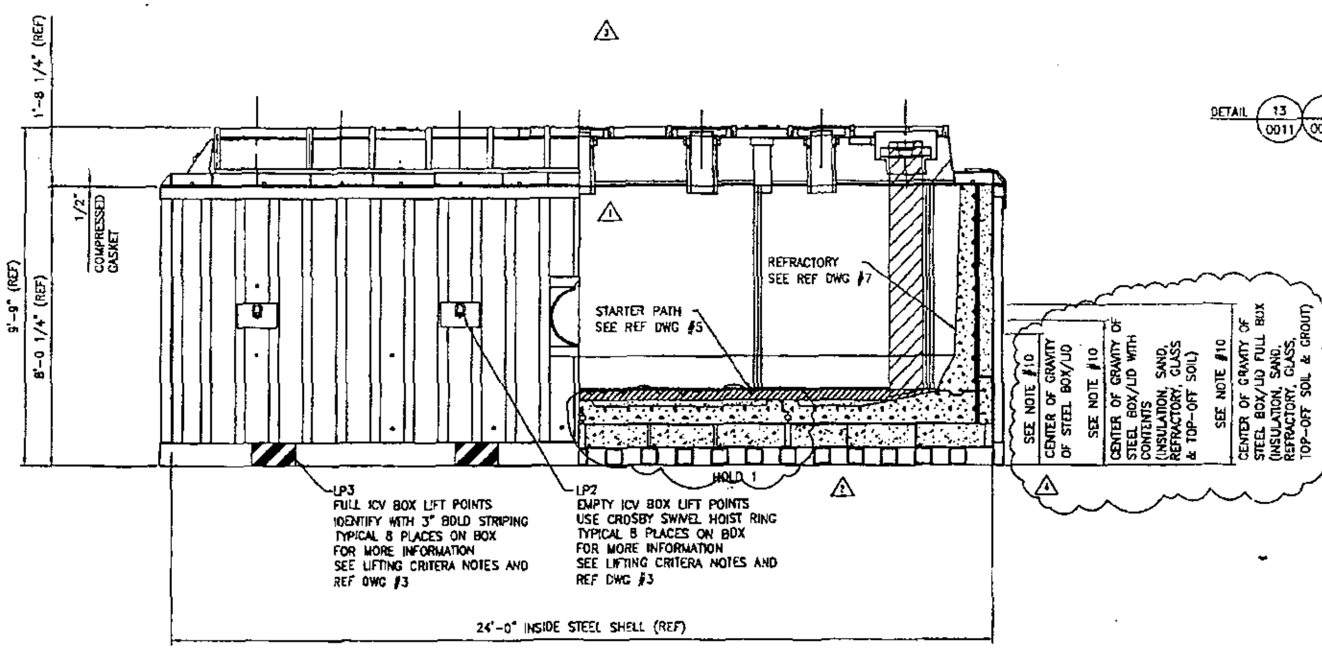
ICV BOX BASE = 19,069#
ICV BOX LID = 4,737#
NOTE:
FOR WEIGHT BREAKDOWN OF ICV BOX & CONTENTS REFER TO DOCUMENT NO. 145579-D-CA-010.

GENERAL

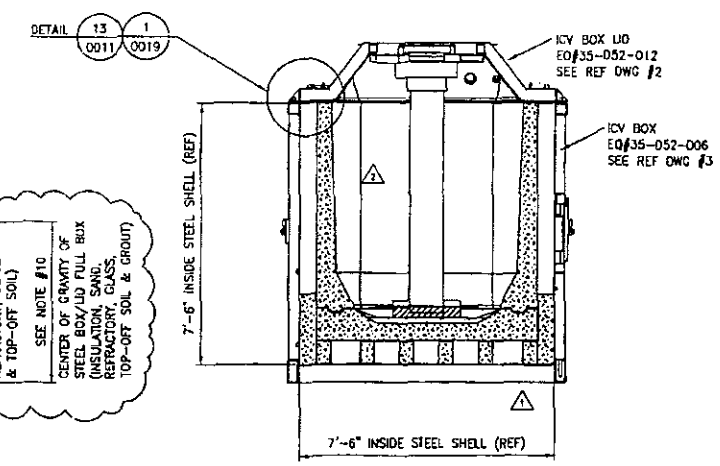
PROJECT	DBVS FINAL DESIGN	PROJECT NUMBER	145579
		NUMBER REQ'D.	50
ITEM NO.	35-052-005 ICV BOX	P.O. NUMBER	
	35-052-012 ICV BOX LID	QUALITY ASSURANCE LEVEL	NQA-1
SITE	HANFORD		ENHANCED QUALITY

PROCUREMENT QUALITY

LEVEL	EQM



SECTION A
SCALE: 1/2"=1'-0"



SECTION B
SCALE: 1/2"=1'-0"

HOLDS

1. ICV REFRACTORY JOINT ASSEMBLY DIMENSIONS ON-HOLD UNTIL VENDOR TESTING OF NEW JOINT DESIGN

Rev.	REVISION DESCRIPTION	Date	By	Chk'd		
4	TECN EE-018	20 MAR 06	RE	SW	SB	JJ
3	ISSUED FOR DESIGN REPORT	06 MAR 06	SW	JM	SB	JSG
2	REVISED ICV BOX CORNER PANEL AND REFRACTORY JOINT	13 JAN 06	SW	SRB	KSW	JSG
1	REVISED ICV BOX LINING	15 AUG 05	JBM	ROB	FWS	TH
0	ISSUED FOR CONSTRUCTION	19 MAY 05	JBM	AA	FWS	TH

F-145579-35-D-0004 REV 4

amec

145579-FINAL DBVS DESIGN

U.S. DEPARTMENT OF ENERGY
Office of River Protection

BULK VITRIFICATION
ICV BOX
DATA SHEET

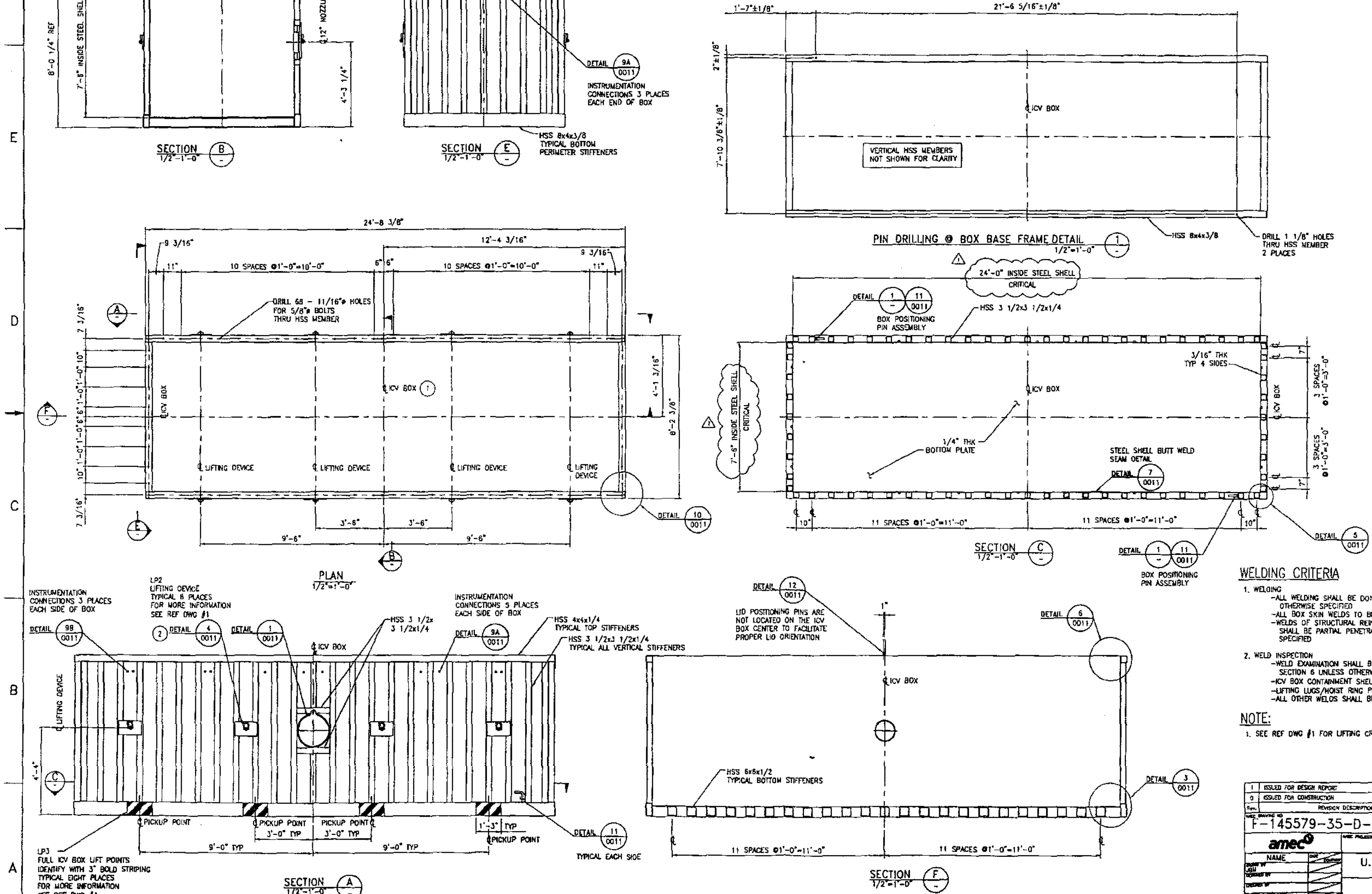
F
AS NOTED

DWG NO | TITLE — DRAWING TRACEABILITY LIST
REF NUMBER | TITLE — REFERENCES
NEXT USED ON
REVISIONS

No.	AMEC Dwg. No.	REFERENCE DRAWINGS
1	F-145579-35-D-0004	ICV BOX DATA SHEET
2	F-145579-35-D-0005	ICV BOX LID ASSEMBLY DETAILS
3	F-145579-35-D-0006	ICV BOX LID STEEL WORK 1 OF 3
4	F-145579-35-D-0011	ICV BOX ASSEMBLY DETAILS
5	F-145579-00-F-0014	ICV BOX INSTRUMENT LOCATIONS

PARTS/MATERIAL LIST

ITEM	REQD	PART/DASH NUMBER	NOMENCLATURE/DESCRIPTION	MATERIAL/REFERENCE	SHT	ITEM NO
1	1	35-D52-006	ICV BOX	VARIES	-	1
2	8	1016920	CROSBY SWIVEL HOIST RING #HR-125	VARIES	-	2



WELDING CRITERIA

1. WELDING
   - ALL WELDING SHALL BE DONE IN ACCORDANCE WITH AWS D1.1 UNLESS OTHERWISE SPECIFIED
   - ALL BOX SKIN WELDS TO BE FULL PENETRATION WELDS
   - WELDS OF STRUCTURAL REINFORCING MEMBERS TO BOX SKIN SHALL BE PARTIAL PENETRATION WELDS TO AWS D1.1 UNLESS OTHERWISE SPECIFIED
2. WELD INSPECTION
   - WELD EXAMINATION SHALL BE DONE IN ACCORDANCE WITH AWS D1.1 SECTION 6 UNLESS OTHERWISE SPECIFIED
   - ICV BOX CONTAINMENT SHELL WELDS SHALL BE CHECKED BY 100% PT/MT
   - LIFTING LUGS/HOIST RING PLATE WELDS SHALL BE CHECKED BY 100% MT
   - ALL OTHER WELDS SHALL BE CHECKED VISUALLY TO AWS D1.1 SECTION 6

NOTE:

1. SEE REF DWG #1 FOR LIFTING CRITERIA AND GENERAL NOTES.

Rev.	REVISION DESCRIPTION	Date	By	Chk'd		
1	ISSUED FOR DESIGN REPORT	06 MAR 06	THB	JM	SRB	JSG
0	ISSUED FOR CONSTRUCTION	19 MAY 05	JBM	AA	FWS	TH

F-145579-35-D-0008 — REV 1

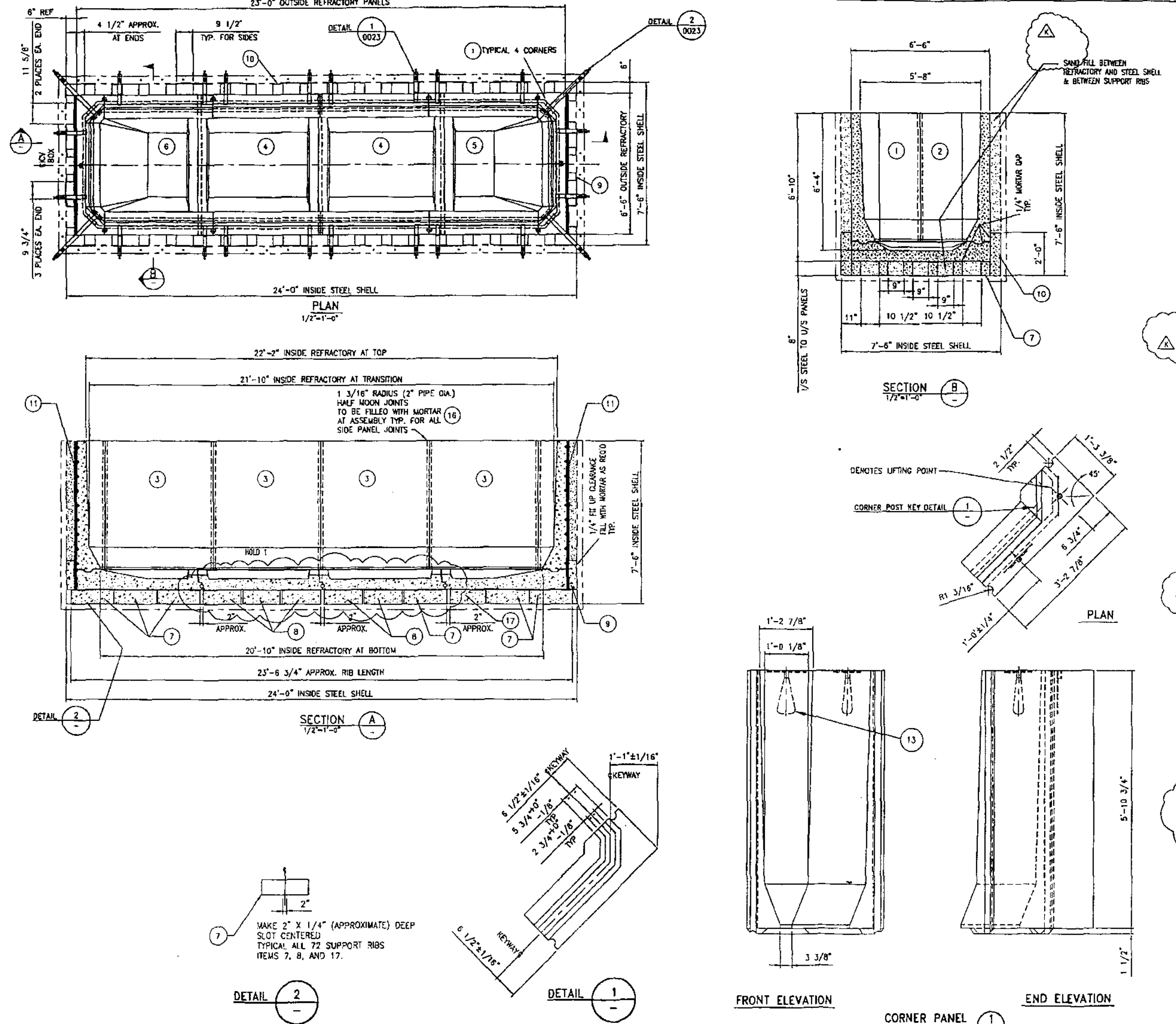
amec — 145579-FINAL DBVS DESIGN

U.S. DEPARTMENT OF ENERGY
Office of River Protection

BULK VITRIFICATION
ICV BOX
PLAN & SECTIONS

SCALE AS NOTED

No.	AMEC Dwg. No.	REFERENCE DRAWINGS
1	F-145579-35-D-0004	ICV BOX DATA SHEET
2	F-145579-35-D-0008	ICV BOX ASSEMBLY
3	F-145579-35-D-0017	ICV BOX REFRACTORY DETAILS
4	F-145579-35-D-0023	ICV BOX REFRACTORY PANEL CLIP DETAILS



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PARTS/MATERIAL LIST

ITEM	REQ'D	PART/DASH NUMBER	NOMENCLATURE/DESCRIPTION	MATERIAL/REFERENCE	SHT	ITEM NO
1	2	–	CORNER PANEL	VIBRACAST 60PC	0016	1
2	2	–	CORNER PANEL	VIBRACAST 60PC	0017	2
3	8	–	SIDE PANEL	VIBRACAST 60PC	0017	3
4	2	–	FLOOR PANEL	VIBRACAST 60PC	0017	4
5	1	–	FLOOR PANEL	VIBRACAST 60PC	0017	5
6	1	–	FLOOR PANEL	VIBRACAST 60PC	0017	6
7	36	–	SUPPORT RIBS – 24" x 7 3/4" x 5"	RESCO 110	0016	7
8	30	–	SUPPORT RIB –21 1/2" x 7 3/4" x 5"	RESCO 110	0016	8
9	12	–	END BACKING BRICK – 4.25"x4.25"x16"	RESCO 110	0016	9
10	36	–	SIDE BACKING BRICK – 5.75"x5.75"x24"	RESCO 110	0016	10
11	2	–	FILLER BOARD – 1.5" x 6'-6" x 6'-10"	KAOWOOL M BOARD	0016	11
12	16	–	BASE PICKUP INSERT – TYPE T-10 x 1 1/4"	N.A.	0017	12
13	24	–	EDGE PICKUP INSERT – TYPE T-3-A x 1"	N.A.	0016 0017	13
14	20	0023 MK 'A'	PANEL CLIP	A36, A307	0023	14
15	4	0023 MK 'B'	CORNER CLIP	A36, A307	0023	15
16	–	SUPER ADAMANT	MORTAR/RECOMMENDED (EJ BARTELLS)	N/A	0023	16
17	6	–	SUPPORT RIBS – 20" x 7 3/4" x 5"	RESCO 110	0016	17

HOLD:
1. ICV REFRACTORY JOINT ASSEMBLY DIMENSIONS ON HOLD UNTIL VENDOR TESTING OF RE-DESIGN

NOTES:
1. THIS DESIGN IS BASED ON:
   - THE CURRENT ICV BOX DESIGN DWG. F-145579-35-D-0004.
   - RESULTS FROM EIT MEETING DISCUSSIONS AND TEST BOX RESULTS
   - INPUT FROM EJ BARTELLS
2. SAND TO BE USED TO FILL SPACES BETWEEN REFRACTORY PANELS AND STEEL SHELL ON SIDES, ENDS AND BOTTOM.
3. HALF MOON JOINT DESIGN IS BASED ON INFORMATION FROM EJ BARTELLS – HALF MOON JOINTS ARE PREFERRED FOR:
   - EASE OF PRODUCTION
   - EASE OF INSTALLATION
   - STRENGTH OF JOINT
   - JOINT IS SEALED AGAINST LEAKAGE UNLIKE A LAP JOINT
4. ALLOWANCE HAS BEEN MADE FOR MORTAR BETWEEN ALL JOINTS BASED ON DISCUSSIONS WITH EJ BARTELLS.
5. FLOOR PANEL SUPPORT RIBS HAVE BEEN SPACED AT THE MAXIMUM DISTANCE RECOMMENDED TO ENSURE THAT LOADS ON FLOOR PANELS ARE TAKEN IN SHEAR AND NOT BENDING.
6. ALL DIMENSIONS SHOWN ARE NOMINAL AND BASED ON AN EXPECTED +/- 1/8" PRODUCTION TOLERANCE FOR DIMENSIONS OVER 12" AND +0/- 1/8" FOR ALL OTHER DIMENSIONS EXCEPT WHERE NOTED.
7. ALL LIFTING DEVICES TO BE REMOVED BEFORE ICV BOX LEAVES ASSEMBLY ENCLOSURE.
8. LIFTING COMPONENT INSERTS NOT TO PROTRUDE BEYOND REFRACTORY SURFACE.

Rev.	REVISION DESCRIPTION	Date	By	Chk'd		
K	ELIMINATE PROPRIETARY INFO	20 MAR 08	RE	JM	SB	JJ
J	REVISED DIMENSIONS	06 MAR 06	SW	JM	SB	JSG
H	REVISED CORNER PANEL AND REFRACTORY JOINT	13 JAN 06	SW	SRB	KSW	JSG
G	REVISED LIFTING POINT LOCATIONS	9 SEPT 05	JBM	RDB	FWS	FWS
F	REVISED – ISSUED FOR CH2M HILL APPROVAL & 90% REPORT	15 AUG 05	JBM	RDB	FWS	TH
E	ISSUED FOR CH2M HILL REVIEW AND 90% REPORT	03 MAR 05	TW	AA	FWS	TH
D	ISSUED FOR INFORMATION	09 FEB 05	JOK		FWS/TW	TH
C	ISSUED FOR INFORMATION	17 JAN 05	JBM	AA	FWS	TH
B	ISSUED FOR APPROVAL	30 SEPT 04	JBM	TW	FWS	TH
A	ISSUED FOR REVIEW	09 SEPT 04	JBM	TW	GJ	TH

F-145579-35-D-0016 REV K

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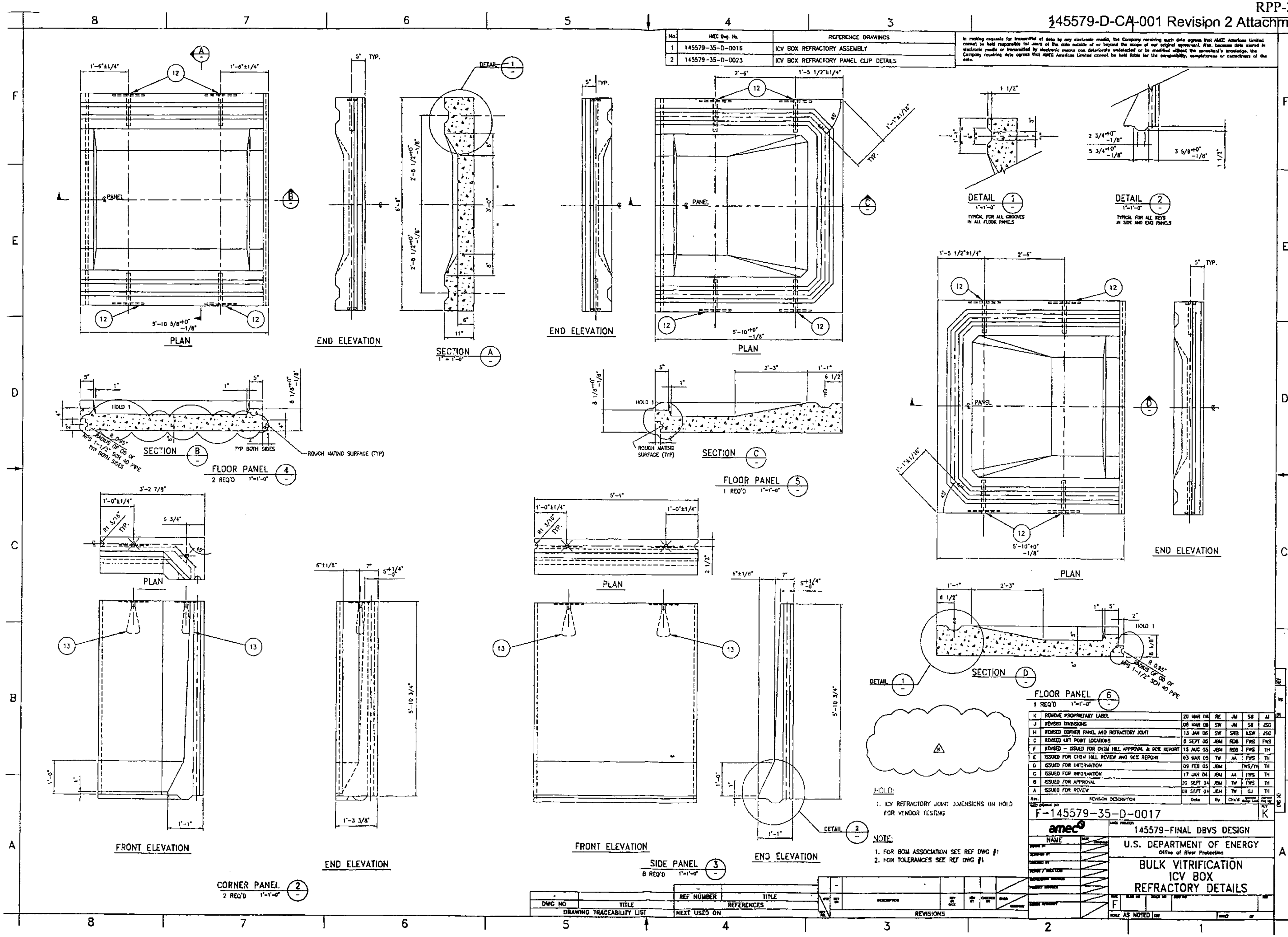
145579-FINAL DBVS DESIGN

U.S. DEPARTMENT OF ENERGY
Office of River Protection

BULK VITRIFICATION
ICV BOX
REFRACTORY ASSEMBLY

F
SCALE AS NOTED

DWG NO	TITLE	REF NUMBER	TITLE
DRAWING TRACEABILITY LIST		REFERENCES	
NEXT USED ON		REVISIONS	


REFERENCE DRAWINGS
1 145579-35-D-0016 ICV BOX REFRACTORY ASSEMBLY
2 145579-35-D-0023 ICV BOX REFRACTORY PANEL CLIP DETAILS
PLAN
END ELEVATION
SECTION A 1" = 1'-0"
SECTION B
FLOOR PANEL 4 2 REQ'D 1"=1'-0"
ROUGH MATING SURFACE (TYP)
SECTION C
FLOOR PANEL 5 1 REQ'D 1"=1'-0"
SECTION D
FLOOR PANEL 6 1 REQ'D 1"=1'-0"
DETAIL 1 1"=1'-0" TYPICAL FOR ALL GROOVES IN ALL FLOOR PANELS
DETAIL 2 1"=1'-0" TYPICAL FOR ALL KEYS IN SIDE AND END PANELS
FRONT ELEVATION
CORNER PANEL 2 2 REQ'D 1"=1'-0"
SIDE PANEL 3 8 REQ'D 1"=1'-0"
HOLD:
1. ICV REFRACTORY JOINT DIMENSIONS ON HOLD FOR VENDOR TESTING
NOTE:
1. FOR BOM ASSOCIATION SEE REF DWG #1
2. FOR TOLERANCES SEE REF DWG #1
K REMOVE PROPRIETARY LABEL 20 MAR 06
J REVISED DIMENSIONS 08 MAR 06
H REVISED CORNER PANEL AND REFRACTORY JOINT 13 JAN 06
G REVISED LIFT POINT LOCATIONS 8 SEPT 05
F REVISED - ISSUED FOR CH2M HILL APPROVAL & 90% REPORT 15 AUG 05
E ISSUED FOR CH2M HILL REVIEW AND 90% REPORT 03 MAR 05
D ISSUED FOR INFORMATION 09 FEB 05
C ISSUED FOR INFORMATION 17 JAN 04
B ISSUED FOR APPROVAL 30 SEPT 04
A ISSUED FOR REVIEW 09 SEPT 04
F-145579-35-D-0017 K
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145579-FINAL DBVS DESIGN
U.S. DEPARTMENT OF ENERGY
Office of River Protection
BULK VITRIFICATION
ICV BOX
REFRACTORY DETAILS
SCALE AS NOTED
DRAWING TRACEABILITY LIST
NEXT USED ON
REVISIONS

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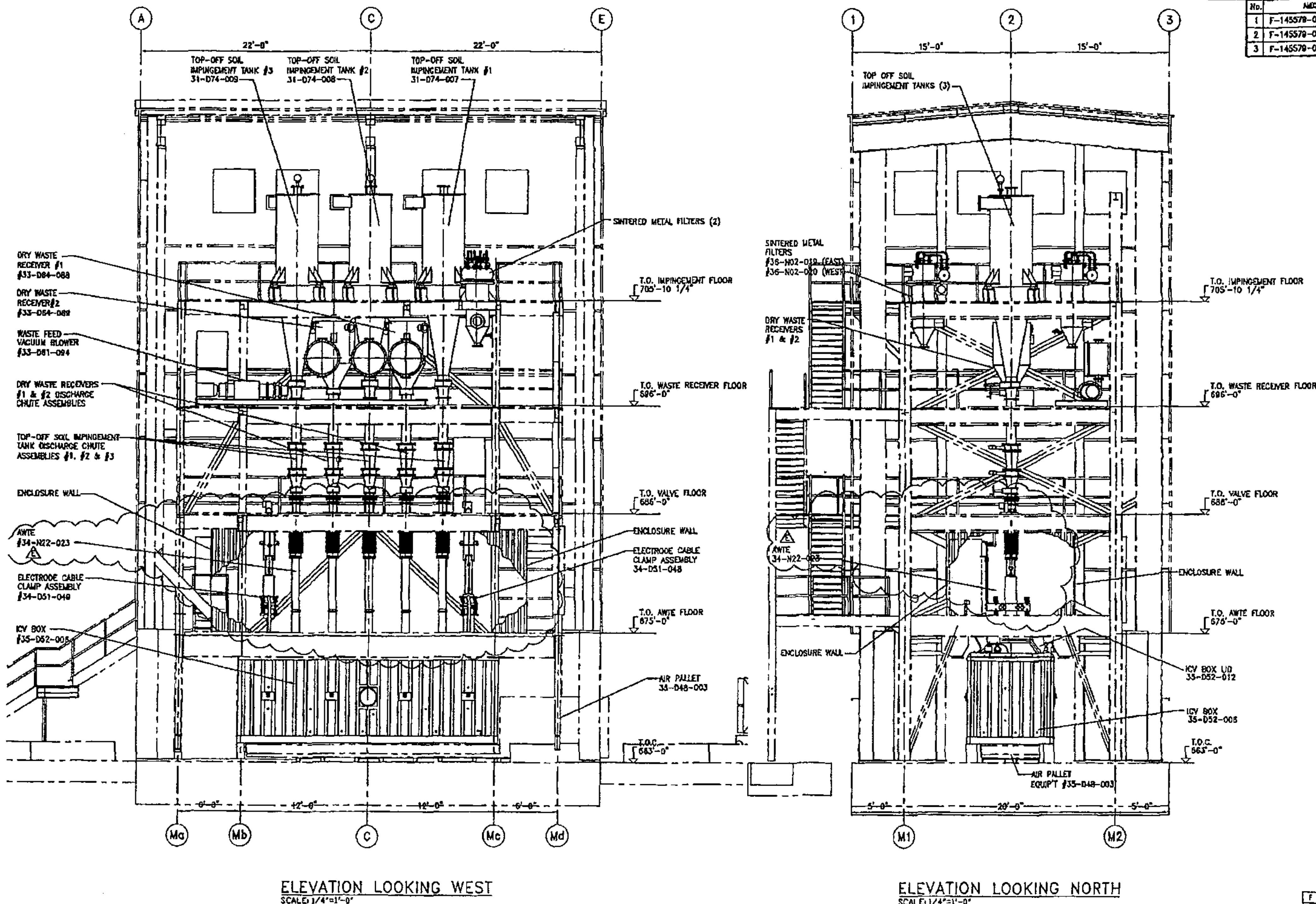
No.	AMEC Dwg. No.	REFERENCE DRAWINGS
1	F-145579-00-D-0051	MELT AREA G.A. PLAN VIEWS
2	F-145579-00-D-0044	MELT AREA G.A. SECTIONS
3	F-145579-00-D-0010	MELT AREA G.A.



NOT APPROVED FOR CONSTRUCTION

Rev.	REVISION DESCRIPTION	Date	By	Chk'd		
F	ISSUED FOR APPROVAL	01 FEB 06	AS		.	
E	ISSUED FOR DESIGN	18 DEC 05	RRB		FWS	JCB
D	ISSUED FOR CH2M HILL APPROVAL/90% REPORT	02 MAR 05	KES	AA	GJ	TH
C	ISSUED FOR CH2M HILL REVIEW/APPROVAL	05 NOV 04	KES		GJ/FS	TH
B	ISSUED FOR INTERNAL APPROVAL	18 OCT 04	KES		FS	JCB
A	ISSUED FOR REVIEW	27 AUG 04	RRB		FS/GJ	TH

AMEC DRAWING NO. F-145579-00-D-0041 REV F

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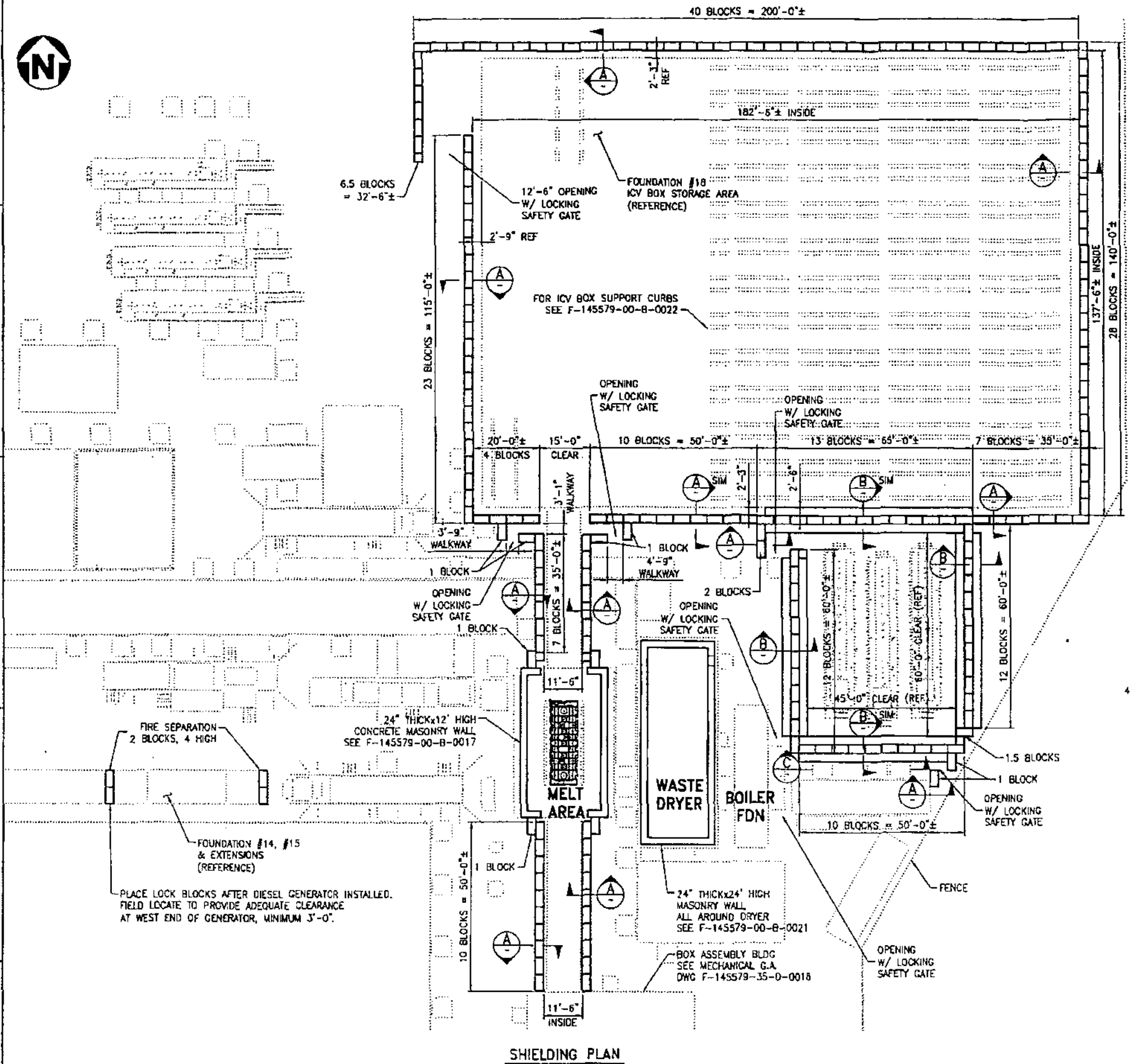
145579-FINAL DBVS DESIGN

U.S. DEPARTMENT OF ENERGY
Office of River Protection

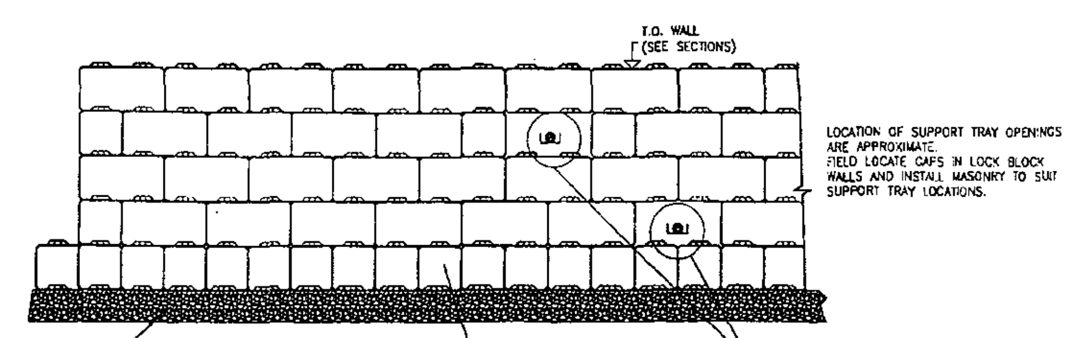
BULK VITRIFICATION
MELT AREA G.A.
SECTIONS

SCALE 1/4" = 1' SHEET 1 OF 1

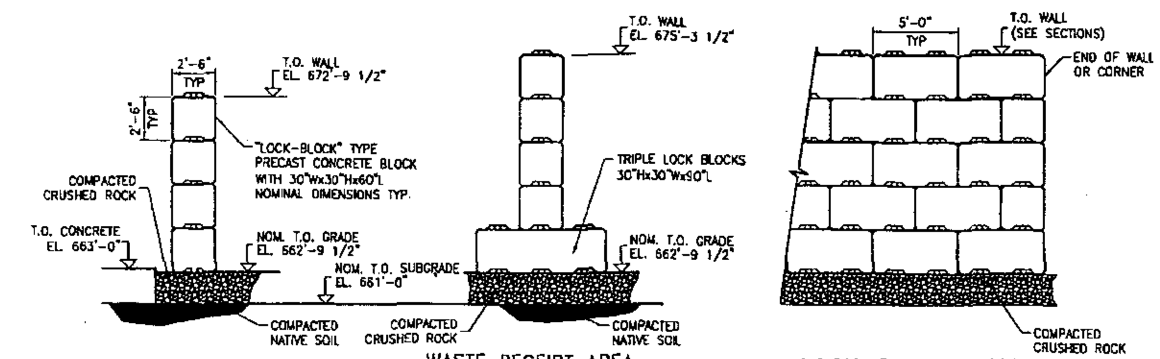
DWG NO | TITLE — DRAWING TRACEABILITY LIST
REF NUMBER | TITLE — REFERENCES
NEXT USED ON
REVISIONS



SHIELDING PLAN
1/16"=1'-0"



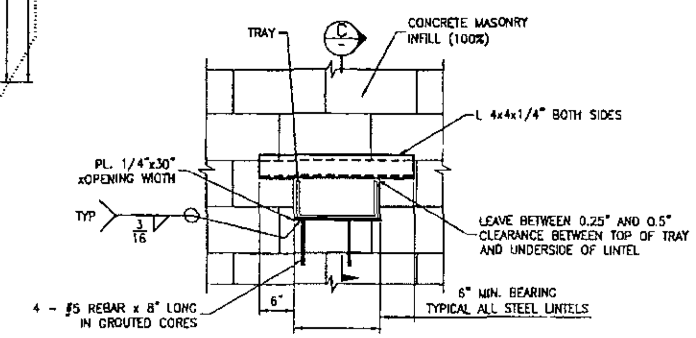
SECTION C
1/4"=1'-0"



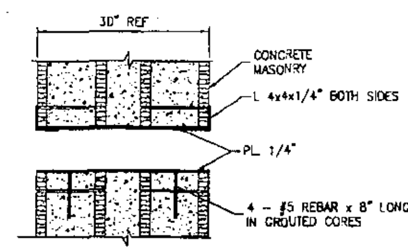
TYPICAL 4 BLOCK HIGH WALL
SECTION A
1/4"=1'-0"

WASTE RECEIPT AREA 5 BLOCK HIGH WALL
SECTION B
1/4"=1'-0"

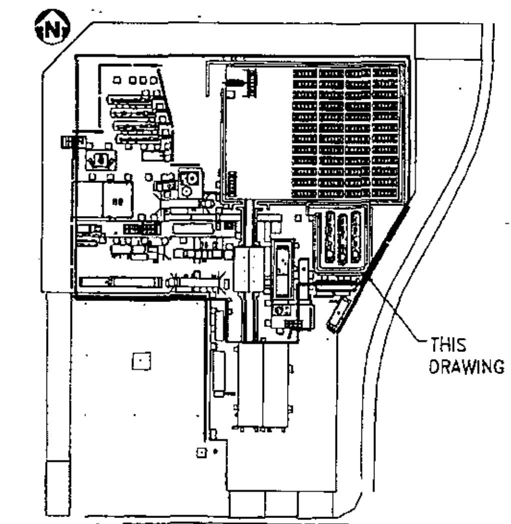
LOCK-BLOCK WALL TYPICAL ELEVATION
1/4"=1'-0"



DETAIL 1
1"=1'-0"



SECTION D
1"=1'-0"



LOCATION PLAN

NOTES:

1. ALL CONSTRUCTION SHALL CONFORM TO CONSTRUCTION SPECIFICATION 145579-Q-SP-001.

2. THE FOLLOWING PROPERTIES ARE REQUIRED FOR THE PRECAST BLOCKS: MINIMUM 28 DAY COMPRESSIVE STRENGTH OF 3000psi. SEE CONSTRUCTION SPECIFICATION 145579-Q-SP-001, SECTION 03480 FOR DETAILS.

3. EACH BLOCK SHALL HAVE A TOLERANCE OF ±0.25 INCHES FROM NOMINAL SIZES. OVERALL PLACED DIMENSIONS WILL VARY DEPENDING ON ACCURACY OF GRAVEL BASE, ±3/8" PER BLOCK.

4. BLOCK JOINTS LAYOUT SHOWS "BASE" LAYER OF BLOCKS EXCEPT AT WASTE RECEIPT AREA WHERE SECOND LAYER IS SHOWN. SUBSEQUENT LAYERS OF BLOCKS SHALL BE PLACED IN RUNNING BOND PATTERN WHERE POSSIBLE USING HALF BLOCKS AS NECESSARY TO MAINTAIN PATTERN.

5. FOR SOIL AND CRUSHED ROCK INSTALLATION SEE DRAWINGS H-14-106788 AND H-14-106789, AND CONSTRUCTION SPECIFICATION 145579-Q-SP-001, SECTIONS 02220 AND 02235.

6. LOCKING SAFETY GATES SHALL BE FIELD FIT AND INSTALLED TO FIT OPENINGS AND SHALL CONFORM TO CONSTRUCTION SPECIFICATION 145579-Q-SP-001, SECTION 02821.

Rev.	Revision Description	Date	By	Chk'd	Approved	Approved
K	ISSUED FOR CH2M HILL APPROVAL & 90% REPORT	18 MAR 08	DPK	PM	PM	FWS
J	ISSUED FOR CH2M HILL APPROVAL & 90% REPORT	24 JAN 08	DPK	PM	PM	JOS
I	ISSUED FOR INTERNAL APPROVAL	19 JAN 08	DPK		PM	FWS
H	ISSUED FOR INTERNAL REVIEW	05 DEC 05	DPK		PM	JTA
G	ISSUED FOR CH2M HILL APPROVAL & 90% REPORT	01 APR 05	DPK		PM	TH
F	ISSUED FOR CH2M HILL APPROVAL & 90% REPORT	18 JAN 05	DPK		PM	TH
E	ISSUED FOR CH2M HILL REVIEW	25 NOV 04	DPK		PM	TH
D	ISSUED FOR INTERNAL APPROVAL	23 NOV 04	DPK		PM	TH
C	ISSUED FOR INTERNAL REVIEW	04 NOV 04	DPK		PM	TH
B	ISSUED FOR REVIEW	01 OCT 04	DPK		PM	TH
A	ISSUED FOR REVIEW	22 SEP 04	DPK		PMM	TH

AMEC DRAWING NO. F-145579-00-B-0020 REV K

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AMEC PROJECT: 145579-FINAL DBVS DESIGN

NAME: Don Kroeker

U.S. DEPARTMENT OF ENERGY
Office of River Protection

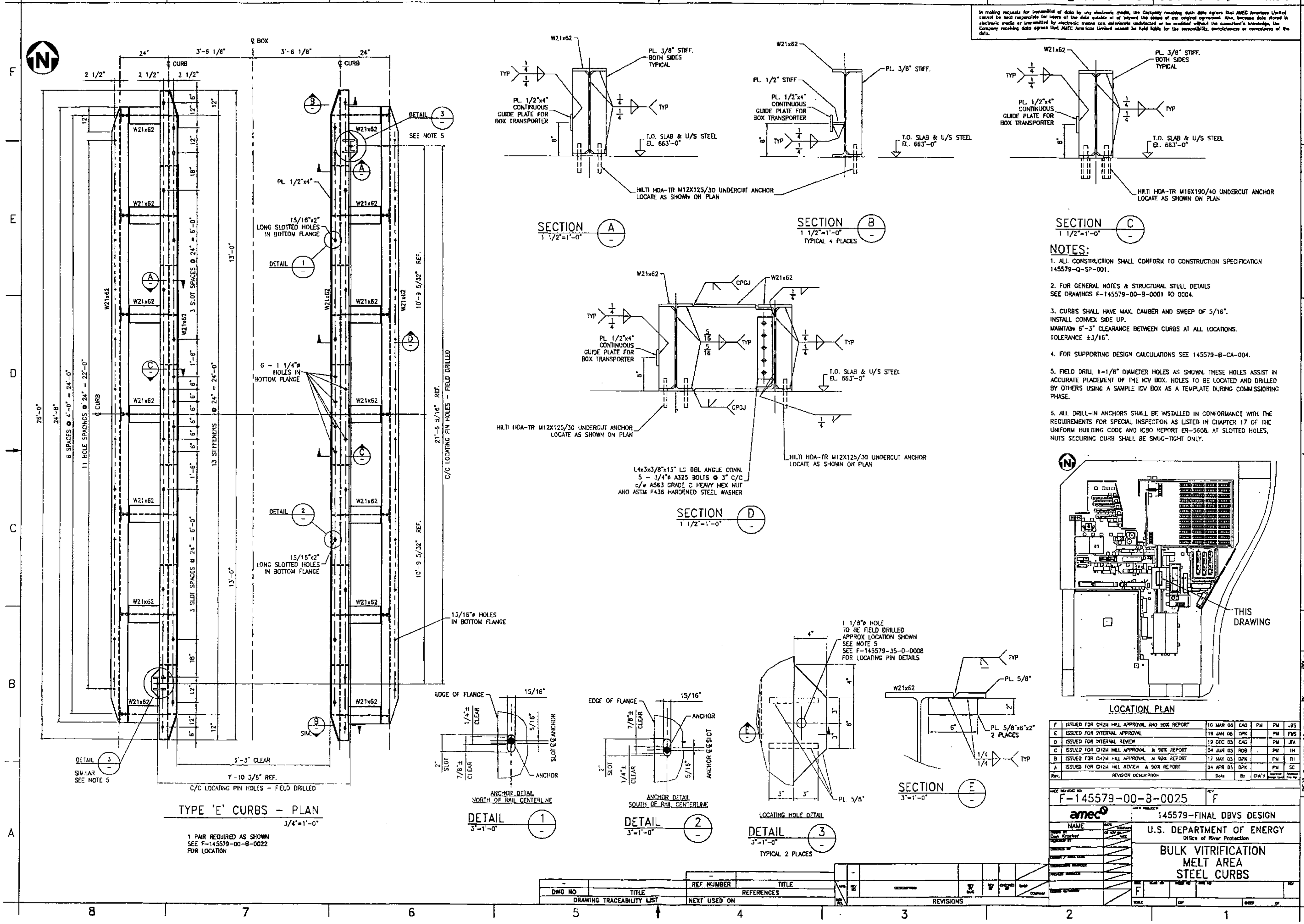
BULK VITRIFICATION
SHIELDING WALLS
GENERAL ARRANGEMENT

SIZE F — SCALE AS NOTED

DWG NO	TITLE
DRAWING TRACEABILITY LIST	

REF NUMBER	TITLE
REFERENCES	
NEXT USED ON	

REVISIONS


TYPE 'E' CURBS - PLAN
3/4"=1'-0"
1 PAIR REQUIRED AS SHOWN
SEE F-145579-00-B-0022
FOR LOCATION
SECTION A
1 1/2"=1'-0"
SECTION B
1 1/2"=1'-0"
TYPICAL 4 PLACES
SECTION C
1 1/2"=1'-0"
SECTION D
1 1/2"=1'-0"
SECTION E
3"=1'-0"
DETAIL 1
3"=1'-0"
DETAIL 2
3"=1'-0"
DETAIL 3
3"=1'-0"
TYPICAL 2 PLACES
ANCHOR DETAIL NORTH OF RAIL CENTERLINE
ANCHOR DETAIL SOUTH OF RAIL CENTERLINE
LOCATING HOLE DETAIL
HILTI HDA-TR M12X125/30 UNDERCUT ANCHOR LOCATE AS SHOWN ON PLAN
HILTI HDA-TR M16X190/40 UNDERCUT ANCHOR LOCATE AS SHOWN ON PLAN
T.O. SLAB & U/S STEEL EL. 663'-0"
NOTES:
1. ALL CONSTRUCTION SHALL CONFORM TO CONSTRUCTION SPECIFICATION 145579-Q-SP-001.
2. FOR GENERAL NOTES & STRUCTURAL STEEL DETAILS SEE DRAWINGS F-145579-00-B-0001 TO 0004.
3. CURBS SHALL HAVE MAX. CAMBER AND SWEEP OF 5/16". INSTALL CONVEX SIDE UP. MAINTAIN 6'-3" CLEARANCE BETWEEN CURBS AT ALL LOCATIONS. TOLERANCE ±3/16".
4. FOR SUPPORTING DESIGN CALCULATIONS SEE 145579-B-CA-004.
5. FIELD DRILL 1-1/8" DIAMETER HOLES AS SHOWN. THESE HOLES ASSIST IN ACCURATE PLACEMENT OF THE ICV BOX. HOLES TO BE LOCATED AND DRILLED BY OTHERS USING A SAMPLE ICV BOX AS A TEMPLATE DURING COMMISSIONING PHASE.
5. ALL DRILL-IN ANCHORS SHALL BE INSTALLED IN CONFORMANCE WITH THE REQUIREMENTS FOR SPECIAL INSPECTION AS LISTED IN CHAPTER 17 OF THE UNIFORM BUILDING CODE AND ICBO REPORT ER-5608. AT SLOTTED HOLES, NUTS SECURING CURB SHALL BE SNUG-TIGHT ONLY.
LOCATION PLAN
THIS DRAWING
F ISSUED FOR CH2M HILL APPROVAL AND 90% REPORT 10 MAR 06 CAG PM PM JDS
E ISSUED FOR INTERNAL APPROVAL 19 JAN 06 DPK PM FWS
D ISSUED FOR INTERNAL REVIEW 19 DEC 05 CAG PM JTA
C ISSUED FOR CH2M HILL APPROVAL & 90% REPORT 04 JUN 05 RDB PM TH
B ISSUED FOR CH2M HILL APPROVAL & 90% REPORT 17 MAY 05 DPK PM TH
A ISSUED FOR CH2M HILL REVIEW & 90% REPORT 04 APR 05 DPK PM SC
F-145579-00-B-0025
F
amec
145579-FINAL DBVS DESIGN
U.S. DEPARTMENT OF ENERGY
Office of River Protection
BULK VITRIFICATION
MELT AREA
STEEL CURBS
Don Kroeker
DRAWING TRACEABILITY LIST
REFERENCES
REVISIONS

DMJM technology

CALCULATION PROCEDURE CHECKLIST

Calculation Number: 145579-D-CA-001 REV. 2

#	ACTION ACCORDING TO PROCEDURE EP 3.3 [a,b]	INITIAL/DATE
1	The calculation number has been obtained from Document Control and the calculation number is logged in the hard copy Calculation Log.	[illegible] 12/23/06
2	The calculation has been prepared using the forms associated with this procedure (i.e., calculation cover sheet, summary sheet, and calculation sheet).	[illegible] 12/23/06
3	The calculation has been formatted per this procedure (header, page number, etc).	[illegible] 12/23/06
4	The appropriate revision number has been assigned.	[illegible] 12/23/06
5	The discipline lead of affected documents has been notified of any changes.	[illegible] 12/20/06
6	All calculation sheets have been signed/initialed and dated.	[illegible] 12/23/06
7	Attachments to the calculation are formatted as required and are included in the calculation package.	[illegible] 12/20/06
8	The calculation package is complete and submitted to the assigned checker.	[illegible] 12/23/06
9	The checker has accepted comment resolution and signed the cover sheet.	[illegible] 12/23/06
10	The Calculation package has been submitted to Document Control (Preliminary) or Discipline Lead (Final).	[illegible] 12/23/06
Final Only		/
11	Design Verifications, where applicable, are complete in accordance with EP3.9.	N/A /
12	The calculations are stamped by a Registered PE (when required).	N/A /
13	The Discipline Lead has approved the calculation and signed the cover sheet.	[illegible] 12/23/06
14	The Discipline Lead has forwarded the calculation package to the Document Control.	[illegible] 12/23/06
Calculation Revisions		
15	The calculation cover page is updated, noting the reason for revision.	[illegible] 12/23/06
16	Calculation sheets are updated in accordance with this procedure.	[illegible] 12/20/06
17	The appropriate revision number has been assigned.	[illegible] 12/23/06
18	The checking and approval (when required) have been completed and cover sheet is signed.	[illegible] 12/23/06

EP 3.3-3F October 03

[a] Each action is to be verified by the Originator.

[b] This checklist applies to preliminary and final calculations

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Subcontractor Calculation Review Checklist.

Page 1 of 1

Subject: **Area 35 – Transient Heat Transfer Calculations of ICV™ Box**

The subject document has been reviewed by the undersigned.
The checker reviewed and verified the following items as applicable.

Documents Reviewed: **145579-D-CA-001, Rev. ~~1c~~ 2** MWL 4/21/06 MLB 4/24/06

Analysis Performed By: **AMEC/DMJM/ARES**

- Design Input
- Basic Assumptions
- Approach/Design Methodology
- Consistency with item or document supported by the calculation
- Conclusion/Results Interpretation
- Impact on existing requirements
- ____________________

Checker (printed name, signature, and date): **M. W. Leonard** M.W. Leonard 3/31/06

Organizational Manager (printed name, signature and date): **D. H. Shuford** David H Shuford 4/5/06

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