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

Section 2 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			

0069628
2/4

CALCULATION SHEET

amec

CALC. NO.: 145579-D-CA-010 REV: 0 DATE: 22-Mar-06

CALC. TITLE: ICV™ Box Weight Calculations

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Superseded by Calculation No.: ☐ Voided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
A	Michael Paul	07-Sept-04	Tom Wilson	07-Sept-04	Tony Heim	09-Sept-04
B	Victor Lourenco	07-Jan-05	Tom Wilson	07-Jan-05	Tony Heim	07-Jan-05
C	Victor Lourenco	21-Jan-05	Tom Wilson	21-Jan-05	Frank Sweet	21-Jan-05
D	Victor Lourenco	02-Mar-05	Tom Wilson	02-Mar-05	Frank Sweet	03-Mar-05
E	Ryan Barrett	12-Sep-05	William Boehnke	12-Sep-05	Ja-Kael Luey	13-Sep-05
F	Ryan Barrett	20-Oct-05	James Van Corbach	20-Oct-05	Ja-Kael Luey	20-Oct-05
0	Jason Engeman	21-Mar-06	James Van Corbach	22-MAR-06	Ja-Kael Luey	22-MAR-06

Jason Engeman JE   JVC   JL

AFFECTED DOCUMENTS

DOCUMENT NUMBER:	TITLE:	REV. NO.:	DISC. LEAD INITIALS
145579-D-CA-011	ICV Box Structural Analysis	2	J.L.
145579-D-CA-028	ICV Box Center of Gravity	0	J.L.

RECORD OF REVISION

REV. NO.	REASON FOR REVISION:
A	For Review
B	Internal Approval
C	CH2M Hill Approval
D	For Inclusion in 90% Report
E	Issued to Address Design Changes to ICV™ Box
F	Incorporated a New Criteria Section (2.2) and Used SolidWorks to Accurately Model the ICV Box
0	Incorporated new lid design changes and configurations per Attachments 11,13 & 14

ATTACHMENTS

DOCUMENT NUMBER/ID:	TITLE:	TOTAL PAGES

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ORIGINATOR:	DATE:	CHECKER:	DATE:
JE	22-Mar-06	JVC	22-MAR-06

CALCULATION SHEET

amec

CALC. NO.: 145579-D-CA-010 **REV:** 0 **DATE:** 22-Mar-06

CALC. TITLE: ICV™ Box Weight Calculations

PROJECT NO.: 145579 **PROJECT TITLE:** Final DBVS Design

DOCUMENT NUMBER/ID:	TITLE:	TOTAL PAGES
Attachment 1	MathCAD Calculations Printout	18
Attachment 2	Not Used	0
Attachment 3	Data Sheets: Resco Products Inc, and Morgan Thermal Ceramics	2
Attachment 4	Facsimile Containing Technical Data on Graphite Electrodes	2
Attachment 5	Vendor Quote Containing Expected Weight of Lifting Device for ICV™[1] Box	3
Attachment 6	Lee Dudley Report on Clean Soil	3
Attachment 7	Datasheet for Unistrut	1
Attachment 8	MathCAD Calculation to Determine Volume of Top-Off Soil	2
Attachment 9	Datasheet SIKA Construction M-Bed Superflow Grout	1
Attachment 10	Excerpts from references 13, 14 & 16	6
Attachment 11	ICV™ Box and Lid Drawings	10
Attachment 12	SolidWorks Model Pictures	11
Attachment 13	Email Garfield, J.S. to Van Corbach, J., "Feed Material Volume."	1
Attachment 14	STCS# 22 12/02/05	3
Attachment 15	SolidWorks 2006 SP0.0 V&V for Computer 9ZTRH31 Cover Sheet	1
	Total Pages	87

[1] ICV™ (In-Container Vitrification™) is a trademark of AMEC Inc.

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CALCULATION SHEET

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CALC. NO.:	145579-D-CA-010	REV:	0	DATE:	22-Mar-06
CALC. TITLE:	ICV™ Box Weight Calculations				
PROJECT NO.:	145579	PROJECT TITLE:	Final DBVS Design		

1 INTRODUCTION

1.1 PURPOSE

The purpose of this calculation is to determine the total weight, including all fill components, of the ICV™ Box and verify the design versus the criteria specified in Section 2.2. The calculation provides a break down of the volume and weight of all insulating layers. This calculation includes the weight of the lid. The result is then verified against the calculation criteria and is used to determine the glass heights of various scenarios based on changes to the amount of glass in the box and to the density of the cooled glass. In particular, the empty steel box and lid weight is used to determine the maximum total weight required to be lifted by the assembly crane located in the ICV™ Box assembly enclosure.

1.2 SCOPE

The scope of this calculation includes weight of all components that support or make up the ICV™ Box, including the insulating layers, the lid, molten glass, top-off soil, and grout.

2 BASIS

2.1 DESIGN INPUTS

1. 145579-A-DC-002, Rev 0F, *Process Design Criteria* (Glass Weight of 42.6 tonne and Density of 2.65 tonne/m^3).
2. F-145579-35-D-0004, Rev. 4, *ICV Box Data Sheet.*
3. F-145579-35-D-0005, Rev. 2, *ICV Box Lid Assembly.*
4. F-145579-35-D-0006, Rev. 2, *ICV Box Lid Steelwork 1 of 3.*
5. F-145579-35-D-0007, Rev. 1, *ICV Box Lid Steelwork 2 of 3.*
6. F-145579-35-D-0008, Rev. 1, *ICV Box Plan & Sections.*
7. F-145579-35-D-0009, Rev. 1, *ICV Box Lid Details Steelwork 3 of 3*
8. F-145579-35-D-0014, Rev. H, *ICV Shell Starter Path Details.*
9. F-145579-35-D-0016, Rev. K, *ICV Box Refractory Assembly.*
10. F-145579-35-D-0017, Rev. K, *ICV Box Refractory Details.*

CALCULATION SHEET

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CALC. NO.:	145579-D-CA-010	**REV:** 0	**DATE:** 22-Mar-06
CALC. TITLE:	ICV™ Box Weight Calculations		
PROJECT NO.:	145579	**PROJECT TITLE:**	Final DBVS Design

11. F-145579-35-D-0024, Rev. A, *ICV Box Port Connections.*

2.2 CRITERIA

1. The weight of each fully processed waste container shall be less than 100 tonne (RPP-17403, Section 3.2.1.7).
2. The ICV™ Box shall have an internal fill volume of at least 90 percent (HNF-EP-0063, Section 3.5.3).

2.3 ASSUMPTIONS

The assumptions used in this calculation are as listed below and within the body of the calculation and attachments.

1. Vendor provided density, specific gravity and bulk density values are accurate.
2. The weight of the starter path can be neglected. During the melt the starter path is consumed and therefore the weight of the processed glass given includes the starter path weight.
3. The weight of the flanges on the lid is negligible. The weight of the 5/16" plate on the lid was conservatively estimated thereby allowing for this assumption.
4. The top-off soil has a conservative angle of repose of 37 degrees.
5. Void space is defined as the empty volume located in the top of the container above the added top-off material.
6. The top-off soil will level to an evenly distributed height prior to grout addition at the Storage Pad.
7. The grout has sufficient fluidity such that it will flow into remaining void space in the box after the addition of top-off soil.
8. Density of the sand used is 88 lb/ft^3.
9. A 6 inch layer of grout will be added to an assumed leveled top-off soil layer.

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CALCULATION SHEET

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CALC. NO.:	145579-D-CA-010	REV:	0	DATE:	22-Mar-06
CALC. TITLE:	ICV™ Box Weight Calculations				
PROJECT NO.:	145579	PROJECT TITLE:	Final DBVS Design		

3 REFERENCES

1. Document: 145579-A-DC-002, Rev 0F, *Process Design Criteria.*
2. F-145579-35-D-0004, Rev. 4, *ICV Box Data Sheet.*
3. F-145579-35-D-0005, Rev. 2, *ICV Box Lid Assembly.*
4. F-145579-35-D-0006, Rev. 2, *ICV Box Lid Steelwork 1 of 3.*
5. F-145579-35-D-0007, Rev. 1, *ICV Box Lid Steelwork 2 of 3.*
6. F-145579-35-D-0008, Rev. 1, *ICV Box Plan & Sections.*
7. F-145579-35-D-0009, Rev. 1, *ICV Box Lid Details Steelwork 3 of 3*
8. F-145579-35-D-0014, Rev. H, *ICV Shell Starter Path Details.*
9. F-145579-35-D-0016, Rev. K, *ICV Box Refractory Assembly.*
10. F-145579-35-D-0017, Rev. K, *ICV Box Refractory Details.*
11. F-145579-35-D-0024, Rev. A, *ICV Box Port Connections.*
12. *Manual of Steel Construction – Allowable Stress Design*, AISC, Ninth Edition.
13. *Pocket Ref*, Thomas J Glover, 1999, Sequoia Publishing, Inc.
14. *The Procedure Handbook of Arc Welding,* The Lincoln Electric Company, Twelfth Edition.
15. 30-Jul-04 facsimile from Charles McClure of Superior Graphite to Fil Szopiak (AMEC) containing technical data on graphite electrodes.
16. RPP-17403, Rev. 3, *DBVS Specification*, CH2M Hill, 2005.
17. HNF-EP-0063, Rev. 10, *Hanford Site Solid Waste Acceptance Criteria.*
18. Product data sheets from Diamondback Technology, Inc, Resco Products Inc, and Morgan Thermal Ceramics.

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CALCULATION SHEET

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CALC. NO.:	145579-D-CA-010	REV:	0	DATE:	22-Mar-06
CALC. TITLE:	ICV™ Box Weight Calculations				
PROJECT NO.:	145579	PROJECT TITLE:	Final DBVS Design		

4 METHODS

Calculations were performed using MathCAD®[2] (V12.1, ©1986-2004, Mathsoft Engineering & Education Inc.) computer software, which were checked and verified using a handheld calculator. Portions of the calculation were also performed using SolidWorks 2006, SP0.0 solid modeling software, which was previously verified and validated (SolidWorks 2006 SP0.0 V&V for Computer 9ZTRH31, see Attachment 15).

However, due to the certainty of the ICV™ Box structural members, the complexity of the ICV™ Box design, and the accuracy required of this revision of the calculation, a model of the ICV™ Box (designed to dimensions provided in the referenced drawings of Section 3 and the component densities provided in Attachment 1) has been created in SolidWorks. This model will be used to determine the weights of all components in the box as well as the glass and top-off soil heights. As applicable, hand calculations were performed to check the weight results of the SolidWorks model for reasonableness (see Attachment 1 and Attachment 8).

5 RESULTS AND CONCLUSIONS

a) ICV™ Box Total Weight:

Based on the SolidWorks model, the total weight of the ICV™ Box with contents at the Melt Station was found to be 96.7 tonne (213126 lbs), which is less than the max limit of 100 tonne established for this project. This weight includes 10.5 inches of evenly distributed top-off soil.

Based on the SolidWorks model, the total weight if the ICV™ Box with contents at the Storage Pad was found to be 100.4 tonne (221406 lbs), which is more than the max limit of 100 tonne established for this project. This weight includes 10.5 inches of evenly distributed top-off soil and 6 inches of evenly distributed grout. With the addition of grout, the box has a void space of less than 8.8%, which is less than the max limit of 10%. Therefore, the filled ICV™ Box at the Storage Pad meets the 90% internal fill volume criteria outlined in Section 2.2, but does not satisfy the maximum weight limit criteria.

[2] MathCAD® is a registered trademark of Mathsoft Engineering & Education Inc.

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CALCULATION SHEET

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CALC. NO.:	145579-D-CA-010	REV:	0	DATE:	22-Mar-06
CALC. TITLE:	ICV™ Box Weight Calculations				
PROJECT NO.:	145579	PROJECT TITLE:	Final DBVS Design		

Note, these weights assume a conservative top-off soil angle of repose of 37 degrees (as is stated in the assumptions). This is conservative when considering top-off soil volume. If a lower angle of repose was used, the top-off soil volume would increase as would the weight of the top-off soil. The total weight of the ICV™ Box would be more for the same 6" of grout addition.

This weight was determined based on the following structural elements and components:

1) Internal Dimensions of the box, LxWxH = 24ftx7.5ftx7.5ft (F-145579-35-D-0004)

2) Components for the box from (F-145579-35-D-0008):

   a) Bottom Plate – ¼"
   b) Side and End Panels – 3/16"
   c) Top Perimeter stiffener – HSS 4"x4"x1/4"
   d) Bottom perimeter Stiffeners – HSS 8"x4"x3/8"
   e) Side and End Panel Stiffeners – HSS – 3.5"x3.5"x1/4"
   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

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CALCULATION SHEET

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CALC. NO.:	145579-D-CA-010	REV: 0	DATE: 22-Mar-06
CALC. TITLE:	ICV™ Box Weight Calculations		
PROJECT NO.:	145579	PROJECT TITLE:	Final DBVS Design

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	5810	lb	5711	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	97577	lb	97509	lb
Top-Off Soil (>10 in)	9458	lb	9458	lb
Melt Station Weight	**213126**	**lb**	**211078**	**lb**

Melt Station Weight	213126	lb
Grout (= 6 in)	8280	lb (calculated)
Storage Pad Weight	**221406**	**lb**

b) Starter Path:

The starter path is absorbed by the molten glass and therefore its weight becomes part of the overall glass weight.

c) Complete Grout Fill:

Based on the SolidWorks model, if, after the addition of top-off soil, the void space in the ICV™ Box were to be filled completely with grout. The total weight would be 106.5 tonne (234882 lb). This is considered a worst case weight. Note that the weight does exceed the weight limit of 100 tonne.

d) Crane Capacity:

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CALCULATION SHEET

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CALC. TITLE:	ICV™ Box Weight Calculations				
PROJECT NO.:	145579	PROJECT TITLE:	Final DBVS Design		

Elements of these calculations were used to determine the capacity of the crane located in the ICV™ Box Assembly Enclosure. The crane capacity is based on lifting an empty ICV™ Box complete with lid. This empty box shell is composed of the following components:

Box (Bolts, Steel, Welds)	19486	lb
Lid	5810	lb
Lifting Bail	2650	lb
Total Weight	**27946**	**lb**

The maximum total weight required to be lifted by the crane is approximately 14.0 ton.

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145579-D-CA-010

Attachment 1

MathCAD Calculations printout

amec	CALCULATION SHEET	Project Number: 145579 Page 1 of 18
Attachment 1 145579-D-CA-010 **Rev. No. 0** **Calculation Title** ICV™ Box Weight Calculations		**Originator:** Jason Engeman JE **Date:** 22-Mar-06 **Checker:** James Van Corbach JVC **Date:** 22-MAR-06

1.0 Calculation and Analysis

This calculation is performed to check the weight results of the SolidWorks Model for reasonableness.

1.1 Constants

Dimension of Box — Dimension from Dwg # F-145579-D-35-0008

$h := 90 \cdot in$ $\quad h = 7.5\,ft$ — Overall Box Height

$w := 90 \cdot in$ $\quad w = 7.5\,ft$ — Overall Box Width

$l := 288 \cdot in$ $\quad l = 24.0\,ft$ — Overall Box Length

Weight per unit area found in Pocket Ref, Thomas Glover, 1999, pp357-358
Weight per foot are all from AISC ASD 9th Edition

$WPA_{0.25PL} := 10.20 \cdot \frac{lb}{ft^2}$ — Plate 1/4in

$WPA_{0.1875PL} := 7.65 \cdot \frac{lb}{ft^2}$ — Plate 3/16in

$WPA_{0.3125PL} := 12.75 \cdot \frac{lb}{ft^2}$ — Plate 5/16in

$WPA_{0.375PL} := 15.3 \cdot \frac{lb}{ft^2}$ — Plate 3/8in

$WPA_{0.5PL} := 20.40 \cdot \frac{lb}{ft^2}$ — Plate 1/2in

$WPF_1 := 7.11 \cdot \frac{lb}{ft}$ — Weight per foot of HSS 3x2x1/4

$WPF_2 := 35.24 \cdot \frac{lb}{ft}$ — Weight per foot of HSS 6x6x1/2

$WPF_3 := 10.51 \cdot \frac{lb}{ft}$ — Weight per foot of HSS 3.5x3.5x1/4

$WPF_4 := 5.59 \cdot \frac{lb}{ft}$ — Weight per foot of HSS 3x2x3/16

$WPF_6 := 27.48 \cdot \frac{lb}{ft}$ — Weight per foot of HSS 8x4x3/8

$WPF_7 := 19.08 \cdot \frac{lb}{ft}$	Weight per foot of HSS 5x5x5/16
$WPF_8 := 12.21 \cdot \frac{lb}{ft}$	Weight per foot of HSS 4x4x1/4
$WPF_9 := 8.81 \cdot \frac{lb}{ft}$	Weight per foot of HSS 4x2x1/4
$WPF_{10} := 8.81 \cdot \frac{lb}{ft}$	Weight per foot of HSS 3x3x1/4

1.2 Weight of Steel in ICV Box

Determine Weight of all Plate Panels

$A_{side} := l \cdot h \qquad A_{end} := h \cdot w$ — Area of Side and End Panels

$A_{side} = 180\,ft^2 \qquad A_{end} = 56.3\,ft^2$

$A_{bottom} := w \cdot l$ — Area of the bottom panel

$A_{bottom} = 180\,ft^2$

$w_{side} := A_{side} \cdot WPA_{0.1875PL}$ — Weight of one Side using 3/16" plate

$w_{side} = 1377\,lb$

$w_{end} := A_{end} \cdot WPA_{0.1875PL}$ — Weight of one end using 3/16" plate

$w_{end} = 430.3\,lb$

$w_{bottom} := A_{bottom} \cdot WPA_{0.25PL}$ — Weight of bottom using 1/4" plate

$w_{bottom} = 1836\,lb$

$w_{plate\_tot} := 2 \cdot w_{side} + 2 \cdot w_{end} + w_{bottom}$ — Weight including 2 sides, 2 ends and bottom

$w_{plate\_tot} = 5451\,lb$ — Total Plate Weight

Determine Weight of all Stiffeners

First the top Perimeter Stiffners - HSS 4"x4"x1/4"

$L_{top\_perim} := [2(l) + 2w]$ — Length of top perimeter stiffener sides and Ends.

$w_{top\_perim} := L_{top\_perim} \cdot WPF_8$

$w_{top\_perim} = 769.2\,lb$ — Weight of top perimeter stiffener

amec	CALCULATION SHEET	Project Number: 145579 Page 3 of 18
Attachment 1 145579-D-CA-010 **Rev. No. 0** **Calculation Title** ICV™ Box Weight Calculations		**Originator:** Jason Engeman JE **Date:** 22-Mar-06 **Checker:** James Van Corbach JVC **Date:** 22-m Ar-06

Now the Bottom Perimeter Stiffeners - HSS 8"x4"x3/8"

$L_{bot\_perim} := 2(l + 8in) + 2(w)$ — Length of bottom perimeter stiffener, sides and ends.

$w_{bot\_perim} := L_{bot\_perim} \cdot WPF_6$

$w_{bot\_perim} = 1767.9\,lb$ — Weight of bottom perimeter stiffener.

$w_{perim\_stiff} := w_{bot\_perim} + w_{top\_perim}$

$w_{perim\_stiff} = 2537.1\,lb$ — Weight of top and bottom perimeter stiffeners.

Now the Side Panel Vertical Stiffeners - 3.5"x3.5"x1/4" @ 12" Centers

$L_{side\_stiff} := h$

$w_{side\_stiff} := 50\left[\left(L_{side\_stiff} - 6in\right) \cdot WPF_3\right]$ — Multiply by 50 for the number of Stiffeners - 25 per side. Minus 6 inches to accomodate for the size of the top (4in) and bottom (2in into the stiffener length) perimeter stiffeners.

$w_{side\_stiff} = 3679\,lb$ — Weight of all side stiffeners

End Panel Stiffeners - HSS 3.5"x3.5"x1/4"

$L_{end\_stiff} := h$

$w_{end\_stiff} := 18\left[\left(L_{end\_stiff} - 6in\right) \cdot WPF_3\right]$ — 18 Stiffeners, 9 for each end at 12" centers with 2 smaller 9" center to center distances on the outside 2 stiffeners. Minus 6 inches to accomodate for the size of the top (4in) and bottom (2in into the end stiffener length) perimeter stiffeners.

$w_{end\_stiff} = 1324\,lb$ — Weight of all end stiffeners

Bottom Plate Stiffeners, Transverse - HSS 6x6x1/2 @ 12" centers

$L_{bot\_trans} := w$ — Length of One Bottom Stiffener Transverse

$L_{bot\_trans} = 90.0\,in$

23 Stiffeners

$w_{bot\_trans} := 23\left(L_{bot\_trans} \cdot WPF_2\right)$ — 23 Beams is the total available 25 minus 2 on each end which are replaced by the perimeter stiffener.

$w_{bot\_trans} = 6078.9\,lb$ — Total Weight of transverse members.

And all the steel weights together

$$w_{steel\_box} := w_{bot\_trans} + w_{end\_stiff} + w_{side\_stiff} + w_{perim\_stiff} + w_{plate\_tot}$$

$$w_{steel\_box} = 19069\,\text{lb}$$

1.3 Weight of Welds and Bolts In Box

$$WPF_{weld} := 0.129 \cdot \frac{\text{lb}}{\text{ft}}$$

Weight per foot for a flat fillet joint weld, 1/4" nominal size. Data from Table 12-2 of The Procedure Handbook of Arc Welding, 12th Ed.

$$L_{w1} := 2 \cdot 50 \cdot h$$

$$L_{w1} = 750\,\text{ft}$$

50 side stiffeners times 2 welds per stiffener

$$L_{w2} := 2 \cdot 25 \cdot L_{bot\_trans}$$

$$L_{w2} = 375\,\text{ft}$$

Length of welds on bottom transverse stiffeners

$$L_{w3} := 2 \cdot (L_{top\_perim} + L_{bot\_perim})$$

$$L_{w3} = 254.7\,\text{ft}$$

Welds for Perimeter stiffeners

$$L_{w4} := 2 \cdot 2 \cdot l$$

$$L_{w4} = 96\,\text{ft}$$

Lengthwise bottom stiffeners

$$L_{w5} := 2 \cdot 4 \cdot h$$

$$L_{w5} = 60\,\text{ft}$$

Length of End Stiffeners

$$L_{weld} := L_{w1} + L_{w2} + L_{w3} + L_{w4} + L_{w5}$$

$$L_{weld} = 1535.7\,\text{ft}$$

Equivalent length of the welds in the box.

$$w_{weld} := WPF_{weld} \cdot L_{weld}$$

$$w_{weld} = 198\,\text{lb}$$

Weight of all welds in the box.

Determine weight of 5/8 dia., 7" long bolts

$$w_{bolt100} := 72.9\,\text{lb}$$

Weight per 100 bolts with nuts from pg 4-144 of AISC ASD 9th Edition

$$w_{bolts} := 0.68 \cdot w_{bolt100}$$

Total number of bolts in box. From F-145579-35-D-0006.

amec	CALCULATION SHEET	Project Number: 145579 Page 5 of 18
Attachment 1 145579-D-CA-010 **Rev. No.** 0 **Calculation Title** ICV™ Box Weight Calculations		**Originator:** Jason Engeman JE **Date:** 22-Mar-06 **Checker:** James Van Corbach JVC **Date:** 22-MAR-06

$w_{bolts} = 49.6\,lb$ — **Total Weight of Bolts**

$w_{box\_steel} := w_{steel\_box} + w_{weld} + w_{bolts}$

$w_{box\_steel} = 19317\,lb$ — **Total Weight of Box**

This total weight is consistent with the SolidWorks Model, which estimates the total weight of the box to be 19486 lb.

1.4 Weight of Insulation Layers in Box

$\rho_{ins} := 17 \cdot \frac{lb}{ft^3}$ $\quad t_i := 1.5 \cdot in \quad h_i := 74.25 \cdot in \quad w_i := 78 \cdot in$ — Density of Insulation Board on ends, See Attachment 3, Kaowool M

$\rho_{ins} = 0.010 \frac{lb}{in^3}$

$\rho_{srb} := 117 \cdot \frac{lb}{ft^3}$ — Density of End Backer Board, See Attachment 3, Rescocast 110

$\rho_{srb} = 0.0677 \frac{lb}{in^3}$

$\rho_{sand} := 88 \cdot \frac{lb}{ft^3}$ $\quad t_s := 4 \cdot in$ — Density of Sand per Assumption 8

$\rho_{sand} = 0.0509 \frac{lb}{in^3}$

$\rho_{ref} := 163 \cdot \frac{lb}{ft^3}$ $\quad t_c := 6 \cdot in$ — Density of Vibrocast Refractory, See Attachment 3

$\rho_{ref} = 0.0943 \frac{lb}{in^3}$

Determine Volume and Weight of Insulation

$vol_{ins} := 2 \cdot t_i \cdot h_i \cdot w_i$

$vol_{ins} = 10.1\ ft^3$

$w_{ins} := vol_{ins} \cdot \rho_{ins}$

$w_{ins} = 171\ lb$ — Weight of Insulation Board

This total weight is consistent with the SolidWorks Model, which estimates the total weight of the insulation board to be 189 lb.

Determine Volume and Weight of Support Ribs and Bricks

Support Ribs

Size and Number of Support Ribs from dwg F-145579-35-D-0016

$w_{sr} := 5 \cdot in$ $\quad h_{sr} := 7.75 \cdot in$

$l_{sr1} := 24 \cdot in$ $\quad l_{sr2} := 21.5 \cdot in$

$n_{sr1} := 36$ $\quad n_{sr2} := 36$

$vol_{sr} := n_{sr1} \cdot (l_{sr1} \cdot w_{sr} \cdot h_{sr}) + n_{sr2} \cdot (l_{sr2} \cdot w_{sr} \cdot h_{sr})$ $\quad vol_{sr} = 36.7\ ft^3$

End and Side Backing Bricks

Size and Number of End and Side Backing Bricks from dwg F-145579-35-D-0016

$t_{ebb} := 4.25 \cdot in$ $\quad l_{ebb} := 4.25 \cdot in$

$h_{ebb} := 16 \cdot in$ $\quad n_{ebb} := 12$

$t_{sbb} := 5.75 \cdot in$ $\quad l_{sbb} := 5.75 \cdot in$

$h_{sbb} := 24 \cdot in$ $\quad n_{sbb} := 36$

$vol_{esbb} := n_{ebb} \cdot (l_{ebb} \cdot t_{ebb} \cdot h_{ebb}) + n_{sbb} \cdot (l_{sbb} \cdot t_{sbb} \cdot h_{sbb})$ $\quad vol_{esbb} = 18.5\ ft^3$

$w_{srb} := \rho_{srb} \cdot (vol_{sr} + vol_{esbb})$

$w_{srb} = 6467\ lb$ — Weight of Support Ribs and Bricks

This total weight is consistent with the SolidWorks Model, which estimates the total weight of the support ribs and bricks to be 6419 lb.

Determine Volume and Weight of Sand

$d_{ref} := 78 \cdot in$ $\quad t_{ss} := 6 \cdot in$ $\quad t_{se} := 4.5 \cdot in$ — Depth of the Inside Steel and Refractory and Thickness of Sand

amec	CALCULATION SHEET	Project Number: 145579 Page 7 of 18
Attachment 1 145579-D-CA-010 **Rev. No. 0** **Calculation Title** ICV™ Box Weight Calculations		**Originator:** Jason Engeman JE **Date:** 22-Mar-06 **Checker:** James Van Corbach JVC **Date:** 22-MAR-06

Volume of Sand in the Bottom

$vol_{bottom} := l \cdot w \cdot h_{sr}$ — Volume of Sand and Support Ribs in the Bottom

$vol_{bottom} = 116.3\,ft^3$

$vol_{sandb} := vol_{bottom} - vol_{sr}$ — Volume of Sand in the Bottom

$vol_{sandb} = 79.5\,ft^3$

Volume of Sand in the Ends

$vol_{end} := 2 \cdot (t_{se} \cdot d_{ref} \cdot h)$

$vol_{sande} := vol_{end} - n_{ebb} \cdot (l_{ebb} \cdot t_{ebb} \cdot h_{ebb})$

$vol_{sande} = 34.6\,ft^3$

Volume of Sand in the Sides

$vol_{side} := 2 \cdot (t_{ss} \cdot l \cdot h)$

$vol_{sands} := vol_{side} - n_{sbb} \cdot (l_{sbb} \cdot t_{sbb} \cdot h_{sbb})$

$vol_{sands} = 163.5\,ft^3$

$w_{sand} := (vol_{sandb} + vol_{sande} + vol_{sands}) \cdot \rho_{sand} \cdot$

$w_{sand} = 24423.7\,lb$ — Weight of Sand

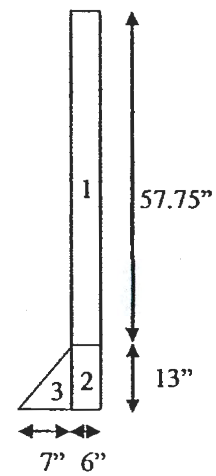
This total weight is consistent with the SolidWorks Model, which estimates the total weight of the sand to be 23095 lb.

Determine Volume and Weight of the Vibrocast Refractory Panels

Dimensions taken from F-145579-35-D-0016 and 0017

Assume the Slope in Area 1 of the Wall is Steep Enough to Consider Flat

Assume an Average Thickness for Area 1 of 6 inches



$t_1 := 6 \cdot in$ $\quad t_2 := 6 \cdot in$ $\quad t_3 := 7 \cdot in$

$h_1 := 57.75 \cdot in$ $\quad h_2 := 13 \cdot in$ $\quad h_3 := 13 \cdot in$

$l_s := 23 \cdot ft$ Length of Sides (from Length of Outside Refractory)

$l_e := 68 \cdot in$ Length of Ends (from Width of Inside Refractory)

$$vol_{ref\_sides} := 2\left[t_1 \cdot h_1 \cdot (l_s + l_e)\right] + 2\left[t_2 \cdot h_2 \cdot (l_s + l_e)\right] + 2\left[0.5 \cdot t_3 \cdot h_3 \cdot (l_s + l_e)\right]$$

$vol_{ref\_sides} = 187.1\ ft^3$ Volume of the Side Walls of the Refractory

Assume the Floor of the Refractory is Rectangular with an Approximate Height of 8 inches

$h_{ref\_floor} := 8 \cdot in$ $\quad l_{ref} := 23 \cdot ft$ $\quad w_{ref} := 78 \cdot in$

$vol_{ref\_floor} := h_{ref\_floor} \cdot w_{ref} \cdot l_{ref}$

$vol_{ref\_floor} = 99.7\ ft^3$

$w_{ref} := (vol_{ref\_sides} + vol_{ref\_floor}) \cdot \rho_{ref}$ Total Weight of the Refractory

$w_{ref} = 46747.8\ lb$

This total weight is consistent with the SolidWorks Model, which estimates the total weight of the refractory to be 49824 lb.

Total Volume and Weight of Insulating Materials

$$Vol_{ins\_tot} := vol_{sr} + vol_{csbb} + vol_{sandb} + vol_{sande} + vol_{sands} + vol_{ref\_sides} + vol_{ref\_floor} + vol_{ins}$$

$Vol_{ins\_tot} = 629.7\ ft^3$ Total Insulating Volume

$Vol_{ins\_tot\_sw} := 453507 \cdot in^3 + 94809 \cdot in^3 + 528190 \cdot in^3 + 9594 \cdot in^3$

$Vol_{ins\_tot\_sw} = 628.5\ ft^3$ Total Insulating Volume from SolidWorks Model

$w_{ins\_tot} := w_{ref} + w_{ins} + w_{srb} + w_{sand}$

$w_{ins\_tot} = 77809.1\ lb$ **Total Insulating Weight**

1.5 Total Weight of Empty Box with Insulation (No Lid)

$w_{empty\_total} := w_{ins\_tot} + w_{box\_steel} + w_{weld}$

$w_{empty\_total} = 97324.2\ lb$

1.6 Weight of Glass and Soil in ICV Box

$SG_{s\_glass} := 2.65 \cdot \frac{tonne}{m^3}$ Density of Solid Glass from Process Design Criteria

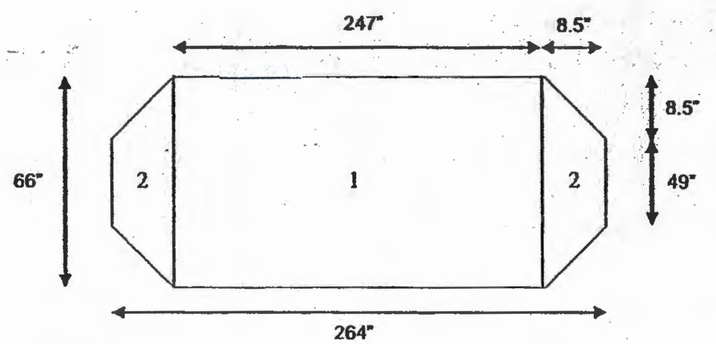
$SG_{s\_glass} = 0.0957 \frac{lb}{in^3}$

$\rho_{soil} := 89 \cdot \frac{lb}{ft^3}$ Bin Bulk Density of Top Off Soil from Report on Clean Soil by Lee Dudley of Diamondback Technology, Inc. Attachment 6

amec	**CALCULATION SHEET**	**Project Number: 145579** **Page 10 of 18**
Attachment 1 145579-D-CA-010 **Rev. No.** 0 **Calculation Title** ICV™ Box Weight Calculations		**Originator:** Jason Engeman JE **Date:** 22-Mar-06 **Checker:** James Van Corbach JVC **Date:** 22-MAR-06

Calculate the Volume of solid glass

Calculate Area as seen from the top of the ICV Box which has a rectangular section and trapezodial areas at the ends. Again, for simplicity, assume the side and end walls of the Refractory are flat.



$Area_1 := 247in \cdot 66in$ — Area of rectangular section with dimensions taken from drawing F-145579-35-D-0016

$Area_2 := 2 \cdot [(8.5 \cdot in \cdot 49 \cdot in) + (8.5 \cdot in \cdot 8.5 \cdot in)]$ — Area of two trapezoidal sections

$Box_{top\_area} := Area_1 + Area_2$

$Box_{top\_area} = 120.0 ft^2$

Electrodes will take up some of the volume in the molten glass therefore calculate surface area taking this into account

$Area_{elec} := 2\pi (6in)^2$ — Area of two 12" diameter electrodes

$Area_{elec} = 1.6 ft^2$

$Glass_{top\_area} := Box_{top\_area} - Area_{elec}$

$Glass_{top\_area} = 118.4 ft^2$

$mass_{glass} := 42.6 tonne$ — Mass of glass from Process Design Criteria

$mass_{glass} = 93917 lb$

$Vol_{glass} := \frac{mass_{glass}}{SG_{s\_glass}}$ $\quad Vol_{glass} = 567.7 ft^3$

amec	CALCULATION SHEET	Project Number: 145579 Page 11 of 18
Attachment 1 145579-D-CA-010 **Rev. No.** 0 **Calculation Title** ICV™ Box Weight Calculations		**Originator:** Jason Engeman JE **Date:** 22-Mar-06 **Checker:** James Van Corbach JVC **Date:** 22-MAR-06

$x := \frac{Vol_{glass}}{Glass_{top\_area}}$ $x = 57.5\,in$ Height of Glass above the base of the refractory

$x_{2.2in\_addition} := 2.2in$ 2.2 inch addition per Email Garfield J.S. to Van Corbach J., "Feed Material Volumes." See Attachment 13

$x_{actual} := x + x_{2.2in\_addition}$

$x_{actual} = 59.7\,in$

$Vol_{glass\_2.2in\_addition} := Glass_{top\_area} \cdot x_{actual}$

$Vol_{glass\_2.2in\_addition} = 589.4\,ft^3$

$mass_{glass\_2.2in\_addition} := SG_{s\_glass} \cdot Vol_{glass\_2.2in\_addition}$

$mass_{glass\_2.2in\_addition} = 97508.7\,lb$ Mass of glass incorporating the addition of 2.2 inches

This glass height is consistent with the SolidWorks Model, which estimates the total glass height above the base of the refractory to be 64.38 in and the total glass height above the box floor to be 78.38 in (= 64.38 in + 14 in).

See Attachment 12 for Sectional Views of the Glass Height.

Volume Remaining in ICV Box for addition of Top Off Soil. This will be performed using data from the SolidWorks model due to the criticality of the Glass Level Height.

$h_{ref\_sw} := 6 \cdot in$ Typical Height of Refractory

$x_{sw} := 64.38 \cdot in$ Height of Glass above Refractory (SolidWorks)

$vol_{box\_top} := Glass_{top\_area} \cdot (h - h_{sr} - h_{ref\_sw} - x_{sw})$ Assume angle of Refractory Wall is negligible

$vol_{box\_top} = 117.1\,ft^3$ Volume left in Box

$h_{top\_off} := h - (h_{sr} + 0.25 \cdot in) - h_{ref\_sw} - x_{sw}$ Height in box remaining for Top Off Soil and Grout

$h_{top\_off} = 11.62\,in$

$area_{lid} := (41in \cdot 16in) + (16in \cdot 12.5in)$ Area of air space in lid taken from dimensions in Section A of drawing F-145579-35-D-0006

$area_{lid} = 5.9\,ft^2$

$vol_{lid} := area_{lid} \cdot 262 \cdot in$

$vol_{lid} = 129.8\,ft^3$ — Volume available in lid

Calculate weight of Top Off Soil using a cone volume

$Vol_{soil} := 107.3ft^3$ — Volume of soil. See Attachment 8

This volume is consistent with the SolidWorks Model, which estimates the total top-off soil volume to be 106.3 ft³.

$Vol_{soil\_sw} := 106.27 \cdot ft^3$ — Volume of Top-Off Soil (SolidWorks)

$$h_{soil} := \frac{Vol_{soil\_sw}}{Glass_{top\_area}}$$

$h_{soil} = 10.8\,in$ — Settled Height of the Top-Off Soil

This height is consistent with the SolidWorks Model, which estimates the total top-off soil height to be 10.5 in.

$h_{soil\_sw} := 10.5 \cdot in$ — Settled Height of the Top-Off Soil (SolidWorks)

$w_{soil} := Vol_{soil\_sw} \cdot \rho_{soil}$

$w_{soil} = 9458\,lb$ — Weight of Top Off Soil

$w_{glass\_soil} := mass_{glass} + w_{soil}$

$w_{glass\_soil} = 103375\,lb$ — **Total Weight of Glass and Soil**

1.7 Weight of Electrodes

Typical Properties of Electrode — Data taken from Electrode Supplier - Superior Graphite - Attachment 4

$$\rho_{elec} := 1.78 \cdot \frac{gm}{cm^3}$$ Density of Electrode

$$\rho_{elec} = 0.0643 \frac{lb}{in^3}$$

$dia_{elec} := 12 \cdot in$ $length_{elec} := 87.5in$ — Dimension of Electrode from F-145579-35-D-0020

$$vol_{elec} := \pi\left(\frac{dia_{elec}}{2}\right)^2 \cdot length_{elec}$$

$vol_{elec} = 5.7\,ft^3$ Volume of one electrode

$w_{elec} := vol_{elec} \cdot \rho_{elec}$ $w_{elec} = 636.4\,lb$ Approximate weight of one electrode.

$w_{2elec} := 2 \cdot w_{elec}$ $w_{2elec} = 1272.8\,lb$ **Total Weight of Two Electrodes**

This total weight is consistent with the SolidWorks Model, which estimates the total weight of the electrodes to be 1268 lb.

1.8 Weight of Lid

Weight of 5/16" Plate in Lid with approximate dimensions from Dwg No. F-145579-35-D-0006.

Area of Lid Flange (Ignore chamfered corners)

$$Area_{lid\_flange} := (296.375in \cdot 98.375in) - (262in \cdot 65.25in)$$

$$Area_{lid\_flange} = 83.8\,ft^2$$

Area of Steel Plate on Hood

Ends

$$Area_{ends} := 2\left[\frac{(41in + 66in) \cdot 16in}{2}\right]$$

$$Area_{ends} = 11.9\,ft^2$$

Sides

$$Area_{sides} := 2(20.3in \cdot 262in)$$

$$Area_{sides} = 73.9\,ft^2$$

Top (Ignore Area lost from ports)

$$Area_{top} := 41in \cdot 262in$$

$$Area_{top} = 74.6\,ft^2$$

$A_{0.3125PL} := Area_{lid\_flange} + Area_{ends} + Area_{sides} + Area_{top}$ Area of 5/16in Plate

$A_{0.3125PL} = 244.1\ ft^2$

$w_{0.3125PL} := A_{0.3125PL} \cdot WPA_{0.3125PL}$ — Weight of 5/16in Plate

$w_{0.3125PL} = 3112.4\ lb$

$L_{HSS4x2} := 12 \cdot 106in$ — Equivalent length of HSS 4x2x1/4 in the lid

$L_{HSS4x2} = 106\ ft$

$w_{HSS4x2} := L_{HSS4x2} \cdot WPF_9$

$w_{HSS4x2} = 933.9\ lb$

$L_{HSS3x3} := 2 \cdot 262in$ — Equivalent length of HSS 3x3x1/4 on the lid

$L_{HSS3x3} = 44\ ft$

$w_{HSS3x3} := L_{HSS3x3} \cdot WPF_{10}$

$w_{HSS3x3} = 384.7\ lb$

$L_{unistrut} := 2 \cdot 262in$ — Equivalent length of 1-5/8" by 1-5/8" unistrut on lid

$WP100FT_{unistrut} := 141\ lb$ — Weight per 100 ft of unistrut. From Attachment 7

$w_{unistrut} := \frac{L_{unistrut} \cdot WP100FT_{unistrut}}{100ft}$ — Weight of Unistrut

$w_{unistrut} = 61.6\ lb$

$Area_{bar} := 2(4in \cdot 262in)$ — Area of 3/8" bar along sides of lid

$w_{bar} := Area_{bar} \cdot WPA_{0.375PL}$

$w_{bar} = 222.7\ lb$

$Area_{gussets} := 30(0.5 \cdot 4in \cdot 4in)$ — Total Area of gussets on lid

$Area_{gussets} = 1.7\ ft^2$

$w_{gussets} := Area_{gussets} \cdot WPA_{0.3125PL}$

$w_{gussets} = 21.3\ lb$

$Area_{Lid.Port.25PL} := 1342in^2$ — Total Area of 1/4" plate used for lid ports

$Area_{Lid.Port.1875} := 1567in^2$ — Total Area of 3/16" plate used for lid ports

amec	CALCULATION SHEET	Project Number: 145579 Page 15 of 18
Attachment 1 145579-D-CA-010 **Rev. No. 0** **Calculation Title** ICV™ Box Weight Calculations		**Originator:** Jason Engeman JE **Date:** 22-Mar-06 **Checker:** James Van Corbach JVC **Date:** 22-MAR-06

$W_{Lid.Port} := \left(Area_{Lid.Port.25PL} \cdot WPA_{0.25PL}\right) + \left(Area_{Lid.Port.1875} \cdot WPA_{0.1875PL}\right)$

$W_{Lid.Port} = 178.3\,lb$

Weight of Lid Chutes

$W_{Exhaust.Chute} := 16.3lb$

$W_{Pour.Chute} := (5 \cdot 54.7lb)$

$W_{Ambient.Air.Chute} := 19lb$

$W_{Chutes} := W_{Exhaust.Chute} + W_{Pour.Chute} + W_{Ambient.Air.Chute}$

$W_{Chutes} = 308.8\,lb$

$Length_{C.Channel} := 33ft$ Total length of C8 x 11.5 C-Channel

$W_{C.Channel} := 11.5\frac{lb}{ft} \cdot Length_{C.Channel}$

$W_{C.Channel} = 379.5\,lb$

$Area_{Port.Lids} := 1521in^2$ Total Area of ICV Port Lids

$W_{Port.Lids} := Area_{Port.Lids} \cdot WPA_{0.25PL}$

$W_{Port.Lids} = 107.7\,lb$

$w_{lid} := w_{HSS4x2} + w_{HSS3x3} + w_{0.3125PL} + w_{bar} + w_{gussets} + w_{unistrut} + W_{Lid.Port} + W_{Chutes} + W_{C.Channel} + W_{Port.Lids}$

$w_{lid} = 5710.8\,lb$ Total Weight of the lid

This total weight is consistent with the SolidWorks Model, which estimates the total weight of the lid to be 5810 lb.

1.9 Total Weight of Box Including Glass, Soil and Lid

Using weights from the SolidWorks model:

$w_{box\_steel} := 19486 \cdot lb$ $w_{lid} := 5810 \cdot lb$

$w_{2elec} := 1268 \cdot lb$ $w_{ins} := 189 \cdot lb$

$w_{srb} := 6419 \cdot lb$ $w_{ref} := 49824 \cdot lb$

$w_{sand} := 23095 \cdot lb$ $w_{glass} := 97577 \cdot lb$

$w_{soil} := 9458 \cdot lb$

$w_{melt\_station} := w_{box\_steel} + w_{lid} + w_{2elec} + w_{ins} + w_{srb} + w_{ref} + w_{sand} + w_{glass} + w_{soil}$

$w_{melt\_station} = 213126\,lb$ Overall weight of Box

$w_{melt\_station} = 96.7\,tonne$ Total Weight in Metric Tonnes

1.10 Assessment of ICV Box at Melt Station

The ICV Box can be transferred to the Storage Pad as the Melt Station Criteria (the ICV Box weight is less than 100 tonne and the top-off soil has a settled height greater than 10 in.) have been met.

1.11 Total Weight of Grout Addition

$h_{grout} := 6 \cdot in$ Height per Assumption 9

$\rho_{grout} := 2240 \cdot \frac{kg}{m^3}$ Wet Density of Grout. See Attachment 9

$vol_{grout} := h_{grout} \cdot Glass_{top\_area}$ $vol_{grout} = 59.2\,ft^3$ Volume of Grout

$w_{grout} := vol_{grout} \cdot \rho_{grout}$

$w_{grout} = 8280\,lb$ Weight of Grout

$w_{storage\_pad} := w_{melt\_station} + w_{grout}$

$w_{storage\_pad} = 221406\,lb$ Total Box Weight with Grout

$w_{storage\_pad} = 100.4\,tonne$

1.12 Assessment of ICV Box at Storage Pad

After the addition of 6 in of grout to meet the shielding criterion, the ICV Box exceeds the weight criterion of being less than 100 tonne.

Void Space Criterion Check:

$h_{total} := h_{sr} + h_{ref\_sw} + x_{sw} + h_{soil\_sw} + h_{grout}$

$h_{total} = 94.6\,in$

This height exceeds the interior height of the box portion of the ICV Box, which has a height of 90 in. This means part of the lid volume will be filled with grout. Conservatively, if the lid volume is less than

10% of the total interior box volume, then the Void Space Criterion is met.

$vol_{lid} = 129.8\,ft^3$

Total Volume of the ICV Box and Lid:

$Vol_{ICV\_int} := h \cdot w \cdot l + vol_{lid}$ — Internal Volume of the Box + Internal Volume of the Lid

$Vol_{ICV\_int} = 1479.8\,ft^3$

$Percent_{void} := \frac{vol_{lid}}{Vol_{ICV\_int}} \cdot 100$

$Percent_{void} = 8.8$

The ICV Box Meets all of the Design Criteria Outlined in Section 2.2 of 145579-D-CA-010.

1.13 Grout Fill

If grout was added to completely fill the ICV box instead of just 6 in:

$Vol_{grout\_fill} := Vol_{ICV\_int} - \left(Vol_{ins\_tot\_sw} + Vol_{glass\_2.2in\_addition} + Vol_{soil\_sw}\right)$

$Vol_{grout\_fill} = 155.6\,ft^3$ — Void Volume for Grout Fill

$w_{grout\_fill} := Vol_{grout\_fill} \cdot \rho_{grout}$

$w_{grout\_fill} = 21755.5\,lb$ — Weight of Grout Fill

$w_{grout\_fill} = 9.9\,tonne$

$w_{total} := w_{melt\_station} + w_{grout\_fill}$

$w_{total} = 234881.5\,lb$ — Total Box Weight with Complete Grout Fill

$w_{total} = 106.5\,tonne$

1.14 Weight of empty steel box, lid and lifting bail to determine capacity of assembly crane

Weight of box and lid

$w_{box} := 19486 \cdot lb$

$w_{lid} := 5810 \cdot lb$

Weights based on SolidWorks Model (See Section 5, Weights Break-down, in 145579-D-CA-010)

$w_{total} := w_{box} + w_{lid}$

$w_{total} = 25296.0\,lb$ $\quad w_{total} = 12.6\,ton$

amec	CALCULATION SHEET	Project Number: 145579 Page 18 of 18
Attachment 1 145579-D-CA-010 Rev. No. 0 Calculation Title ICV™ Box Weight Calculations		Originator: Jason Engeman JE Date: 22-Mar-06 Checker: James Van Corbach JVZ Date: 22-MAR-06

Expected Weight of lifting device based on information obtained from Vendor

$w_{bail} := 2650lb$ See Attachment 5

Total weight to be lifted by assembly crane

$w_{lift\_tot} := w_{total} + w_{bail}$

$w_{lift\_tot} = 27946\,lb$ $w_{lift\_tot} = 14.0\,ton$

The maximum total weight required to be lifted by the crane is approximately 14.0 ton.

145579-D-CA-010

Attachment 3

**Data Sheets: Resco Products Inc.,
and
Morgan Thermal Ceramics**

May. 1. 2003 12:32PM STEVE No. 1393 P. 6/11

RESCO PRODUCTS INC.

Vibratables

Product Data

VIBROCAST 60PC

VIBROCAST 60PC is a sixty percent alumina, mullite based, pumpable, 3100°F, 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 8.0 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

Data shown are average results of standard ASTM tests unless otherwise noted. Results may vary subject to normal variations in manufacturing, testing and installation procedures in the field.

[illegible]

Attachment: 3
Calc. No.: 145579-D-CA-010
Rev. No.: 0
Sheet 1 of 2

Kaowool Lo Temperature Boards

Product Information

sical Properties	Kaowool PM	Kaowool M	Kaowool S	Kaowool HD	Kaowool HS	Kaowool HS-45
Color	white	beige	brown	beige	beige	white
Nominal density, pcf *(kg/m³)*	15 *(240)*	17 *(272)*	20 *(320)*	26 *(416)*	28 *(448)*	42 *(673)*
Maximum temperature rating, °F *(°C)*	2300 *(1260)*	2300 *(1260)*	2300 *(1260)*	2400 *(1316)*	2300 *(1260)*	2400 *(1316)*
Continuous use limit, °F *(°C)*	2100 *(1149)*	2000 *(1093)*	2000 *(1093)*	2300 *(1260)*	2200 *(1204)*	2400 *(1316)*
Melting point, °F *(°C)*	3200 *(1760)*	3200 *(1760)*	3200 *(1760)*	3200 *(1760)*	3200 *(1760)*	2800 *(1538)*
Modulus of rupture, psi *(Mpa)*	175 - 250 *(1.20 - 1.72)*	100 - 130 *(0.68 - 0.89)*	150 - 180 *(1.03 - 1.24)*	150 - 175 *(1.03 - 1.20)*	230 - 260 *(1.58 - 1.79)*	450 - 550 *(3.10 - 3.79)*
Compressive strength, psi *(Mpa)*						
@ 5% deformation	15-25 *(0.10 - 0.17)*	20 - 30 *(0.13 - 0.20)*	30 - 50 *(0.20 - 0.34)*	50 - 70 *(0.34 - 0.48)*	60 - 80 *(0.41 - 0.55)*	200 - 250 *(1.37 - 1.72)*
@ 10% deformation	25 - 40 *(0.17 - 0.27)*	30 - 40 *(0.20 - 0.27)*	50 - 60 *(0.34 - 0.41)*	70 - 90 *(0.48 - 0.62)*	80 - 100 *(0.55 - 0.68)*	250 - 300 *(1.72 - 2.06)*
Linear shrinkage, %, 24 hours						
@ 1500°F *(816°C)*	0.2	1.2	1.0	0.1	0.8	0.5
@ 1800°F *(982°C)*	1.9	2.2	2.0	1.4	1.9	0.7
@ 2000°F *(1093°C)*	2.4	2.8	2.3	2.5	2.1	0.4
@ 2200°F *(1204°C)*	3.4	—	—	2.8	0.2	0.5
@ 2400°F *(1316°C)*	—	—	—	—	+0.3	+0.8
Chemical Analysis						
Alumina, Al_2O_3	44	42	46	41	18	55
Silica, SiO_2	56	56	53	53	81	35
Calcium Oxide, CaO	—	—	—	6	—	8
Other	<1	2	—	—	—	2
Loss of ignition	4-7	4-7	5-8	5-8	5-8	5-8
Organic Material	3-6	3-6	4-7	4-7	4-7	4-7
Thermal Conductivity BTU•in/hr•ft²•°F *(w/m•k)*						
Mean temperature						
@ 500°F *(260°C)*	0.40 *(0.05)*	0.47 *(0.06)*	0.59 *(0.08)*	0.57 *(0.08)*	0.68 *(0.10)*	1.02 *(0.15)*
@ 1000°F *(538°C)*	0.59 *(0.08)*	0.71 *(0.10)*	0.80 *(0.11)*	0.80 *(0.11)*	0.84 *(0.12)*	0.96 *(0.14)*
@ 1500°F *(816°C)*	0.87 *(0.12)*	1.04 *(0.15)*	1.12 *(0.16)*	1.13 *(0.16)*	1.12 *(0.16)*	1.16 *(0.17)*
@ 2000°F *(1093°C)*	1.27 *(0.18)*	1.52 *(0.22)*	1.58 *(0.23)*	1.60 *(0.23)*	1.58 *(0.23)*	1.72 *(0.24)*

Chemical Properties

Caution should be exercised during initial heating. Adequate ventilation should be provided to avoid potential flash ignition of binder out-gassing or avoid air entry while at elevated temperature.

The are average results of tests conducted under standard procedures and are subject to variation. Data contained in this brochure are furnished as a guide only. For specifications and estimating purpose, contact your nearest Thermal Ceramics representative.

Thermal Ceramics Marketing Offices North America Sales Offices United States Eastern Region T: (877) 787 5505 F: (330) 865 2008 United States Western Region South America Sales Offices Argentina Brazil Mexico Chile

Website: www.thermalceramics.com

Attachment: 3
Calc. No.: 145579-D-CA-010
Rev. No.: 0
Sheet 2 of 2

145579-D-CA-010

Attachment 4

Fax Containing Technical Data on Graphite Electrodes

// 09 04 11:35a SUPERIOR GRAPHITE 501 968 8816 p.1

SUPERIOR GRAPHITE

From the office of:
Superior Graphite
3225 Dow Drive
Russellville, AR 72802
Phone: 479-968-8810
Fax: (479)968-8816

Fax

To:	Fil Szapka	From:	C. McClure
Fax:	1-250 368-2480	Pages:	2
Phone:	AMEC	Date:	12/9/04
Re:	Info. Request	CC:	B. Bowden - Cust. Service

☐ Urgent ☑ For Review ☐ Please Comment ☐ Please Reply ☐ Please Recycle

• Comments:

Here is the Typical Properties you requested on our 12 X 72 UHP electrodes + Pins.

Thank you for Selecting our Product - [signature]

If you do not receive all of the pages, please call my office at 479-968-8810, ext 13

Attachment:	4
Calc. No.:	145579- 0-CA-010
Rev. No.:	0
Sheet	1 of 2

ISO 9001 CERTIFIED

QUALITY MANAGEMENT SYSTEMS

12/09/04 THU 08:29 [TX/RX NO 8053]

Dec 09 04 11:35a SUPERIOR GRAPHITE 501 968 8816 p.2

SUPERIOR GRAPHITE

December 9, 2004
Attention: Fil Scopika -AMEC
Fax# (250) 368-2480

12 X 72" UHP Electrode / 7N60 Pin

"Typical Properties"

Typical Property	Electrode	Pin
Diameter / .001"-	11.880"-12"-12.070"	6.965"-6.975"-6.995
Length / .001" –	66.5"-72"-75.4"	10.531"-10.618"-10.656"
Socket & Pin- Size / .001"-	-.005" to +.015"	.990" to 1.020"
Socket & Pin-Taper / .001"-	0 to +2	+0.5 to -3
Density g/cc-	1.70 – 1.78	1.74 – 1.84
Electrical Resistance- micro/ohm/in"x10-5	20.0 – 29.0	19.0 – 25.0
Flex Strength–PSI- 4 point loading-	2000 –3000	3000-4000
CTE (L) 400C	.9	1.5
CTE (T) 400C	1.1	2.9

Here is the information you requested. If you have any questions or need further assistance, please contact me at (479) 968-8810 ext.13

Sincerely,

Charles W. McClure

Charles W. McClure
Quality/ Technical Manager

Mci
Attachment: NA

Attachment: 4
Calc. No.: 145579- 0 - CA - 010
Rev. No.: 0
Sheet 2 of 2

Superior Graphite Co. o 3225 Dow Drive o Russellville, AR 72802 o USA
Phone + 1 4799688810 o fax + 1 4799688816 o www.superiorgraphite.com

12/09/04 THU 08:29 [TX/RX NO 8053]

145579-D-CA-010

Attachment 5

Vendor Quote Containing Expected Weight of Lifting Device for ICV Box

Page: 1

Attachment: 5
Calc. No.: 145579-D-CA-010
Rev. No.: 0
Sheet 1 of 3

Mailing address:
P.O. Box 309
Butler, WI 53007-0309
Shipping address:
W133 N4960 Campbell Dr.
Menomonee Falls, WI 53051
Phone (262) 790-4200
FAX (262) 790-4202
http://www.bushman.com
engineer@bushman.com, custinfo@bushman.com

QUOTE NUMBER

QT0410950

Date: 12/8/2004

AMEC Americas Limited
B.C. Canada

Phone: 250-368-2464
Fax: 250-368-2455

SHIP VIA	F.O.B.	QUOTE TERMS
BEST WAY	MEN. FALLS	Net 30

TERMS OF PAYMENT ARE SUBJECT TO CREDIT APPROVAL AT TIME OF ORDER!

Contact: **Victor Lourenco**

ITEM	DESCRIPTION	QUANTITY	NET PRICE EA.	NET EXT. PRICE
MODEL 439	SPREADER BEAM Bushman Model #439-4 Spreader Beam	1.00	$6,425.00	$6,425.00

Capacity: 25,000 lbs.

Bail Type: Center lift. Flame cut plate welded in place with opening to fit customer's hook.

Beam includes four swivel hooks with safety latches on 13' x 100" centers.

Paint: One coat safety orange enamel.

Approximate shipping weight: 2,100 lbs.

Drawing approval required prior to fabrication.

All Bushman Equipment lifting devices meet or exceed the ANSI Standard B30.20.

Delivery approx. 8 weeks after receipt of signed approval drawing.

Option to add add two 68" cross beams on 10'-6" centers. Add $2,450.00 Includes four additional swivel hooks. Adds approx. 550 lbs.

Warranty: Twelve (12) months from date of shipment, covering defects in material and workmanship and does not include field labor.

The following items or services are not included in our above price:
" Sales or use taxes, import duties or customs fees.
" Export packaging.
" Freight to jobsite.

Page: 2

Mailing address:
P.O. Box 309
Butler, WI 53007-0309
Shipping address:
W133 N4960 Campbell Dr.
Menomonee Falls, WI 53051
Phone (262) 790-4200
FAX (262) 790-4202
http://www.bushman.com
engineer@bushman.com, custinfo@bushman.com

QUOTE NUMBER

QT0410950

Date:
12/8/2004

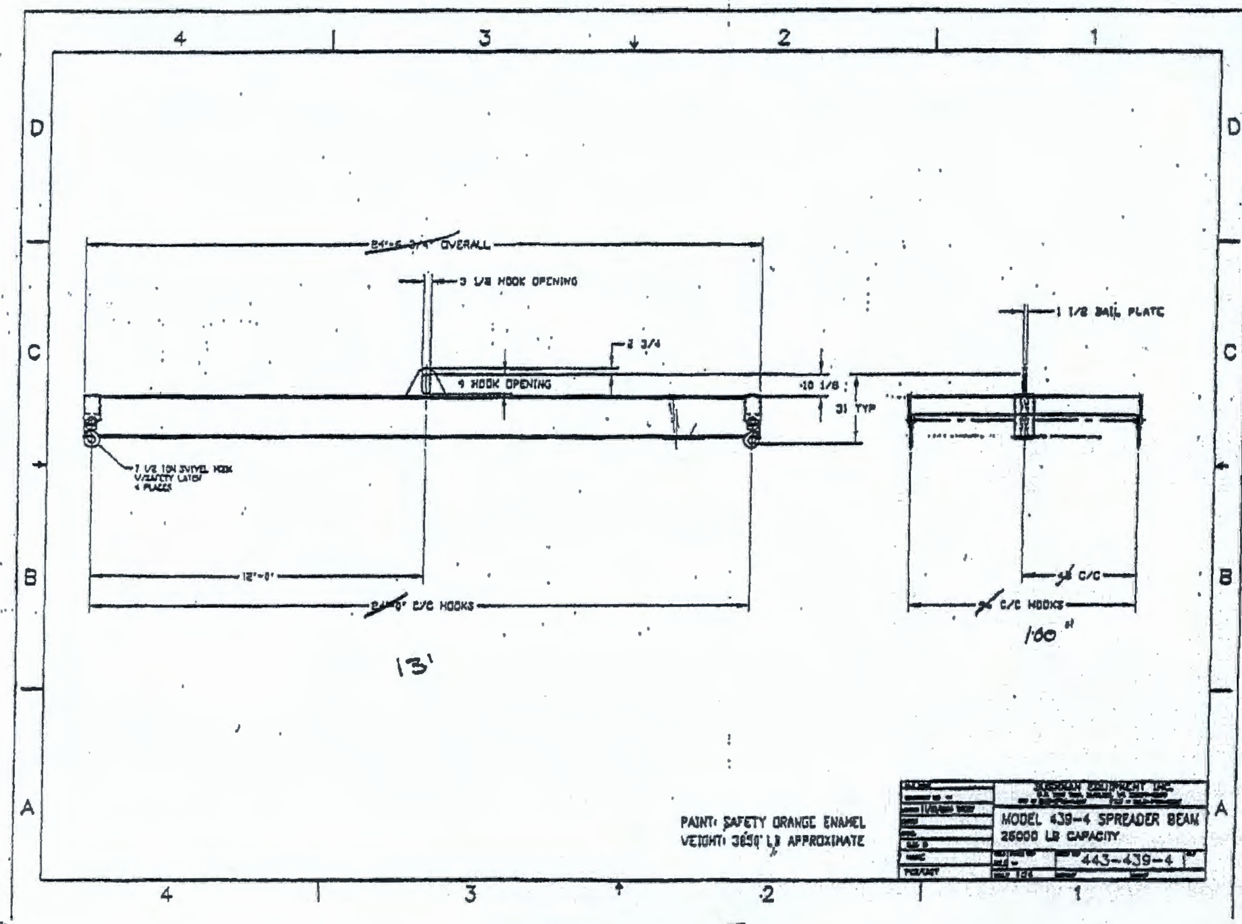
Attachment: 5
Calc. No.: 145579-D-CA-010
Rev. No.: 0
Sheet 2 of 3

(CONT.)

* Factory load testing- full or partial

Best regards,

Kevin Kaiser, Sales.



Attachment: 5
Calc. No.: 145579-0-CA-010
Rev. No.: 0
Sheet 3 of 3

145579-D-CA-010

Attachment 6

Lee Dudley Report on Clean Soil

DIAMONDBACK TECHNOLOGY, INC.

Report to AMEC Americas, Ltd.
Flow Properties of Clean HRTS Soil

Prepared by
Lee Dudley

April 8, 2004

Attachment:	6
Calc. No.:	145579-0-CA-010
Rev. No.:	0
Sheet	1 of 3

We provide the world with solutions to bulk solids handling problems that occur in hoppers, bins and processing units
712 Flero Lane Ste. 37 ♦ San Luis Obispo, CA 93401 ♦ 805-544-3775 ♦ Fax 805-549-8282

DIAMONDBACK TECHNOLOGY, INC.

April 12, 2004
AME\1\LVD040804.RT1

Frank Sweet
AMEC Americas Ltd
1385 Cedar Ave.
Trail, BC, Canada V1R 4C3

Dear Mr. Sweet:

Enclosed please find our report containing the test results of your Clean HRTS Soil and our Diamondback Technology recommendations. If you have any further questions, please feel free to contact me.

We look forward to working with you.

Sincerely,

Lee Dudley /mf

Lee Dudley
Consultant

LVD/mjf

Attachment: 6
Calc. No.: 145579- 0-CA-010
Rev. No.: 0
Sheet 2 of 3

We provide the world with solutions to bulk solids handling problems that occur in hoppers, bins and processing units

712 Fiero Lane Ste. 37 ◆ San Luis Obispo, CA 93401 ◆ 805-544-3775 ◆ Fax 805-549-8282

Report to AMEC Americas, Ltd.
Flow Properties of Clean HRTS Soil
Prepared By Lee Dudley

1.0 Background

AMEC is planning a new system for processing Clean Soil in a DOE project at the Hanford Works in Washington. The process will require reliable flow through a process surge bin into and out of a dryer/mixer. The Clean soil will be stored up to 7 days in a 4.9 mt vessel. It will be filled from a pneumatic conveying system at a rate of 300 kg/hr and discharging at 433 kg/hr.

This report contains the results of material flow properties testing on the Clean Soil including angle-of-repose testing and providing standard Diamondback Technology recommendations

2.0 Executive Summary

The material flow properties test results are summarized in Table 1. Detailed charts and graphs are attached.

The data is also interpreted as Johanson Indices. These are simplified design point values based on the material flow property data of Table 1, the physical constraints of the system, and Dr. JR Johanson's experience and design methodologies. The Johanson Indices are summarized in Table 2 and defined in Figure 1.

Table 1. Summarized Material Flow Properties

	Units	Clean HRTS Soil
Moisture	%	10.22
Bulk Density		
Feed	kg/m^3	1002.8
Bin	kg/m^3	1430.5 (or 89 lb/ft³)
Friction Angles		
Angle of Repose*	Degree	30
Internal Angle of Friction	Degree	27
Effective Angle of Internal Friction	Degree	34
Coefficients		
Wall Friction on 304-2B Stainless Steel		
Static	N/A	0.52
Kinematic	N/A	0.49
Lateral Pressure	N/A	0.58
Wall Friction on 304-1 Stainless Steel		
Static	N/A	0.54

Attachment: 6
Calc. No.: 145579-D-CA-010
Rev. No.: 0
Sheet 3 of 3

145579-D-CA-010

Attachment 7

Datasheet for Unistrut

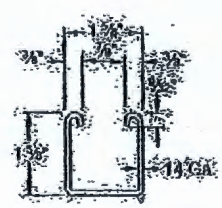
Power Engineering Powerstruts Unistruts Safety Gratings

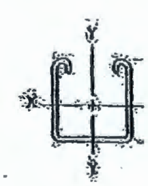
POWERSTRUT

Expert Search: If you know the product part# you are looking for, please enter it below and click "Search"	
Part#:	

PS210	PS210H	PS210EH	PS210S	PS210K06	PS210 Beam & Column Loads	PS210 2T3

PS 210 - Steel Channel (1⅝" x 1⅝" x 14 ga.)





ELEMENTS OF SECTION

Weight (lbs./100 ft.)	Area of Section (Inch²)	X-X Axis			Y-Y Axis		
		Moment of Inertia (Inch⁴)	Section Modulus (Inch³)	Radius of Gyration (Inch)	Moment of Inertia (Inch⁴)	Section Modulus (Inch³)	Radi Gyr (In
141	.417	.140	.166	.597	.183	.225	.6

Modulus of Elasticity: 29,000,000 PSI

Attachment: 7
Calc. No.: 14557 9-0-CA-010
Rev. No.: 0
Sheet 1 of 1

http://www.powerstrut.com/channels210.html

145579-D-CA-010

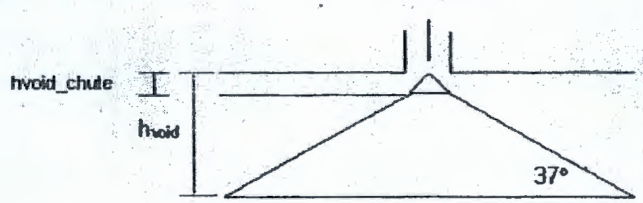
Attachment 8

MathCAD Calculation to Determine Volume of Top-Off Soil

amec	CALCULATION SHEET	Project Number: 145579 Page 1 of 2
Attachment 8 145579-D-CA-010 Rev. No. 0 Calculation Title ICV™ Box Weight Calculations		Originator: Jason Engeman JE Date: 21-Mar-06 Checker: James Van Corbach JVC Date: 22-MAR-06

1.0 Calculation and Analysis

1.1 Approximate Shape of Top-Off Soil Frustum



The top-off soil cone will form a truncated cone with its top approximately equal in diameter to the lid's port.

The top-off soil chute has a diameter of 7.7" (F-145579-35-D-0003)

$r_{chute} := 3.85 \cdot in$

1.2 Height of Void Space

$h_{box} := 90 \cdot in$	Interior Box Height	from Attachment 1
$h_{gasket} := 0.5 \cdot in$	Height of Gasket	F-145579-35-D-0004
$h_{lid} := 16 \cdot in$	Interior Lid Height	F-145579-35-D-0006
$h_{sr\_sand} := 8 \cdot in$	Support Rib and Sand Height	F-145579-35-D-0016
$h_{ref\_floor} := 6 \cdot in$	Refractory Height	F-145579-35-D-0017
$h_{glass} := 64.38 \cdot in$	Glass Height	
$h_{chute\_slot} := 2.31 in$	Chute Slot	F-145579-35-D-0007

$$h_{void} := (h_{box} + h_{lid} + h_{gasket}) - (h_{sr\_sand} + h_{ref\_floor} + h_{glass} + h_{chute\_slot})$$

$h_{void} = 25.8 in$ Void Space Height

amec	CALCULATION SHEET	Project Number: 145579 Page 2 of 2
Attachment 8 145579-D-CA-010 Rev. No. 0 Calculation Title ICV™ Box Weight Calculations		Originator: Jason Engeman JE Date: 21-Mar-06 Checker: James Van Corbach JVC Date: 22-MAR-06

1.3 Base Diameter of Top-Off Soil

Based on the sketch in Section 1.1

$$\frac{h_{void}}{r_{to\_cone}} = \tan(37 \cdot deg)$$

Trigonometric Relationship of a Right Triangle

$$\frac{h_{void\_chute}}{r_{chute}} = \tan(37deg)$$

$$h_{void\_chute} := r_{chute} \cdot \tan(37deg)$$

$$h_{void\_chute} = 2.9\,in$$

$$r_{to\_cone} := \frac{h_{void}}{\tan(37 \cdot deg)} + r_{chute} \qquad r_{to\_cone} = 38.1\,in$$

Base Diameter of Top-Off Soil

1.4 Volume of One Top-Off Soil

$$Vol_{one\_soil} := \pi \frac{r_{to\_cone}^{2} \cdot \left(h_{void} + h_{void\_chute}\right)}{3}$$

$$Vol_{one\_soil} = 25.3\,ft^3$$

1.5 Volume of Five Top-Off Soil

$$Vol_{one\_soil} = 25.3\,ft^3$$

$$V_{total} := Vol_{one\_soil} \cdot 5$$

$$V_{total} = 126.3\,ft^3$$

$$Vol_{reduction} := .85$$

Assume a 15% decrease in total volume due to the shared volume between each cone as seen in Attachment 12

$$Vol_{soil\_reduction} := V_{total} \cdot Vol_{reduction}$$

$$Vol_{soil\_reduction} = 107.3\,ft^3$$

145579-D-CA-010

<u>Attachment 9</u>

Datasheet SIKA Construction M-Bed Superflow Grout

M-Bed Superflow

STERNSON

High Flow, Premixed Cementitious Grout

CONSTRUCTION

TECHNICAL DATA SHEET

B-125

DESCRIPTION:

M-Bed Superflow is a premixed, non-metallic, shrinkage compensating grout composed of specialized cements, flow agents, and graded siliceous sand. It meets the requirements of ASTM 1107 grade classifications A, B and C. M-Bed Superflow requires the addition of water only for use at consistencies ranging from plastic to fluid.

WHERE TO USE:

M-Bed Superflow is a high performance, shrinkage compensating grout that can be used for the installation of anchor bolts, heavy machinery base plates, column sole plates, and all areas requiring a precision grout.

ADVANTAGES:

- Volume Stability – M-Bed Superflow contains special cements that produce a regulated expansion during their hydration. The rate and time of expansion has been designed to offset shrinkage due to settlement in the plastic state and drying in the hardened state.
- Low Expansion Ratio – M-Bed Superflow produces an overall expansion not exceeding 0.4%, eliminating the need for total restraint to achieve design strengths.
- Range of Placing Consistencies – Highly efficient flowability agents enable M-Bed Superflow to be placed at consistencies ranging from plastic to fluid wi[illegible] gation while still maint[illegible] water/cement ratios.

TECHNICAL DATA

Packaging:	25 kg multi-walled, moisture proof bags.
Shelf Life:	12 months in original, unopened packaging when stored dry at 4°C–25°C. Condition material to 18°C–29°C before using.
Colour:	Concrete gray.
Mixing Ratio:	5 litres of water per bag maximum.

PROPERTIES (23°C and 50% R.H.)

	Plastic (Water:Solids 0.15)	Flowable (Water:Solids 0.17)	Fluid (Water:Solids 0.20)
Water per 25 kg bag:	3.75 litres	4.25 litres	5.00 litres
Yield per 25 kg bag:	12.3 litres	12.8 litres	13.3 litres
Wet Density:	2,090 kg/m³	2,050 kg/m³	2,240 kg/m³
Work Life at Various Temperatures:			
10°C	1.25 hrs	1.50 hrs	1.60 hrs
22°C	1.00 hr	1.00 hr	1.00 hr
Initial Setting Times at Various Temperatures:			
10°C	7.50 hrs	7.50 hrs	8.00 hrs
22°C	4.50 hrs	6.50 hrs	7.00 hr
Final Setting Times at Various Temperatures (max.):			
10°C	8.50 hrs	9.00 hrs	9.50 hrs
22°C	5.00 hrs	7.00 hrs	7.50 hrs
Compressive Strength (ASTM C 109-77):			
1 day	40 MPa	30 MPa	15 MPa
7 days	55 MPa	50 MPa	32 MPa
28 days	70 MPa	60 MPa	45 MPa

Attachment: 9
Calc. No.: 145579-0-CA-010
Rev. No.: 0
Sheet 1 of 1

CONSULT SIKA TECHNICAL SERVICE FOR ANY VARIATION IN PRODUCT USAGE, APPLICATION OR CURING METHODS. MADE IN CANADA.

145579-D-CA-010

Attachment 10

Excerpts from references 12, 13, & 14

Ref 12

…s

…perties**	r	J	Z
	in.	in.⁴	in.³
	6.23	2320	214
	6.29	1890	175
	6.35	1450	134
.6	6.38	1220	113
	5.42	1630	161
	5.48	1250	132
7.9	5.54	963	102
1.6	5.57	812	86.1
6.7	4.60	943	116
8.9	4.66	777	95.4
3.4	4.72	599	73.9
4.0	4.75	506	62.6
4.1	4.78	410	50.8
33.8	4.81	312	38.7
64.2	3.78	529	77.6
59.4	3.81	485	71.3
54.2	3.84	439	64.6
42.9	3.90	341	50.4
36.7	3.93	289	42.8
30.1	3.96	235	34.9
23.2	3.99	179	26.6
50.4	3.37	377	61.5
46.8	3.40	347	56.6
42.9	3.43	315	51.4
34.1	3.49	246	40.3
29.3	3.53	209	34.3
24.1	3.56	170	28.0
18.6	3.59	130	21.4

…radius equal to two times the wall

…nstruction

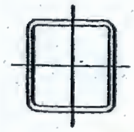
STRUCTURAL TUBING
Square
Dimensions and properties

Dimensions				Properties**					
Nominal* Size	Wall Thickness		Weight per Ft	Area	I	S	r	J	Z
In.	In.		Lb.	In.²	In.⁴	In.³	In.	In.⁴	In.³
8×8	0.6250	5/8	59.32	17.4	153	38.3	2.96	258	47.2
	0.5625	9/16	54.17	15.9	143	35.7	3.00	238	43.6
	0.5000	1/2	48.85	14.4	131	32.9	3.03	217	39.7
	0.3750	3/8	37.69	11.1	106	28.4	3.09	170	31.3
	0.3125	5/16	31.84	9.36	90.9	22.7	3.12	145	26.7
	0.2500	1/4	25.82	7.59	75.1	18.8	3.15	118	21.9
	0.1875	3/16	19.63	5.77	58.2	14.6	3.18	90.6	16.8
7×7	0.5625	9/16	46.51	13.7	91.4	26.1	2.59	154	32.3
	0.5000	1/2	42.05	12.4	84.6	24.2	2.62	141	29.6
	0.3750	3/8	32.58	9.58	68.7	19.6	2.68	112	23.5
	0.3125	5/16	27.59	8.11	59.5	17.0	2.71	95.6	20.1
	0.2500	1/4	22.42	6.59	49.4	14.1	2.74	78.3	16.5
	0.1875	3/16	17.08	5.02	38.5	11.0	2.77	60.2	12.7
6×6	0.5625	9/16	38.86	11.4	54.1	18.0	2.18	92.9	22.7
	0.5000	1/2	35.24	10.4	50.5	16.8	2.21	85.6	20.9
	0.3750	3/8	27.48	8.08	41.6	13.9	2.27	68.5	16.8
	0.3125	5/16	23.34	6.86	36.3	12.1	2.30	58.9	14.4
	0.2500	1/4	19.02	5.59	30.3	10.1	2.33	48.5	11.9
	0.1875	3/16	14.53	4.27	23.8	7.93	2.36	37.5	9.24
5×5	0.5000	1/2	28.43	8.36	27.0	10.8	1.80	46.8	13.7
	0.3750	3/8	22.37	6.58	22.8	9.11	1.86	38.2	11.2
	0.3125	5/16	19.08	5.61	20.1	8.02	1.89	33.1	9.70
	0.2500	1/4	15.62	4.59	16.9	6.78	1.92	27.4	8.07
	0.1875	3/16	11.97	3.52	13.4	5.36	1.95	21.3	6.29

*Outside dimensions across flat sides.
**Properties are based upon a nominal outside corner radius equal to two times the wall thickness.

Attachment: 10
Calc. No.: 145579-D-CA-010
Rev. No.: 0
Sheet 1 of 6

 Ref 12



STRUCTURAL TUBING
Square
Dimensions and properties

Dimensions				Properties**					
Nominal* Size	Wall Thickness		Weight per Ft	Area	I	S	r	J	Z
In.	In.		Lb.	In.²	In.⁴	In.³	In.	In.⁴	In.³
4.5×4.5	0.2500	1/4	13.91	4.09	12.1	5.36	1.72	19.7	6.43
	0.1875	3/16	10.70	3.14	9.60	4.27	1.75	15.4	5.03
4×4	0.5000	1/2	21.63	6.36	12.3	6.13	1.39	21.8	8.02
	0.3750	3/8	17.27	5.08	10.7	5.35	1.45	18.4	6.72
	0.3125	5/16	14.83	4.36	9.58	4.79	1.48	16.1	5.90
	0.2500	1/4	12.21	3.59	8.22	4.11	1.51	13.5	4.97
	0.1875	3/16	9.42	2.77	6.59	3.30	1.54	10.6	3.91
3.5×3.5	0.3125	5/16	12.70	3.73	6.09	3.48	1.28	10.4	4.35
	0.2500	1/4	10.51	3.09	5.29	3.02	1.31	8.82	3.70
	0.1875	3/16	8.15	2.39	4.29	2.45	1.34	6.99	2.93
3×3	0.3125	5/16	10.58	3.11	3.58	2.39	1.07	6.22	3.04
	0.2500	1/4	8.81	2.59	3.16	2.10	1.10	5.35	2.61
	0.1875	3/16	6.87	2.02	2.60	1.73	1.13	4.28	2.10
2.5×2.5	0.3125	5/16	10.58	3.11	3.58	2.39	1.07	3.32	1.96
	0.2500	1/4	7.11	2.09	1.69	1.35	0.899	2.92	1.71
	0.1875	3/16	5.59	1.64	1.42	1.14	0.930	2.38	1.40
2×2	0.3125	5/16	6.32	1.86	0.880	0.880	0.690	1.49	1.11
	0.2500	1/4	5.41	1.59	0.766	0.766	0.694	1.36	1.00
	0.1875	3/16	4.32	1.27	0.668	0.668	0.726	1.15	0.840

*Outside dimensions across flat sides.
**Properties are based upon a nominal outside corner radius equal to two times the wall thickness.

Attachment: 10
Calc. No.: 145574-0-CA-010
Rev. No.: 0
Sheet 2 of 6

Ref 12

BING

perties

r_x (cut off)	I_y	S_y	Z_y	r_y	J
	roperties**				
	Y-Y Axis				
n.	In.⁴	In.³	In.³	In.	In.⁴
.06	4.85	4.85	6.05	0.775	16.5
.10	4.42	4.42	5.33	0.802	14.9
.15	3.85	3.85	4.50	0.830	12.8
.20	3.14	3.14	3.56	0.858	10.3
.24	123	35.1	42.8	2.66	248
.27	115	32.8	39.5	2.69	229
.30	106	30.2	36.1	2.71	209
.37	85.1	24.3	28.4	2.77	164
.40	73.5	21.0	24.3	2.80	140
.43	60.8	17.4	19.9	2.83	114
.46	47.2	13.5	15.3	2.86	87.7
.15	84.5	18.2	34.4	2.28	189
.19	79.2	26.5	31.9	2.31	175
.22	73.2	24.4	29.1	2.34	160
.29	59.4	19.8	23.1	2.40	127
.32	51.4	17.1	19.8	2.43	108
.36	42.7	14.2	16.2	2.46	88.8
.39	33.3	11.1	12.5	2.48	68.2
.09	50.9	20.4	24.7	1.93	126
.12	47.4	18.9	22.7	1.96	115
.20	38.8	15.5	18.1	2.01	92.2
.23	33.8	13.5	15.6	2.04	79.2
.27	28.2	11.3	12.8	2.07	65.2
.30	22.1	8.84	9.90	2.10	50.2
2.86	13.7	9.11	11.3	1.15	41.6
2.94	11.7	7.79	9.29	1.20	34.9
2.98	10.4	6.92	8.08	1.23	30.5
3.02	8.84	5.90	6.73	1.26	25.6
3.06	7.06	4.70	5.26	1.29	20.1

radius equal to two times the wall

NSTRUCTION

STRUCTURAL TUBING
Rectangular
Dimensions and properties

Nominal* Size	Wall Thickness		Weight per Ft	Area	I_x	S_x	Z_x	r_x	I_y	S_y	Z_y	r_y	J
Dimensions				Properties**									
					X-X Axis				Y-Y Axis				
In.	In.		Lb.	In.²	In.⁴	In.³	In.³	In.	In.⁴	In.³	In.³	In.	In.⁴
8×6	0.5625	9/16	46.51	13.7	112	27.9	35.2	2.86	70.8	23.6	28.8	2.28	147
	0.5000	1/2	42.05	12.4	103	25.8	32.2	2.89	65.7	21.9	26.4	2.31	135
	0.3750	3/8	32.58	9.58	83.7	20.9	25.6	2.96	53.5	17.8	21.0	2.36	107
	0.3125	5/16	27.59	8.11	72.4	18.1	21.9	2.99	46.4	15.5	18.0	2.39	91.3
	0.2500	1/4	22.42	6.59	60.1	15.0	18.0	3.02	38.6	12.9	14.8	2.42	74.9
	0.1875	3/16	17.08	5.02	46.8	11.7	13.9	3.05	30.1	10.0	11.4	2.45	67.6
8×4	0.5625	9/16	38.86	11.4	80.5	20.1	26.9	2.65	26.2	13.1	16.2	1.51	69.0
	0.5000	1/2	35.24	10.4	75.1	18.8	24.7	2.69	24.6	12.3	15.0	1.54	64.1
	0.3750	3/8	27.48	8.08	61.9	15.5	19.9	2.77	20.6	10.3	12.2	1.60	52.2
	0.3125	5/16	23.34	6.86	53.9	13.5	17.1	2.80	18.1	9.05	10.5	1.62	45.2
	0.2500	1/4	19.02	5.59	45.1	11.3	14.1	2.84	15.3	7.63	8.72	1.65	37.5
	0.1875	3/16	14.53	4.27	35.3	8.83	11.0	2.88	12.0	6.02	6.77	1.68	29.1
8×3	0.5000	1/2	31.84	9.36	61.0	15.3	21.0	2.55	12.1	8.05	10.1	1.14	35.7
	0.3750	3/8	24.93	7.33	51.0	12.7	17.0	2.64	10.4	6.92	8.31	1.19	29.9
	0.3125	5/16	21.21	6.23	44.7	11.2	14.7	2.68	9.25	6.16	7.24	1.22	26.3
	0.2500	1/4	17.32	5.09	37.6	9.40	12.2	2.72	7.90	5.26	6.05	1.25	22.1
	0.1875	3/16	13.25	3.89	29.6	7.40	9.49	2.76	6.31	4.21	4.73	1.27	17.3
8×2	0.3750	3/8	22.37	6.58	40.1	10.0	14.2	2.47	3.85	3.85	4.83	0.765	12.6
	0.3125	5/16	19.08	5.61	35.5	8.87	12.3	2.51	3.52	3.52	4.28	0.792	11.4
	0.2500	1/4	15.62	4.59	30.1	7.52	10.3	2.56	3.08	3.08	3.63	0.819	9.84
	0.1875	3/16	11.97	3.52	23.9	5.97	8.02	2.60	2.52	2.52	2.88	0.847	7.94
7×5	0.5000	1/2	35.24	10.4	63.5	18.1	23.1	2.48	37.2	14.9	18.2	1.90	79.9
	0.3750	3/8	27.48	8.08	52.2	14.9	18.5	2.54	30.8	12.3	14.6	1.95	64.2
	0.3125	5/16	23.34	6.86	45.5	13.0	15.9	2.59	26.9	10.8	12.6	1.98	55.3
	0.2500	1/4	19.02	5.59	38.0	10.9	13.2	2.61	22.6	9.04	10.4	2.01	45.6
	0.1875	3/16	14.53	4.27	29.8	8.50	10.2	2.64	17.7	7.10	8.10	2.04	35.3

*Outside dimensions across flat sides.
**Properties are based upon a nominal outside corner radius equal to two times the wall thickness.

Attachment: 10
Calc. No.: 145579-0-CA-010
Rev. No.: 0
Sheet 3 of 6

Ref 12

ING

erties

...	Y-Y Axis				J
...	I_y	S_y	Z_y	r_y	
-	In.⁴	In.³	In.³	In.	In.⁴
8	21.5	10.8	13.3	1.52	53.0
5	18.1	9.08	10.8	1.57	43.3
9	16.0	7.98	9.36	1.60	37.5
2	13.5	6.75	7.78	1.63	31.2
5	10.7	5.34	6.06	1.66	24.2
5	10.5	6.99	8.84	1.12	29.8
3	9.08	6.05	7.32	1.18	25.1
7	8.11	5.41	6.40	1.20	22.0
1	6.95	4.63	5.36	1.23	18.5
5	5.57	3.71	4.21	1.26	14.6
26	2.69	2.69	3.19	0.812	8.36
31	2.21	2.21	2.54	0.839	6.74
14	32.1	12.8	16.0	1.85	62.9
21	26.8	10.7	12.9	1.91	50.9
24	23.5	9.40	11.2	1.94	43.9
27	19.8	7.91	9.26	1.97	36.3
30	15.6	6.23	7.20	2.00	28.1
.06	18.4	9.21	11.5	1.48	42.1
.13	15.6	7.82	9.44	1.54	34.6
.16	13.8	6.92	8.21	1.57	30.1
.19	11.7	5.87	6.84	1.60	25.0
.23	9.92	4.66	5.34	1.63	19.5
.02	7.78	5.19	6.34	1.16	20.3
.06	6.98	4.65	5.56	1.18	17.9
.09	6.08	4.00	4.67	1.21	15.1
.13	4.83	3.22	3.68	1.24	11.9

radius equal to two times the wall

STRUCTURAL TUBING
Rectangular
Dimensions and properties

Dimensions				Properties**									
Nominal* Size	Wall Thickness		Weight per Ft	Area	X-X Axis				Y-Y Axis				J
					I_x	S_x	Z_x	r_x	I_y	S_y	Z_y	r_y	
In.	In.		Lb.	In.²	In.⁴	In.³	In.³	In.	In.⁴	In.³	In.³	In.	In.⁴
6x2	0.3750	3/8	17.27	5.08	17.8	5.94	8.33	1.87	2.84	2.84	3.61	0.748	8.72
	0.3125	5/16	14.83	4.36	16.0	5.34	7.33	1.92	2.62	2.62	3.22	0.775	7.94
	0.2500	1/4	12.21	3.59	13.8	4.60	6.18	1.96	2.31	2.31	2.75	0.802	6.88
	0.1875	3/16	9.42	2.77	11.1	3.70	4.88	2.09	1.90	1.90	2.20	0.829	5.56
5x4	0.3750	3/8	19.82	5.83	18.7	7.50	9.44	1.79	13.2	6.58	8.08	1.50	26.3
	0.3125	5/16	16.96	4.98	16.6	6.65	8.24	1.83	11.7	5.85	7.05	1.53	22.9
	0.2500	1/4	13.91	4.09	14.1	5.65	6.89	1.86	9.98	4.99	5.90	1.56	19.1
	0.1875	3/16	10.70	3.14	11.2	4.49	5.39	1.89	7.96	3.98	4.63	1.59	14.9
5x3	0.5000	1/2	21.63	6.36	16.9	6.75	9.20	1.63	7.33	4.88	6.35	1.07	18.2
	0.3750	3/8	17.27	5.08	14.7	5.89	7.71	1.70	6.48	4.32	5.35	1.13	15.6
	0.3125	5/16	14.83	4.36	13.2	5.27	6.77	1.74	5.85	3.90	4.72	1.16	13.8
	0.2500	1/4	12.21	3.59	11.3	4.52	5.70	1.77	5.05	3.37	3.99	1.19	11.7
	0.1875	3/16	9.42	2.77	9.06	3.62	4.49	1.81	4.08	2.72	3.15	1.21	9.21
5x2	0.3125	5/16	12.70	3.73	9.74	3.90	5.31	1.62	2.16	2.16	2.70	0.762	6.24
	0.2500	1/4	10.51	3.09	8.48	3.39	4.51	1.66	1.92	1.92	2.32	0.789	5.43
	0.1875	3/16	8.15	2.39	6.89	2.75	3.59	1.70	1.60	1.60	1.86	0.816	4.40
4x3	0.3125	5/16	12.70	3.73	7.45	3.72	4.75	1.41	4.71	3.14	3.88	1.12	9.89
	0.2500	1/4	10.51	3.09	6.45	3.23	4.03	1.45	4.10	2.74	3.30	1.15	8.41
	0.1875	3/16	8.15	2.39	5.23	2.62	3.20	1.48	3.34	2.23	2.62	1.18	6.67
4x2	0.3125	5/16	10.58	3.11	5.32	2.66	3.60	1.31	1.71	1.71	2.17	0.743	4.58
	0.2500	1/4	8.81	2.59	4.69	2.35	3.09	1.35	1.54	1.54	1.88	0.770	4.01
	0.1875	3/16	6.87	2.02	3.87	1.93	2.48	1.38	1.29	1.29	1.52	0.798	3.26
3.5x2.5	0.2500	1/4	8.81	2.59	3.97	2.27	2.88	1.24	2.33	1.86	2.28	0.948	4.99
	0.1875	3/16	6.87	2.02	3.26	1.86	2.31	1.27	1.93	1.54	1.83	0.977	4.02
3x2	0.2500	1/4	7.11	2.09	2.21	1.47	1.92	1.03	1.15	1.15	1.44	0.742	2.63
	0.1875	3/16	5.59	1.64	1.86	1.24	1.57	1.06	0.977	0.977	1.18	0.771	2.16

*Outside dimensions across flat sides.
**Properties are based upon a nominal outside corner radius equal to two times the wall thickness.

Attachment: 10
Calc. No.: 14579-0-CA-016
Rev. No.: 0
Sheet 4 of 6

Ref 13

STEEL PLATE SIZES

Thickness Inches	Weight Lbs/sq foot	Thickness Inches	Weight Lbs/sq foot
3/16	7.65	2-1/8	86.70
1/4	10.20	2-1/4	91.80
5/16	12.75	2-1/2	102.00
3/8	15.30	2-3/4	112.20
7/16	17.85	3	122.40
1/2	20.40	3-1/4	132.60
9/16	22.95	3-1/2	142.80
5/8	25.50	3-3/4	153.00
11/16	28.05	4	163.20
3/4	30.60	4-1/4	173.40
13/16	33.15	4-1/2	183.60
7/8	35.70	5	204.00
1	40.80	5-1/2	224.40
1-1/8	45.90	6	244.80
1-1/4	51.00	6-1/2	265.20
1-3/8	56.10	7	285.60
1-1/2	61.20	7-1/2	306.00
1-5/8	66.30	8	326.40
1-3/4	71.40	9	367.20
1-7/8	76.50	10	408.00
2	81.60		

WIRE and SHEET SPECIFICATIONS

Weight values listed on the previous three pages are based on a theoretical specific gravity of 7.7 for Iron (480 lbs/cubic foot) and 7.854 for Steel (489.6 lbs/cubic foot). B.W. gauge weights are based on a steel weight of 40.8 lbs/ square foot.

US Standard Gauge was established by Congress in 1893 and establishes that the weight determines the gauge, not the thickness. Galvanized Sheet Gauge is customarily assumed to be based on the US Standard Gauge except 2.5 ounces per square foot is added to the gauge weight of the same US Standard Gauge number.

358 *Steel and Metals*

CHANNEL STEEL SPECS

Size (Bar) Inches	Weight Lbs/foot
3/4 x 5/16 x 1/8	0.50
3/4 x 3/8 x 1/8	0.56
7/8 x 3/8 x 1/8	0.61
7/8 x 7/16 x 1/8	0.69
1 x 3/8 x 1/8	0.69
1 x 1/2 x 1/8	0.84
1-1/8 x 9/16 x 3/16	1.16
1-1/4 x 1/2 x 1/8	1.01
1-1/2 x 1/2 x 1/8	1.12
1-1/2 x 9/16 x 3/16	1.44
1-1/2 x 3/4 x 1/8	1.17
1-1/2 x 1-1/2 x 3/16	2.65
1-3/4 x 1/2 x 3/16	1.55
2 x 1/2 x 1/8	1.43
2 x 9/16 x 3/16	1.86
2 x 5/8 x 1/4	2.28
2 x 1 x 1/8	1.59
2 x 1 x 3/16	2.32
2-1/2 x 5/8 x 3/16	2.27

STRUCTURAL CHANNEL

C = Standard Channel

MC = Miscellaneous Channel

Size Inches	Weight Lbs/foot
C 3 x 1-3/8 x 0.170	4.1
x 1-1/2 x 0.258	5.0
x 1-5/8 x 0.356	6.0
MC 3 x 1-7/8 x 0.312	7.1
x 0.500	9.0
C 4 x 1-5/8 x 0.184	5.4
x 1-5/8 x 0.247	6.25
x 1-3/4 x 0.321	7.25
MC 4 x 2-1/2 x 0.500	13.8
C 5 x 1-3/4 x 0.190	6.7
x 1-7/8 x 0.325	9.0
C 6 x 1-7/8 x 0.200	8.2
x 2 x 0.314	10.5
x 2-1/8 x 0.437	13.0
MC 6 x 2-1/2 x 0.310	12.0
MC 6 x 3 x 0.316	15.1
x 0.375	16.3
MC 6 x 3-1/2 x 0.340	15.3

STRUCTURAL CHANNEL

Size Inches	Weight Lbs/ foot
MC 6 x 3-1/2 x 0.379	18.0
C 7 x 2-1/8 x 0.210	9.8
x 2-1/4 x 0.314	12.25
x 2-1/4 x 0.419	14.75
MC 7 x 3 x 0.375	17.6
x 3-1/2 x 0.352	19.1
x 3-5/8 x 0.503	22.7
MC 8 x 1-7/8 x 0.179	8.50
C 8 x 2-1/4 x 0.220	11.5
x 2-3/8 x 0.303	13.75
x 2-1/2 x 0.487	18.75
MC 8 x 3 x 0.353	18.7
x 0.400	20.0
x 3-1/2 x 0.377	21.4
x 0.427	22.8
C 9 x 2-3/8 x 0.233	13.4
x 2-1/2 x 0.285	15.0
x 2-5/8 x 0.448	20.0
MC 9 x 3-1/2 x 0.400	23.9
x 0.450	25.4
MC 10 x 1-1/8 x 0.152	6.5
x 1-1/2 x 0.170	8.4
x 3-3/8 x 0.290	22.0
x 0.380	25.0
C 10 x 2-5/8 x 0.240	15.3
x 2-3/4 x 0.379	20.0
x 2-7/8 x 0.526	25.0
x 3 x 0.673	30.0
MC 10 x 4 x 0.425	28.5
x 4-1/8 x 0.575	33.6
x 4-3/8 x 0.796	41.1
C 12 x 3 x 0.282	20.7
x 0.387	25.0
x 3-1/8 x 0.510	30.0
MC 12 x 1-1/2 x 0.190	10.6
x 3-5/8 x 0.370	31.0
x 3-3/4 x 0.467	35.0
x 3-7/8 x 0.590	40.0
x 4 x 0.712	45.0
x 4-1/8 x 0.835	50.0
MC 13 x 4 x 0.375	31.8
x 4-1/8 x 0.447	35.0

Steel and Metals 359

Attachment: 10

Calc. No.: 145579-0-CA-010

Rev. No.: 0

Sheet 5 of 6

Ref 14

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another, or taking a coffee break, he is not joining. The total hours he works are always more than the hours he welds, and the ratio of the hours spent in welding to the total hours worked is known as the operating factor. This factor is one of the most basic factors in cost formulas, and must be determined accurately in order to make sound evaluations of costs.

The operating factor may be defined by the equation:

$$OF = \frac{\text{Arc Time}}{\text{Total Time}}$$

where total time is arc time plus the time the weldor spends in operations other than welding, including time for personal purposes. Since arc time is always divided by a larger number, the ratio is always less than 1.0; and thus a decimal. For convenience in referring to operation factors, the ratio is multiplied by 100 and expressed as a percentage. Thus, one speaks of an operating factor of 30, 40, or 50%. When using an operating factor in a cost formula, however, it must be kept in the decimal form. Thus, a 40% operating factor would be written .40 in a cost formula. Values for (OF) usually range from 0.2 to 0.6, but may be higher for automated welding or lower for construction field welding. However, the (OF) should be carefully determined since it has considerable bearing on the final estimated welding cost.

By adding the values calculated for (CM) and (CL), the welding cost per linear foot of weld is found:

$$\text{Cost per linear foot of weld} = (CM) + (CL) \quad . . (3)$$

Multiplying the cost per linear foot by the number of feet of weld gives the calculated cost of welding. The accuracy of the value obtained will depend upon the accuracy of the factors used.

Attachment: 10
Calc. No.: 145579-0-CA-010
Rev. No.: 0
Sheet 6 of 6

...DS NOT LISTED

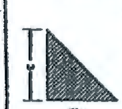
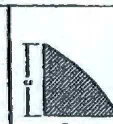
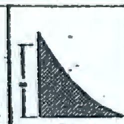
...sideration is not listed ...is handbook, the same ... values for (WE) and ann... applicable — must be ...or by measurement ...s are required for

...cessary to make a ...eight of electrode ...ht of weld metal ...esses (the notable exception is the submerged-arc process), not all of the electrode ends up as a useful deposit of weld metal. Some is lost as spatter and vaporization, and a substantial portion of the weight of the electrode may be made up of materials for providing an arc shield and a protective slag. Consequently, the weight of electrode (WE) required to produce a given length of weld is usually greater than the weight of metal (WW) required for the weld.

The proportion of the electrode that ends up as weld metal, however, is fairly constant for each welding process and, as shown later in Equation 4, weight of electrode required can be calculated if the weight of weld metal is known. The weight of electrode can also be measured directly from a test weld, in which case a computation for (WW) is not required.

A similar distinction must be made between the two quantities that can be used to compute welding time (T). One of these is the melt-off rate (M) in pounds per hour at which the electrode is melted during welding. The other quantity is the deposition rate (D) in pounds per hour at which weld metal is

TABLE 12-2. Weight of Steel Weld Metal for Fillet Joints

	 Flat	 Convex	 Concave
Size of Fillet (in.)	Weight of Metal (lb/ft)		
1/8	0.032	0.039	0.037
3/16	0.072	0.087	0.083
1/4	0.129	0.155	0.147
5/16	0.201	0.242	0.230
3/8	0.289	0.349	0.331
7/16	0.394	0.475	0.451
1/2	0.514	0.620	0.589
9/16	0.651	0.785	0.745
5/8	0.804	0.970	0.920
3/4	1.16	1.40	1.32
7/8	1.58	1.90	1.80
1	2.06	2.48	2.36
1-1/8	2.60	3.14	2.98
1-1/4	3.21	3.88	3.68
1-3/8	3.89	4.69	4.45
1-1/2	4.62	5.58	5.30
1-5/8	5.43	6.55	6.22
1-3/4	6.29	7.59	7.21
1-7/8	7.23	8.72	8.28
2	8.23	9.93	9.43

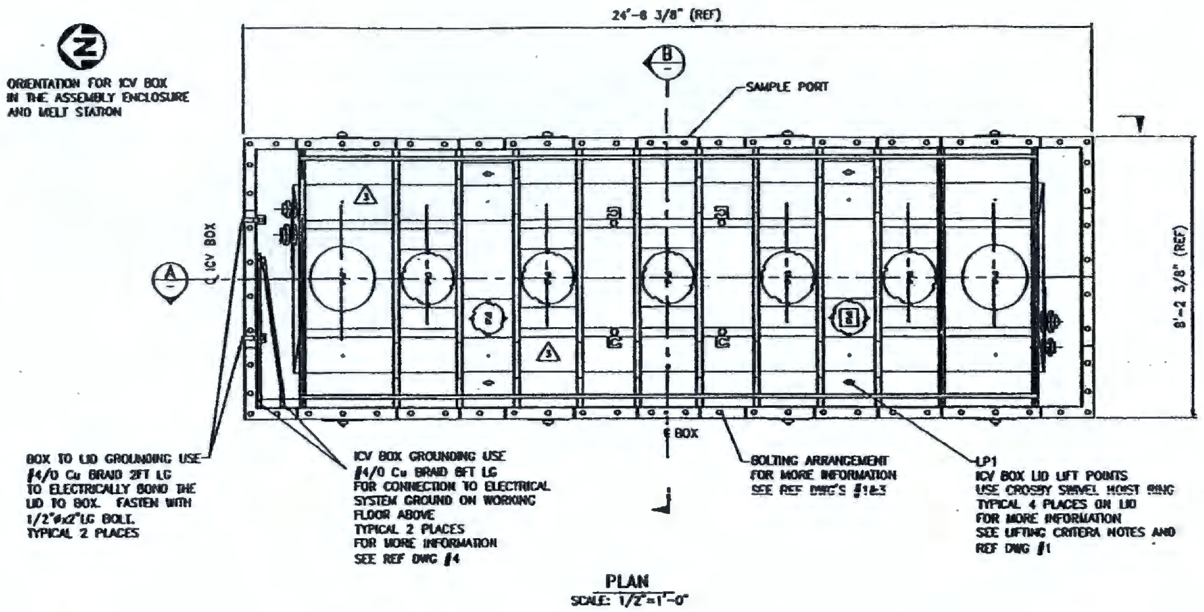
Note: Values are for leg size 10% oversize, consistent with normal shop practices.

145579-D-CA-010

Attachment 11

ICV Box and Lid Drawings

No	AMEC Dwg. No.	REFERENCE DRAWINGS
1	F-145579-35-D-0005	ICV BOX LID ASSEMBLY
2	F-145579-35-D-0006	ICV BOX LID STEEL WORK 1 OF 3
3	F-145579-35-D-0008	ICV BOX ASSEMBLY
4	F-145579-35-D-0012	ICV BOX CAMERA, T/C AND GROUND ASSEMBLY
5	F-145579-35-D-0014	ICV BOX STARTER PATH DETAILS
6	F-145579-35-D-0021	ICV BOX LID BREATHER HEPA FILTER
7	F-145579-35-D-0016	ICV BOX REFRACTORY ASSEMBLY



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	VEROCAST 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

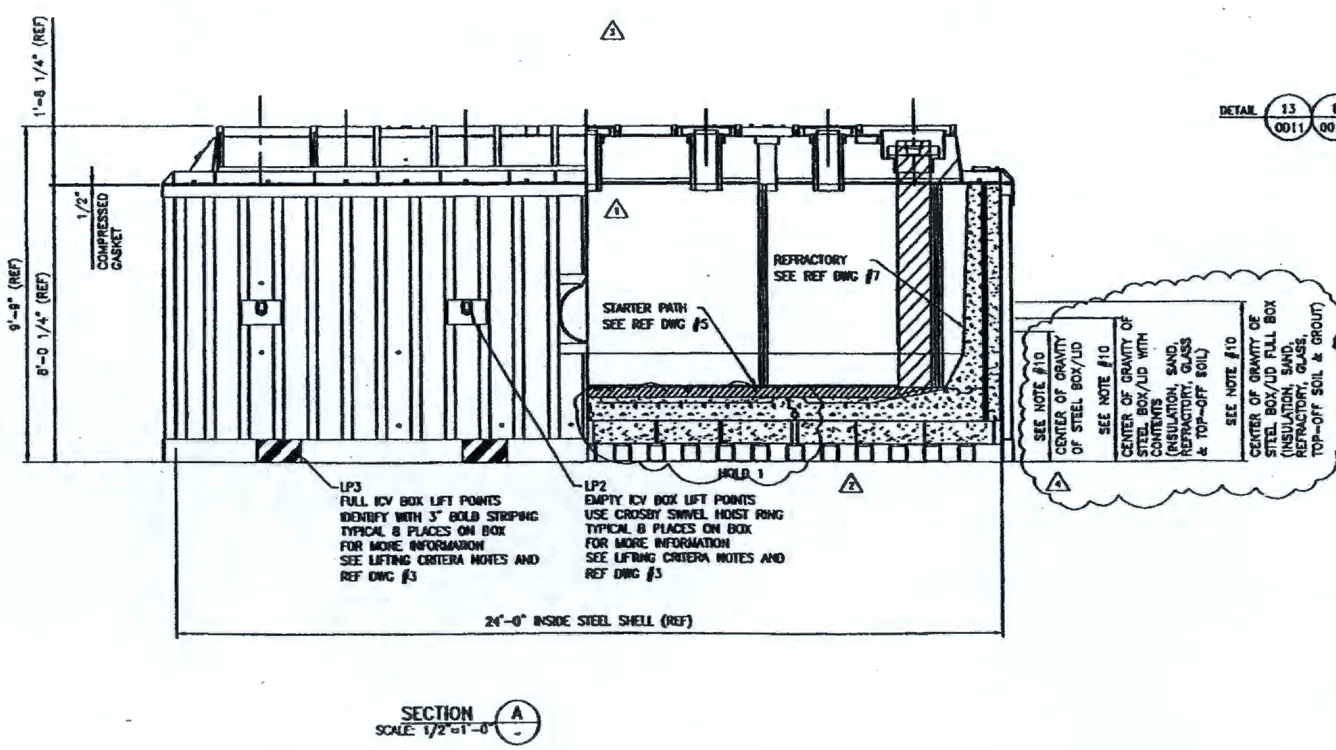
ICV BOX BASE = 19,001#
ICV BOX LID = 4,737#
NOTE:
FOR WEIGHT BREAKDOWN OF ICV BOX & CONTENTS REFER TO DOCUMENT NO. 145579-D-CA-010.

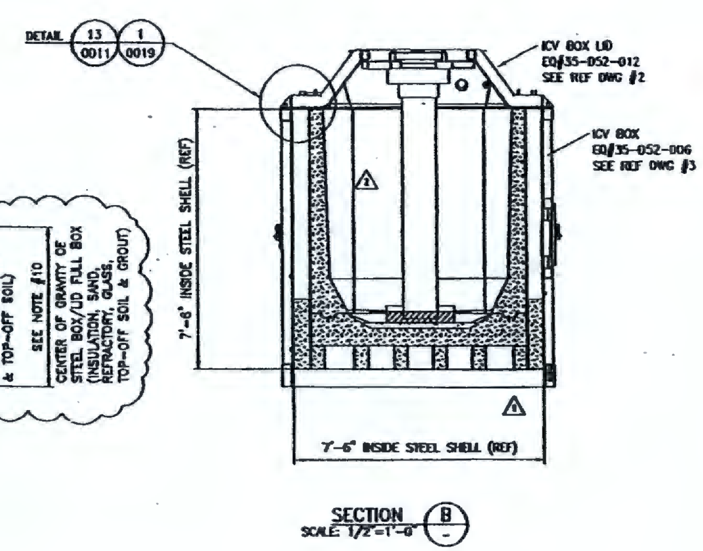
GENERAL

PROJECT	DBVS FINAL DESIGN	PROJECT NUMBER	145579
		NUMBER REQ'D.	50
ITEM NO.	35-052-006 ICV BOX	P.O. NUMBER	
	35-052-012 ICV BOX LID	QUALITY ASSURANCE LEVEL	NQA-1
SITE	HANFORD		ENHANCED QUALITY

PROCUREMENT QUALITY

LEVEL	EQM	





HOLDS

1. ICV REFRACTORY JOINT ASSEMBLY DIMENSIONS ON-HOLD UNTIL VENDOR TESTING OF NEW JOINT DESIGN

Rev.	REVISION DESCRIPTION	Date	By	Chk'd	Approved Design Lead	Approved Proj Mgr
4	TECH EE-016	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	SRD	KSW	JSG
1	REVISED ICV BOX LINING	15 AUG 05	JBM	RDD	PWS	TH
0	ISSUED FOR CONSTRUCTION	19 MAY 05	JBM	AA	PWS	TH

AMEC DRAWING NO. F-145579-35-D-0004 REV 4

amec

AMEC PROJECT: 145579-FINAL DBVS DESIGN

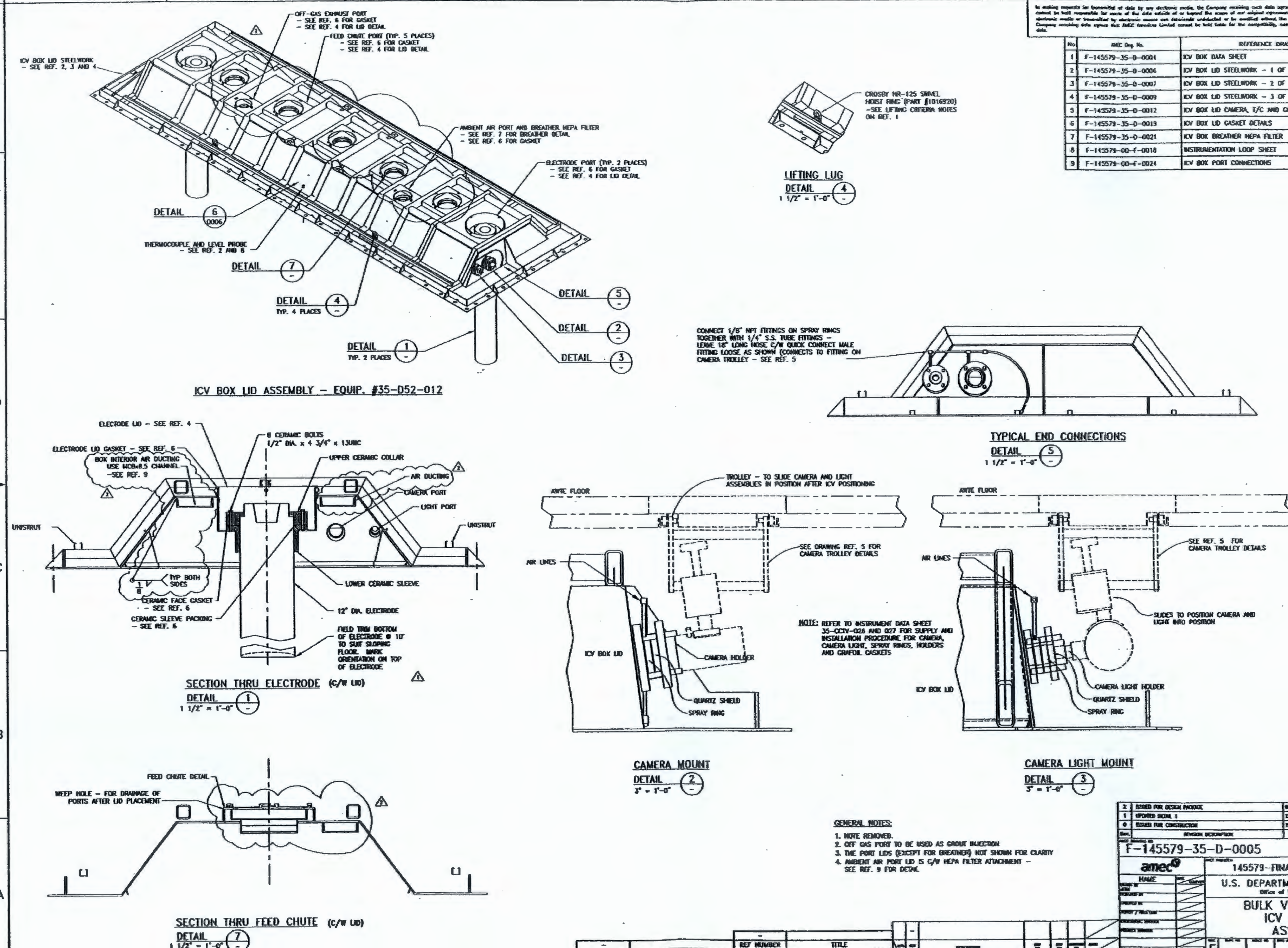
U.S. DEPARTMENT OF ENERGY
Office of River Protection

BULK VITRIFICATION
ICV BOX
DATA SHEET

SIZE F SCALE AS NOTED

DWG NO	TITLE	REF NUMBER	TITLE
DRAWING TRACEABILITY LIST		NEXT USED ON	REFERENCES

REVISIONS



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No	AMEC Drg. No.	REFERENCE DRAWINGS
1	F-145579-35-D-0004	ICV BOX DATA SHEET
2	F-145579-35-D-0006	ICV BOX LID STEELWORK – 1 OF 3
3	F-145579-35-D-0007	ICV BOX LID STEELWORK – 2 OF 3
4	F-145579-35-D-0009	ICV BOX LID STEELWORK – 3 OF 3
5	F-145579-35-D-0012	ICV BOX LID CAMERA, T/C AND GROUND ASSEMBLY
6	F-145579-35-D-0019	ICV BOX LID GASKET DETAILS
7	F-145579-35-D-0021	ICV BOX BREATHER HEPA FILTER
8	F-145579-00-F-0018	INSTRUMENTATION LOOP SHEET
9	F-145579-00-F-0024	ICV BOX PORT CONNECTIONS

GENERAL NOTES:

1. NOTE REMOVED.
2. OFF GAS PORT TO BE USED AS GROUT INJECTION
3. THE PORT LIDS (EXCEPT FOR BREATHER) NOT SHOWN FOR CLARITY
4. AMBIENT AIR PORT LID IS C/W HEPA FILTER ATTACHMENT – SEE REF. 9 FOR DETAIL

Rev.	REVISION DESCRIPTION	Date	By	Chk'd		
2	ISSUED FOR DESIGN PACKAGE	06 FEB 06	THR	JH	SRB	JSG
1	UPDATED DETAIL 1	15 AUG 05	JBM	BDB	FWS	TH
0	ISSUED FOR CONSTRUCTION	19 MAY 05	JBM	AA	FWS	TH

F-145579-35-D-0005 Rev 2

amec

145579-FINAL DBVS DESIGN

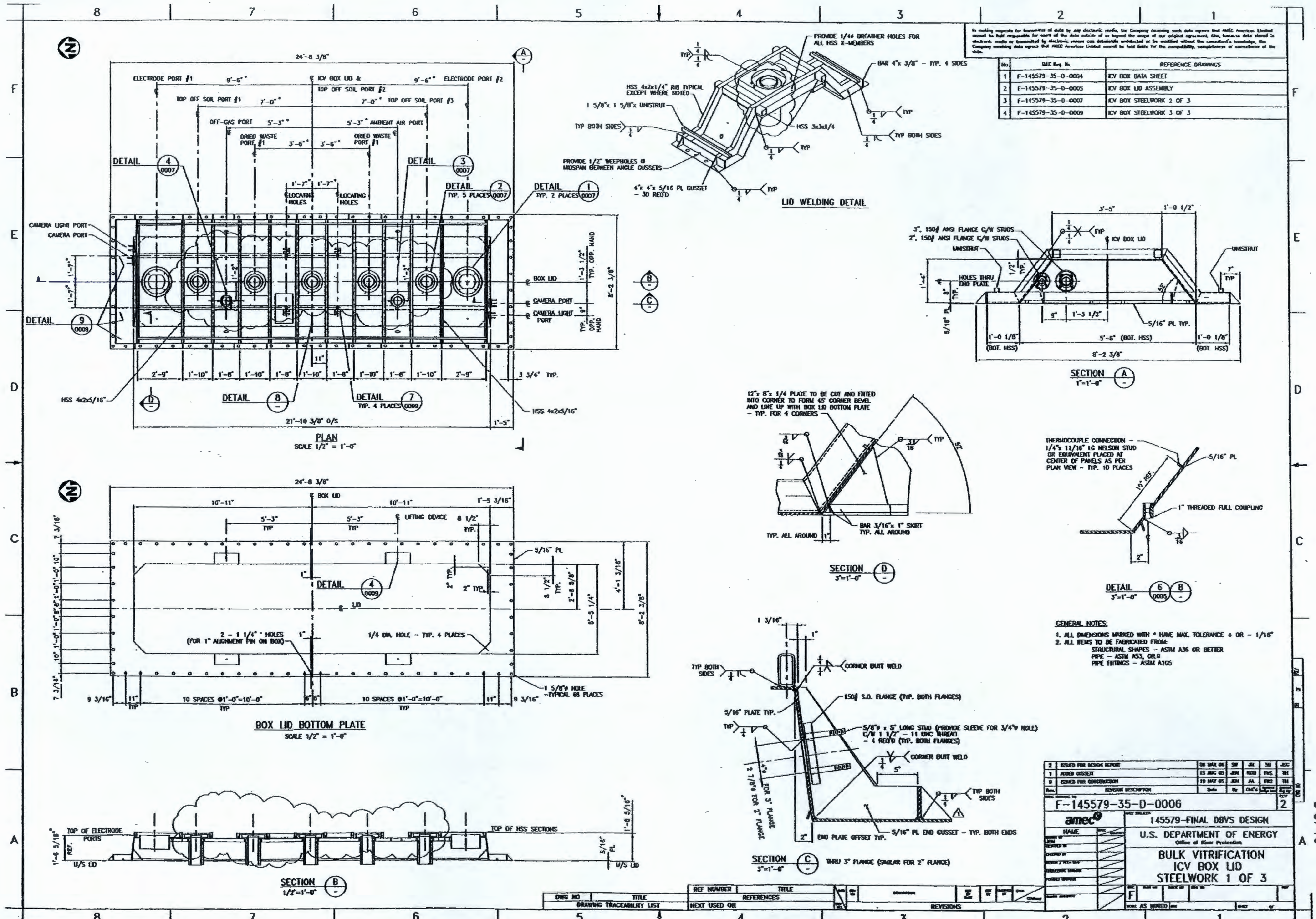
U.S. DEPARTMENT OF ENERGY
Office of River Protection

BULK VITRIFICATION
ICV BOX LID
ASSEMBLY

F — SCALE AS SHOWN

DRAWING TRACEABILITY LIST — REFERENCES — REVISIONS

Rev.0
2 of 10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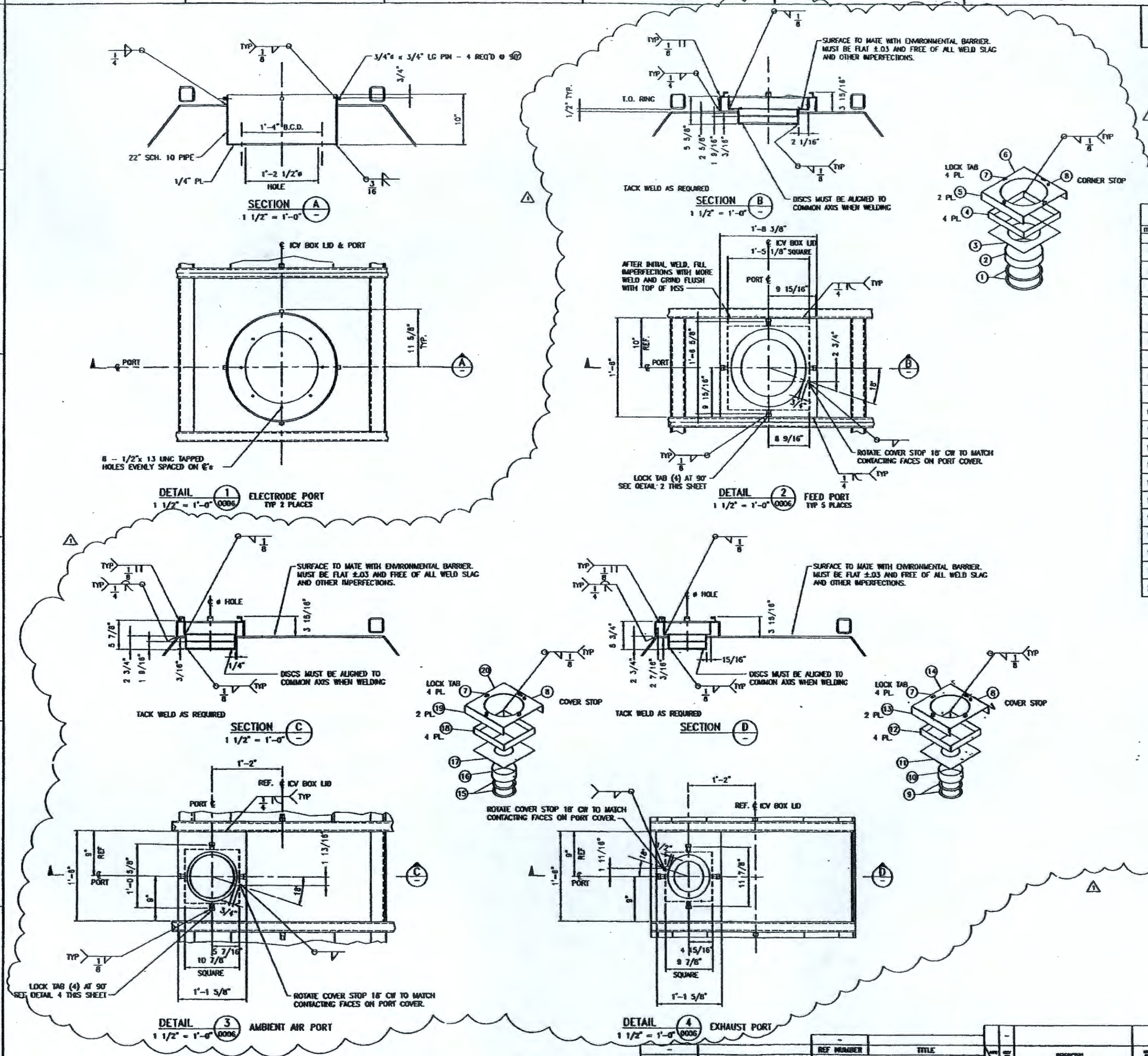
No. | AMEC Dwg. No. | REFERENCE DRAWINGS
1 | F-145579-35-0-0004 | ICV BOX DATA SHEET
2 | F-145579-35-0-0005 | ICV BOX LID ASSEMBLY
3 | F-145579-35-0-0007 | ICV BOX STEELWORK 2 OF 3
4 | F-145579-35-0-0009 | ICV BOX STEELWORK 3 OF 3
PLAN
SCALE 1/2" = 1'-0"
BOX LID BOTTOM PLATE
SCALE 1/2" = 1'-0"
SECTION B
1/2"=1'-0"
LID WELDING DETAIL
SECTION A
1"=1'-0"
SECTION D
3"=1'-0"
SECTION C
3"=1'-0"
DETAIL 6 8
3"=1'-0"
GENERAL NOTES:
1. ALL DIMENSIONS MARKED WITH * HAVE MAX. TOLERANCE + OR - 1/16"
2. ALL ITEMS TO BE FABRICATED FROM:
STRUCTURAL SHAPES - ASTM A36 OR BETTER
PIPE - ASTM A53, GR.B
PIPE FITTINGS - ASTM A105
2 ISSUED FOR DESIGN REPORT 06 MAR 06
1 ADDED GUSSET 15 AUG 05
0 ISSUED FOR CONSTRUCTION 19 MAY 05
F-145579-35-D-0006
REV 2
amec
145579-FINAL DBVS DESIGN
U.S. DEPARTMENT OF ENERGY
Office of River Protection
BULK VITRIFICATION
ICV BOX LID
STEELWORK 1 OF 3
SCALE AS NOTED
DRAWING TRACEABILITY LIST
REFERENCES
NEXT USED ON
REVISIONS



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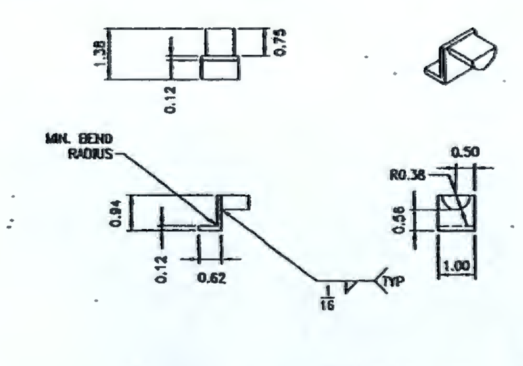
No.	AMEC Dwg. No.	REFERENCE DRAWINGS
1	F-145579-35-D-0004	ICV BOX DATA SHEET
2	F-145579-35-D-0005	ICV BOX LID ASSEMBLY
3	F-145579-35-D-0006	ICV BOX STEELWORK 1 OF 3
4	F-145579-35-D-0009	ICV BOX STEELWORK 3 OF 3

GENERAL NOTES:

1. ALL DIMENSIONS MARKED WITH * HAVE MAX. TOLERANCE + OR - 1/16"
2. ALL ITEMS TO BE FABRICATED FROM:
   STRUCTURAL SHAPES - ASTM A36 OR BETTER
   PIPE - ASTM A53, GR.B
   PIPE FITTINGS - ASTM A105

PARTS/MATERIAL LIST

ITEM	REQD	PART/DASH NUMBER	NOMENCLATURE/DESCRIPTION	MATERIAL/REFERENCE	SHT	ITEM NO
1	2		PLATE, 3/16 THK x 12.25 OD x 10.88 ID	ASTM A240 TYPE 316L	–	1
2	1		PIPE, 12 SCHED 10 x 3.00 LG	ASTM A312 TYPE 316L	–	2
3	1		PLATE 3/16 THK x 16.88 SQ x 10.88 ID	A36	–	3
4	4		PLATE, 3/16 THK x 16.69 x 2.31	A36	–	4
5	2		PLATE, 1/4 THK x 19.88 x 3.00	A36	–	5
6	1		PLATE, 1/4 THK x 19.88 x 15.75 ID	A36	–	6
7	4		SEE DETAIL 4 THIS SHEET	A36	–	7
8	2		BAR, 1/2 x 1/2 x .88	A36	–	8
9	2		PLATE, 3/16 THK x 7.50 OD x 6.13 ID	ASTM A240 TYPE 316L	–	9
10	1		MECH. TUBE ø8 x .188 WALL x 3.00 LG	ASTM A312 TYPE 316L	–	10
11	1		PLATE 3/16 THK x 14.13 SQ x 6.13 ID	A36	–	11
12	4		PLATE, 3/16 THK x 13.94 x 2.31	A36	–	12
13	2		PLATE, 1/4 THK x 17.88 x 3.00	A36	–	13
14	1		PLATE, 1/4 THK x 17.88 x 13.63 x 13.00 ID	A36	–	14
15	2		PLATE, 3/16 THK x 9.50 OD x 8.13 ID	ASTM A240 TYPE 316L	–	15
16	1		MECH. TUBE ø 10 x .188 WALL x 3.00 LG	ASTM A312 TYPE 316L	–	16
17	1		PLATE, 3/16 THK x 10.50 SQ x 8.13 ID	A36	–	17
18	4		PLATE, 3/16 THK x 10.31 x 2.31	A36	–	18
19	2		PLATE, 1/4 THK x 17.88 x 3.00	A36	–	19
20	1		PLATE, 1/4 THK x 17.88 x 13.63 x 10.00 ID	A36	–	20



DETAIL 4 LOCK TAB
6" = 1'-0"

Rev.	REVISION DESCRIPTION	Date	By	Chk'd		
1	REVISED PORTS AND DELETED RADAR PORT	06 MAR 06	THD	AK	SRB	JSC
0	ISSUED FOR CONSTRUCTION	11 MAY 05	JBM	AA	PHS	TH

F-145579-35-D-0007 REV 1

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145579-FINAL DBVS DESIGN

U.S. DEPARTMENT OF ENERGY
Office of River Protection

BULK VITRIFICATION
ICV BOX LID
STEELWORK - 2 OF 3

SIZE F — SCALE 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

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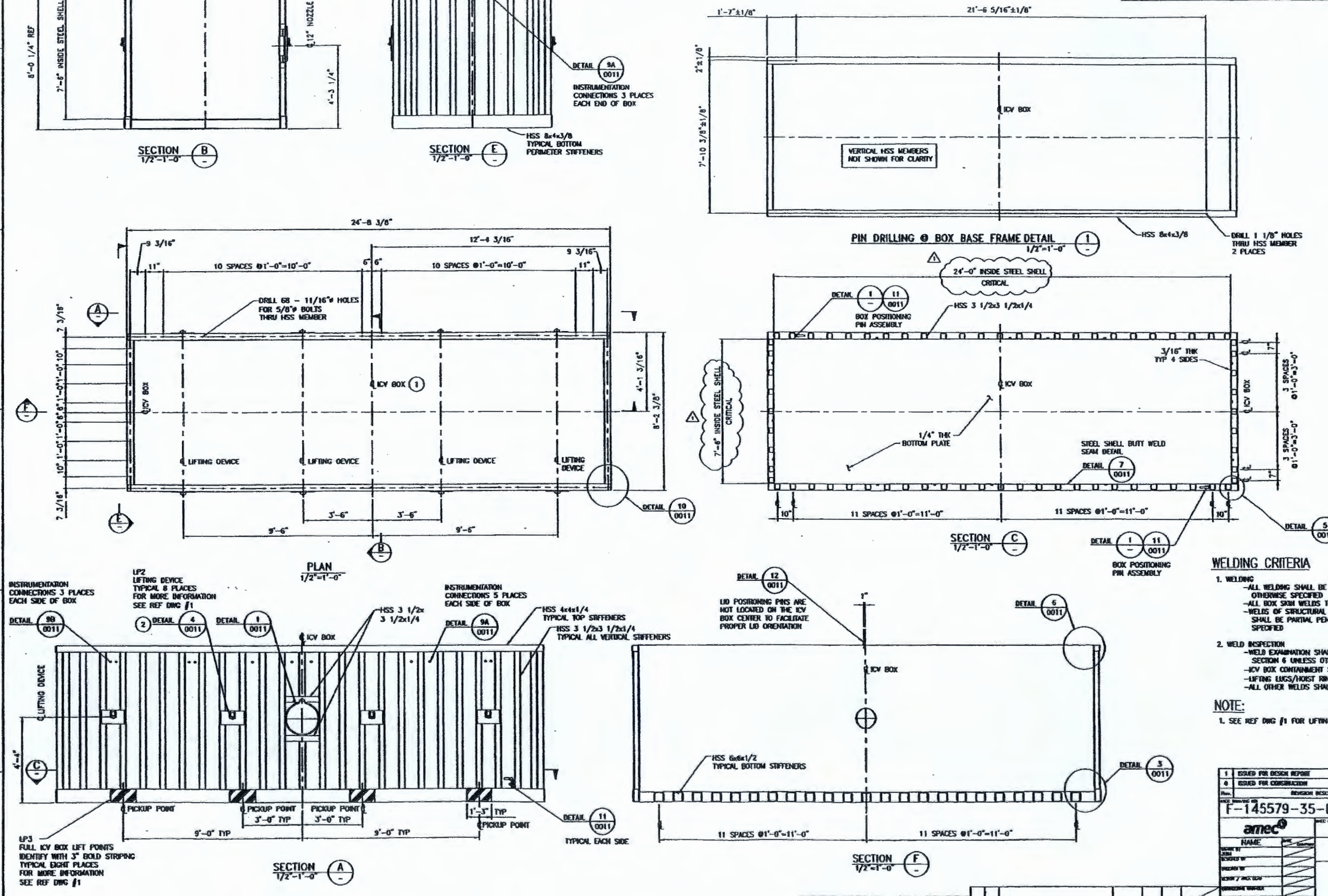
PARTS/MATERIAL LIST

ITEM	REQD	PART/DASH NUMBER	NOMENCLATURE/DESCRIPTION	MATERIAL/REFERENCE	SHT	ITEM NO
1	1	35-052-006	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	JAI	SRB	JSC
0	ISSUED FOR CONSTRUCTION	15 MAY 05	JBM	AA	PBS	TH

F-145579-35-D-0008 REV 1

amec

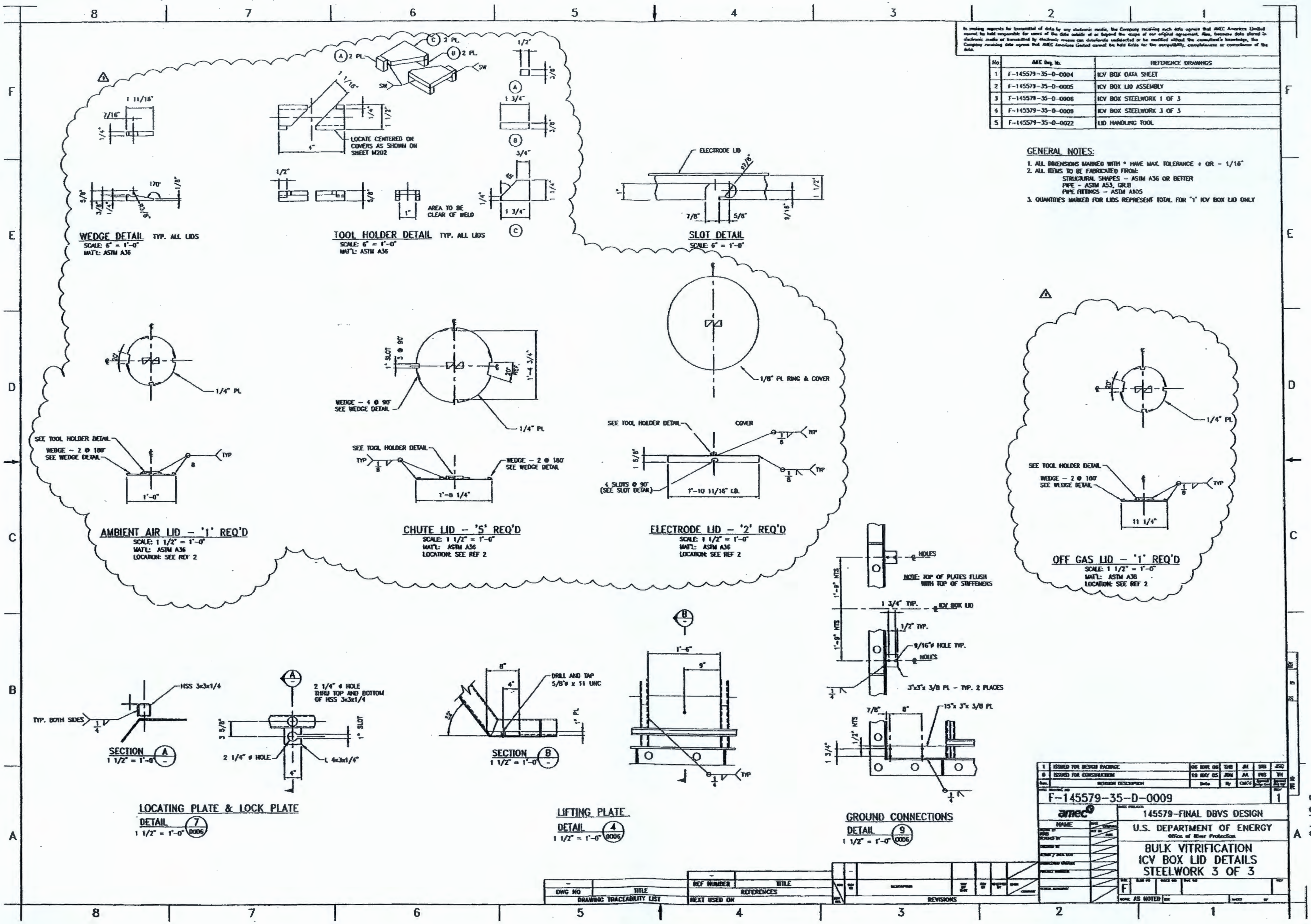
145579–FINAL DBVS DESIGN

U.S. DEPARTMENT OF ENERGY
Office of River Protection

BULK VITRIFICATION
ICV BOX
PLAN & SECTIONS

SIZE F SCALE AS NOTED

DWG NO | TITLE — DRAWING TRACEABILITY LIST
REF NUMBER | TITLE — REFERENCES
NEXT USED ON
REVISIONS

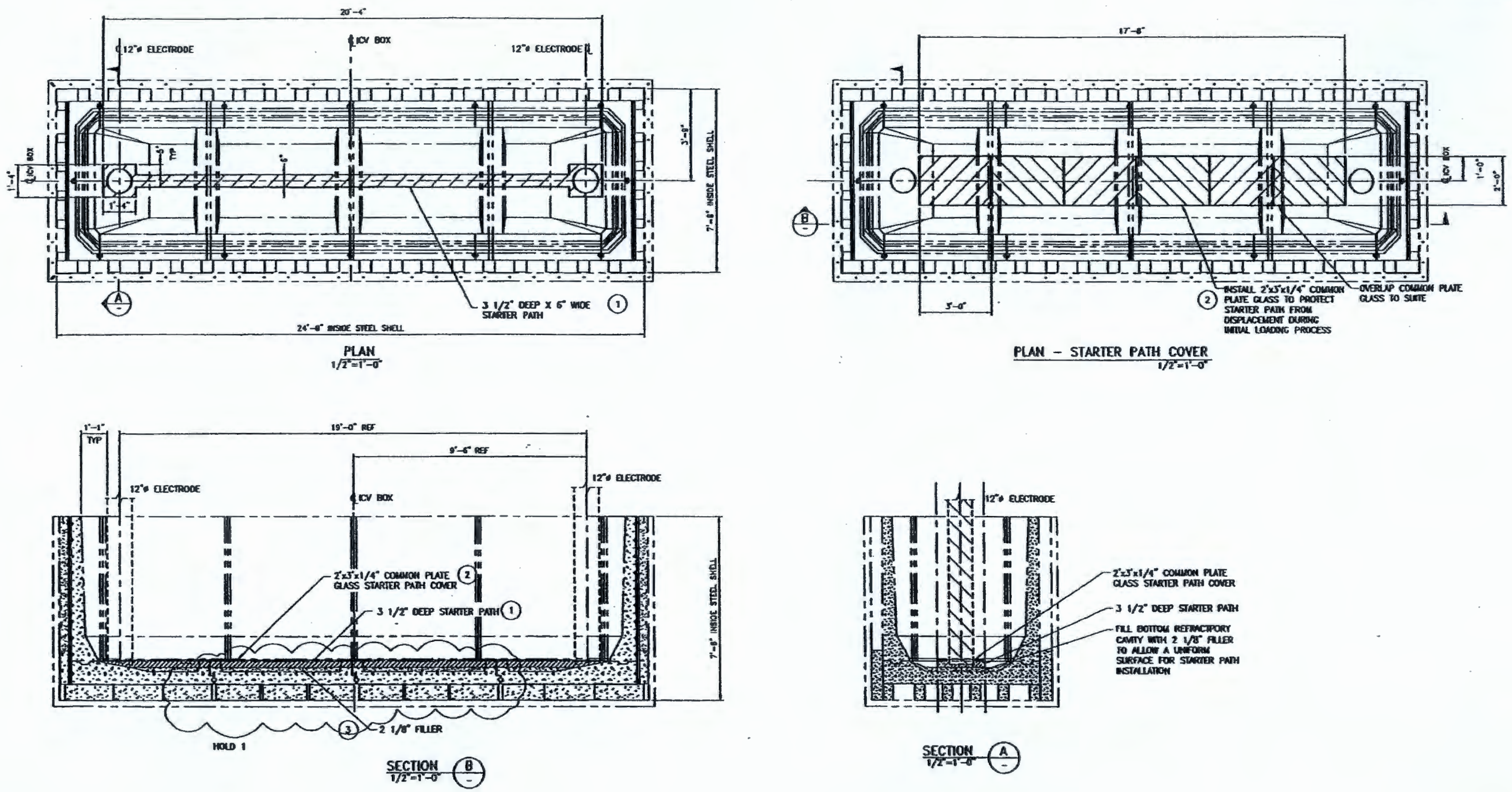

WEDGE DETAIL TYP. ALL LIDS
SCALE: 6" = 1'-0"
MAT'L: ASTM A36
TOOL HOLDER DETAIL TYP. ALL LIDS
SCALE: 6" = 1'-0"
MAT'L: ASTM A36
LOCATE CENTERED ON COVERS AS SHOWN ON SHEET M202
AREA TO BE CLEAR OF WELD
SLOT DETAIL
SCALE: 6" = 1'-0"
ELECTRODE LID
1/4" PL
1/8" PL RING & COVER
SEE TOOL HOLDER DETAIL
WEDGE - 2 @ 180° SEE WEDGE DETAIL
WEDGE - 4 @ 90° SEE WEDGE DETAIL
4 SLOTS @ 90° (SEE SLOT DETAIL)
COVER
TYP
AMBIENT AIR LID - '1' REQ'D
SCALE: 1 1/2" = 1'-0"
MAT'L: ASTM A36
LOCATION: SEE REF 2
CHUTE LID - '5' REQ'D
SCALE: 1 1/2" = 1'-0"
MAT'L: ASTM A36
LOCATION: SEE REF 2
ELECTRODE LID - '2' REQ'D
SCALE: 1 1/2" = 1'-0"
MAT'L: ASTM A36
LOCATION: SEE REF 2
OFF GAS LID - '1' REQ'D
SCALE: 1 1/2" = 1'-0"
MAT'L: ASTM A36
LOCATION: SEE REF 2
HSS 3x3x1/4
TYP. BOTH SIDES
SECTION A
1 1/2" = 1'-0"
2 1/4" ϕ HOLE THRU TOP AND BOTTOM OF HSS 3x3x1/4
2 1/4" ϕ HOLE
L 4x3x1/4"
LOCATING PLATE & LOCK PLATE DETAIL 7
1 1/2" = 1'-0" 0006
DRILL AND TAP 5/8"ϕ x 11 UNC
SECTION B
1 1/2" = 1'-0"
LIFTING PLATE DETAIL 4
1 1/2" = 1'-0" 0006
HOLES
NOTE: TOP OF PLATES FLUSH WITH TOP OF STIFFENERS
ICV BOX LID
9/16"ϕ HOLE TYP.
3"x3"x 3/8 PL - TYP. 2 PLACES
15"x 3"x 3/8 PL
GROUND CONNECTIONS DETAIL 9
1 1/2" = 1'-0" 0006
In making requests for transmittal of data by any electronic media, the Company receiving such data agrees that AMEC Americas Limited cannot be held responsible for users of the data outside of or beyond the scope of our original agreement. Also, because data stored in electronic media or transmitted by electronic means can deteriorate undetected or be modified without the consultant's knowledge, the Company receiving data agrees that AMEC Americas Limited cannot be held liable for the compatibility, completeness or correctness of the data.
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
3 | F-145579-35-D-0006 | ICV BOX STEELWORK 1 OF 3
4 | F-145579-35-D-0009 | ICV BOX STEELWORK 3 OF 3
5 | F-145579-35-D-0022 | LID HANDLING TOOL
GENERAL NOTES:
1. ALL DIMENSIONS MARKED WITH * HAVE MAX. TOLERANCE + OR - 1/16"
2. ALL ITEMS TO BE FABRICATED FROM:
STRUCTURAL SHAPES - ASTM A36 OR BETTER
PIPE - ASTM A53, GR.B
PIPE FITTINGS - ASTM A105
3. QUANTITIES MARKED FOR LIDS REPRESENT TOTAL FOR "1" ICV BOX LID ONLY
1 ISSUED FOR DESIGN PACKAGE 06 MAR 06
0 ISSUED FOR CONSTRUCTION 19 MAY 05
REVISION DESCRIPTION
F-145579-35-D-0009
1
amec
145579-FINAL DBVS DESIGN
U.S. DEPARTMENT OF ENERGY
Office of River Protection
BULK VITRIFICATION
ICV BOX LID DETAILS
STEELWORK 3 OF 3
AS NOTED
DWG NO
TITLE
DRAWING TRACEABILITY LIST
REF NUMBER
REFERENCES
NEXT USED ON
REVISIONS

No	AMEC Dwg. No.	REFERENCE DRAWINGS
1	F-145579-35-D-0004	ICV BOX DATA SHEET

In making requests for transmittal of data by any electronic media, the Company receiving such data agrees that AMEC Americas Limited cannot be held responsible for users of the data outside of or beyond the scope of our original agreement. Also, because data stored in electronic media or transmitted by electronic means can deteriorate undetected or be modified without the consultant's knowledge, the Company receiving data agrees that AMEC Americas Limited cannot be held liable for the compatibility, completeness or correctness of the data.

PARTS/MATERIAL LIST

ITEM	REQD	PART/DASH NUMBER	NOMENCLATURE/DESCRIPTION	MATERIAL/REFERENCE	SHT	ITEM NO
1		1	STARTER PATH	SEE PDC	–	1
2	6	–	STARTER PATH COVER	2'x3'x1/4" COMMON PLATE GLASS	–	2
3	–	–	FILLER	SEE PDC	–	3



HOLD:

1. ICV REFRACTORY JOINT ASSEMBLY DIMENSIONS ON HOLD FOR VENDOR TESTING OF RE-DESIGN

NOTES:

1. STARTER PATH TO BE MANUALLY DISTRIBUTED TO A UNIFORM DEPTH OF NOT LESS THAN 3 1/2"

Rev.	REVISION DESCRIPTION	Date	By	Chk'd		
H	ISSUED FOR DESIGN REPORT	06 MAR 06	SW	JLM	SB	JSG
G	REVISED – REVISED CORNER PANEL AND REFRACTORY JOINT	13 JAN 06	SW	SRB	KSM	JSG
F	REVISED – ISSUED FOR CH2M HILL APPROVAL & 90% REPORT	15 AUG 05	JBM	RDB	FWS	TH
E	REVISED – ISSUED FOR CH2M HILL REVIEW AND 90% REPORT	01 APR 05	RRB	TW	FWS	TH
D	ISSUED FOR CH2M HILL REVIEW AND 90% REPORT	03 MAR 05	TW	AA	FWS	TH
C	ISSUED FOR INFORMATION	09 FEB 05	JBM		FWS/TH	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-0014 REV H

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NAME

145579-FINAL DBVS DESIGN

U.S. DEPARTMENT OF ENERGY
Office of River Protection

BULK VITRIFICATION
ICV SHELL
STARTER PATH DETAILS

F
1/2"=1'-0"

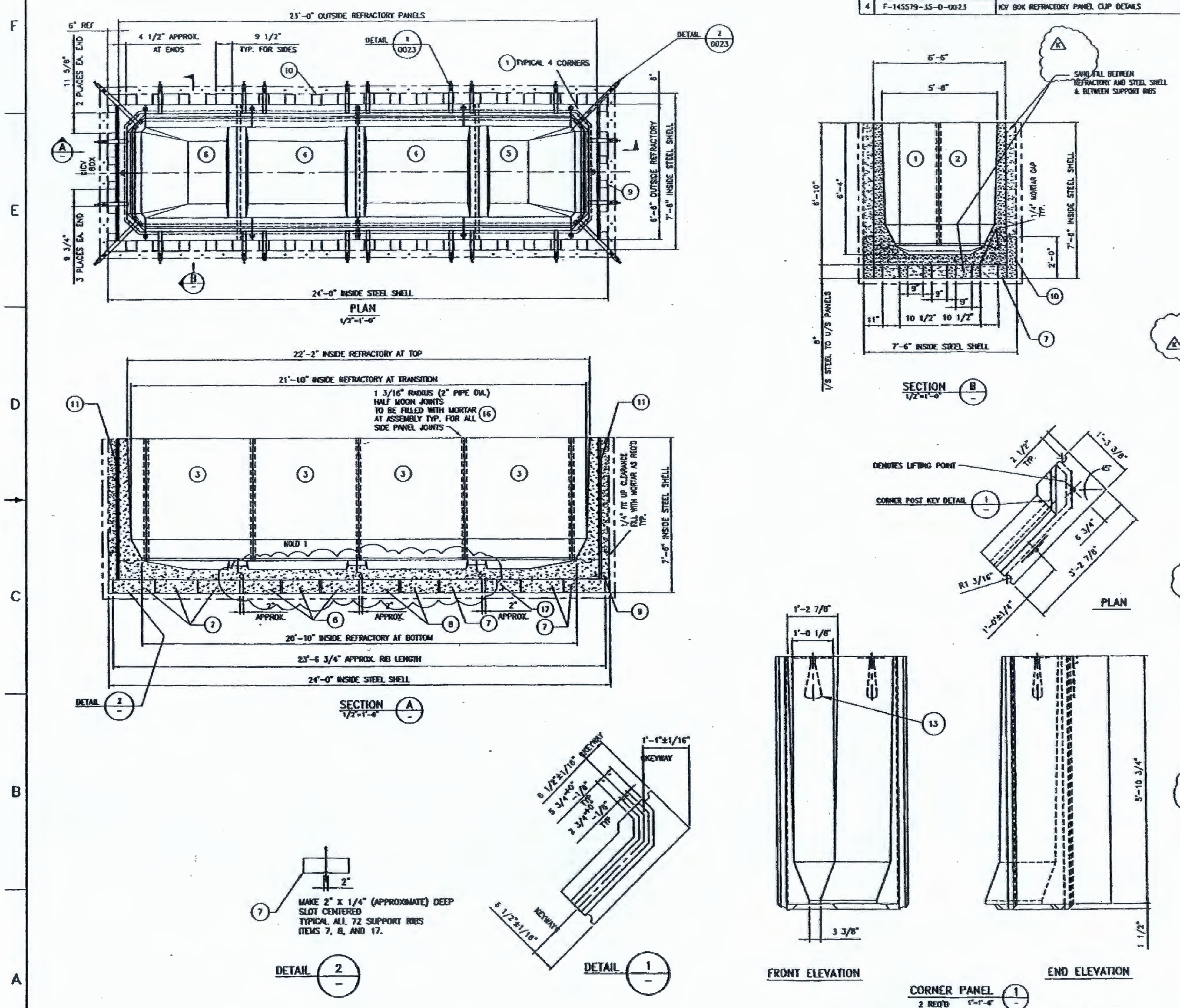
DWG NO	TITLE	REF NUMBER	TITLE
DRAWING TRACEABILITY LIST		NEXT USED ON	REFERENCES

REVISIONS

No.	AMEC Dwg. No.	REFERENCE DRAWINGS
1	F-145579-35-0-0004	ICV BOX DATA SHEET
2	F-145579-35-0-0008	ICV BOX ASSEMBLY
3	F-145579-35-0-0017	ICV BOX REFRACTORY DETAILS
4	F-145579-35-0-0023	ICV BOX REFRACTORY PANEL CLIP DETAILS

PARTS/MATERIAL LIST

ITEM	REQD	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-145579-35-0-0004.
   - 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	Approval	Approval
K	ELIMINATE PROPRIETARY INFO	20 MAR 06	RC	JM	SB	JJ
J	REVISED DIMENSIONS	06 MAR 06	SH	JM	SB	JSG
H	REVISED CORNER PANEL AND REFRACTORY JOINT	13 JAN 06	SH	SRB	KSB	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	JBM		FWS/TH	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 K

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145579-FINAL DBVS DESIGN

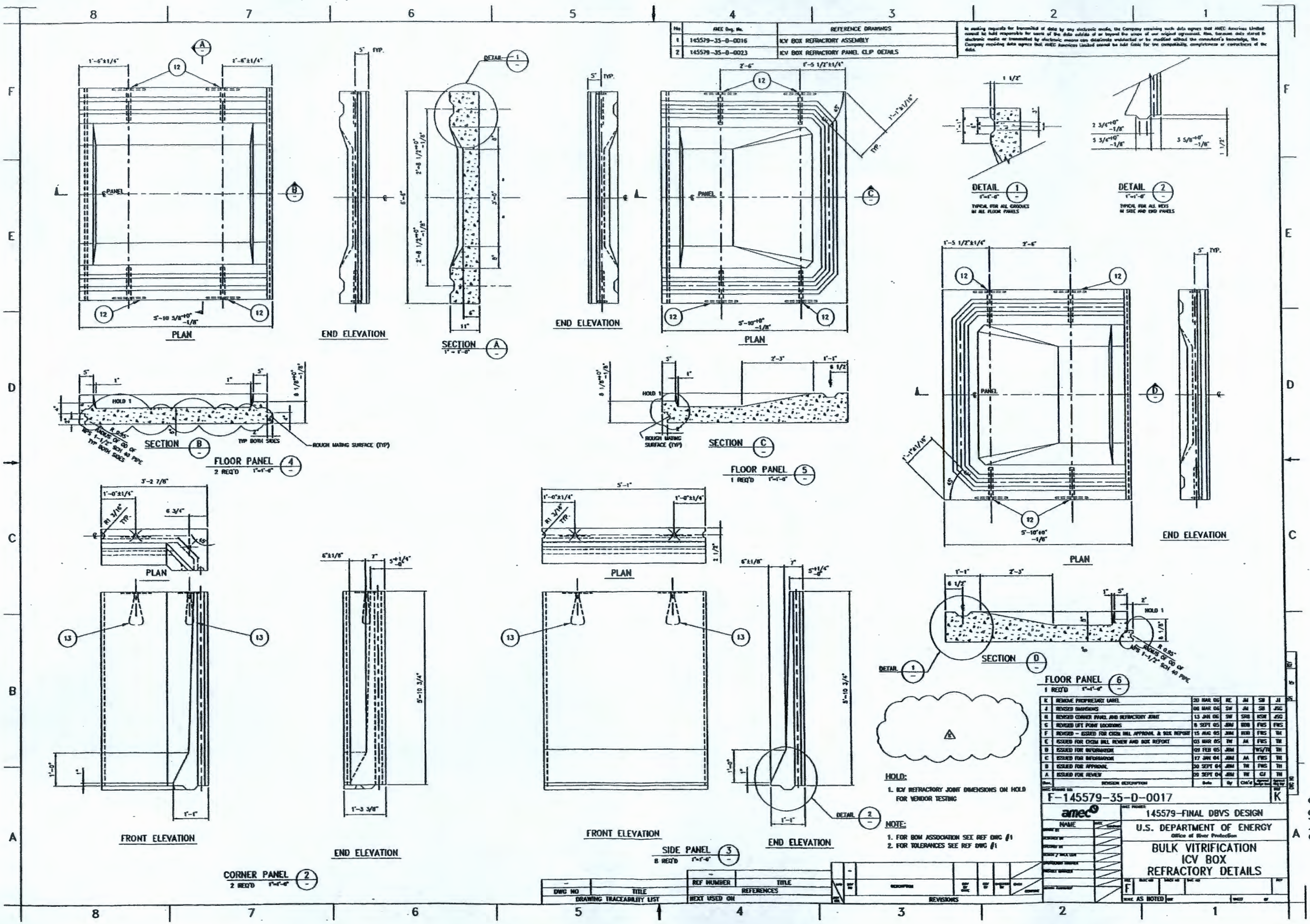
U.S. DEPARTMENT OF ENERGY
Office of River Protection

BULK VITRIFICATION
ICV BOX
REFRACTORY ASSEMBLY

SIZE F — SCALE AS NOTED

DWG NO	TITLE	REF NUMBER	TITLE
DRAWING TRACEABILITY LIST		NEXT USED ON	REFERENCES

REVISIONS


REFERENCE DRAWINGS
145579-35-D-0016 ICV BOX REFRACTORY ASSEMBLY
145579-35-D-0023 ICV BOX REFRACTORY PANEL CLIP DETAILS
PLAN
END ELEVATION
SECTION A
DETAIL 1
TYPICAL FOR ALL GROOVES IN ALL FLOOR PANELS
DETAIL 2
TYPICAL FOR ALL KEYS IN SIDE AND END PANELS
SECTION B
FLOOR PANEL 4
2 REQ'D
ROUGH MATING SURFACE (TYP)
SECTION C
FLOOR PANEL 5
1 REQ'D
SECTION D
FLOOR PANEL 6
1 REQ'D
FRONT ELEVATION
CORNER PANEL 2
2 REQ'D
SIDE PANEL 3
8 REQ'D
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 06 MAR 06
H REVISED CORNER PANEL AND REFRACTORY JOINT 13 JAN 06
G REVISED LIFT POINT LOCATIONS 8 SEPT 05
F REVISED - ISSUED FOR CIVIL BILL APPROVAL & BOX REPORT 15 AUG 05
E ISSUED FOR CIVIL BILL REVIEW AND BOX 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 29 SEPT 04
F-145579-35-D-0017 K
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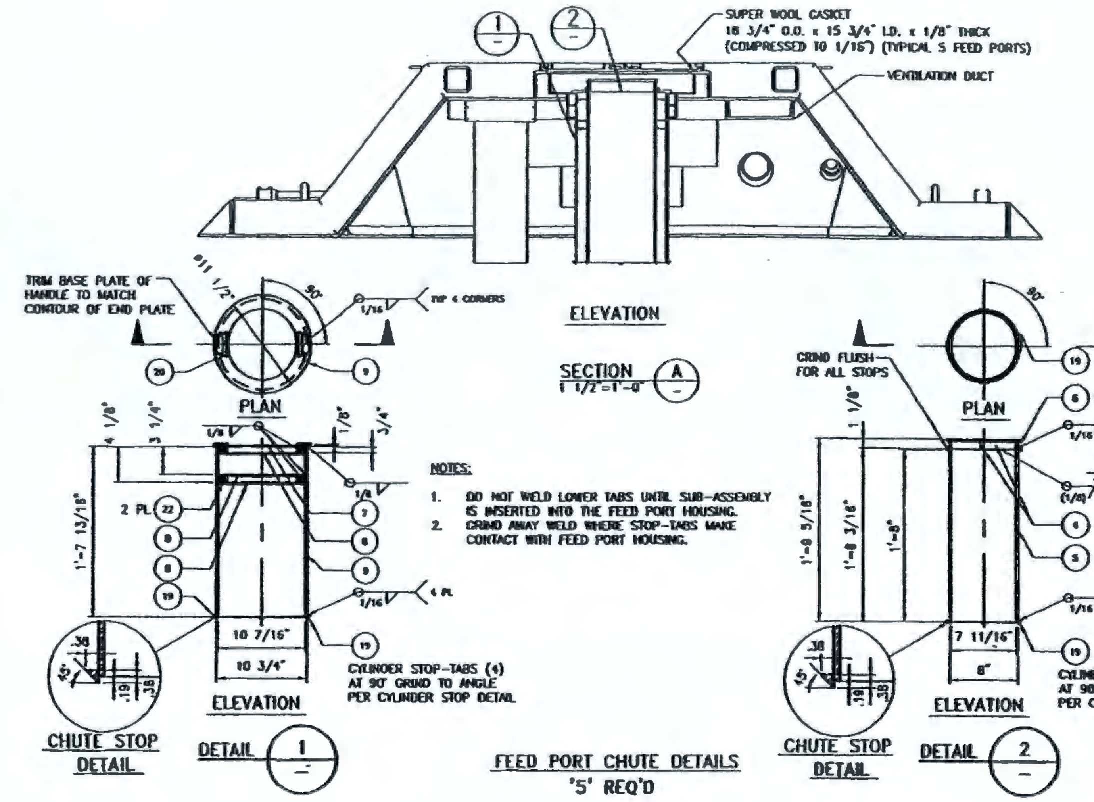
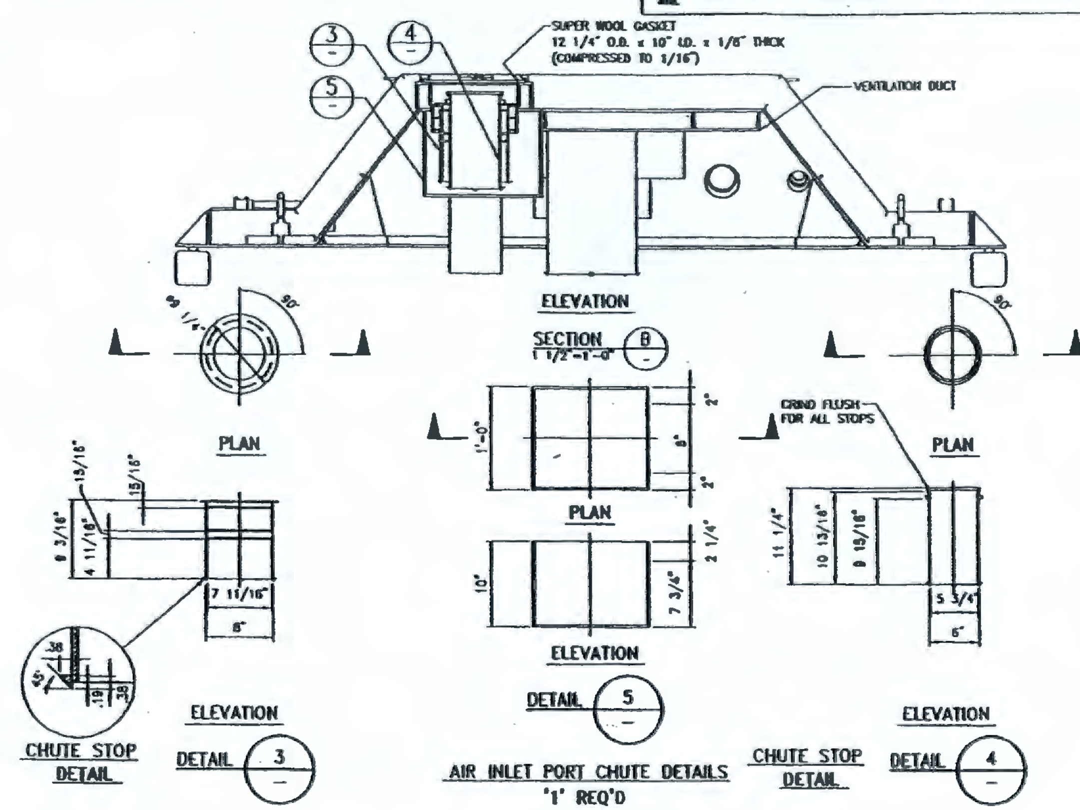
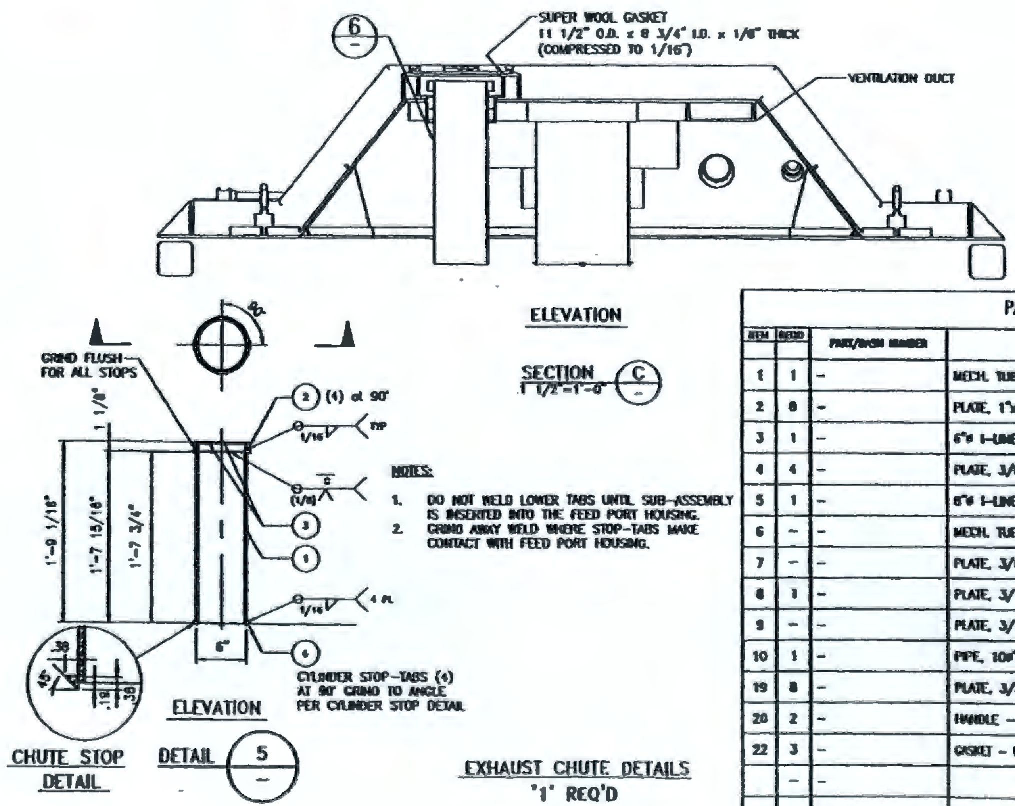
145579-FINAL DBVS DESIGN
U.S. DEPARTMENT OF ENERGY
Office of River Protection
BULK VITRIFICATION
ICV BOX
REFRACTORY DETAILS
SCALE AS NOTED
DRAWING TRACEABILITY LIST
REFERENCES
REVISIONS



FEED PORT CHUTE DETAILS
'5' REQ'D

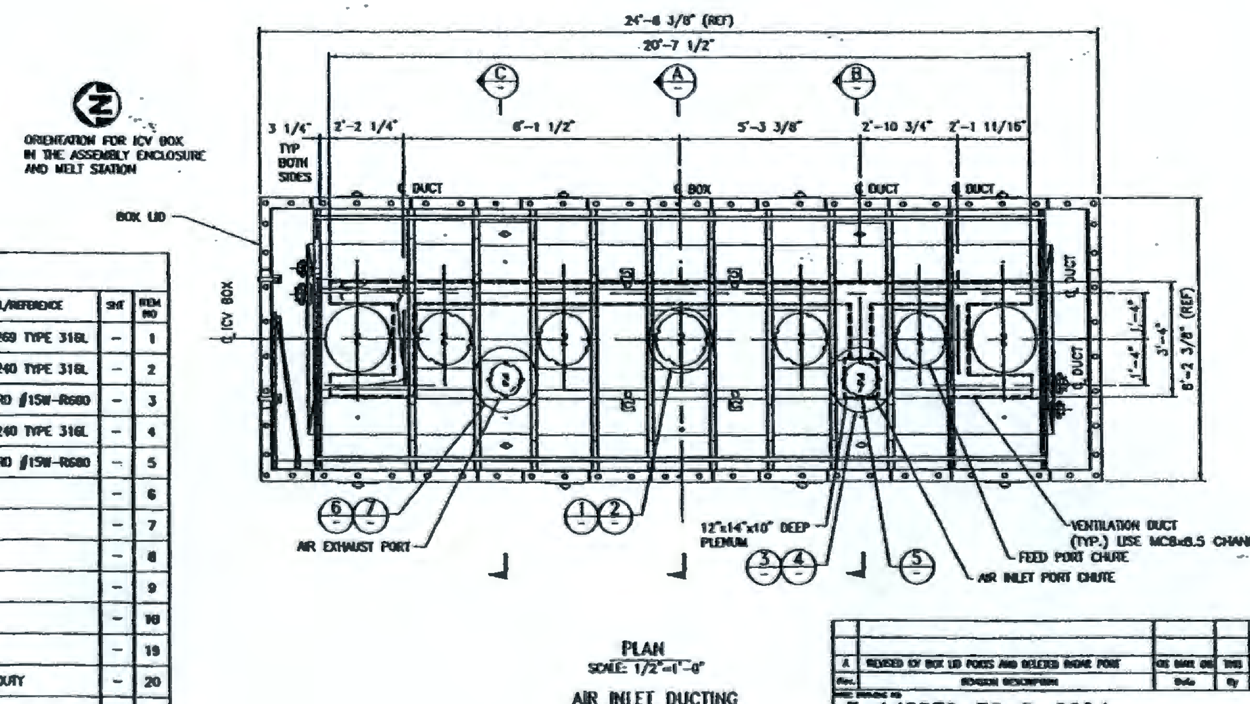


AIR INLET PORT CHUTE DETAILS
'1' REQ'D



EXHAUST CHUTE DETAILS
'1' REQ'D

PARTS/MATERIAL LIST						
ITEM	REQ'D	PART/DASH NUMBER	NOMENCLATURE/DESCRIPTION	MATERIAL/REFERENCE	SHT	ITEM NO
1	1	–	MECH. TUBE 6"Ø x.134 WALL x19.93 LG	ASTM A269 TYPE 316L	–	1
2	8	–	PLATE, 1"x3/8"x3/8"	ASTM A240 TYPE 316L	–	2
3	1	–	6"Ø I-LINE FEMALE FERRULE	BRADFORD #15W-R600	–	3
4	4	–	PLATE, 3/8"x3/8"x3/8"	ASTM A240 TYPE 316L	–	4
5	1	–	8"Ø I-LINE FEMALE FERRULE	BRADFORD #15W-R600	–	5
6	–	–	MECH. TUBE, 8Ø x.148" WALL x20.19" LG		–	6
7	–	–	PLATE, 3/8" THK x1.50"x.38"		–	7
8	1	–	PLATE, 3/16" THK x11.50" OD x8.13" ID	A36	–	8
9	–	–	PLATE, 3/16" THK x10.31" OD x8.13" ID		–	9
10	1	–	PIPE, 10Ø" SCHED 10S x 19.81" LG	A36	–	10
19	8	–	PLATE, 3/8"x3/8"x3/8"	A36	–	19
20	2	–	HANDLE – McMASTER-CARR #1647A34	HEAVY DUTY	–	20
22	3	–	GASKET – McMASTER-CARR #88185K06	2300°F, 1"Ø	–	22
	–	–			–	
		–			–	
		–			–	



PLAN
SCALE: 1/2"=1'-0"

AIR INLET DUCTING

A	REVISED ICV BOX LID PORTS AND DELETED INSIDE PORT		
REV.	REVISION DESCRIPTION	Date	By

F-145579-35-D-0024 A

amec

145579-FINAL DBVS DESIGN

U.S. DEPARTMENT OF ENERGY
Office of River Protection

BULK VITRIFICATION
ICV BOX
PORT CONNECTIONS

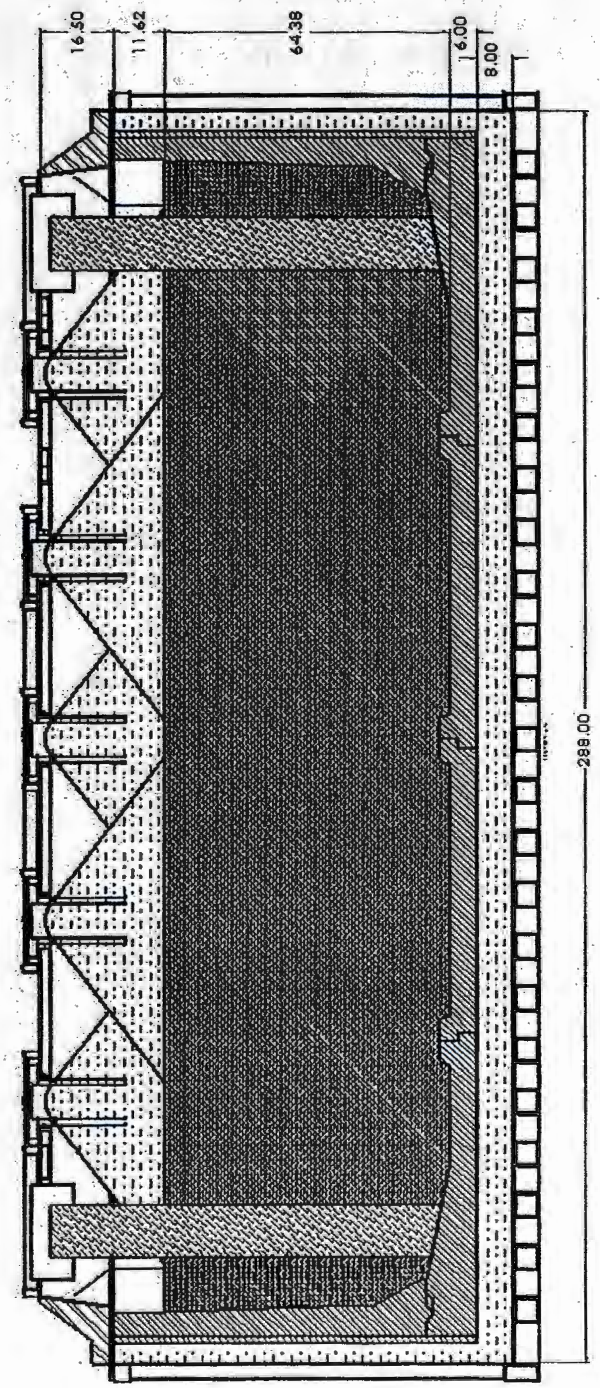
SCALE AS NOTED

DWG NO	TITLE	REF NUMBER	TITLE
DRAWING TRACEABILITY LIST		REFERENCES	
NEXT USED ON		REVISIONS	

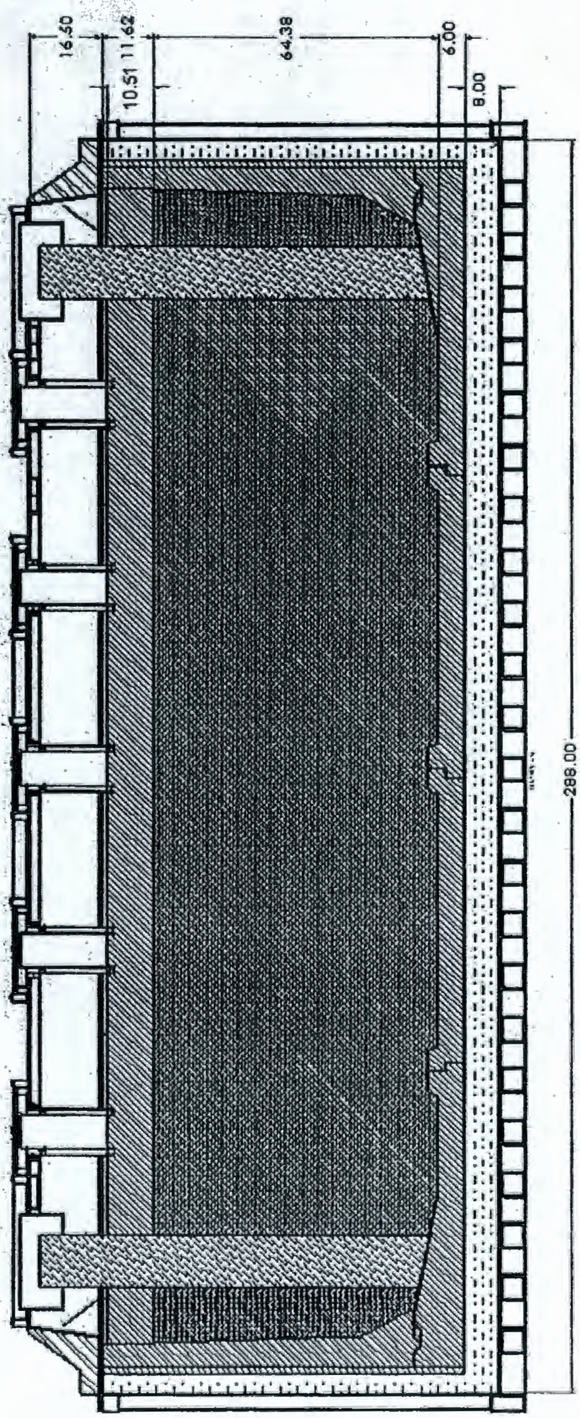
145579-D-CA-010

Attachment 12

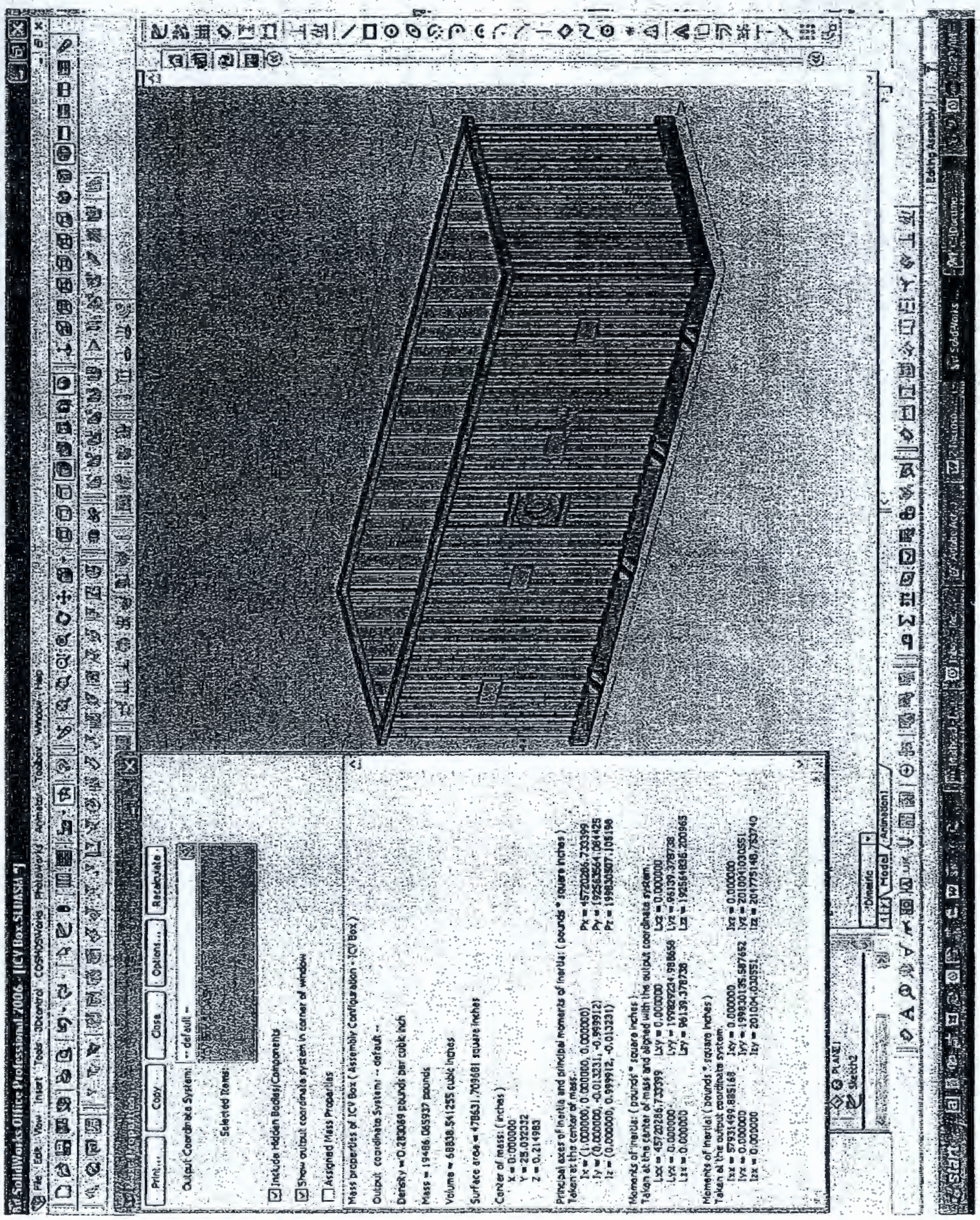
SolidWorks Model Pictures

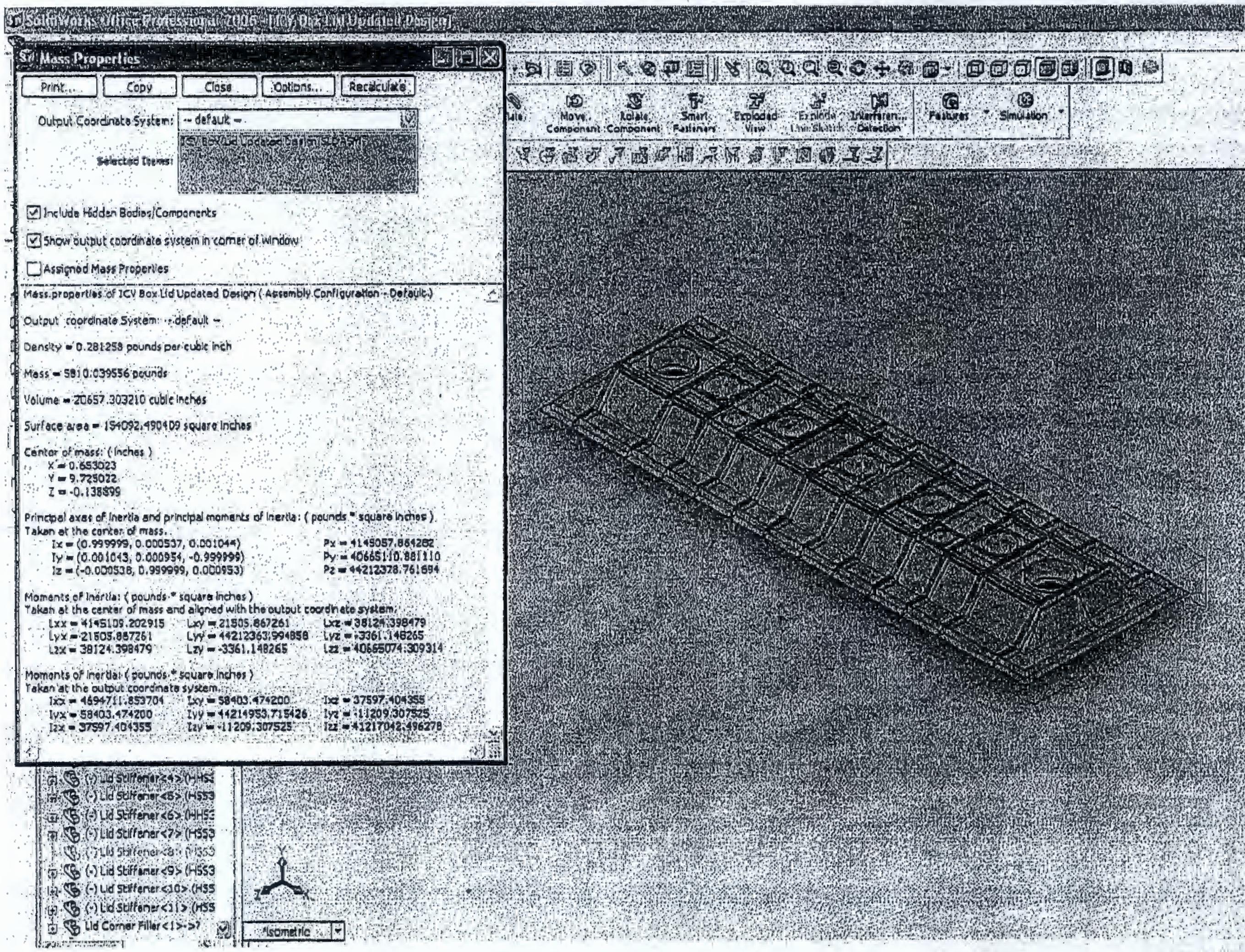


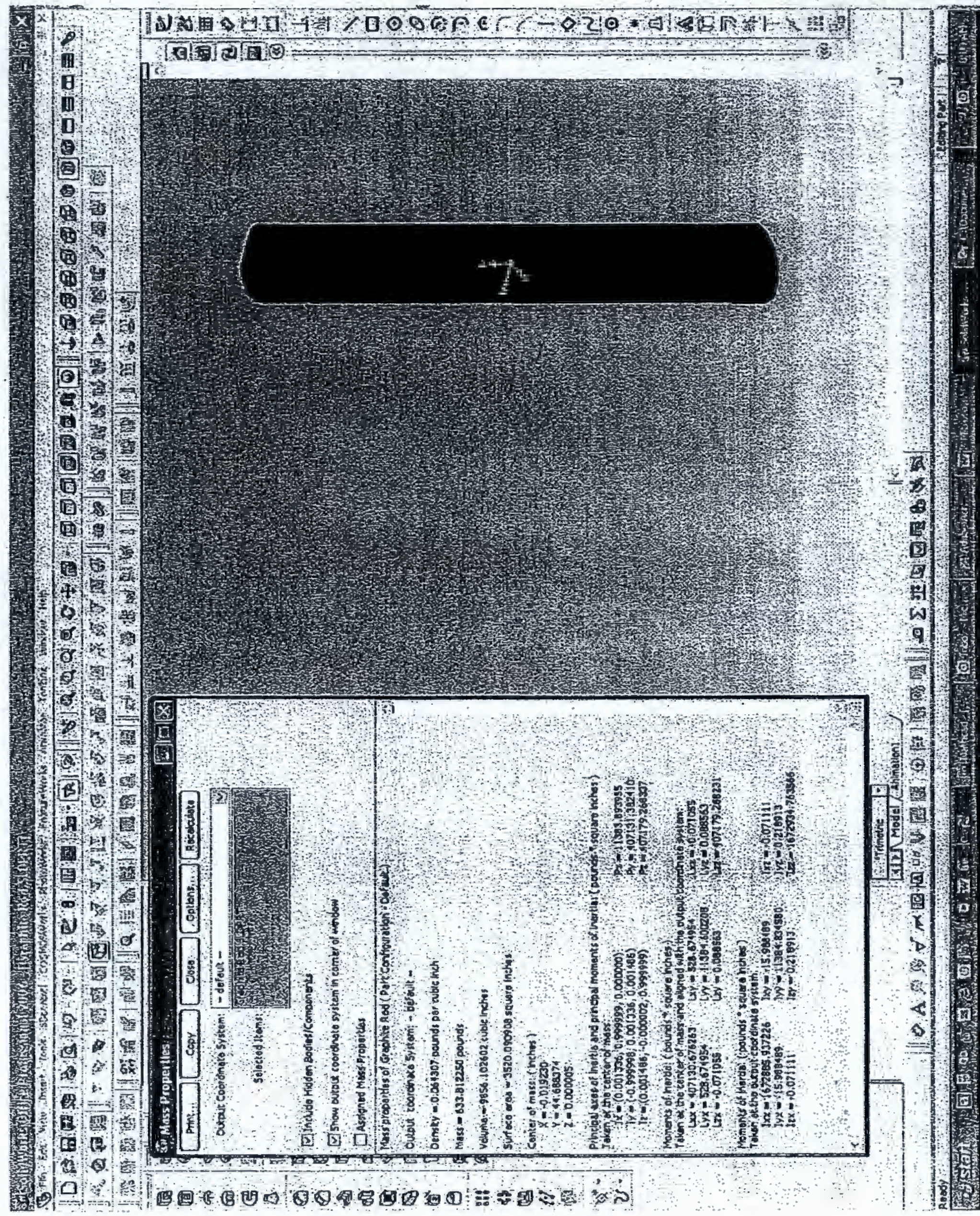
Sectional View of ICV™ Box (Top-Off Soil Cones)

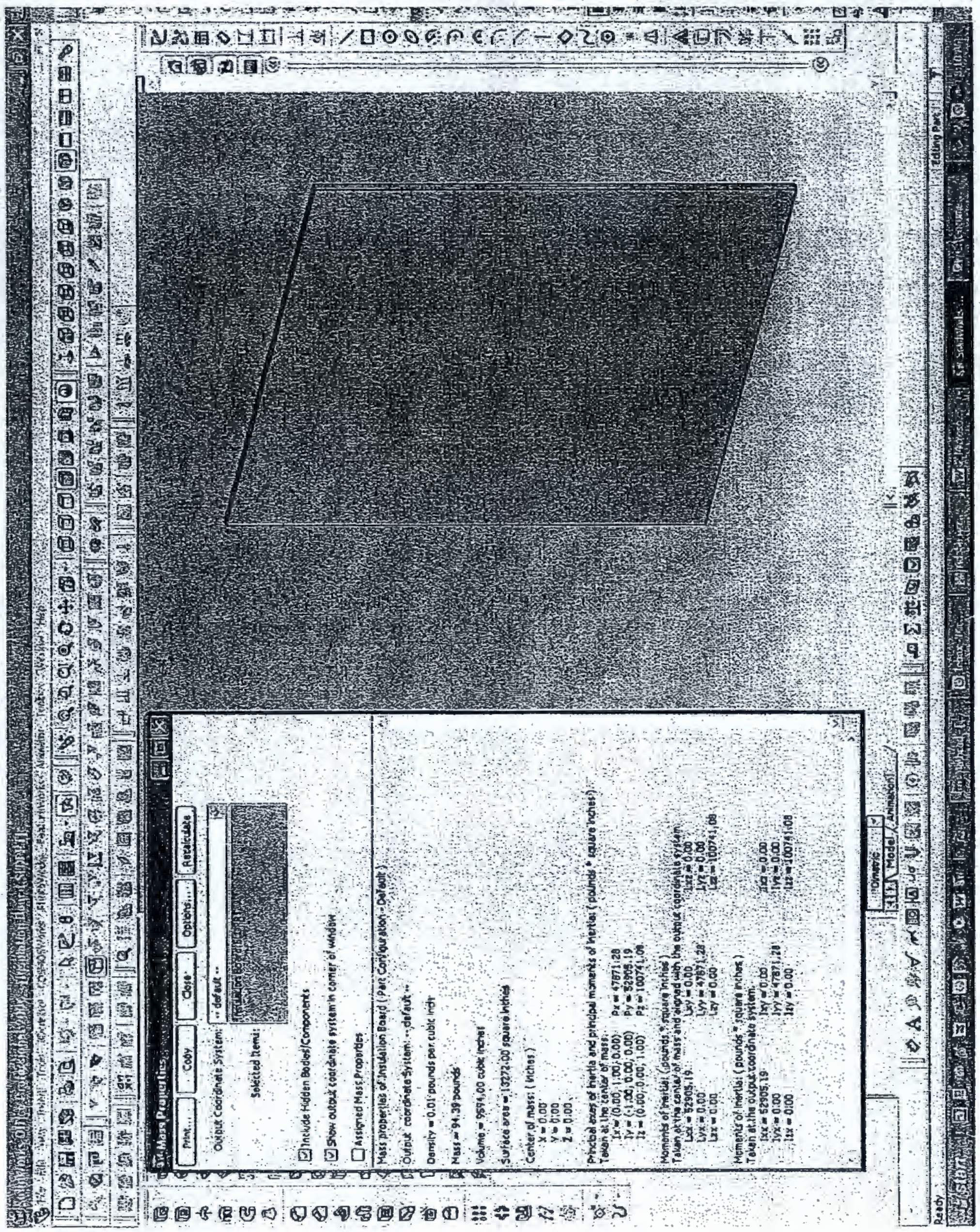


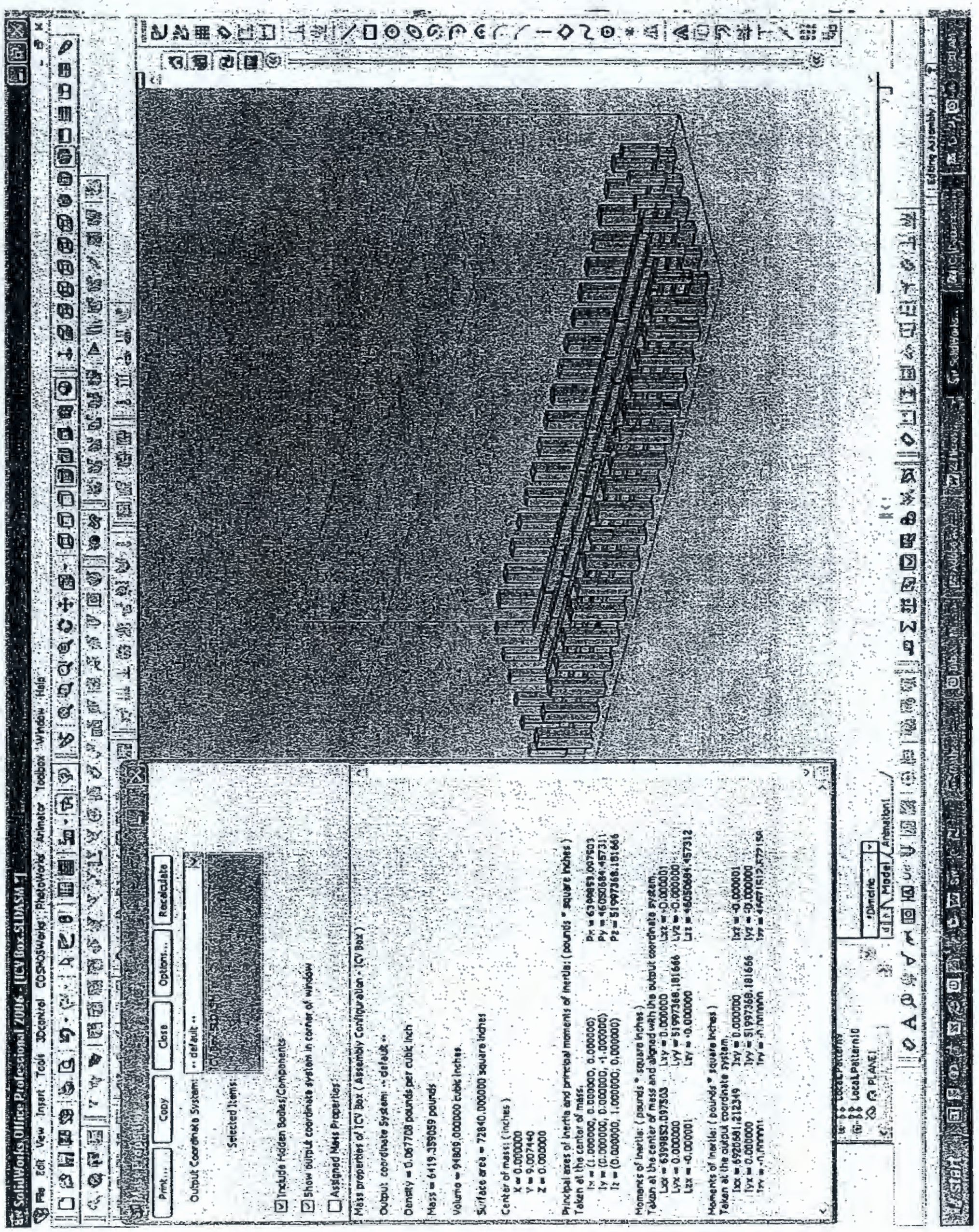
Sectional View of ICV™ Box (Settled Top-Off Soil)

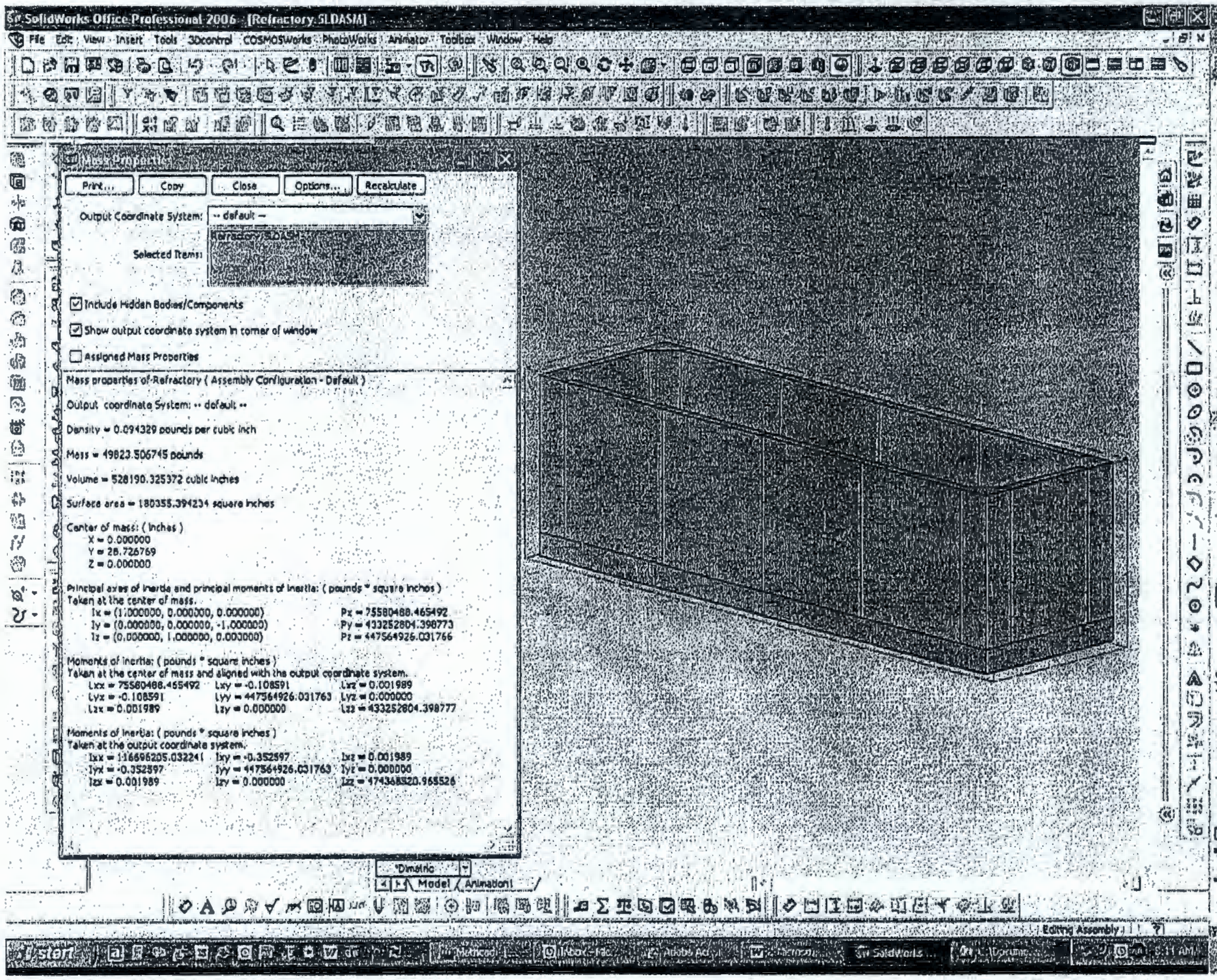

SolidWorks Office Professional 2006 - [ICV Box.SLDASM *]
Print... Copy Close Options... Recalculate
Output Coordinate System: -- default --
Selected Items:
Include Hidden Bodies/Components
Show output coordinate system in corner of window
Assigned Mass Properties
Mass properties of ICV Box (Assembly Configuration - ICV Box)
Output coordinate System: -- default --
Density = 0.283069 pounds per cubic inch
Mass = 19486.065937 pounds
Volume = 68838.541255 cubic inches
Surface area = 478631.709681 square inches
Center of mass: (inches)
X = 0.000000
Y = 25.032332
Z = 0.214983
Principal axes of inertia and principal moments of inertia: (pounds * square inches)
Taken at the center of mass.
Ix = (1.000000, 0.000000, 0.000000) Px = 45720286.733399
Iy = (0.000000, -0.013231, -0.999912) Py = 192563564.084425
Iz = (0.000000, 0.999912, -0.013231) Pz = 199830507.105198
Moments of inertia: (pounds * square inches)
Taken at the center of mass and aligned with the output coordinate system.
Lxx = 45720286.733399 Lxy = 0.000000 Lxz = 0.000000
Lyx = 0.000000 Lyy = 199829234.988658 Lyz = 96139.378738
Lzx = 0.000000 Lzy = 96139.378738 Lzz = 192564836.200965
Moments of inertia: (pounds * square inches)
Taken at the output coordinate system.
Ixx = 57931499.885168 Ixy = 0.000000 Ixz = 0.000000
Iyx = 0.000000 Iyy = 199830135.587652 Iyz = 201004.030551
Izx = 0.000000 Izy = 201004.030551 Izz = 204775148.753740
Dimetric
Model
Animation1
Editing Assembly

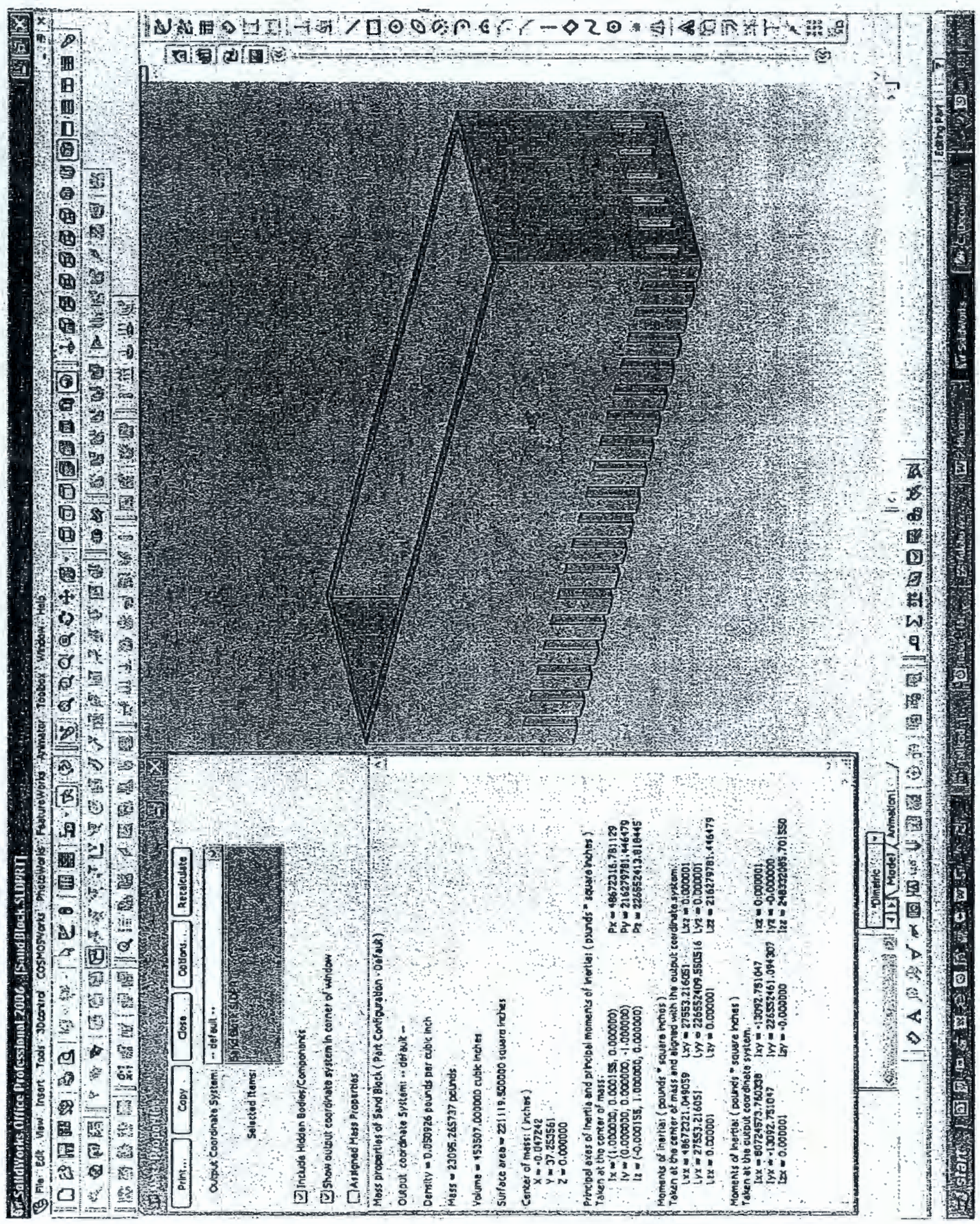

SolidWorks Office Professional 2006 - [ICV Box Lid Updated Design]
Mass Properties
Print...
Copy
Close
Options...
Recalculate
Output Coordinate System:
-- default --
Selected Items:
Include Hidden Bodies/Components
Show output coordinate system in corner of window
Assigned Mass Properties
Mass properties of ICV Box Lid Updated Design (Assembly Configuration - Default)
Output coordinate System: -- default --
Density = 0.281258 pounds per cubic inch
Mass = 5810.039556 pounds
Volume = 20657.303210 cubic inches
Surface area = 154092.490409 square inches
Center of mass: (inches)
X = 0.653023
Y = 9.725022
Z = -0.138899
Principal axes of inertia and principal moments of inertia: (pounds * square inches)
Taken at the center of mass.
Ix = (0.999999, 0.000537, 0.001044)
Px = 4145057.864282
Iy = (0.001043, 0.000954, -0.999999)
Py = 40665110.881110
Iz = (-0.000538, 0.999999, 0.000953)
Pz = 44212378.761694
Moments of inertia: (pounds * square inches)
Taken at the center of mass and aligned with the output coordinate system.
Lxx = 4145109.202915
Lxy = 21505.867261
Lxz = 38124.398479
Lyx = 21505.867261
Lyy = 44212363.994858
Lyz = -3361.148265
Lzx = 38124.398479
Lzy = -3361.148265
Lzz = 40665074.309314
Moments of inertia: (pounds * square inches)
Taken at the output coordinate system.
Ixx = 4694711.853704
Ixy = 58403.474200
Ixz = 37597.404355
Iyx = 58403.474200
Iyy = 44214953.715426
Iyz = -11209.307525
Izx = 37597.404355
Izy = -11209.307525
Izz = 41217042.496278
Move Component
Rotate Component
Smart Fasteners
Exploded View
Interference Detection
Features
Simulation
(-) Lid Stiffener<4>
(-) Lid Stiffener<5>
(-) Lid Stiffener<6>
(-) Lid Stiffener<7>
(-) Lid Stiffener<9>
(-) Lid Stiffener<10>
(-) Lid Stiffener<11>
Lid Corner Filler<1>
*Isometric

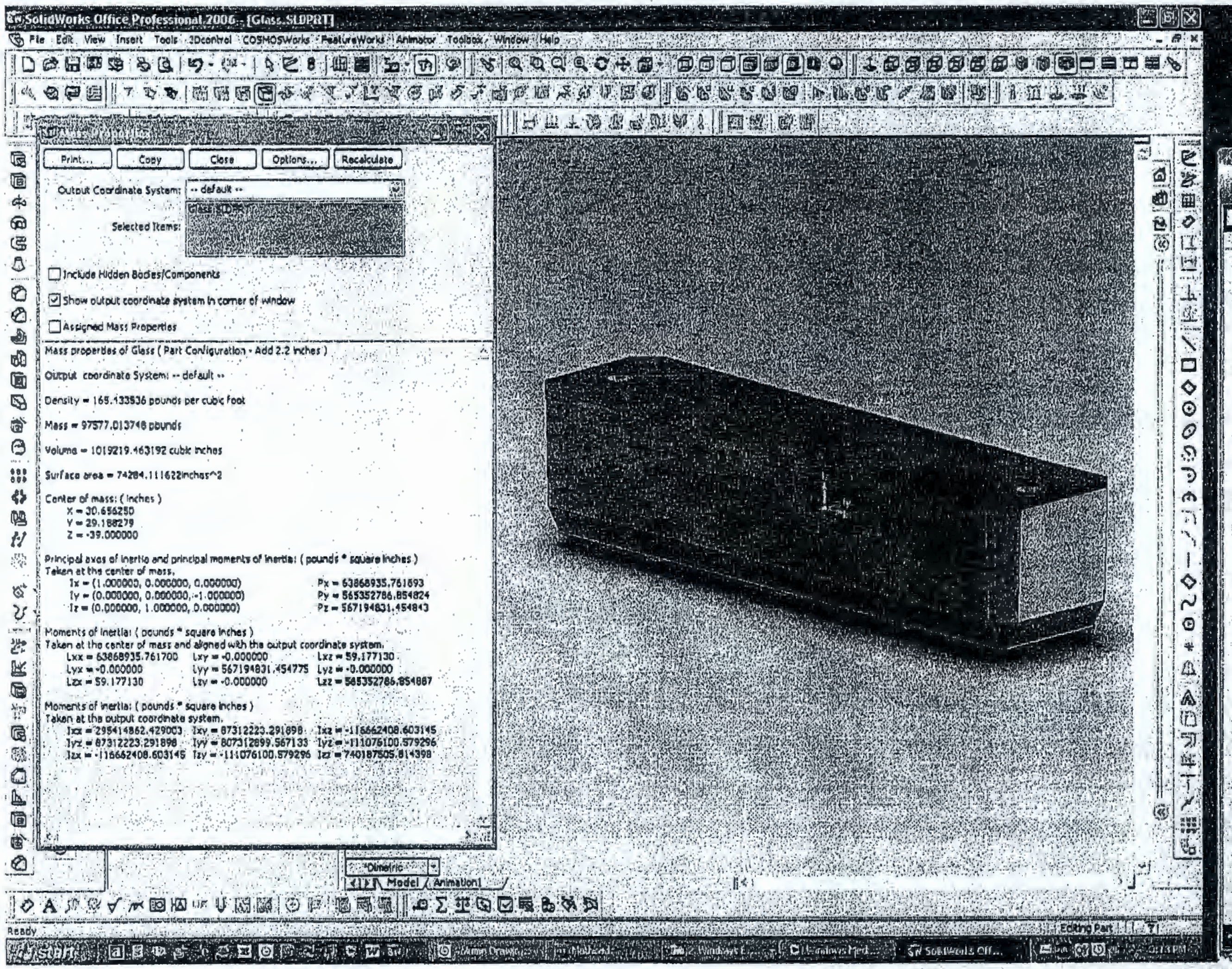

Mass Properties
Print...
Copy
Close
Options...
Recalculate
Output Coordinate System:
-- default --
Selected items:
Include Hidden Bodies/Components
Show output coordinate system in corner of window
Assigned Mass Properties
Mass properties of Graphite Rod (Part Configuration - Default)
Output coordinate System: -- default --
Density = 0.064307 pounds per cubic inch
Mass = 633.812250 pounds
Volume = 9856.102602 cubic inches
Surface area = 3520.090908 square inches
Center of mass: (inches)
X = -0.019230
Y = 44.688374
Z = 0.000005
Principal axes of inertia and principal moments of inertia: (pounds * square inches)
Taken at the center of mass.
Ix = (0.001336, 0.999999, 0.000000)
Iy = (-0.999998, 0.001336, 0.001486)
Iz = (0.001486, -0.000002, 0.999999)
Px = 11383.893955
Py = 407131.382410
Pz = 407179.268337
Moments of inertia: (pounds * square inches)
Taken at the center of mass and aligned with the output coordinate system.
Lxx = 407130.676263
Lxy = 528.674954
Lxz = -0.071055
Lyx = 528.674954
Lyy = 11384.600208
Lyz = 0.088563
Lzx = -0.071055
Lzy = 0.088563
Lzz = 407179.268231
Moments of inertia: (pounds * square inches)
Taken at the output coordinate system.
Ixx = 1672885.937226
Ixy = -15.988489
Ixz = -0.071111
Iyx = -15.988489
Iyy = 11384.834580
Iyz = 0.218913
Izx = -0.071111
Izy = 0.218913
Izz = 1672934.763566
Trimetric
Model
Animation1
Ready
Editing Part
start

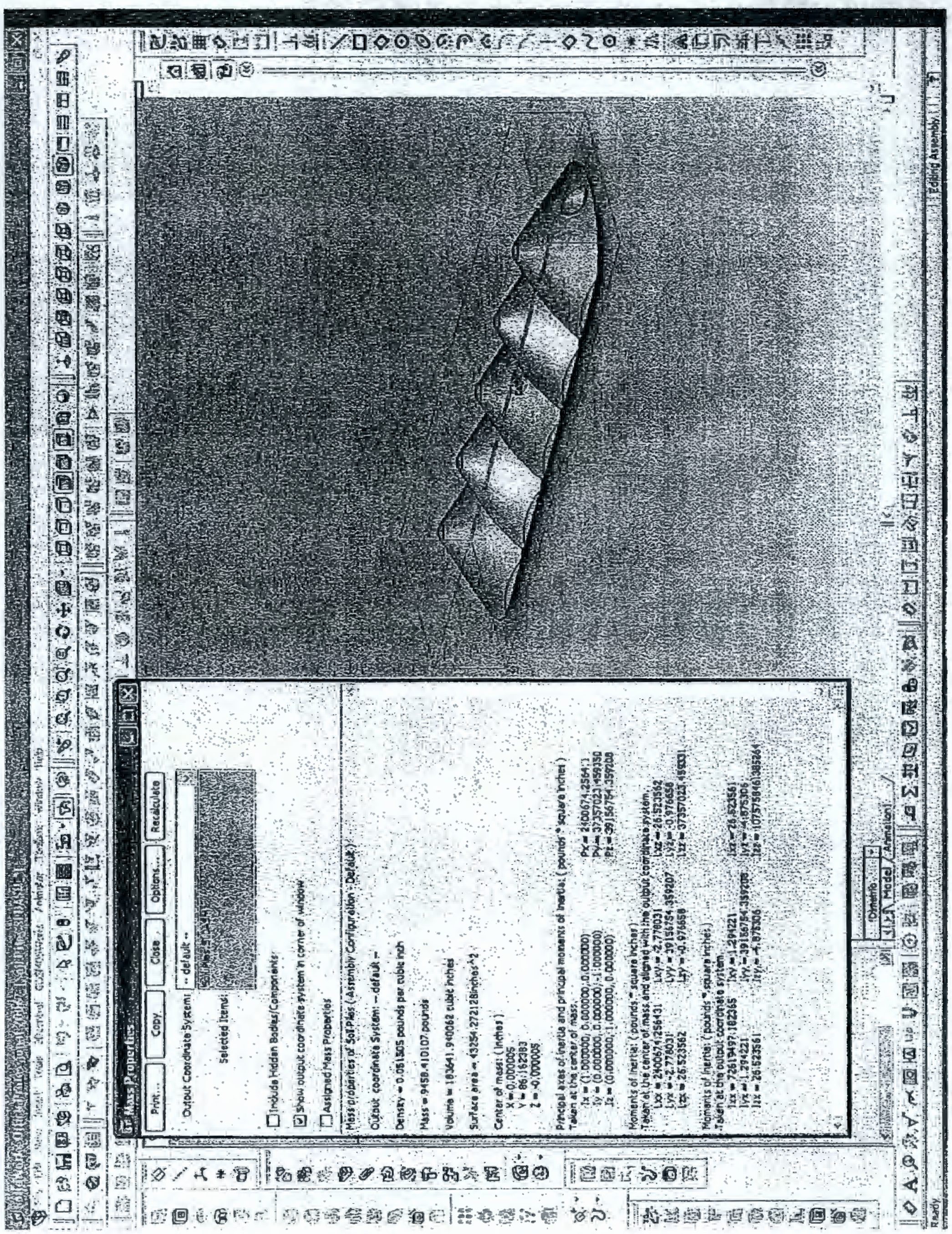

Mass Properties
Print...
Copy
Close
Options...
Recalculate
Output Coordinate System: -- default --
Selected Items:
Include Hidden Bodies/Components
Show output coordinate system in corner of window
Assigned Mass Properties
Mass properties of Insulation Board (Part Configuration - Default)
Output coordinate System: -- default --
Density = 0.01 pounds per cubic inch
Mass = 94.39 pounds
Volume = 9594.00 cubic inches
Surface area = 13272.00 square inches
Center of mass: (inches)
X = 0.00
Y = 0.00
Z = 0.00
Principal axes of inertia and principal moments of inertia: (pounds * square inches)
Taken at the center of mass.
Ix = (0.00, 1.00, 0.00) Px = 47871.28
Iy = (-1.00, 0.00, 0.00) Py = 52905.19
Iz = (0.00, 0.00, 1.00) Pz = 100741.08
Moments of inertia: (pounds * square inches)
Taken at the center of mass and aligned with the output coordinate system.
Lxx = 52905.19 Lxy = 0.00 Lxz = 0.00
Lyx = 0.00 Lyy = 47871.28 Lyz = 0.00
Lzx = 0.00 Lzy = 0.00 Lzz = 100741.08
Moments of inertia: (pounds * square inches)
Taken at the output coordinate system.
Ixx = 52905.19 Ixy = 0.00 Ixz = 0.00
Iyx = 0.00 Iyy = 47871.28 Iyz = 0.00
Izx = 0.00 Izy = 0.00 Izz = 100741.08
Dimetric
Model
Animation1
Ready
Editing Part


SolidWorks Office Professional 2006 - [ICV Box.SLDASM *]
File Edit View Insert Tools 3Dcontrol COSMOSWorks PhotoWorks Animator Toolbox Window Help
Print... Copy Close Options... Recalculate
Output Coordinate System: -- default --
Selected Items:
Include Hidden Bodies/Components
Show output coordinate system in corner of window
Assigned Mass Properties
Mass properties of ICV Box (Assembly Configuration - ICV Box)
Output coordinate System: -- default --
Density = 0.067708 pounds per cubic inch
Mass = 6419.359059 pounds
Volume = 94809.000000 cubic inches
Surface area = 72840.000000 square inches
Center of mass: (inches)
X = 0.000000
Y = 9.007440
Z = 0.000000
Principal axes of inertia and principal moments of inertia: (pounds * square inches)
Taken at the center of mass.
Ix = (1.000000, 0.000000, 0.000000) Px = 6399853.097503
Iy = (0.000000, 0.000000, -1.000000) Py = 46050684.457311
Iz = (0.000000, 1.000000, 0.000000) Pz = 51997368.181666
Moments of inertia: (pounds * square inches)
Taken at the center of mass and aligned with the output coordinate system.
Lxx = 6399853.097503 Lxy = 0.000000 Lxz = -0.000001
Lyx = 0.000000 Lyy = 51997368.181666 Lyz = -0.000000
Lzx = -0.000001 Lzy = -0.000000 Lzz = 46050684.457312
Moments of inertia: (pounds * square inches)
Taken at the output coordinate system.
Ixx = 6920581.212349 Ixy = 0.000000 Ixz = -0.000001
Iyx = 0.000000 Iyy = 51997368.181666 Iyz = -0.000000
LocalPattern10
PLANE1
*Dimetric
Model Animation1
Editing Assembly


SolidWorks Office Professional 2006 - [Refractory.SLDASM]
Mass Properties
Print... Copy Close Options... Recalculate
Output Coordinate System: -- default --
Selected Items: Refractory.SLDASM
Include Hidden Bodies/Components
Show output coordinate system in corner of window
Assigned Mass Properties
Mass properties of Refractory (Assembly Configuration - Default)
Output coordinate System: -- default --
Density = 0.094329 pounds per cubic inch
Mass = 49823.506745 pounds
Volume = 528190.325372 cubic inches
Surface area = 180355.394234 square inches
Center of mass: (inches)
X = 0.000000
Y = 28.726769
Z = 0.000000
Principal axes of inertia and principal moments of inertia: (pounds * square inches)
Taken at the center of mass.
Ix = (1.000000, 0.000000, 0.000000) Px = 75580488.465492
Iy = (0.000000, 0.000000, -1.000000) Py = 433252804.398773
Iz = (0.000000, 1.000000, 0.000000) Pz = 447564926.031766
Moments of inertia: (pounds * square inches)
Taken at the center of mass and aligned with the output coordinate system.
Lxx = 75580488.465492 Lxy = -0.108591 Lxz = 0.001989
Lyx = -0.108591 Lyy = 447564926.031763 Lyz = 0.000000
Lzx = 0.001989 Lzy = 0.000000 Lzz = 433252804.398777
Moments of inertia: (pounds * square inches)
Taken at the output coordinate system.
Ixx = 116696205.032241 Ixy = -0.352597 Ixz = 0.001989
Iyx = -0.352597 Iyy = 447564926.031763 Iyz = 0.000000
Izx = 0.001989 Izy = 0.000000 Izz = 474368520.965526
*Dimetric
Model Animation1
Editing Assembly
start


SolidWorks Office Professional 2006 - [Sand Block.SLDPRT]
Print... Copy Close Options... Recalculate
Output Coordinate System: -- default --
Selected Items:
Include Hidden Bodies/Components
Show output coordinate system in corner of window
Assigned Mass Properties
Mass properties of Sand Block (Part Configuration - Default)
Output coordinate System: -- default --
Density = 0.050926 pounds per cubic inch
Mass = 23095.265737 pounds
Volume = 453507.000000 cubic inches
Surface area = 221119.500000 square inches
Center of mass: (inches)
X = -0.047242
Y = 37.253561
Z = 0.000000
Principal axes of inertia and principal moments of inertia: (pounds * square inches)
Taken at the center of mass.
Ix = (1.000000, 0.000155, 0.000000) Px = 48672316.781129
Iy = (0.000000, 0.000000, -1.000000) Py = 216279781.446479
Iz = (-0.000155, 1.000000, 0.000000) Pz = 226552413.818445
Moments of inertia: (pounds * square inches)
Taken at the center of mass and aligned with the output coordinate system.
Lxx = 48672321.049059 Lxy = 27553.216051 Lxz = 0.000001
Lyx = 27553.216051 Lyy = 226552409.550516 Lyz = 0.000001
Lzx = 0.000001 Lzy = 0.000001 Lzz = 216279781.446479
Moments of inertia: (pounds * square inches)
Taken at the output coordinate system.
Ixx = 80724573.760338 Ixy = -13092.751047 Ixz = 0.000001
Iyx = -13092.751047 Iyy = 226552461.094307 Iyz = -0.000000
Izx = 0.000001 Izy = -0.000000 Izz = 248332085.701550
Dimetric
Model Animation1
Editing Part


SolidWorks Office Professional 2006 - [Glass.SLDPRT]
File Edit View Insert Tools 2Dcontrol COSMOSWorks FeatureWorks Animator Toolbox Window Help
Print... Copy Close Options... Recalculate
Output Coordinate System: -- default --
Selected Items:
Include Hidden Bodies/Components
Show output coordinate system in corner of window
Assigned Mass Properties
Mass properties of Glass (Part Configuration - Add 2.2 inches)
Output coordinate System: -- default --
Density = 165.133536 pounds per cubic foot
Mass = 97577.013748 pounds
Volume = 1019219.463192 cubic inches
Surface area = 74284.111622inches^2
Center of mass: (inches)
X = 30.656250
Y = 29.188279
Z = -39.000000
Principal axes of inertia and principal moments of inertia: (pounds * square inches)
Taken at the center of mass.
Ix = (1.000000, 0.000000, 0.000000) Px = 63868935.761693
Iy = (0.000000, 0.000000, -1.000000) Py = 565352786.854824
Iz = (0.000000, 1.000000, 0.000000) Pz = 567194831.454843
Moments of inertia: (pounds * square inches)
Taken at the center of mass and aligned with the output coordinate system.
Lxx = 63868935.761700 Lxy = -0.000000 Lxz = 59.177130
Lyx = -0.000000 Lyy = 567194831.454775 Lyz = -0.000000
Lzx = 59.177130 Lzy = -0.000000 Lzz = 565352786.854887
Moments of inertia: (pounds * square inches)
Taken at the output coordinate system.
Ixx = 295414862.429003 Ixy = 87312223.291898 Ixz = -116662408.603145
Iyx = 87312223.291898 Iyy = 807312899.567133 Iyz = -111076100.579296
Izx = -116662408.603145 Izy = -111076100.579296 Izz = 740187505.814398
*Dimetric
Model Animation1
Editing Part
Ready
start


Mass Properties
Print...
Copy
Close
Options...
Recalculate
Output Coordinate System:
-- default --
Selected Items:
Include Hidden Bodies/Components
Show output coordinate system in corner of window
Assigned Mass Properties
Mass properties of Soil Piles (Assembly Configuration - Default)
Output coordinate System: -- default --
Density = 0.051505 pounds per cubic inch
Mass = 9458.410107 pounds
Volume = 183641.940062 cubic inches
Surface area = 43254.272128inches^2
Center of mass: (inches)
X = 0.000005
Y = 86.162383
Z = -0.000005
Principal axes of inertia and principal moments of inertia: (pounds * square inches)
Taken at the center of mass.
Moments of inertia: (pounds * square inches)
Taken at the center of mass and aligned with the output coordinate system.
Moments of inertia: (pounds * square inches)
Taken at the output coordinate system.
Model
Animation1
Ready
Editing Assembly

145579-D-CA-010

Attachment 13

Email Garfield, J.S. to Van Corbach, J., "Feed Volume Material."

Attachment: 13 Calc No: 145579-D-CA-010 Rev.0

From: Garfield, John S [mailto:John.Garfield@amec.com]
Sent: Monday, February 13, 2006 11:42 AM
To: Van Corbach, James
Cc: Frederickson, Jim; Luey, Ja-Kael; Jeffers, Wilfred C (Jeff); Reddick, Julie; Witwer, Keith S
Subject: FW: Feed Material Volumes

James,
Since your last update of the topoff soil we decided to add a 9th batch per a STCS that results in 2.2" of glass above the previous "full" level. Can you update solid works and these files for me?

Thanks,

John Garfield

145579-D-CA-010

<u>Attachment 14</u>

STCS# 22

#22

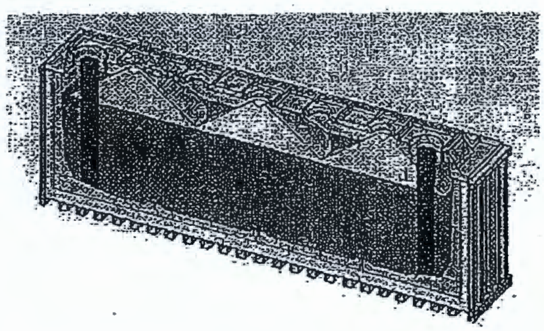
Bulk Vit – Suggestion to Change Something (STCS)

Title: ICV Box Soil Cover (9th and 10th Batch)
Date: 12/02/05
Author: John Garfield (AMEC)

Description of Change:
Introduction – The current DBVS baseline adds clean top-off to the melt and the end of vitrification for shielding purposes. The mounds of soil are equivalent in shielding value to 10" of soil evenly distributed. The baseline has three drawbacks.

1. Additional shielding is required to mitigate sky-shine from the box storage area equivalent to 19" of soil evenly distributed. Where and how to make this addition has been a design issue to be resolved.
2. The three mounds represent the maximum amount of soil that can be added through the top-off chutes. However, the mounds do not cover the entire melt surface. Direct shine paths during the disconnect activities exist and contribute to extremity doses that are difficult to calculate.

Lastly the disposal criteria require a maximum of 10% void volume in the disposed package; another reason for material addition beyond the three mounds of top-off soil.

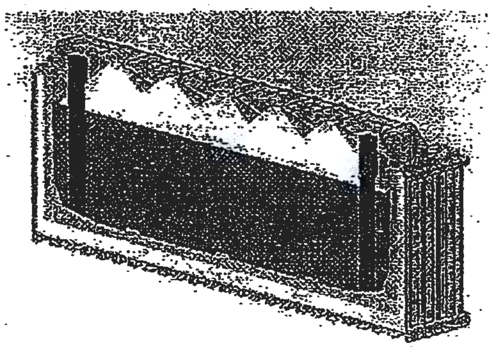


Background – A number of concepts have been entertained and rejected to add additional material for shielding and the void space;

- Marbles would have a better angle of repose but were rejected on cost
- Grout adds water to a hot melt and results in a steam release. Grout could be an option for a cool box however, there are issues with the chemistry of the glass and impacts on the performance assessment that would require low PH materials.
- Box shakers threaten the integrity of the full box at temperature
- Soil distribution concepts (slingers) have been discounted because of complexity.

1

Benefits and/or Justification:
The portion of the uncovered melt can be dealt with by adding additional top-off soil through the dryer and dried waste feed chutes such that soil cover is added through all 5 ports above the box. No new equipment or testing is required to implement this suggestion from a mechanical or control system standpoint. However, an interface with other test exists to confirm the shielding and PA impacts.



The decision factors include the following points.
Pro's

1. ALARA Benefit - Addition of 5 batches of top-off soil instead of three improves shielding and may reduce or eliminate the need for additional material to mitigate sky shine as discussed in item 2. This assertion will be confirmed during the revision of the Shielding Calc and the ALARA analysis. The disconnect activities will also benefit from a reduced exposure to workers. This is likely a key to the viability of the AWTE redesign and mock-up.
2. 5 mounds of soil cover instead of three will help mitigate the sky shine concern without the addition of more shielding. Assuming the mounds are leveled, 3 mounds equate to 11.25" and 5 mounds equates to 15".
3. The 5 mounds solve the 10% maximum void space issue in the disposal criteria. The ICV is filled to 92% of the volume with the 5 mounds using a conservative 37° angle of repose. The Soil vendor quoted a 30° angle of repose.
4. There is a minor benefit in keeping residue build-up in the dryer and transfer system minimal for maintenance and ALARA.

Other Information:
Con's

1. Top-off soil added through the dryer and feed chutes would not contain any new liquid feed. However, the soil would carry contaminated residue from the dryer and transfer lines that would not be incorporated into the melt. It is unlikely that this contribution to the unincorporated inventory would affect the PA. Tracers per item 2 below (interfacing STCS) could provide data to substantiate this.
2. The box weight Calc would be impacted by the additional soil and a revision would be necessary. The impact is minimal.

3. An operational means of estimating the volume of soil to be added in the 9th and 10th batches will have to be addressed as a procedural issue. Note: the purpose of the 9th batch is a test item intended to insure full incorporation of the 8th batch containing feed.

Interfacing STCS

1. **9th Batch STCS** - Addition of the 9th batch is a separate STCS that will be addressed after the next full scale test. The 9th batch will effectively clean the dryer and transfer lines of residual contamination. It will also be incorporated in the melt to a large degree. This means the 10th batch (top-off soil for shielding) would be relatively contamination free and the PA impact will be negligible. Tracers per item 2 below could provide data to substantiate this.
2. **Full Scale Dryer Testing STCS** - Use of tracers in a full scale test will provide a flowsheet basis for estimating unincorporated contamination in the 10th batch. In the absence of the full scale test, a bench scale test may provide an adequate basis to predict contamination carryover.

ROM Cost Impacts:
1. Revise box weight Calc (DMJM) – 5K
2. Estimate unincorporated Residue and interface with PA (AMEC / CH2M Hill)
3. Revise shielding Calc, ALARA analysis (already in budget)

Potential Schedule Impacts: None

Supported:

Shuford	(Yes) No N/A	Comments:
Hoffman	(Yes) No N/A	Comments:
Miera	(Yes) No N/A	Comments:
True	(Yes) No N/A	Comments:
Rieck	(Yes) No N/A	Comments:
Garner	Yes No N/A	Comments: AMEC Proposal

Approved: AE Van Beek 12/28/05 Denied: ____________
Van Beek Van Beek

Actions to Implement: Execute items 1 and 2 under cost impacts

145579-D-CA-010

Attachment 15

SolidWorks 2006 SP0.0 V&V for Computer 9ZTRH31

ATTACHMENT 15
CALCULATION NO. 145579-D-CA-010
REVISION NO. 0
SHEET 1 OF 1

DMJM technology

VERIFICATION & VALIDATION REVIEW AND APPROVAL FORM

SOFTWARE TITLE	DMJM H+N SOFTWARE ID NO.	DMJM H+N COMPUTER ID NO.
SolidWorks 2006, SP0.0		102561 / 9ZTRH31

VALIDATION PERFORMED BY (Print Name/Sign): James Van Corbach **DATE:** October 12, 2005

PURPOSE AND SCOPE OF VALIDATION:

PURPOSE:
The purpose of this verification and validation is to ensure SolidWorks produces reliable volume data consistent with standard geometric equations.

SCOPE:
The scope of this verification and validation includes a volume analysis of a sphere, right cone, and tube.

REQUIREMENTS FOR SOFTWARE (INPUT RANGE, ETC):
None.

REV.	AFFECTED PAGES	REVISION DESCRIPTION	PREPARER	APPROVED BY	DATE:
0	All	Initial V & V	James Van Corbach	[signature]	10/14/05

DESCRIPTION OF SOFTWARE/USE:
Software can be used to determine heating and cooling loads for simple and complex buildings and building systems, including multiple zone buildings, constant volume systems, VAV systems, heating only, or cooling only.

ORIGIN OF SOFTWARE: Elite Software Development, Inc.

REVISION	DOCUMENT NUMBER	TITLE	DATE	

METHOD OF SOFTWARE VALIDATION

A. ☐ COMPARE TO HAND CALCULATIONS
B. ☒ COMPARE TO VALIDATED COMPUTER ANALYSIS RESULTS
C. ☐ OTHER (DESCRIBE):

METHOD OF HARDWARE VALIDATION

A. ☐ COMPARE TO HAND CALCULATIONS
B. ☐ COMPARE TO VALIDATED COMPUTER ANALYSIS RESULTS
C. ☐ OTHER (DESCRIBE):

RESULTS: The Verification and Validation of SolidWorks 2006 on DMJMH+N computer # 102561 is acceptable.

ATTACHMENTS

Attachment	Name	Sheets
A	Calculation of Volumes Using Standard Geometric Equations	1
B	SolidWorks Mass Properties Screenshots	3

Total number of pages of this V&V, including cover sheets and attachments – 6

DMJM technology

CALCULATION PROCEDURE CHECKLIST

Calculation Number: 145579-D-CA-010 Revision 0

#	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.	JJ / 3/22/06
2	The calculation has been prepared using the forms associated with this procedure (i.e., calculation cover sheet, summary sheet, and calculation sheet).	JJ / 3/22
3	The calculation has been formatted per this procedure (header, page number, etc).	JJ / 3/22
4	The appropriate revision number has been assigned.	JJ / 3/22
5	The discipline lead of affected documents has been notified of any changes.	JJ / 3/22
6	All calculation sheets have been signed/initialed and dated.	JJ / 3/22
7	Attachments to the calculation are formatted as required and are included in the calculation package.	JJ / 3/22
8	The calculation package is complete and submitted to the assigned checker.	JJ / 3/22
9	The checker has accepted comment resolution and signed the cover sheet.	JJ / 3/22
10	The Calculation package has been submitted to Document Control (Preliminary) or Discipline Lead (Final).	JJ / 3/22
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.	J.J / 3/22
14	The Discipline Lead has forwarded the calculation package to the Document Control.	JJ / 3/22
Calculation Revisions		
15	The calculation cover page is updated, noting the reason for revision.	JJ / 3/22
16	Calculation sheets are updated in accordance with this procedure.	JJ / 3/22
17	The appropriate revision number has been assigned.	JJ / 3/22
18	The checking and approval (when required) have been completed and cover sheet is signed.	JJ / 3/22

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

Subcontractor Calculation Review Checklist.

Subject: **ICV™ Box Weight Calculations**

The subject document has been reviewed by the undersigned.
The checker reviewed and verified the following items as applicable.

Documents Reviewed: **145579-D-CA-010, Rev. 0**

Analysis Performed By: **AMEC/DMJM**

- 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

* Note that the maximum weight calculated for the ICV box, 100.4 tonnes, slightly exceeds the RPP-17403 100 tonne limit. The 100 tonne limit was based on an Integrated Disposal Facility (IDF) criteria which would allow placement of the box anywhere in the trench. An ICV box which exceeds 100 tonne would still be acceptable in IDF with some restrictions on where it might be placed in the trench. DH Shuford 4/5/06

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145579-D-CA-028

amec

CALCULATION SHEET

CALC. NO.: 145579-D-CA-028 **REV:** 0 **DATE:** 22-Mar-06

CALC. TITLE: ICV™ Box Center of Gravity Calculation

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
A	Victor Lourenco	10-Jan-05	Tom Wilson	10-Jan-05	Frank Sweet	10-Jan-05
B	Victor Lourenco	26-Jan-05	Tom Wilson	26-Jan-05	Frank Sweet	26-Jan-05
C	Victor Lourenco	02-Mar-05	Tom Wilson	02-Mar-05	Frank Sweet	03-Mar-05
D	Ryan Barrett	12-Sep-05	William Boehnke	12-Sep-05	Ja-Kael Luey	13-Sep-05
E	Ryan Barrett	20-Oct-05	James Van Corbach	20-Oct-05	Ja-Kael Luey	20-Oct-05
0	Jason Engeman	22-Mar-06	James Van Corbach	22-MAR-06	Ja-Kael Luey	22-MAR-06

Jason Engeman JE   [signature] JVC   [signature] J.L.

AFFECTED DOCUMENTS

DOCUMENT NUMBER:	TITLE:	REV. NO.:	DISC. LEAD INITIALS
145579-D-SP-012	Air Pallet Caster System Specification	0	J.L.
145579-D-SP-026	ICV™ Box Assembly Crane Specification	C	J.L.

RECORD OF REVISION

REV. NO.	REASON FOR REVISION:
A	Issued for Information
B	Issued for CH2M Review. Document Number changed from 145579-D-CA-027
C	Issued for inclusion in 90% report
D	Issued to Address Design Changes to ICV™ Box
E	Used SolidWorks Model of ICV™ Box to Verify Accuracy of Calculation
0	Incorporate ICV Box design changes & 2.2 inch addition of glass per 145579-D-CA-010

amec

CALCULATION SHEET

CALC. NO.: 145579-D-CA-028 REV: 0 DATE: 22-Mar-06

CALC. TITLE: ICV™ Box Center of Gravity Calculation

PROJECT NO.: 145579 PROJECT TITLE: Final DBVS Design

ATTACHMENTS

DOCUMENT NUMBER/ID:	TITLE:	TOTAL PAGES
Attachment 1	MathCAD printout of the Empty ICV™ Box Center of Gravity Calculations	2
Attachment 2	MathCAD printout of the Full ICV™ Box Center of Gravity Calculations	10
Attachment 3	Referenced Drawings	3
Attachment 4	Excerpt from Reference 6	1
Attachment 5	SolidWorks Model Picture	2
Attachment 6	SolidWorks 2006 SP0.0 V&V for Computer 9ZTRH31 Cover Sheet	1
	Total Pages	30

ORIGINATOR:	DATE:	CHECKER:	DATE:
JE	22-Mar-06	JJC	22-MAR-06

amec

CALCULATION SHEET

CALC. NO.:	145579-D-CA-028	REV:	0	DATE:	22-Mar-06
CALC. TITLE:	ICV™ Box Center of Gravity Calculation				
PROJECT NO.:	145579	PROJECT TITLE:	Final DBVS Design		

1 INTRODUCTION

1.1 PURPOSE

The purpose of this calculation is to determine the center of gravity of the large-scale In-Container Vitrification™[1] (ICV™) test container.

1.2 SCOPE

The scope of this calculation includes the analysis of the empty steel container and lid, and a full container with lining and processed glass.

2 BASIS

2.1 DESIGN INPUTS

The dimensions of the ICV™ Box were taken from the following drawings while the weights and density values of the materials were taken from the calculation listed below:

1. 145579-D-CA-010, Rev. 0, ICV™ Box Weight Calculations.
2. F-145579-35-D-0006, Rev. 2, ICV Box Lid Steelwork 1 of 3.
3. F-145579-35-D-0008, Rev. 1, ICV Box Plan & Sections.
4. F-145579-35-D-0016, Rev. K, ICV Box Refractory Assembly.

[1] In-Container Vitrification™ (ICV™) is a trademark of AMEC Inc.

ORIGINATOR:	DATE:	CHECKER:	DATE:
JE	22-Mar-06	JRC	22-Mar-06

CALCULATION SHEET

amec

CALC. NO.:	145579-D-CA-028	REV: 0	DATE: 22-Mar-06
CALC. TITLE:	ICV™ Box Center of Gravity Calculation		
PROJECT NO.:	145579	PROJECT TITLE:	Final DBVS Design

2.2 ASSUMPTIONS

1. All materials are assumed to have a uniform density.
2. The sampling port on the side of the box will not significantly change the center of gravity.
3. Components on the Lid such as the Off-Gas Ports and Camera Ports do not have a significant impact on the center of gravity.
4. The weight of the welds will have a negligible effect on the center of gravity.

3 REFERENCES

1. AMEC Calculation 145579-D-CA-010 Rev. 0; *ICV™ Box Weight Calculations*
2. AMEC Drawing F-145579-35-D-0006, Rev. 2, *ICV Box Lid Steelwork 1 of 3.*
3. AMEC Drawing F-145579-35-D-0008, Rev. 1, *ICV Box Plan & Sections.*
4. AMEC Drawing F-145579-35-D-0016, Rev. K, *ICV Box Refractory Assembly.*
5. Young, Hugh and Freedom, Roger; University Physics; 9th ed., 1996 Addison Wesley Publishing Company.

4 METHODS

Calculations were performed using MathCAD (V12.1, ©1986-2004, Mathsoft Engineering & Education Inc.) computer software, and verified using a handheld calculator. MathCAD Calculations for the empty and full ICV™ Box center of gravity can be found in Attachments 1 and 2 respectively. These calculations were performed to check the center of gravity results of the SolidWorks Model for reasonableness. SolidWorks 2006 SP0.0 V&V for Computer 9ZTRH31, see Attachment 6.

The center of gravity (CG) height for each box component was determined with the bottom of the box (i.e. the underside of the bottom stiffener) used as the reference point. For example the center of gravity height of one of the steel panels located on the sides of the box would be its own center of gravity plus the height to the bottom

ORIGINATOR:	DATE:	CHECKER:	DATE:
JE	22-Mar-06	JRC	22-MAR-06

CALCULATION SHEET

amec

CALC. NO.:	145579-D-CA-028	REV: 0	DATE: 22-Mar-06
CALC. TITLE:	ICV™ Box Center of Gravity Calculation		
PROJECT NO.:	145579	PROJECT TITLE:	Final DBVS Design

of the ICV™ Box. The mass of each component was then calculated and the center of gravity for the overall box was calculated using the following formula:

$$CG = \Sigma h_i w_i / \Sigma w_i$$

Where the CG is determined by the sum of all the components' CG heights multiplied by its weight with the total being divided the sum of the all components' weights.

5 RESULTS AND CONCLUSIONS

By inspection the ICV™ Box is approximately symmetrical along its width and length. Therefore, the center of gravity must be located on a vertical axis in the center of its horizontal plane.

Scenario	SolidWorks Model[1]		Attachments 1 & 2	
Empty Box & Lid	46.8	in	46.4	in
Filled ICV™ Box (10+ inches of Top-Off Soil)	50.0	in	48.8	in
Filled ICV™ Box (10+ inches of Top-Off Soil, 6 inches of Grout)	51.7	in	50.6	in
Completely Filled ICV™ Box (10+ inches of Top-Off Soil, 17.6 inches of Grout)	55.0	in	54.0	in

[1] MathCAD Calculation of Grout Additions

The value for all ICV™ Box scenarios is below the geometrical center of the box, which is 58.5 inches considering the height from the bottom of the box to the top of the lid (when in place). The lateral center of gravity, as per the SolidWorks model (Attachment 5), is close to the geometric center of the box (0.013 inches in the x-direction and 0.016 inches in the z-direction).

ORIGINATOR:	DATE:	CHECKER:	DATE:
JE	22-Mar-06	JC	22-MAR-06

145579-D-CA-028

Attachment 1

MathCAD printout of the Empty ICV Box Center of Gravity Calculations

amec	CALCULATION SHEET	Project Number: 145579 Page 1 of 2
Attachment 1 145579-D-CA-028 Rev. No. 0 Calculation Title ICV™ Box Center of Gravity Calculation		Originator: Jason Engeman JE Date: 22-Mar-06 Checker: James Van Corbach JVC Date: 22-MAR-06

1.0 Calculations and Analysis for the Empty ICV™ Box

This calculation is performed to check the reasonableness of the CG calculated by the SolidWorks Model.

1.1 Constants

Dimension of Box

$l := 24ft$ $\quad w := 7.5ft$

$h := 7.5ft$

$h_{beam} := 6.25in$

All dimensions for the box and center of gravity heights were determined from drawings F-145579-35-D-0006, and F-145579-35-D-0008.

Height of Supporting Beam and Steel Plate on Bottom of Box

1.2 Center of Gravity of the Lid

$w_{lid} := 5711lb$ — Weight of Lid from Calculation 145579-D-CA-010

$h_{lid} := 20in$ — Height of Lid

$$H_{lid} := h_{beam} + h + \frac{h_{lid}}{2}$$

$H_{lid} = 106in$ — Height of Center of Gravity of lid.

1.3 Center of Gravity for the Steel

Side Sections

$w_{stse} := 3614.6lb$ — Weight of Side (2 @ 1377 lb) and End (2 @ 430.3 lb) Steel Panels from Calculation 145579-D-CA-010

$H_{stse} := h_{beam} + \frac{h}{2}$ $\quad H_{stse} = 51.25\,in$ — Center of Gravity Height of Steel Sides and Ends

$w_{stb1} := 6078.9lb$ — Weight of Bottom Stiffeners from Calculation 145579-D-CA-010

$H_{stb1} := \frac{h_{beam} - 0.25 \cdot in}{2}$ $\quad H_{stb1} = 3.0\,in$ — Center of Gravity Height of Bottom Stiffeners

$w_{stb2} := 1836lb$ — Weight of Bottom Plate from Calculation 145579-D-CA-010

$H_{stb2} := h_{beam} - 0.125 \cdot in$ $\quad H_{stb2} = 6.125\,in$ — Center of Gravity Height of Bottom Plate

$w_{bperim} := 1767.9lb$ — Weight of Bottom Perimeter Stiffener from Calculation 145579-D-CA-010

amec	CALCULATION SHEET	Project Number: 145579 Page 2 of 2
Attachment 1 145579-D-CA-028 **Rev. No. 0** **Calculation Title** ICV™ Box Center of Gravity Calculation		**Originator:** Jason Engeman JE **Date:** 22-Mar-06 **Checker:** James Van Corbach JVC **Date:** 22-MAR-06

$h_{bperim} := 8in$ — Equivalent length of the welds in the box.

$H_{bperim} := \frac{h_{bperim}}{2}$ $\quad H_{bperim} = 4.0\,in$ — Center of Gravity Height of Bottom Perimeter Stiffener

$w_{tperim} := 769.2lb$ — Weight of top perimeter Stiffener from Calculation 145579-D-CA-010

$H_{tperim} := h_{beam} + h - 2in$ $\quad H_{tperim} = 94.25\,in$ — Center of Gravity Height of Top Perimeter Stiffener

$w_{side\_stiff} := 5003lb$ — Weight of Stiffeners located on Sides (3679 lb) and Ends (1324 lb) of Box from Calculation 145579-D-CA-010

$h_{side\_stiff} := 84in$ — Length of Side Stiffeners

$H_{side\_stiff} := \left(\frac{h_{side\_stiff}}{2}\right) + h_{bperim}$ $\quad H_{side\_stiff} = 50.0\,in$ — Height of CG for side stiffeners

1.4 Overall Center of Gravity

CG Height Multiplied by corresponding weight for simplification of equation below

$a := H_{lid} \cdot w_{lid}$	$e := H_{bperim} \cdot w_{bperim}$	$a = 605366\,lb \cdot in$	$e = 7072\,lb \cdot in$
$b := H_{stse} \cdot w_{stse}$	$f := H_{tperim} \cdot w_{tperim}$	$b = 185248\,lb \cdot in$	$f = 72497\,lb \cdot in$
$c := H_{stb1} \cdot w_{stb1}$	$g := H_{side\_stiff} \cdot w_{side\_stiff}$	$c = 18237\,lb \cdot in$	$g = 250150\,lb \cdot in$
$d := H_{stb2} \cdot w_{stb2}$		$d = 11246\,lb \cdot in$	

$w_{box\_and\_lid} := w_{lid} + w_{stse} + w_{stb1} + w_{stb2} + w_{bperim} + w_{tperim} + w_{side\_stiff}$

$w_{box\_and\_lid} = 24781\,lb$ — Weight of Box and Lid

CG per mass to find overall CG

$CG := \frac{a + b + c + d + e + f + g}{w_{box\_and\_lid}}$ $\quad CG = 46.4\,in$ — Equation taken from Attachment 4

The geometric center of the box is 58.5 inches. Our calculated value is lower than this due to the concentration of steel on the box bottom relative to the lid.

This center of gravity is consistent with the model, which estimates the center of gravity of the box to 46.8 in.

145579-D-CA-028

Attachment 2

MathCAD printout of the Full ICV Box Center of Gravity Calculations

amec	CALCULATION SHEET	Project Number: 145579 Page 1 of 10
Attachment 2 145579-D-CA-028 Rev. No. 0 Calculation Title ICV™ Box Center of Gravity Calculation		Originator: Jason Engeman JE Date: 22-Mar-06 Checker: James Van Corbach JVC Date: 22-MAR-06

2.0 Calculations and Analysis for the Full ICV™ Box

This calculation is performed to check the reasonableness of the CG calculated by the SolidWorks Model.

2.1 Constants

$l := 24ft$

$w := 7.5ft$

$h := 7.5ft$

All dimensions for the box and center of gravity heights were determined from drawings F-145579-35-D-0006, and F-145579-35-D-0008.

$h_{beam} := 6.25in$ — Height of Supporting Beam and Plate on Bottom of Box

Material Properties taken from calculation 145579-D-CA-010

$\rho_{ins} := 17\frac{lb}{ft^3}$ — Density of Insulation

$\rho_{srb} := 117\frac{lb}{ft^3}$ — Density of End and Side Backer Brick

$\rho_{sand} := 88\frac{lb}{ft^3}$ — Density of Sand

$\rho_{ref} := 163\frac{lb}{ft^3}$ — Density of Vibrocast Refractory

$h_{ref\_floor} := 6in$ — Approximate Height of Refractory Floor

2.2 Weight and Center of Gravity Height of Insulation

$w_{ins} := 171lb$ — Weight of Insulation from Calculation 145579-D-CA-010

$h_{ins} := 74.25in$ — Height of Insulation from Calculation 145579-D-CA-010

$h_{srb} := 8in$ — Height of Support Rib and Sand from Calculation 145579-D-CA-010

$$H_{ins} := h_{beam} + h_{srb} + \frac{h_{ins}}{2}$$

$H_{ins} = 51.4\ in$ — Height of CG from bottom section

2.3 Weight and Center of Gravity of Support Ribs and Bricks

Support Ribs

$vol_{sr} := 36.7ft^3$ — Volume of Support Ribs from Calculation 145579-D-CA-010

$w_{sr} := vol_{sr} \cdot \rho_{srb}$

$w_{sr} = 4293.9\,lb$ — Weight of Support Ribs

$H_{sr} := h_{beam} + \frac{h_{srb}}{2}$

$H_{sr} = 10.3\,in$ — Height of CG from Bottom

End and Side Backing Bricks

$vol_{esbb} := 18.5ft^3$ — Volume of End and Side Backing Bricks from Calculation 145579-D-CA-010

$w_{esbb} := vol_{esbb} \cdot \rho_{srb}$

$w_{esbb} = 2164.5\,lb$ — Weight of Support Ribs

$h_{sbb} := 24 \cdot in$ — Height of Side Backing Bricks from Drawing F-145579-35-D-0016

$H_{esbb} := h_{beam} + \frac{h_{sbb}}{2}$

$H_{esbb} = 18.3\,in$ — Height of CG from Bottom

2.4 Weight and Center of Gravity Height of Sand

Bottom

$vol_{sb} := 79.5ft^3$ — Volume from Calculation 145579-D-CA-010

$w_{sb} := vol_{sb} \cdot \rho_{sand}$

$w_{sb} = 6996.0\,lb$ — Weight of Sand on the Bottom

$H_{sb} := H_{sr}$

$H_{sb} = 10.3\,in$ — Height of CG for Bottom

Ends

$vol_{se} := 34.6ft^3$ — Volume from Calculation 145579-D-CA-010

$w_{se} := vol_{se} \cdot \rho_{sand}$

$w_{se} = 3044.8\,lb$ — Weight of Sand on the Ends

$h_{ebb} := 16 \cdot in$ — Height of End Backing Bricks from F-145579-35-D-0016

$h_{se} := 66 \cdot in$ — Height of Sand on Ends from F-145579-35-D-0016

$$H_{se} := h_{beam} + h_{srb} + h_{ebb} + \frac{h_{se}}{2}$$

$H_{se} = 63.3\,in$ — Height of CG for Ends

Sides

$vol_{ss} := 163.5ft^3$ — Volume from Calculation 145579-D-CA-010

$w_{ss} := vol_{ss} \cdot \rho_{sand}$

$w_{ss} = 14388.0\,lb$ — Weight of Sand on the Sides

$h_{ss} := 66 \cdot in$ — Height of Sand on Sides from F-145579-35-D-0016

$$H_{ss} := h_{beam} + h_{sbb} + \frac{h_{ss}}{2}$$

$H_{ss} = 63.3\,in$ — Height of CG for Sides

2.5 Weight and Center of Gravity Height of the Vibrocast Refractory Panels

Floor

$vol_{ref\_floor} := 99.7ft^3$ — Volume from Calculation 145579-D-CA-010

$w_{ref\_floor} := vol_{ref\_floor} \cdot \rho_{ref}$

$w_{ref\_floor} = 16251.1\,lb$ — Weight of Refractory Floor

$$H_{ref\_floor} := h_{beam} + h_{srb} + \frac{h_{ref\_floor}}{2}$$

$H_{ref\_floor} = 17.3\,in$ — Height of CG for Floor

amec

CALCULATION SHEET

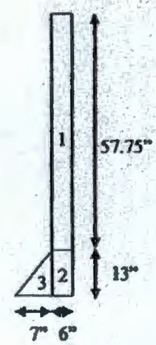
Project Number: 145579

Page 4 of 10

Attachment 2
145579-D-CA-028
Rev. No. 0
Calculation Title ICV™ Box Center of Gravity Calculation

Originator: Jason Engeman JE
Date: 22-Mar-06
Checker: James Van Corbach JVC
Date: 22-MAR-06

End and Sides — Dimensions from Calculation 145579-D-CA-010



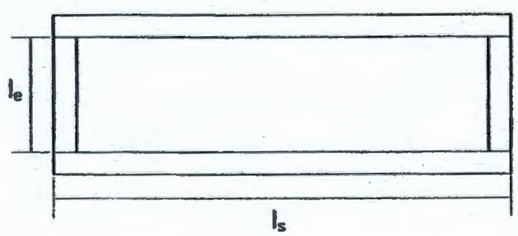
$t_1 := 6 \cdot in$ $t_2 := 6 \cdot in$ $t_3 := 7 \cdot in$

$h_1 := 57.75 \cdot in$ $h_2 := 13 \cdot in$ $h_3 := 13 \cdot in$

$l_s := 23 \cdot ft$ Length of Sides (from Length of Outside Refractory)

$l_e := 68 \cdot in$ Length of Ends (from Width of Inside Refractory)

The refractory will be estimated by 4 panels. The two sides will be approximated by the entire outer length of the refractory side, and the two ends will be approximated by the inside length of the refractory end.



$vol_{ref\_1} := 2 \cdot t_1 \cdot h_1 \cdot (l_s + l_e)$ $vol_{ref\_1} = 138.0 ft^3$ Volume of Area 1 of Refractory

$w_{ref\_1} := vol_{ref\_1} \cdot \rho_{ref}$ $w_{ref\_1} = 22487.2 lb$ Weight of Area 1 of Refractory

$H_{ref\_1} := h + h_{beam} - \frac{h_1}{2}$ $H_{ref\_1} = 67.4 in$ Height of CG for Area 1 of Refractory

$vol_{ref\_2} := 2[t_2 \cdot h_2 \cdot (l_s + l_e)]$ $vol_{ref\_2} = 31.1 ft^3$ Volume of Area 2 of Refractory

$w_{ref\_2} := vol_{ref\_2} \cdot \rho_{ref}$ $w_{ref\_2} = 5062.1 lb$ Weight of Area 2 of Refractory

$H_{ref\_2} := h + h_{beam} - h_1 - \frac{h_2}{2}$ $H_{ref\_2} = 32.0 in$ Height of CG for Area 2 of Refractory

$vol_{ref\_3} := 2[0.5 \cdot t_3 \cdot h_3 \cdot (l_s + l_e)]$

$vol_{ref\_3} = 18.1 ft^3$ Volume of Area 3 of Refractory

$w_{ref\_3} := vol_{ref\_3} \cdot \rho_{ref}$ $w_{ref\_3} = 2952.9 lb$ Weight of Area 3 of Refractory

$H_{ref\_3} := h + h_{beam} - h_1 - \frac{2}{3} \cdot h_3$ $H_{ref\_3} = 29.8 in$ Center of Gravity of Height is 1/3 Height from the Base, Height of CG for Area 3 of Refractory

amec	CALCULATION SHEET	Project Number: 145579 Page 5 of 10
Attachment 2 145579-D-CA-028 **Rev. No. 0** **Calculation Title** ICV™ Box Center of Gravity Calculation		**Originator:** Jason Engeman JE **Date:** 22-Mar-06 **Checker:** James Van Corbach JVC **Date:** 22-MAR-06

2.6 Glass, Top-Off Soil, and Grout

$h_{glass} := 64.38in$ — Height of Glass. From SolidWorks 145579-D-CA-010

$mass_{glass\_2.2in\_addition} := 97508.7lb$ — Weight of glass from 145579-D-CA-010 based on an additional 2.2 inches of glass

$w_{glass} := 44.22tonne$

$$H_{glass} := h_{beam} + h_{srb} + (h_{ref\_floor} - 2 \cdot in) + \frac{h_{glass}}{2}$$

$H_{glass} = 50.4\ in$ — Height of CG of Solid Glass block

Center of Gravity for Top Off Soil

$w_{soil} := 9458lb$ — Weight of Top Off Soil calculated from 145579-D-CA-010

$h_{soil} := 10.5in$ — Height of a full Top Off Soil Cone from 145579-D-CA-010, Attachment 1

$$H_{soil} := h_{beam} + h_{srb} + (h_{ref\_floor} - 2 \cdot in) + h_{glass} + \frac{h_{soil}}{2}$$

$H_{soil} = 87.9\ in$ — Height of CG of Soil

$w_{grout} := 8280 \cdot lb$ — Weight of 6" of Grout calculated from 145579-D-CA-010

$h_{grout} := 6 \cdot in$

$$H_{grout} := h_{beam} + h_{srb} + (h_{ref\_floor} - 2 \cdot in) + h_{glass} + h_{soil} + \frac{h_{grout}}{2}$$

$H_{grout} = 96.1\ in$ — Height of CG of Grout

2.7 Center of Gravity for the Steel Box and Lid

From Attachment 1:

$w_{box\_and\_lid} := 24781 \cdot lb$ — Weight of ICV™ Box and Lid

$H_{box\_and\_lid} := 46.4 \cdot in$ — CG Height of ICV™ Box and Lid

2.8 Center of Gravity for Electrodes

$length_{elec} := 87.5in$

$w_{elec} := 1273lb$

Length and weight of electrodes from 145579-D-CA-010

$$H_{elec} := h_{beam} + h_{stb} + h_{ref\_floor} + \frac{length_{elec}}{2}$$

$H_{elec} = 64.0\,in$

CG Height of Electrode

2.9 Overall Center of Gravity of Filled ICV™ Box

CG Height Multiplied by corresponding weight for simplification of equation below

$a := H_{ins} \cdot w_{ins}$	$f := H_{ss} \cdot w_{ss}$	$k := H_{glass} \cdot w_{glass}$
$b := H_{sr} \cdot w_{sr}$	$g := H_{ref\_floor} \cdot w_{ref\_floor}$	$l := H_{soil} \cdot w_{soil}$
$c := H_{esbb} \cdot w_{esbb}$	$h := H_{ref\_1} \cdot w_{ref\_1}$	$m := H_{grout} \cdot w_{grout}$
$d := H_{sb} \cdot w_{sb}$	$i := H_{ref\_2} \cdot w_{ref\_2}$	$n := H_{box\_and\_lid} \cdot w_{box\_and\_lid}$
$e := H_{se} \cdot w_{se}$	$j := H_{ref\_3} \cdot w_{ref\_3}$	$o := H_{elec} \cdot w_{elec}$

$a = 8785\,lb \cdot in$	$f = 910041\,lb \cdot in$	$k = 4917316\,lb \cdot in$
$b = 44012\,lb \cdot in$	$g = 280331\,lb \cdot in$	$l = 831169\,lb \cdot in$
$c = 39502\,lb \cdot in$	$h = 1515076\,lb \cdot in$	$m = 795956\,lb \cdot in$
$d = 71709\,lb \cdot in$	$i = 161986\,lb \cdot in$	$n = 1149838\,lb \cdot in$
$e = 192584\,lb \cdot in$	$j = 88094\,lb \cdot in$	$o = 81472\,lb \cdot in$

CG per mass to find overall CG without Grout — Equation taken from Attachment 4

$$w_{a\_to\_g} := w_{ins} + w_{sr} + w_{esbb} + w_{sb} + w_{se} + w_{ss} + w_{ref\_floor}$$

$$w_{a\_to\_g} = 47309\ lb$$

$$w_{h\_to\_o} := w_{ref\_1} + w_{ref\_2} + w_{ref\_3} + w_{glass} + w_{soil} + w_{box\_and\_lid} + w_{elec}$$

$$w_{h\_to\_o} = 163503\ lb$$

$$CG := \frac{a+b+c+d+e+f+g+h+i+j+k+l+n+o}{w_{a\_to\_g} + w_{h\_to\_o}}$$

$$CG = 48.8\ in$$

CG per mass to find overall CG with Grout — Equation taken from Attachment 4

$$w_{a\_to\_g} := w_{ins} + w_{sr} + w_{esbb} + w_{sb} + w_{se} + w_{ss} + w_{ref\_floor}$$

$$w_{a\_to\_g} = 47309\ lb$$

$$w_{h\_to\_o} := w_{ref\_1} + w_{ref\_2} + w_{ref\_3} + w_{glass} + w_{soil} + w_{grout} + w_{box\_and\_lid} + w_{elec}$$

$$w_{h\_to\_o} = 171783\ lb$$

$$CG := \frac{a+b+c+d+e+f+g+h+i+j+k+l+m+n+o}{w_{a\_to\_g} + w_{h\_to\_o}}$$

$$CG = 50.6\ in$$

The geometric center of the box height of 58.5 inches. Our calculated value is lower than this due to the concentration of glass and refractory materials below the center of gravity.

From the SolidWorks Model of the ICV™ Box (Attachment 5):

$w_{sw} := 213126 \cdot lb$ — Weight of Box from SolidWorks Model, 145579-D-CA-010. Note that this differs from the tabulated weight in 145579-D-CA-010 (213126 lb). The difference is due to the gasket between the box and the lid. This weight is included in the model but is considered negligible in calculation 145579-D-CA-010.

$H_{sw} := 49.98in$ — Center of Gravity for SolidWorks Model, without Grout, Attachment 5

amec	CALCULATION SHEET	Project Number: 145579 Page 8 of 10
Attachment 2 145579-D-CA-028 Rev. No. 0 Calculation Title ICV™ Box Center of Gravity Calculation		Originator: Jason Engeman JE Date: 22-Mar-06 Checker: James Van Corbach JVC Date: 22-MAR-06

CG Height Multiplied by corresponding weight for simplification of equation below

$a := H_{sw} \cdot w_{sw}$ $\quad b := H_{grout} \cdot w_{grout}$

$a = 10652037\,lb \cdot in$ $\quad b = 795956\,lb \cdot in$

CG per mass to find overall CG — Equation taken from Attachment 4

$$CG := \frac{a+b}{w_{sw} + w_{grout}}$$

$CG = 51.7\,in$ — Center of Gravity for SolidWorks Model with Grout

This center of gravity is consistent with the calculated model, which estimates the center of gravity of the box to 50.6 in.

2.10 Overall Center of Gravity of Completely Filled ICV™ Box

$w_{grout} := 21755.5 \cdot lb$ — Weight of Complete Grout fill calculated from 145579-D-CA-010

$h := 7.5 \cdot ft$

$H_{level} := h_{beam} + h_{srb} + h_{ref\_floor} + h_{glass} + h_{soil}$ $\quad H_{level} = 95.1\,in$ — Height to top of Sand

$H_{grout} := H_{level} + 0.5 \cdot \left[\left(h + h_{beam} + 16.5 \cdot in\right) - H_{level}\right]$ $\quad H_{grout} = 103.9\,in$ — Height of Grout Center

CG Height Multiplied by corresponding weight for simplification of equation below

$a := H_{ins} \cdot w_{ins}$ $\quad f := H_{ss} \cdot w_{ss}$ $\quad k := H_{glass} \cdot w_{glass}$

$b := H_{sr} \cdot w_{sr}$ $\quad g := H_{ref\_floor} \cdot w_{ref\_floor}$ $\quad l := H_{soil} \cdot w_{soil}$

$c := H_{esbb} \cdot w_{esbb}$ $\quad h := H_{ref\_1} \cdot w_{ref\_1}$ $\quad m := H_{grout} \cdot w_{grout}$

$d := H_{sb} \cdot w_{sb}$ $\quad i := H_{ref\_2} \cdot w_{ref\_2}$ $\quad n := H_{box\_and\_lid} \cdot w_{box\_and\_lid}$

$e := H_{se} \cdot w_{se}$ $\quad j := H_{ref\_3} \cdot w_{ref\_3}$ $\quad o := H_{elec} \cdot w_{elec}$

$a = 8785\,lb \cdot in$ $\quad f = 910041\,lb \cdot in$ $\quad k = 4917316\,lb \cdot in$

$b = 44012\,lb \cdot in$ $\quad g = 280331\,lb \cdot in$ $\quad l = 831169\,lb \cdot in$

$c = 39502\,lb \cdot in$	$h = 1515076\,lb \cdot in$	$m = 2261267\,lb \cdot in$
$d = 71709\,lb \cdot in$	$i = 161986\,lb \cdot in$	$n = 1149838\,lb \cdot in$
$e = 192584\,lb \cdot in$	$j = 88094\,lb \cdot in$	$o = 81472\,lb \cdot in$

CG per mass to find overall CG — Equation taken from Attachment 4

$$w_{a\_to\_g} := w_{ins} + w_{sr} + w_{csbb} + w_{sb} + w_{se} + w_{ss} + w_{ref\_floor}$$

$$w_{a\_to\_g} = 47309\,lb$$

$$w_{h\_to\_o} := w_{ref\_1} + w_{ref\_2} + w_{ref\_3} + w_{glass} + w_{soil} + w_{grout} + w_{box\_and\_lid} + w_{elec}$$

$$w_{h\_to\_o} = 185258\,lb$$

$$CG := \frac{a+b+c+d+e+f+g+h+i+j+k+l+m+n+o}{w_{a\_to\_g} + w_{h\_to\_o}}$$

$$CG = 54.0\,in$$

The geometric center of the box height of 58.5 inches. Our calculated value is lower than this due to the concentration of glass and refractory materials below the center of gravity.

From the SolidWorks Model of the ICV™ Box (Attachment 5):

$w_{sw} := 213149 \cdot lb$ — Weight of Box from SolidWorks Model, 145579-D-CA-010. Note that this differs from the tabulated value in 145579-D-CA-010 (213126 lb). The difference is due to the gasket between the box and the lid. This weight is included in the model but is considered negligible in calculation 145579-D-CA-010.

$H_{sw} := 49.98in$ — Center of Gravity for SolidWorks Model, without Grout, Attachment 5

CG Height Multiplied by corresponding weight for simplification of equation below

$a := H_{sw} \cdot w_{sw}$ $\qquad$ $b := H_{grout} \cdot w_{grout}$

$a = 10653187\,lb \cdot in$ $\qquad$ $b = 2261267\,lb \cdot in$

amec	CALCULATION SHEET	Project Number: 145579 Page 10 of 10
Attachment 2 145579-D-CA-028 **Rev. No. 0** **Calculation Title** ICV™ Box Center of Gravity Calculation		**Originator:** Jason Engeman JE **Date:** 22-Mar-06 **Checker:** James Van Corbach JVC **Date:** 22-MAR-06

CG per mass to find overall CG

Equation taken from Attachment 4

$$CG := \frac{a + b}{w_{sw} + w_{grout}}$$

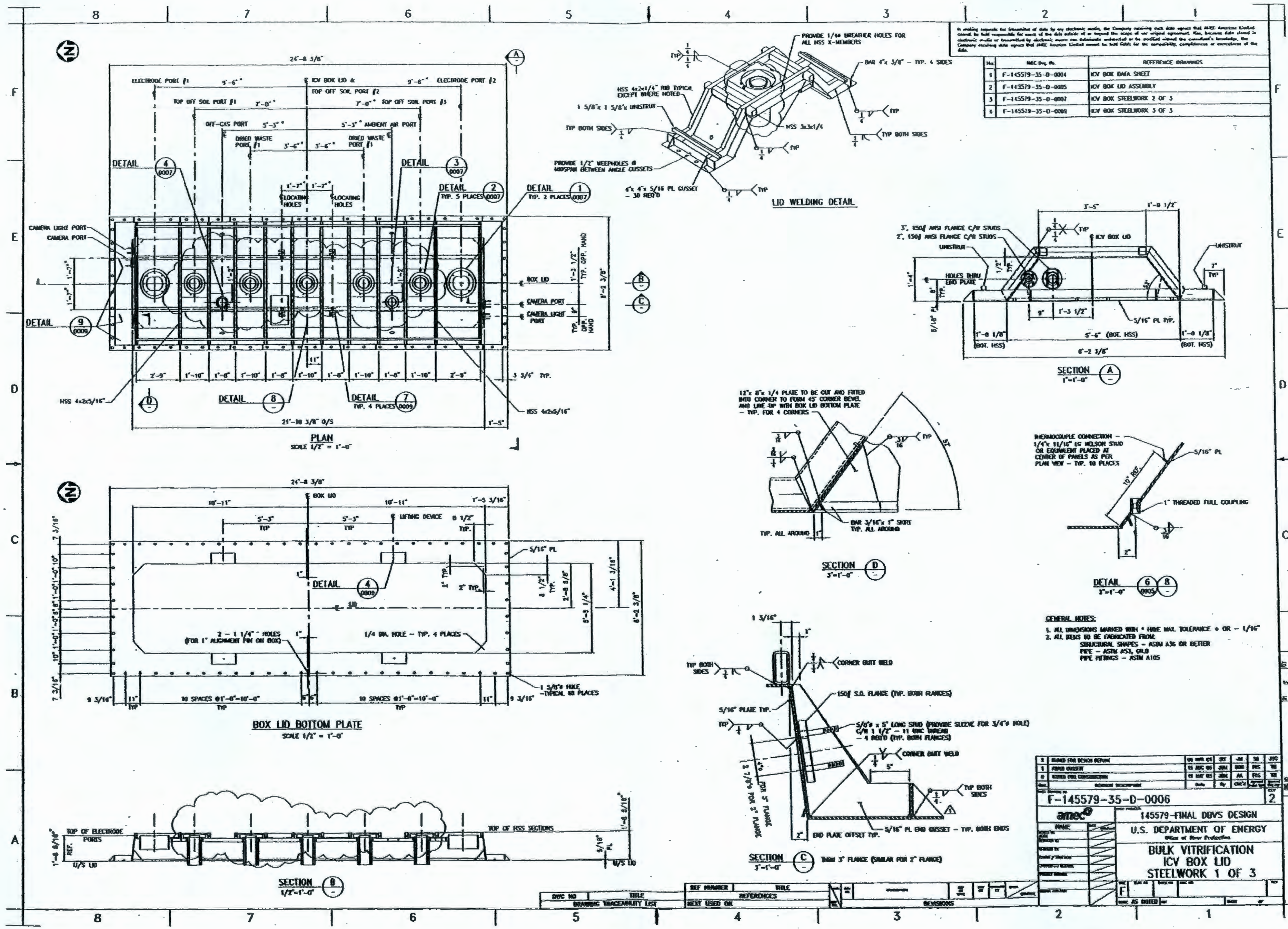
$$CG = 55.0\,in$$

This center of gravity is consistent with the calculated model, which estimates the center of gravity of the box to 54.0 in.

145579-D-CA-028

<u>Attachment 3</u>

Referenced Drawings


PLAN
SCALE 1/2" = 1'-0"
BOX LID BOTTOM PLATE
SCALE 1/2" = 1'-0"
SECTION B
1/2"=1'-0"
LID WELDING DETAIL
SECTION A
1"=1'-0"
SECTION D
3"=1'-0"
SECTION C
3"=1'-0"
THRU 3" FLANGE (SIMILAR FOR 2" FLANGE)
DETAIL 6 8
3"=1'-0"
ELECTRODE PORT #1
ELECTRODE PORT #2
ICV BOX LID &
TOP OFF SOIL PORT #2
TOP OFF SOIL PORT #1
TOP OFF SOIL PORT #3
OFF-GAS PORT
AMBIENT AIR PORT
DRIED WASTE PORT #1
LOCATING HOLES
CAMERA LIGHT PORT
CAMERA PORT
BOX LID
HSS 4x2x5/16"
PROVIDE 1/4 BREATHER HOLES FOR ALL HSS X-MEMBERS
BAR 4"x 3/8" - TYP. 4 SIDES
HSS 4x2x1/4" RIB TYPICAL EXCEPT WHERE NOTED
1 5/8"x 1 5/8"x UNISTRUT
HSS 3x3x1/4
PROVIDE 1/2" WEEPHOLES @ MIDSPAN BETWEEN ANGLE GUSSETS
4"x 4"x 5/16 PL GUSSET - 30 REQ'D
3", 150# ANSI FLANGE C/W STUDS
2", 150# ANSI FLANGE C/W STUDS
UNISTRUT
HOLES THRU END PLATE
5/16" PL TYP.
12"x 8"x 1/4 PLATE TO BE CUT AND FITTED INTO CORNER TO FORM 45° CORNER BEVEL AND LINE-UP WITH BOX LID BOTTOM PLATE - TYP. FOR 4 CORNERS
BAR 3/16"x 1" SKIRT TYP. ALL AROUND
THERMOCOUPLE CONNECTION - 1/4"x 11/16" LG NELSON STUD OR EQUIVALENT PLACED AT CENTER OF PANELS AS PER PLAN VIEW - TYP. 10 PLACES
1" THREADED FULL COUPLING
LIFTING DEVICE
2 - 1 1/4" - HOLES (FOR 1" ALIGNMENT PIN ON BOX)
1/4 DIA. HOLE - TYP. 4 PLACES
1 5/8"ø HOLE - TYPICAL 68 PLACES
10 SPACES @1'-0"=10'-0"
CORNER BUTT WELD
150# S.O. FLANGE (TYP. BOTH FLANGES)
5/8"ø x 5" LONG STUD (PROVIDE SLEEVE FOR 3/4"ø HOLE) C/W 1 1/2" - 11 UNC THREAD - 4 REQ'D (TYP. BOTH FLANGES)
5/16" PL END GUSSET - TYP. BOTH ENDS
END PLATE OFFSET TYP.
TOP OF ELECTRODE PORTS
TOP OF HSS SECTIONS
U/S LID

GENERAL NOTES:
1. ALL DIMENSIONS MARKED WITH * HAVE MAX. TOLERANCE + OR - 1/16"
2. ALL ITEMS TO BE FABRICATED FROM:
STRUCTURAL SHAPES - ASTM A36 OR BETTER
PIPE - ASTM A53, GR.B
PIPE FITTINGS - ASTM A105

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
3	F-145579-35-D-0007	ICV BOX STEELWORK 2 OF 3
4	F-145579-35-D-0009	ICV BOX STEELWORK 3 OF 3

F-145579-35-D-0006
2
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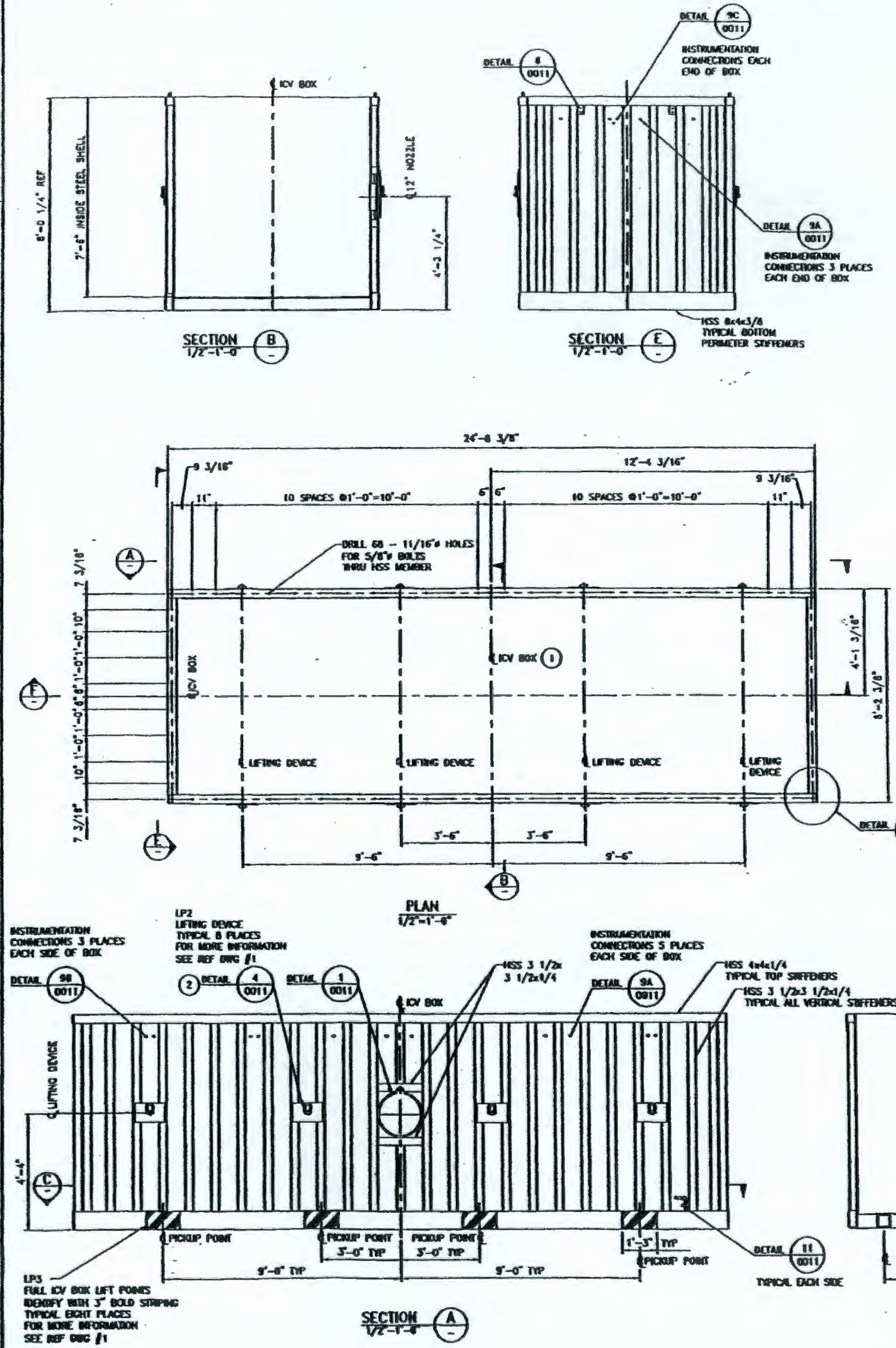
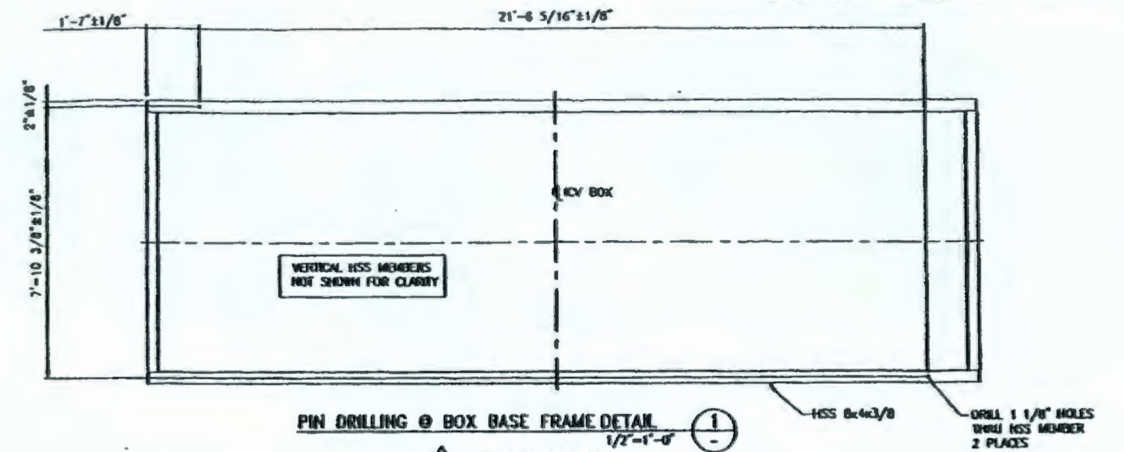
145579-FINAL DBVS DESIGN
U.S. DEPARTMENT OF ENERGY
BULK VITRIFICATION
ICV BOX LID
STEELWORK 1 OF 3
AS NOTED

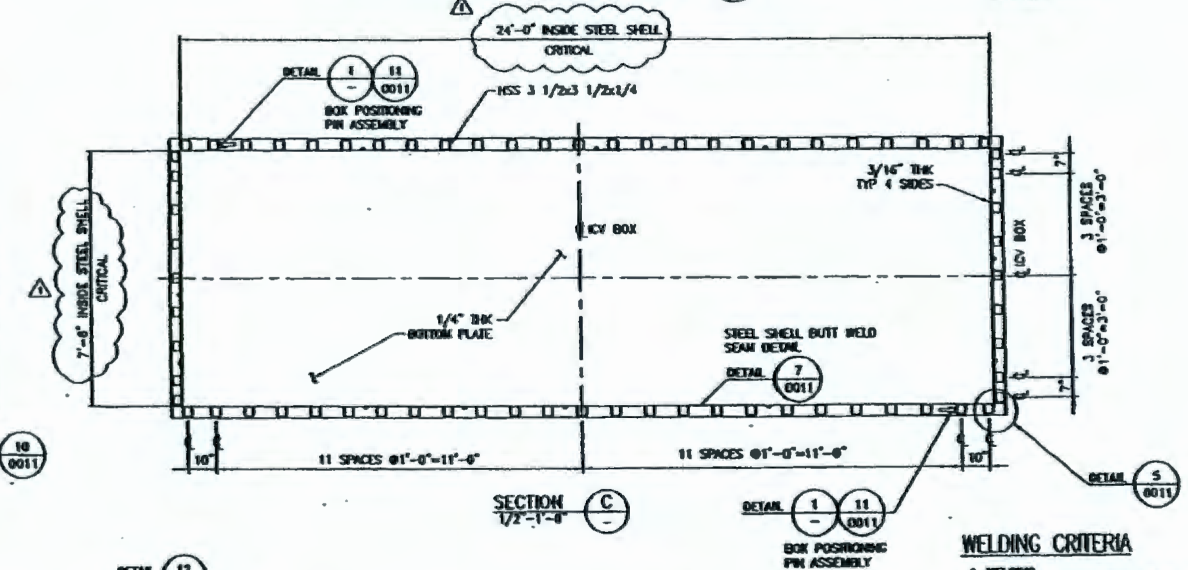
No	AMEC Dwg. No.	REFERENCE DRAWINGS
1	F-145579-35-D-0004	ICV BOX DATA SHEET
2	F-145579-35-D-0005	ICV BOX LID ASSEMBLY DETAILS
3	F-145579-35-D-0006	ICV BOX LID STEEL WORK 1 OF 3
4	F-145579-35-D-0011	ICV BOX ASSEMBLY DETAILS
5	F-145579-00-F-0014	ICV BOX INSTRUMENT LOCATIONS

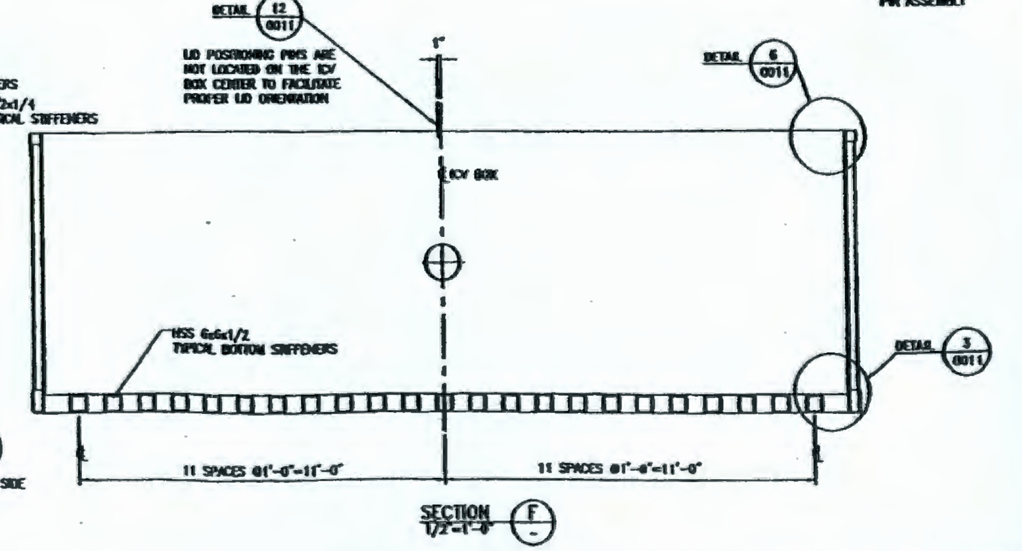
PARTS/MATERIAL LIST

ITEM	REQD	PART/DASH NUMBER	NOMENCLATURE/DESCRIPTION	MATERIAL/REFERENCE	SH	ITEM NO
1	1	35-052-006	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 REVIEW	06 MAR 06	THB	JR	SRB	JSC
0	ISSUED FOR CONSTRUCTION	10 MAY 05	JBM	AK	PHS	[illegible]

F-145579-35-D-0008 — Rev 1

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145579-FINAL DBVS DESIGN

U.S. DEPARTMENT OF ENERGY
Office of River Protection

BULK VITRIFICATION
ICV BOX
PLAN & SECTIONS

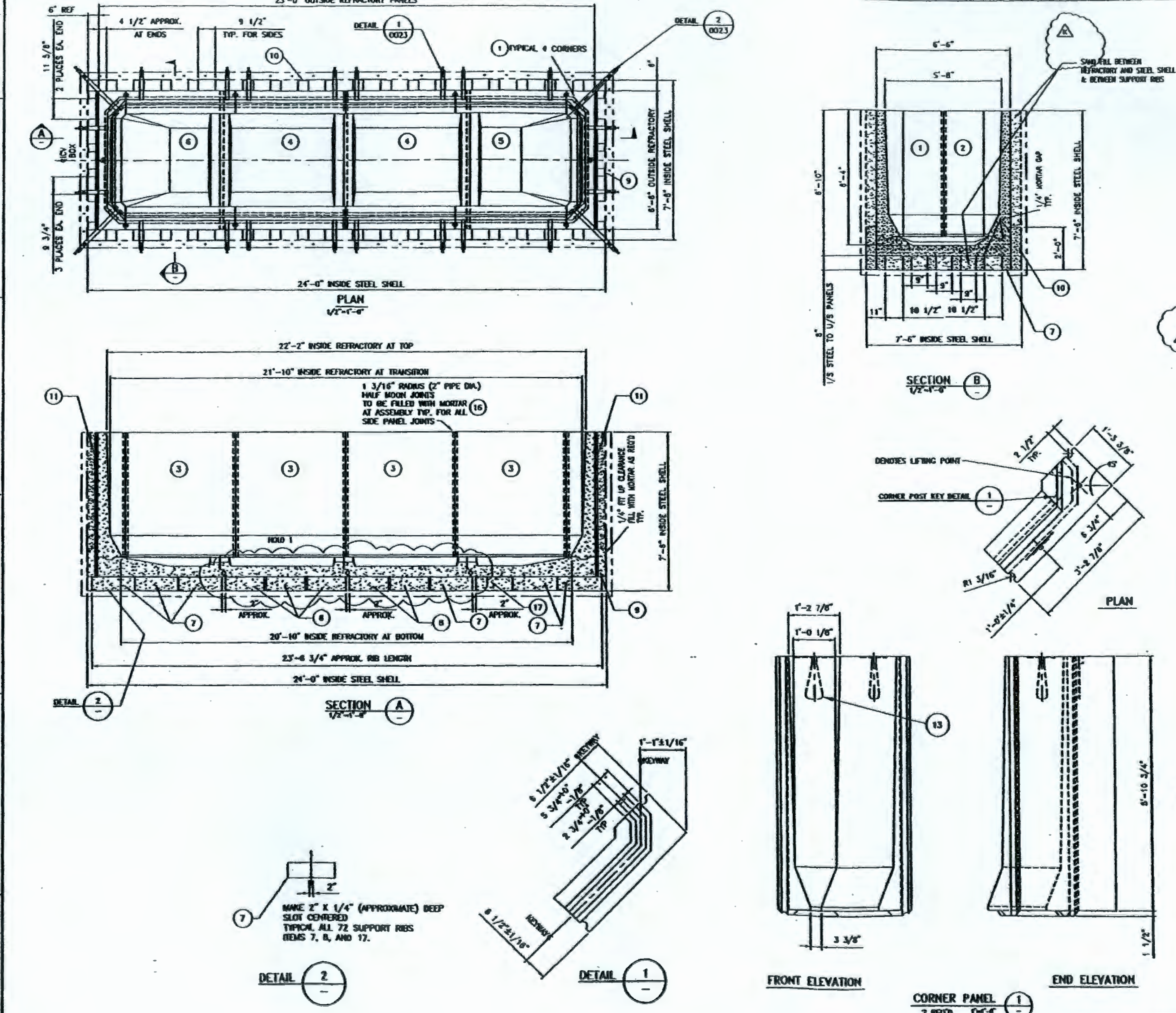
Size F — Scale AS NOTED

DWG NO	TITLE
DRAWING TRACEABILITY LIST	

REF NUMBER	TITLE
NEXT USED ON	REFERENCES

REVISIONS

No	AMEC Dwg. No.	REFERENCE DRAWINGS
1	F-145579-35-0-0004	ICV BOX DATA SHEET
2	F-145579-35-0-0008	ICV BOX ASSEMBLY
3	F-145579-35-0-0017	ICV BOX REFRACTORY DETAILS
4	F-145579-35-0-0023	ICV BOX REFRACTORY PANEL CLIP DETAILS



In making requests for transmittal of data by any electronic media, the Company receiving such data agrees that AMEC Americas Limited cannot be held responsible for errors of the data outside of or beyond the scope of our original agreement. Also, because data stored in electronic media or transmitted by electronic means can deteriorate undetected or be modified without the consultant's knowledge, the Company receiving data agrees that AMEC Americas Limited cannot be held liable for the compatibility, completeness or correctness of the data.

PARTS/MATERIAL LIST

ITEM	REQD	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-145579-35-0-0004.
   - RESULTS FROM EJ 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 06	[illegible]	[illegible]	[illegible]	[illegible]
J	REVISED DIMENSIONS	[illegible] MAR 06	[illegible]	[illegible]	[illegible]	[illegible]
H	REVISED CORNER PANEL AND REFRACTORY JOINT	13 JAN 06	[illegible]	[illegible]	[illegible]	[illegible]
G	REVISED LIFTING POINT LOCATIONS	1 SEPT 05	[illegible]	[illegible]	[illegible]	[illegible]
F	[illegible]	15 AUG 05	[illegible]	[illegible]	[illegible]	[illegible]
E	[illegible]	[illegible] MAR 05	[illegible]	[illegible]	[illegible]	[illegible]
D	ISSUED FOR INFORMATION	[illegible] FEB 05	[illegible]		[illegible]	[illegible]
C	ISSUED FOR INFORMATION	17 JAN 05	[illegible]	[illegible]	[illegible]	[illegible]
B	ISSUED FOR APPROVAL	30 SEPT 04	[illegible]	[illegible]	[illegible]	[illegible]
A	ISSUED FOR REVIEW	[illegible] SEPT 04	[illegible]	[illegible]	[illegible]	[illegible]

F-145579-35-D-0016 K

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145579–FINAL DBYS DESIGN

U.S. DEPARTMENT OF ENERGY

BULK VITRIFICATION
ICV BOX
REFRACTORY ASSEMBLY

F — AS NOTED

DWG NO — TITLE — DRAWING TRACEABILITY LIST
REF NUMBER — TITLE — REFERENCES — NEXT USED ON
REVISIONS

145579-D-CA-028

Attachment 4

Excerpt from Reference 6

Attachment: 4
Calc. No.: 145579-D-CA-028
Rev. No.: 0
Sheet 1 of 1

condition is based on Newton's first law. A rigid body that, in an inertial frame, ... rotating about a certain point has zero angular momentum about that point, $\vec{L} = 0$ ... not to start rotating about that point, the rate of change of angular momentum $d\vec{L}/dt$ ... *also* be zero. From the discussion in Section 10–6, particularly Eq. (10–32), this ... that the sum of torques $\Sigma\vec{\tau}$ due to all the external forces acting on the body must be ... A rigid body in equilibrium can't have any tendency to start rotating about *any* point, ... the sum of external torques must be zero about any point. This is the second condition **for equilibrium:**

$$\Sigma\vec{\tau} = 0 \quad \text{about any point} \quad \text{(second condition for equilibrium)} \qquad (11–$$

The sum of the torques due to all external forces acting on the body, with respect to any specified point, must be zero.

CAUTION▸ Although the choice of reference point is arbitrary, once you choose a point you must use the *same* point to calculate *all* of the torques on a body. An important element of problem-solving strategy is to pick the point so as to simplify the calculations as much as possible. ◂

In this chapter we will apply the first and second conditions for equilibrium to situations in which a rigid body is at rest (no translation or rotation). Such a body is said to be in **static equilibrium**. But the same conditions apply to a rigid body in uniform *translational* motion (without rotation), such as an airplane in flight with constant speed, direction, and altitude. Such a body is in equilibrium but is not static.

11–3 Center of Gravity

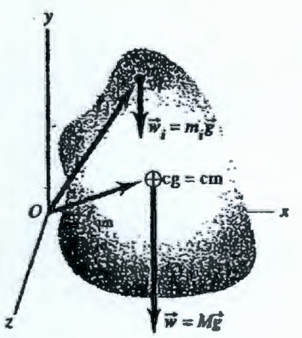
In most equilibrium problems, one of the forces acting on the body is its weight. We need to be able to calculate the *torque* of this force. The weight doesn't act at a single point; it is distributed over the entire body. But we can always calculate the torque due to the body's weight by assuming that the entire force of gravity (weight) is concentrated at a point called the **center of gravity** (abbreviated "cg"). The acceleration due to gravity $\vec{g}$ decreases with altitude; but if we can ignore this variation over the vertical dimension of the body, then the body's center of gravity is identical with its *center of mass*, which we defined in Section 8–6. We stated this result without proof in Section 10–3, and now we'll prove it.

First let's review the definition of the center of mass. For a collection of particles with masses $m_1, m_2, \ldots$ and coordinates $(x_1, y_1, z_1), (x_2, y_2, z_2), \ldots$, the coordinates x_{cm}, y_{cm}, and z_{cm} of the center of mass are given by

$$x_{cm} = \frac{m_1x_1 + m_2x_2 + m_3x_3 + \cdots}{m_1 + m_2 + m_3 + \cdots}$$

$$y_{cm} = \frac{m_1y_1 + m_2y_2 + m_3y_3 + \cdots}{m_1 + m_2 + m_3 + \cdots} \quad \text{(center of mass)} \qquad (11–3)$$

$$z_{cm} = \frac{m_1z_1 + m_2z_2 + m_3z_3 + \cdots}{m_1 + m_2 + m_3 + \cdots}$$



11–1 The gravitational torque about any point can be found by assuming that all the weight of the body acts as its center of gravity (cg), which is identical to its center of mass (cm) if $\vec{g}$ is the same at all points on the body.

Also, x_{cm}, y_{cm}, and z_{cm} are the components of the position vector $\vec{r}_{cm}$ of the center of mass, so Eqs. (11–3) are equivalent to the vector equation

$$\vec{r}_{cm} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + \cdots}{m_1 + m_2 + \cdots} = \frac{\sum_i m_i\vec{r}_i}{\sum_i m_i}. \qquad (11–4)$$

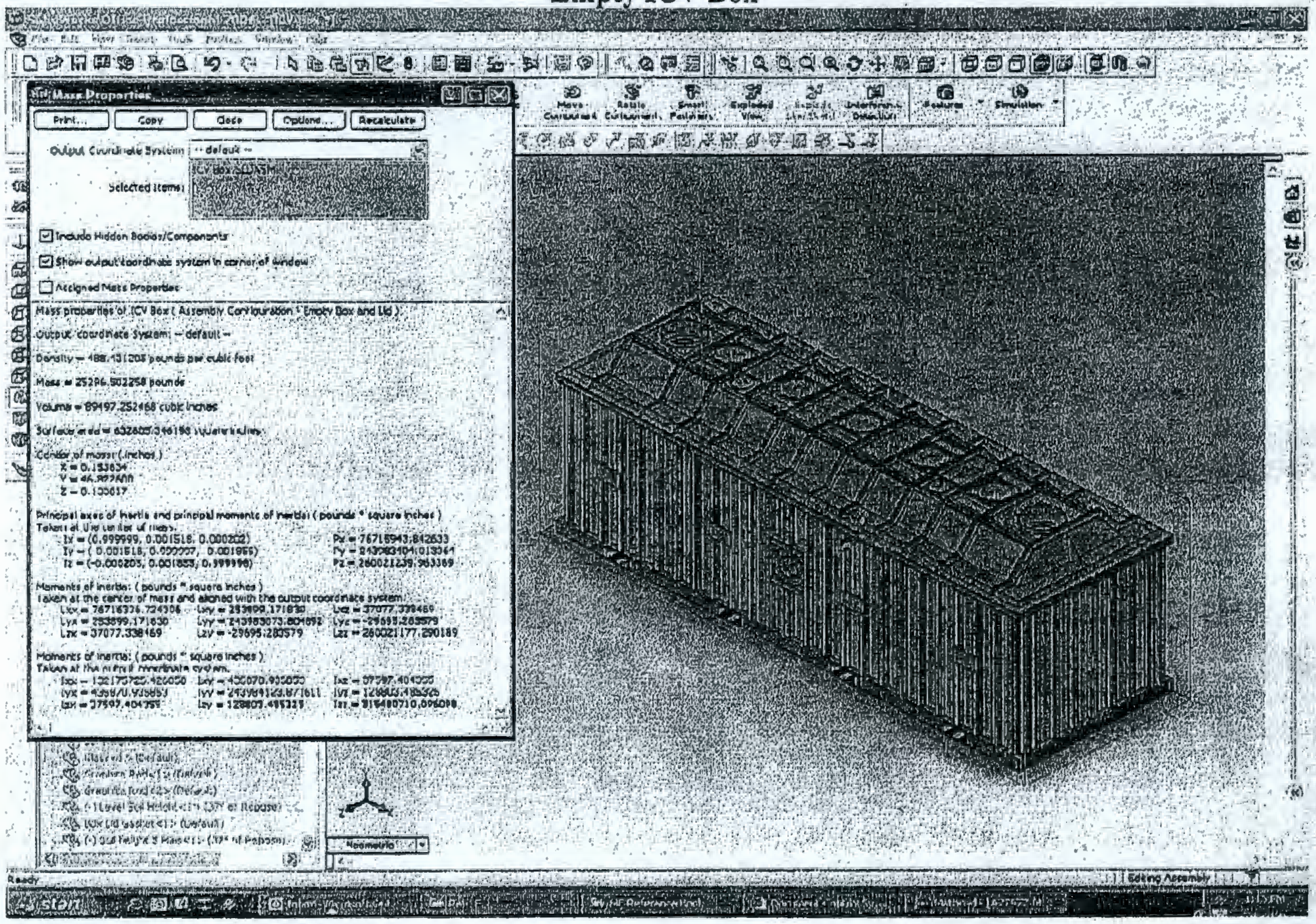
Now let's consider the gravitational torque on a body of arbitrary shape (Fig. 11–1). We assume that the acceleration due to gravity $\vec{g}$ has the same magnitude and direction

145579-D-CA-028

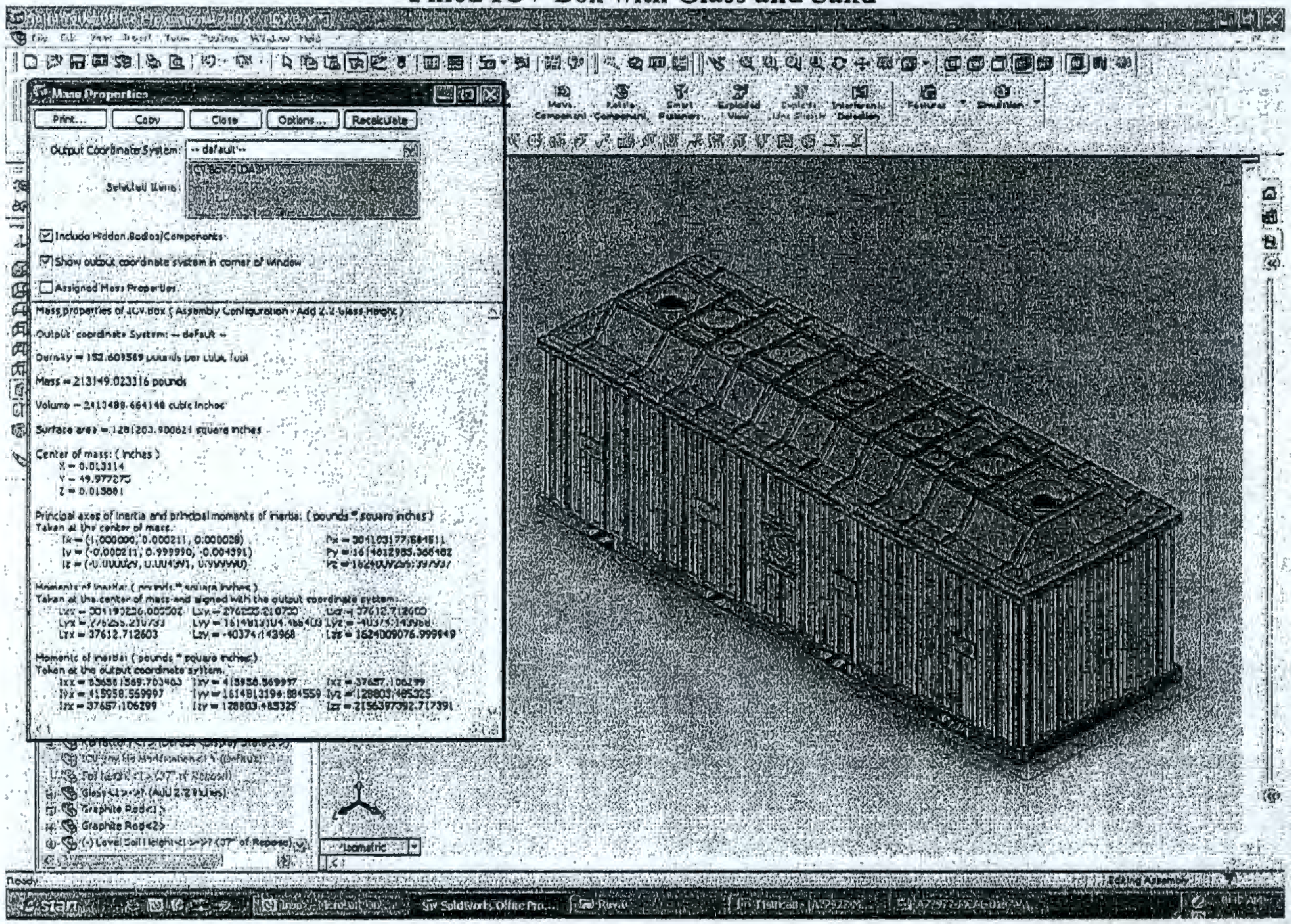
Attachment 5

SolidWorks Model Pictures

Empty ICV Box



Filled ICV Box with Glass and Sand



145579-D-CA-028

Attachment 6

SolidWorks 2006 SP0.0 V&V for Computer 9ZTRH31

ATTACHMENT 6
CALCULATION NO. 145579-D-CA-028
REVISION NO. 0
SHEET 1 OF 1

DMJM technology

VERIFICATION & VALIDATION REVIEW AND APPROVAL FORM

SOFTWARE TITLE	DMJM H+N SOFTWARE ID NO.	DMJM H+N COMPUTER ID NO.
SolidWorks 2006, SP0.0		102561 / 9ZTRH31

VALIDATION PERFORMED BY (Print Name/Sign): James Van Corbach **DATE: October 12, 2005**

PURPOSE AND SCOPE OF VALIDATION:

PURPOSE:

The purpose of this verification and validation is to ensure SolidWorks produces reliable volume data consistent with standard geometric equations.

SCOPE:

The scope of this verification and validation includes a volume analysis of a sphere, right cone, and tube.

REQUIREMENTS FOR SOFTWARE (INPUT RANGE, ETC):
None.

REV.	AFFECTED PAGES	REVISION DESCRIPTION	PREPARER	APPROVED BY	DATE:
0	All	Initial V & V	James Van Corbach	[signature]	10/14/05

DESCRIPTION OF SOFTWARE/USE:
Software can be used to determine heating and cooling loads for simple and complex buildings and building systems, including multiple zone buildings, constant volume systems, VAV systems, heating only, or cooling only.

ORIGIN OF SOFTWARE: Elite Software Development, Inc.

REVISION	DOCUMENT NUMBER	TITLE	DATE	

METHOD OF SOFTWARE VALIDATION	METHOD OF HARDWARE VALIDATION
A. ☐ COMPARE TO HAND CALCULATIONS	A. ☐ COMPARE TO HAND CALCULATIONS
B. ☒ COMPARE TO VALIDATED COMPUTER ANALYSIS RESULTS	B. ☐ COMPARE TO VALIDATED COMPUTER ANALYSIS RESULTS
C. ☐ OTHER (DESCRIBE):	C. ☐ OTHER (DESCRIBE):

RESULTS: The Verification and Validation of SolidWorks 2006 on DMJMH+N computer # 102561 is acceptable.

ATTACHMENTS

Attachment	Name	Sheets
A	Calculation of Volumes Using Standard Geometric Equations	1
B	SolidWorks Mass Properties Screenshots	3

Total number of pages of this V&V, including cover sheets and attachments – 6

DMJM technology

CALCULATION PROCEDURE CHECKLIST

Calculation Number: 145579-D-CA-028 Revision 0

#	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.	JJ / 3/22/06
2	The calculation has been prepared using the forms associated with this procedure (i.e., calculation cover sheet, summary sheet, and calculation sheet).	JJ. / 3/22/06
3	The calculation has been formatted per this procedure (header, page number, etc).	JJ. / 3/22/06
4	The appropriate revision number has been assigned.	JJ. / 3/22
5	The discipline lead of affected documents has been notified of any changes.	JJ. / 3/22
6	All calculation sheets have been signed/initialed and dated.	J.J / 3/22
7	Attachments to the calculation are formatted as required and are included in the calculation package.	JJ / 3/22
8	The calculation package is complete and submitted to the assigned checker.	JJ. / 3/22
9	The checker has accepted comment resolution and signed the cover sheet.	JJ / 3/22
10	The Calculation package has been submitted to Document Control (Preliminary) or Discipline Lead (Final).	J.J. / 3/22
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.	J.J / 3/22
14	The Discipline Lead has forwarded the calculation package to the Document Control.	J.J / 3/22
Calculation Revisions		
15	The calculation cover page is updated, noting the reason for revision.	J.J. / 3/22
16	Calculation sheets are updated in accordance with this procedure.	JJ / 3/22
17	The appropriate revision number has been assigned.	J.J / 3/22
18	The checking and approval (when required) have been completed and cover sheet is signed.	JJ / 3/22

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

Subcontractor Calculation Review Checklist.

Page 1 of 1

Subject: ICV™ Box Center of Gravity Calculation

The subject document has been reviewed by the undersigned.
The checker reviewed and verified the following items as applicable.

Documents Reviewed: **145579-D-CA-028, Rev. 0**

Analysis Performed By: **AMEC/DMJM**

- 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

145579-D-CA-060

DMJM TECHNOLOGY

CALCULATION COVER SHEET

Date: February 21, 2006

Calculation No: 145579-D-CA-060
Calculation Title: Heat Transfer Analysis – ICV Lid
Project No. & Title: 145579 – Final DBVS Design
Design Verification Required: ☐ Yes ☒ No
Calculation Type: ☐ Scoping ☒ Preliminary ☐ Final
☐ Superseded by Calculation No: _____ ☐ Voided
☐ Supersedes Calculation No: _____

ORIGINAL AND REVISED CALCULATION/ANALYSIS APPROVAL

	Rev. A Printed Name/Signature/Initials/Dat	Rev. _____ Printed Name/Signature/Initials/Date	Rev. _____ Printed Name/Signature/Initials/Date
Originator:	[signature] 2/21/06 Ja-Kael Luey		
Checked By:	[signature] 2/21/06 Kurt McCracken		
Approved By:	[signature] 2/21/06 Kurt McCracken		
Other:			

AFFECTED DOCUMENTS

Document Number	Document Title	Rev. Number	Responsible Discipline Lead Initials

RECORD OF REVISION

Rev.	Reason for Revision
A	Initial Release

ATTACHMENTS

Attachment #	Title	Total Pages
1	Calculation 0509206.01-M-002: DBVS ICV Off-Gas Hood Thermal Analysis	253

TOTAL CALCULATION PAGE COUNT - 257

EP 3.3-2F, April 2005

Calculation No. 145579-D-CA-060	ORIGINATOR: Ja-Kael Luey DATE 3/21/06
Rev. No. A	CHECKER: Kurt McCracken DATE 3/21/06
Calculation Title: Heat Transfer Analysis – ICV Lid	

1.0 INTRODUCTION

The In-Container Vitrification (ICV™) box is comprised of a lined box and lid. During processing the ICV lid provides a confinement barrier for gases generated. After processing, the penetrations into the lid are sealed and the complete box and lid provide a confinement barrier for the processed waste as it awaits shipment from the Demonstration Bulk Vitrification System (DBVS) site to a disposal location. This calculation estimates the temperature of the ICV lid for its installed condition during processing at the DBVS site.

1.1 Purpose

The ICV box lid (referred to as an off-as hood in Attachment 1 because of its function as a confinement barrier for gases) will experience elevated temperature as a result of processing conditions associated with the vitrification process. This vitrification process is initiated at the bottom of the box; as waste material is added, the melt surface "moves" upward as material is vitrified. The distance between the melt surface and the ICV lid is smallest near the completion of processing when the ICV box is fullest. This analysis focuses on determining the lid temperature at this point in processing, which is considered to be conservative for design.

1.2 Scope

This calculation analyzes the heat transfer to and from the ICV lid and neighboring structures, accounting for all three modes of heat transfer – radiation, conduction, and convection. The current DBVS design does not employ forced-air cooling in the Melt Area. Therefore, only natural convection heat transfer is modeled in this analysis.

2.0 Basis

2.1 Design Inputs

Design inputs are discussed in Sections 1.0 and 2.0 of Attachment 1.

2.2 Criteria

Operationally the DBVS Project has set 1058°F (570°C) as the limit for the ICV lid. This is based on full-scale testing experience with non-regulated testing materials (exceeding this temperature may impact the lid integrity and function of components/instruments that interact with the ICV lid).

Calculation No. 145579-D-CA-060	ORIGINATOR: [signature] DATE 2/21/06 Ja-Kael Luey CHECKER: [signature] DATE 2/21/06 Kurt McCracken
Rev. No. A	
Calculation Title: Heat Transfer Analysis – ICV Lid	

2.3 Assumptions

The melt surface temperature has the greatest impact on the results of the analysis. A melt surface temperature 1922°F (1050°C) with different boundary conditions was used in the analysis to determine the range of potential lid temperatures. An additional condition evaluated used data from full-scale testing with non-regulated material to estimate the melt surface temperature; then used this estimated temperature to calculate a lid temperature for the DBVS site configuration.

3.0 References

References are discussed in Attachment 1, Section 8.0.

4.0 Methods

Methodology used is discussed in Attachment 1.

5.0 Results and Conclusions

Sections 3.0 through 6.0 of Attachment 1 discuss the different cases run. The analysis in Section 3.0 for "Design Conditions" considered the DBVS site configuration with a melt surface of 1922°F (1050°C) and different AWTE floor temperatures. For this configuration, the temperature of the lid was relatively insensitive to the AWTE floor temperature and averaged about 1391°F (755°C). What was found to have the greatest impact on the lid temperature for this configuration was whether there is any soil overburden present. Soil overburden of one-inch lowers the lid temperature to 999°F (537°C) while three-inches lowers the lid temperature to 750°F (399°C). From an operational standpoint, control of melt surface soil overburden thickness is difficult for the design of the DBVS.

The analysis in Section 4.0 evaluated the impact of an insulation layer on the bottom surface of the AWTE floor. This results in a reduced heat flux through the AWTE floor. However, the presence of this insulating layer increases the average temperature of the ICV lid to 1665°F (907°C). No soil overburden is included in this analysis and the melt surface temperature is 1922°F (1050°C).

In Section 5.0 of Attachment 1, the AWTE floor was removed to simulate an "Open Air" condition that is most similar to the configuration used for full-scale testing with non-regulated materials. Results from this analysis shows that the melt surface temperature is the main driver for the lid temperature, with a predicted lid temperature of 1353°F (734°C). In order to reduce this temperature, the emissivity of the melt surface must be reduced or soil overburden needs to be present.

DMJM TECHNOLOGY

Project Number: 145779

Calculation No. 145579-D-CA-060	ORIGINATOR: Ja-Kael Luey DATE 3/21/06
Rev. No. A	CHECKER: Kurt McCracken DATE 3/21/06
Calculation Title: Heat Transfer Analysis – ICV Lid	

The analysis in Section 6.0 of Attachment 1 utilizes full-scale testing data with non-regulated material to estimate a temperature of the melt surface. Full-scale data is available for a prototypical lid in an open air configuration. Direct data for the melt surface is not available; however, data estimating the distance between the melt surface and lid is. Using the full-scale field data, the melt surface is estimated to be 1157°F (625°C). For the DBVS site configuration, using this melt surface temperature leads to a lid temperature of 800°F (427°C)

In summary, the melt surface temperature is the critical parameter that influences the ICV lid temperature. Conditions from full-scale testing have been used to predict a melt surface temperature that is consistent with measured ICV lid temperatures. Application of this melt surface temperature for the DBVS site configuration indicates that the lid temperature can be maintained below 1058°F (570°C) for prototypical operating conditions within the ICV box.

DMJM TECHNOLOGY

Calculation No. 145579-D-CA-060	Calculation Title: Heat Transfer Analysis – ICV Lid
Rev. No. A	

Attachment 1
DBVS ICV Off-Gas Hood Thermal Analysis: 0509206.01-M-002 Revision 1
(253 pages including Attachment Cover)

EP 3.3-2F, April 2005

ARES CORPORATION	CALCULATION COVER SHEET	Page No. 1 of 252
		Calculation No: 0509206.01-M-002
Project No. 0509206.01	Project Title: DBVS Thermal Analysis Authorization	Client: AMEC/DMJMH+N

Title:

DBVS ICV™ Off-Gas Hood Thermal Analysis

Purpose and Objective:

A thermal analysis of the temperature in the Demonstration Bulk Vitrification System (DBVS) In-Container Vitrification™ (ICV™) off-has hood is performed to support design of the hood and associated equipment and structures. In addition, the analysis computes the temperature on the bottom surface of the steel floor separating the ICV™ processing area from the Ancillary Waste Transfer Enclosure (AWTE). The corresponding heat flux through the floor is also estimated in this calculation. This information will be used as input to design of the AWTE Heating, Ventilation, and Air Conditioning (HVAC) system.

The analysis reflects a conservative, upper-bound melt condition assumed to exist during the late stages of processing. Consequently, the free-surface of the melt is relatively high in the ICV™ container. Moreover, DMJM H+N has specified that a melt-top temperature of 1922°F be assumed for the entire free-surface of the melt. In addition however, the analysis considers the effects of a thin layer of soil separating the melt surface from the off-gas plenum for its impact on hood temperature.

Rev. 1

The melt surface temperature used in the Rev. 0 analyses was derived from estimates based upon the judgment of vitrification experts, without the support of specific experimental measurements of this quantity. This estimate yielded results from the models that were inconsistent with experimental data (viz. – hood surface temperatures). The hood temperatures are strongly coupled to the actual melt surface temperature realized during testing. Therefore, the model developed in Rev. 0 of the calculations is re-visited in this revision, turning the problem around. That is, adjust the melt surface temperature until the hood temperatures predicted are consistent with those realized in the BulkVit testing performed at the Horn Rapids Test Site (HRTS). Then, use this value in the DBVS-specific version of the model to determine the corresponding hood temperatures that result with this revised melt surface temperature .

Rev. No.	Total Pages	Revision Description (Add Continuation Sheet If Required)	Prepared By Name/Date	Checked By Name/Date	PM/TL Approval/Date
0	156	Original	P.S. Lowery	S.R. Pierce	S.R. Pierce
1	252	Revised to include model with modified melt surface temperature	P.S. Lowery [signature] 2/17/06	S.R. Pierce [signature] 2/19/06	S.R. Pierce [signature] 2/19/06

Calculation Cover Sheet: QAP 3.1, Rev. 6 (11-15-05)

ARES CORPORATION	CALCULATION REVIEW CHECKLIST		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. 1	Page No. 2 of 252

Items Checked	Accept Y	Accept N	Accept N/A	Initial/Date
1. Cover sheets properly completed.	✓			SRP 2/19/06
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): S.R. Pierce [signature]	Date: 2/19/06
Originator (Print Name and Sign): P.S. Lowery [signature]	Date: 2/17/06

Signatures obtained only after discrepancies are corrected and comments are resolved.

Calculation Review Checklist: QAP 3.1, Rev. 6 (11-15-05)

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 3 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

Table of Contents

Figures

Tables

CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 4 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

APPENDICES

Appendix A
MathCad Model for the Design Conditions

Appendix B
Mathcad Model for the Design Conditions with Soil Overburen

Appendix C
Mathcad Model for the Insulated Floor Conditions

Appendix D
Mathcad Model for the "Open Air" Conditions

Appendix E
Mathcad Model for the "Open Air" Conditions with Soil Overburden

Appendix F
HRTS BulkVit Test 38A-1 & 38B Conditions

Appendix G
Mathcad Model for the HRTS Conditions with Adjusted Melt Surface Temperature

Appendix H
Mathcad Model for the HRTS Conditions with Adjusted Melt Surface Temperature and Lower Melt Surface Level

Appendix I
Mathcad Model for the DBVS Conditions with Adjusted Melt Surface Temperature

Acronyms

AWTE	Ancillary Waste Transfer Enclosure
DBVS	Demonstration Bulk Vitrification System
HRTS	Horn Rapids Test Site
HVAC	Heating, Ventilation, and Air Conditioning
ICV™	In-Container Vitrification™

CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 5 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

1.0 INTRODUCTION

A conservative, reasonably high estimate of the temperature of the Demonstration Bulk Vitrification System (DBVS) In-Container Vitrification (ICV™) off-gas hood is an important parameter used in the design of the structure. The off-gas hood will experience elevated temperatures as a result of the high operating temperatures associated with the vitrification process performed within the ICV™ box. Typically, the BulkVit process will generate nominal temperatures of approximately 1350°C in the core of the melt. The temperature at the top of the melt, where it is exposed to the off-gas hood plenum region, is somewhat lower, but still relatively high. For this analysis, DMJM H+N has specified that a temperature of 1922°F (1050°C) be assumed for the melt's entire top surface. The off-gas hood is maintained at a relatively high temperature as well. Project process flow sheets indicate that the temperature in the off-gas plenum will be approximately 875°F (468°C). The analysis assumes a worst-case ambient temperature of 55°C, reflecting operation during a very hot summer day.

An Ancillary Waste Transfer Enclosure (AWTE) is situated above the ICV™ container. A 3½" steel floor separates the AWTE from the BulkVit processing region. The AWTE houses a number of the process' ancillary equipment and structures. The thermal environment within the AWTE must be controlled to allow periodic access by operating personnel. Therefore, it is necessary to also provide a conservative, reasonably high estimate of the heat load imposed by the ICV™ off-gas hood so that the AWTE HVAC system can be adequately designed.

Finally, to put these assumptions and their corresponding results in perspective, the model generated is modified to simulate the case of operating at the Horn Rapids Test Site (HRTS). The results for this case are then compared against comparable experimental data obtained from test performed at this Site.

Revision 1 Modifications

The melt surface temperature used in the Rev. 0 analyses was derived from estimates based upon the judgment of vitrification experts, without the support of specific experimental measurements of this quantity. This estimate yielded results from the models that were inconsistent with experimental data (viz. – hood surface temperatures). The hood temperatures are strongly coupled to the actual melt surface temperature realized during testing. Therefore, the model developed in Rev. 0 of the calculations is re-visited in this revision, turning the problem around. That is, adjust the melt surface temperature until the hood temperatures predicted are consistent with those realized in the BulkVit testing performed at the HRTS. Then, use this value in the DBVS-specific version of the model to determine the corresponding hood temperatures that result with this revised melt surface temperature.

Two HRTS operational scenarios are considered:

1) when the melt surface level is the same as was considered in the Rev. 0 analysis (~30" below the off-gas hood top surface), and
2) when the melt surface is 75" below the off-gas hood top surface.

For both scenarios, the temperature modeled for the melt surface is adjusted until the computed average hood temperature agrees with the data measured during the HRTS BulkVit Tests 38A-1 and 38B data. Per Ref. 7 (also in Appendix F), these values are:

1) 400°C when the melt surface is at its highest level, ~ 30" below the off-gas hood top surface, and
2) 350°C when the melt surface is 75" below the off-gas hood top surface.

The higher of the two melt surface temperatures obtained from these cases is then used in the DBVS-version of the model to generate the average hood temperature for that configuration. The results are addressed in Section 6.0 of the calculation.

2.0 CALCULATION METHODOLOGY

This calculation analyzes the heat transfer to and from the ICV™ off-gas hood and neighboring structures, accounting for all three modes of heat transfer – radiation, conduction, and convection. The current design does not employ forced-air cooling in the BulkVit processing region. Therefore, only natural convection heat transfer is modeled in this analysis.

The general layout of the ICV™ box and AWTE steel floor has been provided in Reference 1. Detailed drawings of the off-gas hood, ICV™ box and internals, and associated neighboring structures were also provided in this reference. As the materials provided in this reference indicate, the top surface of the melt is located 30.32" below the top of the ICV™ off gas hood. A relatively narrow 2½" air gap separates the top of the off-gas hood from the bottom surface of the AWTE floor. Drawing F-145579-35-D-0004, Rev. 1 (provided with Ref. 1) indicates that the panels covering the top, east, and west sides of the off-gas hood are stiffened with 4"x2" steel tubing spaced at approximately 12" intervals along the long-axis of the hood. The additional surface provided by these tubes is included in the convective heat transfer considerations in the model.

The calculation presented herein expands on the method and results presented in a previous calculation of the off-gas hood temperatures (Ref. 2). Many of the material properties used in that analysis are also employed in this analysis. Specifically, the emissivity used to compute the radiation heat transfer from the melt surface was specified as 0.7 in the Ref. 2. This same value is used in this calculation. Moreover, the emissivity assigned for radiant heat transfer off steel surfaces was assigned a value of 0.85 in Ref. 2. Again, this same value is used in this calculation.

The calculation presented herein represents a considerably more elaborate model of the thermal energy exchange between the surfaces of the ICV™ box, off-gas hood, and AWTE floor, however. The model is used to perform a parametric study of the effects of variations in AWTE floor temperature on the heat load to the AWTE air space as well as for its effect on hood temperatures.. Several values are prescribed for the melt surface temperature and the temperature of the top surface of the AWTE floor. The cases discussed in Sections 3.0, 4.0, and 5.0 assume a melt surface temperature of 1922°F (1050°C). The temperatures prescribed for the top surface of the AWTE floor are 77°F, 250°F, and 400°F. The off-gas hood and AWTE floor bottom-surface temperatures, along with an estimate of the thermal heat flux through the AWTE floor are computed for each case. In addition, the effect on hood temperatures of including a layer of yet-to-be processed soil resting on top of the melt surface is also considered in these parametric studies. Soil layer thicknesses ranging from 1" to 6" are considered in this study. The cases discussed in Section 6.0 address the effect of varying the melt surface temperature to achieve agreement with measured off-gas hood temperature data.

The analysis develops a coupled, non-linear system of equations describing energy conservation on each surface of the model. Radiation heat transfer view factors were obtained using the relationships provided in Ref. 3. MathCad v2001i (Ref. 4) was used to formulate the system of equations and effect their solution. The relevant surfaces of the ICV™ box and off-gas hood are modeled, as is the 3½" thick steel AWTE floor. A schematic diagram of the ICV™ box and off-gas hood surfaces modeled is provided in Figure 1. Index numbers used to identify each constituent surface of the model are indicated in this figure. Alphanumeric designators for the box and hood dimensions are indicated. These designators correspond to the values included in the MathCad models presented in the Appendices.

Surface 0 represents the top surface of a soil layer covering the melt. The thickness of this layer (δ_{soil}) is a parameter that is varied in the simulations. In addition, a relatively crude model is included to allow the capability to address the "participating-media" effects of constituents in the gas-phase of the off-gas plenum. This effect could result from the presence of NO_x, CO, CO_2, SO_2, water vapor, dust, and other media present in the off-gas plenum region. It is included through the use of an absorbtivity parameter, α_{OG}, and corresponding transmissivity parameter, $\tau_{OG} = 1 - \alpha_{OG}$. For the cases presented in this calculation however, this off-gas absorbtivity parameter is set to zero, indicating no participating-media radiation heat transfer effects for the gases and particulates present in the off-gas plenum.

As discussed above, the drawings provided in Ref. 1 indicate that several of the surfaces are backed-up with a series of 4"x2" steel tubes, effectively forming an exoskeleton for these hood surfaces. This tubing is present on modeled surfaces 6, 8, and 9. The horizontal and vertical components of the surfaces associated with these tubes are included to enhance the convective heat transfer surfaces areas of these modeled surfaces.

Surfaces 1 through 4 in the model represent the portions of the ICV™ box sidewalls that are above the melt surface but beneath the off-gas hood. These surfaces conduct energy in the lateral direction through the 60PC and refractory sand composite liner out to the sidewalls of the ICV™ box where it is passed to the surrounding air space by convective and radiative heat transfer. Surfaces 1 through 4 represent the inside surface of the melt confinement structure. The corresponding surfaces representing the outside surfaces of the box have ID tags 11, 12, 13, and 14. These surfaces are not shown in Figure 1. They have the same width and height dimensions as their internal mating surfaces 1 through 4, however. Surface 11 mates with surface 1, surface 12 with 2, and so on. The surfaces are separated by a 6" thick layer of 60PC castable refractory, backed by a corresponding 6" thick layer of refractory sand. The steel skin of the ICV™ box separates the refractory sand from the ambient air surrounding the box.

Surface 10 (not pictured in Figure 1) represents the AWTE floor. The floor is composed of a 3½" steel plate and spans an area 24 ft x 30 ft. Per the drawings provided in Ref. 1, the bottom surface of the floor is 2½" above the top surface of the off-gas hood. Only a portion of the AWTE floor is assumed to participate in the heat transfer with the off-gas hood. As indicated in the Appendices, the effective AWTE floor area is 3 ft larger on any side than the plan area of the ICV™ box. All heat transferred from the hood to the AWTE floor is

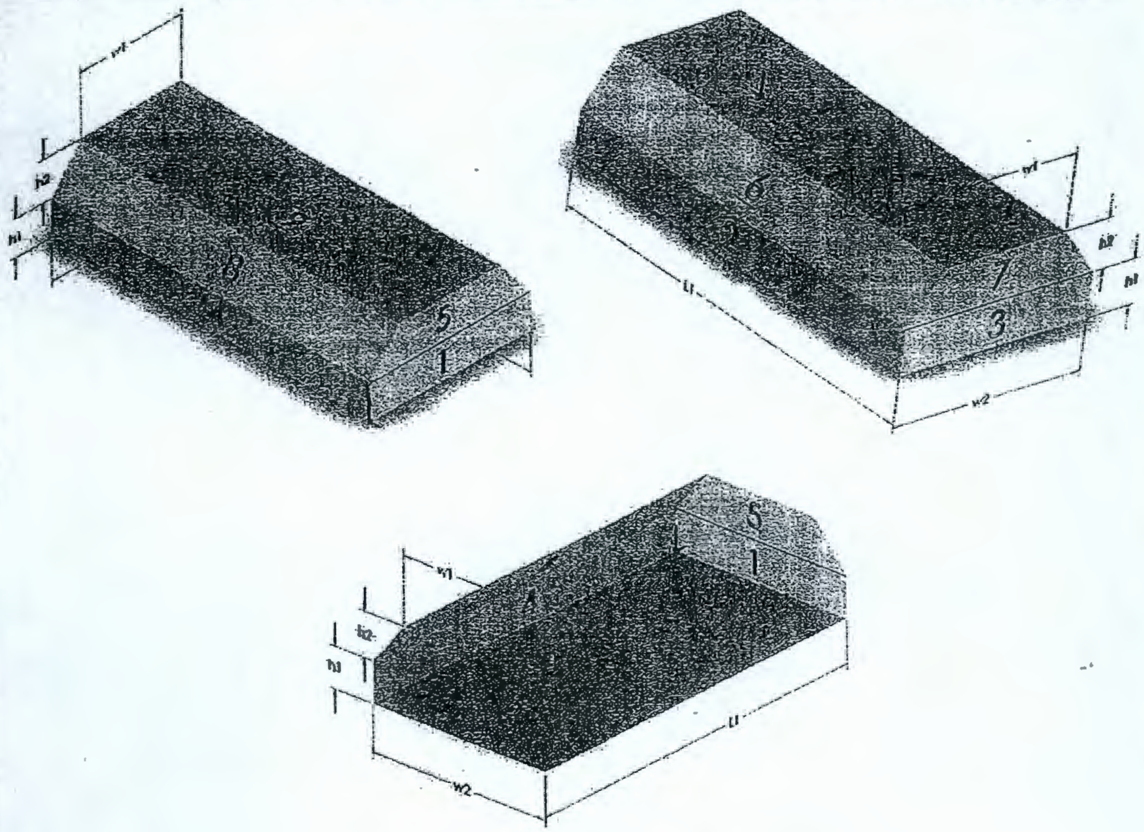


Figure 1. Model Schematic.

restricted to communication through this area. The temperature for the top surface of this floor is set to one of three values (per Ref. 1) – 77°F, 250°F, and 400°F. The heat flux through the AWTE floor is computed by the model for each of these temperatures. The AWTE HVAC system must include the heat load associated with this flux in order to be properly sized to maintain this prescribed floor temperature. The HVAC design and analysis is provided by others.

In addition to analyzing for the design conditions described above, two more scenarios are considered. In the first scenario, the effect of including an insulating blanket on the bottom surface of the AWTE steel floor (the surface exposed to the ICV™ off-gas hood) is considered. This is done to evaluate the benefits for reduced heat transfer to the AWTE through the steel floor. The potentially detrimental effect on off-gas hood temperatures is also addressed in this case. The second case considers the effect of performing the analysis assuming conditions representative of performing the BulkVit process in the out-of-doors [analogous to the conditions present during the testing performed by AMEC at the Horn Rapids Test Site (HRTS)]. This is done to benchmark results generated by the model against the available experimental data. The tests generated a wealth of thermocouple data. However, the conditions of the melt that were driving these temperatures were less well defined in the tests. Therefore, while comparison of these results with experimental data is illustrative, quantitative comparison of the computed vs. experimental results will necessarily require these differences be kept in perspective. When reasonable assumptions for the thickness of a yet-to-be-processed soil layer are included in the model, results are obtained that are well within the band of temperatures measured in the HRTS tests.

3.0 ANALYSIS FOR DESIGN CONDITIONS

Three cases were considered in which the upper surface of the AWTE floor was set at 77°F, 250°F, and 400°F. This condition is introduced in the model through changes to one parameter only – T_{AWTE}. The rest of the model is unchanged. The MathCad listing of the model for one of these cases is presented in Appendix A. The results for each case are summarized in Table 1 below. The average hood temperature and total heat loss emanating from the 1922°F melt surface are listed in this table. In addition, the heat flux passing through the AWTE floor under these conditions is also presented in the table. As these results indicate, the average hood temperature and overall melt heat loss parameters are relatively insensitive to changes in the prescribed temperature on the upper-surface of the AWTE floor.

Table 1. ICV™ Off-Gas Hood Thermal Analysis Results for Design Conditions

T_{AWTE} (°F)	Avg. Off-Gas Hood Temperature (°C)	Total Heat Loss from Melt Surface (kW)	Heat Flux Through AWTE Floor (kW/m²)
77	751	952	21.7
250	755	943	20.7
400	760	932	19.3

Table 2 presents the results obtained when a relatively thin layer of yet-to-be-processed soil is modeled. This thin soil layer separates the melt surface from direct exposure to the off-gas hood and plenum regions. It can be argued that the presence of this soil layer effectively increases the temperature at the melt-soil interface. Therefore, to address this concern, the temperature of this interface is increased from the 1050°C valued used to simulate an exposed melt top, to 1250°C. This is only approximately 100°C less than the targeted bulk temperature at the core of the melt and therefore should be conservative. For each of these cases, a temperature of 77°F was assumed for the top surface of the AWTE. As the results presented in Table 2 indicate, the hood temperatures and associated AWTE floor heat fluxes are reduced considerably when the effect of a soil overburden layer is included. The MathCad model used to simulate these conditions is provided in

Appendix B.

Table 2. ICV™ Off-Gas Hood Thermal Analysis Results for Design Conditions with Soil Overburden Layer

δ_{soil} (in)	Avg. Off-Gas Hood Temperature (°C)	Total Heat Loss from Melt Surface (kW)	Heat Flux Through AWTE Floor (kW/m²)
½	627	578	13.2
1	537	383	8.9
3	399	181	4.4
6	330	109	2.9

4.0 ANALYSIS FOR INSULATED AWTE FLOOR CONDITIONS

Again, three cases were considered in which the upper surface of the AWTE floor was set at 77°F, 250°F, and 400°F. There is no soil overburden layer included in this model, however. For each case, the effect of including a 1½" thick blanket of calcium-silicate insulation affixed to the bottom surface of the AWTE floor is assessed. This material has been suggested in Ref. 5 as a candidate material for insulating this and other surfaces in and around the AWTE. The properties for this material were obtained from this reference. As before, the AWTE floor surface temperature condition is introduced in the model through changes to one parameter only – T_{AWTE}. The model was revised to include the effect of the insulating blanket, however. The rest of the model is unchanged. The MathCad listing of the model for one of the cases performed in this study is presented in Appendix C. The results for each case are summarized in Table 3 below. The average hood temperature and total heat loss emanating from the 1922°F (1050°C) melt surface are listed in this table. In addition, the heat flux passing through the AWTE floor under these conditions is also presented in the table. As these results indicate, while the heat loss through the AWTE floor is reduced substantially, the average hood temperature increases significantly, to approximately 905°C.

Table 3. ICV™ Off-Gas Hood Thermal Analysis Results for Insulated Floor Conditions.

T_{AWTE} (°F)	Avg. Off-Gas Hood Temperature (°C)	Total Heat Loss from Melt Surface (kW)	Heat Flux Through AWTE Floor (kW/m²)
77	906	549	1.3
250	907	546	1.2
400	908	544	1.1

5.0 ANALYSIS FOR "OPEN AIR" OPERATING CONDITIONS

The MathCad model was modified to remove the influence of the AWTE floor in an effort to represent conditions of operating in an "open air" environment. In addition, parameters associated with modeling heat transfer from the external surfaces of the ICV™ container were modified to reflect direct communication with ambient conditions. The resulting MathCad model for this scenario is provided in Appendix D.

Three cases were considered. The first case employs the same set of assumptions for the melt and ambient temperatures as was done for the preceding analysis sets. In particular, a temperature of 1922°F was assumed for the melt's free-surface. An emissivity of 0.7 was also assumed for radiative heat losses from the melt (as before). An ambient temperature of 55°C was also assumed for this case. The results obtained for this case are presented in the first row of Table 4. As the results for this case (and, in fact, all the preceding cases) indicate, under these conditions, the heat loss from the surface of the melt to the surrounding surfaces of the ICV™ box walls and off-gas hood panels far exceeds the power delivered to the melt under normal operating conditions. At the present time, a nominal power level of approximately 700 kW is targeted. These results indicate that the heat loss from the melt surface is nearly 1000 kW. This is largely a consequence of imposing the 1922°F temperature to represent the top surface of the melt. To assess the impact of this, a second case was considered in which the effective emissivity of the melt was reduced until the heat flux from the melt approximates that realized in traditional in-situ vitrification (ISV) conditions – viz., 32.5 kW/m^2 (Ref. 6). This required that the melt emissivity be reduced to 0.045. The second row of results presented in Table 4 provides the results obtained for this case. Finally, a third case was analyzed in which the ambient temperature was reduced from 55°C to 0°C. The "open-air" HRTS tests were conducted in ambient conditions nearer this than the hot summer-day conditions represented by the 55°C temperature. The results obtained for this case are presented in the third row of data provided in Table 4.

Table 4. ICV™ Off-Gas Hood Thermal Analysis Results for "Open Air" Conditions.

$T_{ambient}$ (°C)	Melt Emissivity	Avg. Off-Gas Hood Temperature (°C)	Total Heat Loss from Melt Surface (kW)
55	0.7	734	986
55	0.045	487	363
0	0.045	476	366

When a layer of yet-to-be-processed soil overburden is included in this model, the off-gas hood and total heat loss results are dramatically reduced. To compensate for the fact that the melt is somewhat insulated by this soil overburden, the temperature at the melt-to-soil overburden interface is increased from 1922°F (1050°C) to 2282°F (1250°C). Table 5 presents the results obtained when a 1", 3", and 6" thick layer of overburden soil is modeled. An ambient temperature of 25°C is assumed for each case – approximating nominal ambient conditions at the HRTS. In addition, the emissivity of soil surface is set to the same value as was used to represent the melt's surface, 0.7. The Mathcad model for these cases is presented in Appendix E.

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 12 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

The results obtained from this model are compared against experimental data obtained from two relatively recent BulkVit demonstrations performed at the HRTS. Figure 2 presents results for off-gas hood skin temperature measurements during BulkVit Tests 38A-1. Hood skin temperatures realized during Test 38B are provided in Figures 3 and 4. Since these tests were intended (in part) to demonstrate the feed-while-melt approach to processing, for most of the test duration, a substantial layer of soil feed was maintained on top of the melt. As indicated in these figures, the hood skin temperatures exhibited considerable variation during the course of the process. For Test 38A-1, the hood skin temperatures ranged from approximately 150°C to 500°C. The average temperature appears to be approximately 250 to 300°C for this test. The hood skin temperatures realized in Test 38B ranged from 100°C to 400°C, with one apparently outlier thermocouple indicating temperatures up to 700°C. It's likely that this thermocouple was the recipient of direct radiant "shine" from an exposed portion of the melt. The average hood skin temperature for this test appears to be approximately 200 to 250°C. The results obtained using the MathCad model of the configuration and test conditions are presented in Table 5. These results are consistent with these experimental values.

Table 5. ICV™ Off-Gas Hood Thermal Analysis Results for "Open Air" Conditions with Soil Overburden.

δ_{soil} (in)	Avg. Off-Gas Hood Temperature (°C)	Total Heat Loss from Melt Surface (kW)
1	505	393
3	364	186
6	296	112

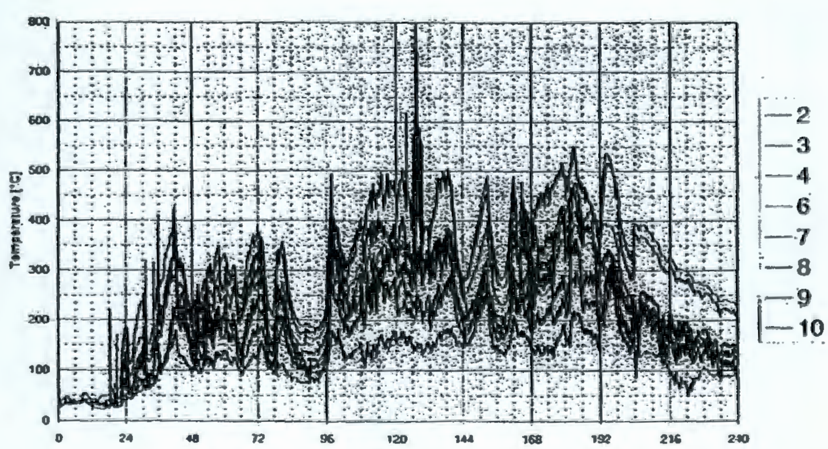


Figure 2. BulkVit Test 38A-1 Hood Skin Temperature Data.

ARES CORPORATION

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 13 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

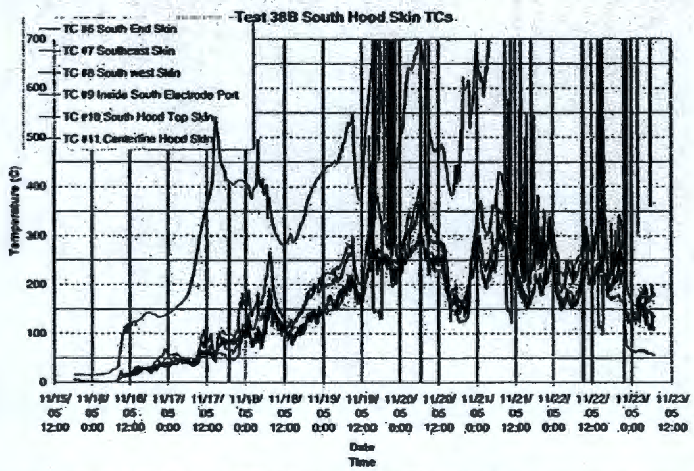


Figure 3. BulkVit Test 38B South-Side Hood Skin Temperature Data.

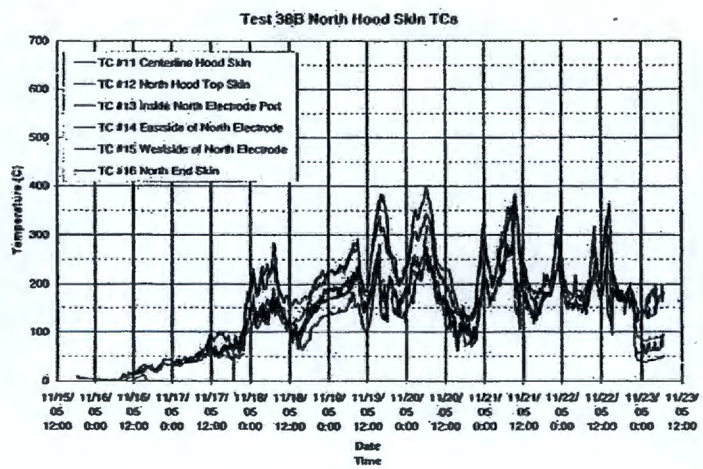


Figure 4. BulkVit Test 38B North-Side Hood Skin Temperature Data.

6.0 ANALYSIS FOR ADJUSTED MELT SURFACE TEMPERATURE

The melt surface temperatures used to drive the analyses presented in the preceding sections was estimated based upon the judgment of vitrification experts, without the benefit of direct measurements of this value. As the results in the preceding sections indicate, the results are tightly coupled to the value chosen. As was also indicated in the preceding analyses, without the inclusion of a yet-to-be-processed soil layer on top of the melt, the hood temperatures that result are not consistent with those realized in recent BulkVit demonstrations. Therefore, the "Open Air" model discussed in Section 5.0 is re-visited to investigate the effect of adjusting the melt surface temperature until the resulting average hood temperature is consistent with experimental data obtained from HRTS BulkVit Tests 38A-1 and 38B. Two cases are considered (per Ref. 7; also provided in Appendix F):

1) when the melt surface is at a level ~ 30" below the top surface of the off-gas hood (as was modeled in the cases considered in the preceding sections of this calculation), and

2) when the melt surface level is 75" below the top surface of the off-gas hood.

Per the guidance provided in Ref. 7 (also Appendix F), for the Case (1) conditions, an ambient temperature of 12°C and off-gas plenum temperature of 600°C are included in the model. For Case (2), the ambient temperature is reduced to 0°C to better reflect conditions experienced during the BulkVit demonstration for which the hood temperature data for this case was obtained (viz. – Test 38B). The off-gas temperature is again prescribed at 600°C for this case. The Case (2) melt surface conditions, while indicating lower hood temperatures, may result in a higher required melt surface temperature due to the lower melt surface elevation within the ICV™ box.

The Mathcad model for Case (1) is presented in Appendix G. A melt surface temperature of 625°C yielded an average hood temperature of ~400°C for these conditions. The Mathcad model for Case (2) is presented in Appendix H. For this case, a melt surface temperature of 605°C resulted in an average hood temperature of ~350°C.

Since the Case (1) results are more limiting, the melt surface temperature of 625°C obtained from the case is prescribed for the DBVS-version of the model when the upper surface of the AWTE floor is maintained at 77°F and operations are conducted with an ambient outside-air temperature of 50°C. The Mathcad model for this case is presented in Appendix I. The results indicate that the average hood temperature is ~427°C for this case. Under these conditions, ~153 kW (~44 tons refrigeration) of thermal energy is transferred to the AWTE floor.

ARES CORPORATION	CALCULATION SHEET				
Project No. 0509206.01	Calculation No. 0509206.01-M-002			Rev. No. 1	Page 15 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis					
Prepared By: P.S. Lowery		Date: 2.17.06	Checked By: S.R. Pierce		Date: 2.17.06

7.0 CONCLUSIONS

The results presented in Table 1 for the design conditions indicate that an average off-gas hood temperature of approximately 750°C would result from the assumed configuration and melt temperature. The previous analysis performed by AMEC (Ref. 2) indicated that this temperature would be approximately 661°C. The differences are, to some extent, the result of changes in the assumed configuration (e.g. – the separation between the top surface of the off-gas hood and the bottom surface of the AWT floor). The increased complexity and detail provided in the model and analysis approach employed in this calculation are, however, more likely the predominant cause for the differences. For the "design conditions", the heat transfer through the AWTE floor represents a considerable heat load to the AWTE. Applying this flux over the 322 ft^2 (~30 m^2) of the affected portion of the AWTE floor indicates that the total heat load to the AWTE is as high as 650 kW (~185 tons refrigeration). It is likely that this load will require a sizeable HVAC system to maintain the targeted 77°F air-space temperature in the AWTE.

When a ½" thick layer of yet-to-be-processed soil is included in the model, in effect separating the melt surface from the off-gas hood and plenum regions, the average off-gas hood temperature is reduced substantially, from approximately 750°C to approximately 630°C. The heat load to the AWTE floor is also significantly reduced, to approximately 13.2 kW/m^2. This translates to a heat load of 400 kW (~115 tons refrigeration), roughly 60% of the load when no soil overburden is accounted-for. This reduces even further with increasing soil overburden thickness. For example, when a 6" thick layer of soil overburden is included in the model, the average off-gas hood temperature reduces to 330°C. The AWTE floor heat flux is reduced to3 kW/m^2 for this case.

Including the 1½" thick CaSi insulating blanket on the bottom surface of the AWTE floor reduces this heat load to approximately 30 kW. The average temperature of the off-gas hood increases considerably however, to approximately 905°C.

The heat losses emanating from the melt surface in either of these scenarios appears incredibly high. This heat loss is associated with the assumption of a 1050°C temperature over the entire free-surface of the melt. Were this condition to be realized, it is likely that the melt would rather quickly cool down to a lower temperature, even if this occurred while providing the 700 kW steady-state power to the melt. Still, these conditions certainly provide a conservatively-high estimate of off-gas hood temperatures.

To help assess the adequacy and conservatism of the model, the model is applied to the system under an "open air" operating scenario – analogous to what was done for the HRTS testing program. The results obtained for the case wherein the emissivity of the melt is reduced to produce a heat flux from the melt surface consistent with what has been realized in traditional ISV melts (viz.– approximately 32½ kW/m^2) are more in-line with the hood temperatures measured in Test 38A-1 and 38B. The data from those tests indicates that the hood temperature ranged from 150°C to 500°C for test 38A-1, and 100°C to 700°C in Test 38B. The average hood skin temperatures appears to be in the range from 250°C to 300°C for Test 38A-1, and from 200°C to 250°C for Test 38B. When the melt emissivity is reduced to a level such that the heat flux of the top surface of the melt is commensurate with the 32.5 kW/m^2 realized in traditional ISV applications, the average off-gas hood temperature is reduced to approximately 490°C. This level is still a bit higher than that realized in the test data, but not far off. When the effect of a soil overburden layer is included in the HRTS version of the model, the average off-gas hood temperatures are reduced further still. A soil overburden layer in the range of 3" to 6" yields average off-gas hood temperatures comparable to those obtained in the Tests, in the range 365°C to 300°C.

Two cases are considered to assess the impact of adjusting the melt surface temperature to make the results obtained for the average off-gas hood temperature in the "Open Air" version of the model consistent with experimental data obtained from the HRTS BulkVit demonstrations. The results from these cases indicate that a melt surface temperature of ~625°C results in an average hood temperature of ~400°C – consistent with data obtained from BulkVit Demonstration #38A-1 performed at the HRTS. Using the 625°C melt surface temperature in the DBVS-version of the model results in an average hood temperature of 427°C and a heat load of ~153 kW (~44 tons refrigeration) to the AWTE floor (assuming the top surface of the AWTE floor is maintained at 77°F and an ambient outside-air temperature of 50°C).

8.0 REFERENCES

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CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 17 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

APPENDIX A

MATHCAD MODEL FOR THE DESIGN CONDITIONS

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 18 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

$^\circ F \equiv 1$

$^\circ C \equiv 1$

$CtoF(x) := \left(\frac{9}{5}\frac{x}{^\circ C} + 32\right)^\circ F \quad CtoK(x) := \left(\frac{x}{^\circ C} + 273.15\right)K \quad KtoC(x) := \left(\frac{x}{K} - 273.15\right)^\circ C$

$FtoC(x) := \frac{5}{9}\left(\frac{x}{^\circ F} - 32\right)^\circ C \quad FtoR(x) := \left(\frac{x}{^\circ F} + 459.67\right)R$

$w_1 := 5.5ft \quad w_2 := 3.5ft \quad L_1 := 22ft \quad h_1 := 14in \quad h_2 := 16in \quad \theta := 52deg \quad N_{ribs} := 12 \quad w_{ribs} := 2in \quad h_{ribs} := 4in$

$\delta_{hood} := 0.3125in \quad \theta := 52deg \quad \delta_{floor} := 3.5in \quad \delta_{CR} := 6in \quad \delta_{sand} := 6in$

Matrix of surface areas ...

$$A := \begin{bmatrix} w_1 \cdot L_1 & 0 & 0 \\ w_1 \cdot h_1 & 0 & 0 \\ L_1 \cdot h_1 & 0 & 0 \\ w_1 \cdot h_1 & 0 & 0 \\ L_1 \cdot h_1 & 0 & 0 \\ \frac{(w_1 + w_2) \cdot h_2}{2} & 0 & 0 \\ L_1 \cdot \frac{h_2}{\sin(\theta)} & N_{ribs} \cdot w_{ribs} \cdot \frac{h_2}{\sin(\theta)} & 2N_{ribs} \cdot h_{ribs} \cdot \frac{h_2}{\sin(\theta)} \\ \frac{(w_1 + w_2) \cdot h_2}{2} & 0 & 0 \\ L_1 \cdot \frac{h_2}{\sin(\theta)} & N_{ribs} \cdot w_{ribs} \cdot \frac{h_2}{\sin(\theta)} & 2N_{ribs} \cdot h_{ribs} \cdot \frac{h_2}{\sin(\theta)} \\ w_2 \cdot L_1 & N_{ribs} \cdot w_{ribs} \cdot w_2 & 2N_{ribs} \cdot h_{ribs} \cdot w_2 \\ (3ft + w_1 + 3ft) \cdot (3ft + L_1 + 3ft) & 0 & 0 \\ w_1 \cdot h_1 & 0 & 0 \\ L_1 \cdot h_1 & 0 & 0 \\ w_1 \cdot h_1 & 0 & 0 \\ L_1 \cdot h_1 & 0 & 0 \end{bmatrix}$$

The first column of dat contains the area of the element for radiant heat transfer. The second column of data contains the horizontal component of area associated with the 4"x2" steel tubing ribs on that elemental area. The third column of data contains the vertical component of the ribs for that elemental area.

A = (ft^2)

	0	1	2
0	121	0	0
1	6.4	0	0
2	25.7	0	0
3	6.4	0	0
4	25.7	0	0
5	6	0	0
6	37.2	3.4	13.5
7	6	0	0
8	37.2	3.4	13.5
9	77	7	28
10	322	0	0
11	6.4	0	0
12	25.7	0	0
13	6.4	0	0
14	25.7	0	0

ARES CORPORATION	**CALCULATION SHEET**		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 19 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

$$F := \begin{pmatrix} 0 & .021 & .091 & .021 & .091 & .028 & .177 & .028 & .177 & .366 & 0 \\ .397 & 0 & .026 & .004 & .026 & 0 & .129 & .021 & .129 & .265 & 0 \\ .428 & .006 & 0 & .006 & .052 & .019 & .039 & .019 & .077 & .354 & 0 \\ .400 & .004 & .026 & 0 & .026 & .021 & .129 & 0 & .129 & .265 & 0 \\ .428 & .006 & .052 & .006 & 0 & .019 & .077 & .019 & .039 & .354 & 0 \\ .565 & 0 & .081 & .022 & .081 & 0 & .081 & .003 & .081 & .086 & 0 \\ .575 & .022 & .027 & .022 & .053 & .013 & 0 & .013 & .015 & .125 & .616 \\ .565 & .022 & .081 & 0 & .081 & .003 & .081 & 0 & .081 & .086 & 0 \\ .575 & .022 & .053 & .022 & .027 & .013 & .150 & .013 & 0 & .125 & .616 \\ .574 & .022 & .118 & .022 & .118 & .013 & .060 & .013 & .060 & 0 & 1 \end{pmatrix}$$

Matrix F contains the view factors for radiant heat transfer between surfaces of the model. The first (row) index corresponds to the ID of the source surface; the second to the receiving surface. For example, the top of the soil surface above the melt has ID=0; the ID of the "short" box wall surface (width = 5.5 ft, height = 14in) has ID = 1. The view factor between these two surfaces is located at F[0,1] = 0.021 (obtained from Configuration 16, p. 1030 in Siegel & Howell's Thermal Radiation Heat Transfer, 3rd Edition). The "reciprocity" view factor for these two surfaces is F[1,0]= A[0,0]*F[0,1]/A[1,0] = 0.397.

F =

	0	1	2	3	4	5	6	7	8	9	10
0	0	0.021	0.091	0.021	0.091	0.028	0.177	0.028	0.177	0.366	0
1	0.397	0	0.026	0.004	0.026	0	0.129	0.021	0.129	0.265	0
2	0.428	0.006	0	0.006	0.052	0.019	0.039	0.019	0.077	0.354	0
3	0.4	0.004	0.026	0	0.026	0.021	0.129	0	0.129	0.265	0
4	0.428	0.006	0.052	0.006	0	0.019	0.077	0.019	0.039	0.354	0
5	0.565	0	0.081	0.022	0.081	0	0.081	0.003	0.081	0.086	0
6	0.575	0.022	0.027	0.022	0.053	0.013	0	0.013	0.015	0.125	0.616
7	0.565	0.022	0.081	0	0.081	0.003	0.081	0	0.081	0.086	0
8	0.575	0.022	0.053	0.022	0.027	0.013	0.15	0.013	0	0.125	0.616
9	0.574	0.022	0.118	0.022	0.118	0.013	0.06	0.013	0.06	0	1

ARES CORPORATION

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 20 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery, Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06	

DBVS Off-Gas Hood Thermal Model

Temperature Boundary Conditions ...

$Tmelt := 1922°F$ $TmC := FtoC(Tmelt)$ $T_{melt} := CtoK(TmC)$ $T_{melt} = 1323.15\,K$

$TAWTE := 77°F$ $TAC := FtoC(TAWTE)$ $T_{AWTE} := CtoK(TAC)$ $T_{AWTE} = 298.1\,K$

$TOG := 875°F$ $Tog := FtoC(TOG)$ $T_{OG} := CtoK(Tog)$ $T_{OG} = 741.483\,K$

$Tamb := 55°C$ $T_{amb} := CtoK(Tamb)$ $T_{amb} = 328.1\,K$

Initial guess for temperatures ...

$T_0 := T_{melt}$ $T_0 = 1323.15\,K$

$T_1 := 773K$ $T_2 := 723K$ $T_3 := 773K$ $T_4 := 773K$ $T_5 := 773K$ $T_6 := 773K$ $T_7 := 773K$ $T_8 := 773K$ $T_9 := 773K$ $T_{10} := 773K$

$T_{11} := 473K$ $T_{12} := 473K$ $T_{13} := 473K$ $T_{14} := 473K$ $T_{15} := T_{OG}$

Material properties ...

$\varepsilon_{melt} := 0.7$ $\sigma := 5.67\cdot10^{-8}\cdot\frac{W}{m^2\cdot K^4}$

$\varepsilon_{stl} := .85$ $k_{stl} := 60.5\frac{W}{m\cdot K}$

$\varepsilon_{CR} := 0.66$ $k_{CR} := 1.44\frac{W}{m\cdot K}$ $k_{sand} := 2\frac{W}{m\cdot K}$

$\alpha_{OG} := 0$ $\tau_{OG} := 1 - \alpha_{OG}$ $\tau_{OG} = 1$

Convective heat transfer coefficients ...

$n := \frac{1}{3}$ $\xi_V := 1.32\cdot W\cdot m^{-2}\cdot K^{-\frac{4}{3}}$ $\xi_{HD} := 0.691\cdot W\cdot m^{-2}\cdot K^{-\frac{4}{3}}$ $\xi_{HU} := 1.52\cdot W\cdot m^{-2}\cdot K^{-\frac{4}{3}}$

$T_{amb} = 328.1\,K$ $T_{OG} = 741.5\,K$

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 21 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

Given

j=1

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} \ldots = 0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{1,0}\cdot\left(\left|T_1-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_1-T_{OG}\right) \ldots$$

$$+\frac{A_{1,0}\cdot\left(T_1-T_{11}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_1^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}}}$$

ARES Corporation	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 22 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=2

$$
\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} \ldots = 0
$$

$$
+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)} \ldots
$$

$$
+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} \ldots
$$

$$
+\xi_V\cdot A_{2,0}\cdot\left(\left|T_2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_2-T_{OG}\right)+\frac{A_{2,0}\cdot\left(T_2-T_{12}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T_2^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}
$$

A.R.E.S CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 23 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=3

$$\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{3,0}\cdot\left(\left|T_3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_3-T_{OG}\right)-$$

$$+\frac{A_{3,0}\cdot\left(T_3-T_{13}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T_3^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}$$

A.R.E.S CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 24 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=4

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots = 0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{A_{4,0}\cdot\left(T_4-T_{14}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V\cdot A_{4,0}\cdot\left(\left|T_4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_4-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_4^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}\quad\ldots$$

ARES CORPORATION	CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002		Rev. No. 1	Page 25 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis				
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce		Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=5

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T_5^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\cdot\left[\left|T_5-\left(\frac{T_5+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_5-\left(\frac{T_5+T_{10}}{2}\right)\right]+\xi_V\cdot A_{5,0}\cdot\left(\left|T_5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_5-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_5^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}=0$$

CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 26 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=6

$$\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \ldots = 0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} \ldots$$

$$+\frac{\sigma\cdot\left(T_6^4-T_{10}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T_6^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\left(1-F_{6,10}\right)}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\cdot\left[\left|T_6-\left(\frac{T_6+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_6-\left(\frac{T_6+T_{10}}{2}\right)\right] \ldots$$

$$+\xi_{HU}\cdot A_{6,1}\cdot\left[\left|T_6-\left(\frac{T_6+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_6-\left(\frac{T_6+T_{10}}{2}\right)\right]+\xi_V\cdot A_{6,0}\cdot\left(\left|T_6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_6^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 27 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

$j = 7$

$$\frac{\sigma \cdot \tau_{OG} \cdot \left(T_7^{\,4} - T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,7}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{7,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T_5^{\,4} - T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{7,0}}\right) + \frac{1}{A_{7,0} \cdot F_{7,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T_7^{\,4} - T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{7,0}}\right) + \frac{1}{A_{7,0} \cdot F_{7,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{2,0}}\right)} \ldots = 0$$

$$+ \frac{\sigma \cdot \tau_{OG} \cdot \left(T_7^{\,4} - T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{7,0}}\right) + \frac{1}{A_{7,0} \cdot F_{7,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{4,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T_7^{\,4} - T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{7,0}}\right) + \frac{1}{A_{7,0} \cdot F_{7,5}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{5,0}}} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T_7^{\,4} - T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{7,0}}\right) + \frac{1}{A_{7,0} \cdot F_{7,6}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{6,0}}} \ldots$$

$$+ \frac{\sigma \cdot \tau_{OG} \cdot \left(T_7^{\,4} - T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{7,0}}\right) + \frac{1}{A_{7,0} \cdot F_{7,8}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{8,0}}} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T_7^{\,4} - T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{7,0}}\right) + \frac{1}{A_{7,0} \cdot F_{7,9}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{9,0}}} \ldots$$

$$+ \frac{\sigma \cdot \left(T_7^{\,4} - T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{7,0}}\right) + \frac{1}{A_{7,0}}} + \xi_V \cdot A_{7,0} \cdot \left[\left|T_7 - \left(\frac{T_7 + T_{10}}{2}\right)\right|\right]^{\frac{1}{3}} \cdot \left[T_7 - \left(\frac{T_7 + T_{10}}{2}\right)\right] + \xi_V \cdot A_{7,0} \cdot \left(\left|T_7 - T_{OG}\right|\right)^{\frac{1}{3}} \cdot \left(T_7 - T_{OG}\right) + \frac{\sigma \cdot \alpha_{OG} \cdot \left(T_7^{\,4} - T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{7,0}}\right) + \frac{1}{A_{7,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 28 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=8

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T_8^{\,4}-T_{10}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T_8^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot\left(1-F_{8,10}\right)}}+\xi_V\cdot\left(A_{8,0}+A_{8,2}\right)\cdot\left[\left|T_8-\left(\frac{T_8+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_8-\left(\frac{T_8+T_{10}}{2}\right)\right]\ldots$$

$$+\xi_{HU}\cdot A_{8,1}\cdot\left[\left|T_8-\left(\frac{T_8+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_8-\left(\frac{T_8+T_{10}}{2}\right)\right]+\xi_V\cdot A_{8,0}\cdot\left(\left|T_8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_8^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}=0$$

ARES CORPORATION	CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002		Rev. No. 1	Page 29 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis				
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce		Date: 2.17.06

j=9

DBVS Off-Gas Hood Thermal Model

$$\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\ldots$$

$$+\frac{\sigma\left(T_9^{\,4}-T_{10}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left[\left|T_9-\left(\frac{T_9+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_9-\left(\frac{T_9+T_{10}}{2}\right)\right]\ldots$$

$$+\xi_{HD}\cdot A_{9,1}\left[\left|T_9-\left(\frac{T_9+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_9-\left(\frac{T_9+T_{10}}{2}\right)\right]+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T_9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_9^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

ARES CORPORATION	CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002		Rev. No. 1	Page 30 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis				
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce		Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=10

$$\frac{\sigma\left(T_{10}^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\left(T_{10}^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\ldots$$

$$+\frac{\sigma\left(T_{10}^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\frac{\sigma\left(T_{10}^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{10,0}\left(1-\frac{A_{6,0}\cdot F_{6,10}}{A_{10,0}}-\frac{A_{8,0}\cdot F_{8,10}}{A_{10,0}}-\frac{A_{9,0}\cdot F_{9,10}}{A_{10,0}}\right)}}\ldots = 0$$

$$+\xi_{HD}\cdot A_{10,0}\left[\left|T_{10}-\left(\frac{T_9+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\left[T_{10}-\left(\frac{T_9+T_{10}}{2}\right)\right]+\frac{A_{10,0}\cdot\left(T_{10}-T_{AWTE}\right)}{\left(\frac{\delta_{floor}}{k_{stl}}\right)}$$

j=11

$$\frac{A_{11,0}\cdot\left(T_{11}-T_1\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\left(T_{11}^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{11,0}}\right)+\frac{1}{A_{11,0}}}+\xi_V\cdot A_{11,0}\cdot\left(\left|T_{11}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{11}-T_{amb}\right)=0$$

j=12

$$\frac{A_{12,0}\cdot\left(T_{12}-T_2\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\left(T_{12}^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right)+\frac{1}{A_{12,0}}}+\xi_V\cdot A_{12,0}\cdot\left(\left|T_{12}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{12}-T_{amb}\right)=0$$

DBVS Off-Gas Hood Thermal Model

j=13

$$\frac{A_{13,0}\cdot(T_{13}-T_3)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{13}^{\ 4}-T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{13,0}}\right)+\frac{1}{A_{13,0}}}+\xi_V\cdot A_{13,0}\cdot\left(\left|T_{13}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{13}-T_{amb}\right)=0$$

j=14

$$\frac{A_{14,0}\cdot(T_{14}-T_4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{14}^{\ 4}-T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{14,0}}}+\xi_V\cdot A_{14,0}\cdot\left(\left|T_{14}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{14}-T_{amb}\right)=0$$

$$\begin{pmatrix} T1 \\ T2 \\ T3 \\ T4 \\ T5 \\ T6 \\ T7 \\ T8 \\ T9 \\ T10 \\ T11 \\ T12 \\ T13 \\ T14 \end{pmatrix} := \mathrm{Find}(T_1,T_2,T_3,T_4,T_5,T_6,T_7,T_8,T_9,T_{10},T_{11},T_{12},T_{13},T_{14})$$

A.R.E.S CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 32 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

T1 = 1145.6K	T1C := KtoC(T1)	T1C = 872.5
T2 = 1156.4K	T2C := KtoC(T2)	T2C = 883.2
T3 = 1145.6K	T3C := KtoC(T3)	T3C = 872.5
T4 = 1156.4K	T4C := KtoC(T4)	T4C = 883.2
T5 = 1035.4K	T5C := KtoC(T5)	T5C = 762.3
T6 = 1014.4K	T6C := KtoC(T6)	T6C = 741.3
T7 = 1035.4K	T7C := KtoC(T7)	T7C = 762.3
T8 = 1014.4K	T8C := KtoC(T8)	T8C = 741.3
T9 = 1031.5K	T9C := KtoC(T9)	T9C = 758.3
T10 = 330K	T10C := KtoC(T10)	T10C = 56.9
T11 = 495.7K	T11C := KtoC(T11)	T11C = 222.6
T12 = 497.2K	T12C := KtoC(T12)	T12C = 224.1
T13 = 495.7K	T13C := KtoC(T13)	T13C = 222.6
T14 = 497.2K	T14C := KtoC(T14)	T14C = 224.1

T1F := CtoF(T1C) T2F := CtoF(T2C) T3F := CtoF(T3C) T4F := CtoF(T4C) T5F := CtoF(T5C) T6F := CtoF(T6C)

T7F := CtoF(T7C) T8F := CtoF(T8C) T9F := CtoF(T9C) T10F := CtoF(T10C) T11F := CtoF(T11C) T12F := CtoF(T12C)

T13F := CtoF(T13C) T14F := CtoF(T14C)

Results in °F ...

T1F = 1602.465 T2F = 1621.821 T3F = 1602.465 T4F = 1621.821 T5F = 1404.089 T6F = 1366.258

T7F = 1404.089 T8F = 1366.258 T9F = 1396.967 T10F = 134.4 T11F = 432.6 T12F = 435.3 T13F = 432.6 T14F = 435.3

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 33 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

Check results ...

$T_0 = 1323.2K$

$T1 = 1145.6K$ $T2 = 1156.4K$ $T3 = 1145.6K$ $T4 = 1156.4K$ $T5 = 1035.4K$ $T6 = 1014.4K$

$T7 = 1035.4K$ $T8 = 1014.4K$ $T9 = 1031.5K$ $T10 = 330K$ $T11 = 495.3K$ $T12 = 497.2K$ $T13 = 495.3K$

$T14 = 497.2K$ $T_{AWTE} = 298.1K$ $T_{amb} = 328.1K$ $T_{OG} = 741.5K$

j=1

$$\frac{\sigma \cdot \tau_{OG} \cdot (T1^4 - T_0^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot (T1^4 - T2^4)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0} \cdot F_{1,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{2,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot (T1^4 - T3^4)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0} \cdot F_{1,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right)} \ldots = 0W$$

$$+ \frac{\sigma \cdot \tau_{OG} \cdot (T1^4 - T4^4)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0} \cdot F_{1,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{4,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot (T1^4 - T6^4)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0} \cdot F_{1,6}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{6,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot (T1^4 - T7^4)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0} \cdot F_{1,7}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{7,0}}} \ldots$$

$$+ \frac{\sigma \cdot \tau_{OG} \cdot (T1^4 - T8^4)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0} \cdot F_{1,8}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{8,0}}} + \frac{\sigma \cdot \tau_{OG} \cdot (T1^4 - T9^4)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0} \cdot F_{1,9}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{9,0}}} + k_V \cdot A_{1,0} \cdot \left(\left|T1 - T_{OG}\right|\right)^{\frac{1}{3}} \cdot (T1 - T_{OG}) \ldots$$

$$+ \frac{A_{1,0} \cdot (T1 - T11)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma \cdot \alpha_{OG} \cdot (T1^4 - T_{15}^4)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0}}}$$

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 34 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=2

$$\frac{\sigma\cdot\tau_{OG}\left(T2^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots = -0W$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\xi_{50}\cdot A_{2,0}\cdot\left(\left|T2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T2-T_{OG}\right)+\frac{A_{2,0}\cdot(T2-T12)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T2^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 35 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=3

$$
\begin{aligned}
&\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \ldots = 0\,W \\
&+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}} \ldots \\
&+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+h_V\cdot A_{3,0}\cdot\left(\left|T3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T3-T_{OG}\right) \ldots \\
&+\frac{A_{3,0}\cdot(T3-T13)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T3^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}
\end{aligned}
$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 36 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

$j = 4$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4 - T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4 - T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ \ldots = -0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4 - T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4 - T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4 - T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ \ldots$$

$$+\frac{A_{4,0}\cdot(T4 - T14)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V\cdot A_{4,0}\cdot\left(\left|T4 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T4 - T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T4^4 - T_{15}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 37 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=5

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots = 0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T5^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\cdot\left[\left|T5-\left(\frac{T5+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T5-\left(\frac{T5+T10}{2}\right)\right]+\xi_V\cdot A_{5,0}\cdot\left(\left|T5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T5-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T5^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 38 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=6

$$\frac{\sigma\cdot\tau_{OG}\left(T6^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\dots = -0W$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\dots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\dots$$

$$+\frac{\sigma\cdot\left(T6^4-T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T6^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot\left(1-F_{6,10}\right)}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\left[\left|T6-\left(\frac{T6+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T6-\left(\frac{T6+T10}{2}\right)\right]\dots$$

$$+\xi_{HU}\cdot A_{6,1}\left[\left|T6-\left(\frac{T6+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T6-\left(\frac{T6+T10}{2}\right)\right]+\xi_V\cdot A_{6,0}\cdot\left(\left|T6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T6^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 39 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=7

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T7^4-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\cdot\left[\left|T7-\left(\frac{T7+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T7-\left(\frac{T7+T10}{2}\right)\right]+\xi_V\cdot A_{7,0}\cdot\left(\left|T7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T7-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T7^4-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}=0\cdot W$$

ARES CORPORATION	CALCULATION SHEET				
Project No. 0509206.01	Calculation No. 0509206.01-M-002		Rev. No. 1	Page 40 of 252	
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis					
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce		Date: 2.17.06	

DBVS Off-Gas Hood Thermal Model

j=8

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \ldots = -0W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} \ldots$$

$$+\frac{\sigma\cdot\left(T8^4 - T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)} + \frac{\sigma\cdot\left(T8^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot\left(1-F_{8,10}\right)}} + \xi_V\cdot\left(A_{8,0}+A_{8,2}\right)\cdot\left[\left|T8-\left(\frac{T8+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T8-\left(\frac{T8+T10}{2}\right)\right] \ldots$$

$$+\xi_{HU}\cdot A_{8,1}\cdot\left[\left|T8-\left(\frac{T8+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T8-\left(\frac{T8+T10}{2}\right)\right] + \xi_V\cdot A_{8,0}\cdot\left(\left|T8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T8-T_{OG}\right) + \frac{\sigma\cdot\alpha_{OG}\cdot\left(T8^4 - T_{15}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}$$

A.R.E.S CORPORATION	CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002		Rev. No. 1	Page 41 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis				
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce		Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

F9

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ \ldots = 0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\ \ldots$$

$$+\frac{\sigma\cdot\left(T9^4-T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left[\left|T9-\left(\frac{T9+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T9-\left(\frac{T9+T10}{2}\right)\right]\ \ldots$$

$$+\xi_{HU}\cdot A_{9,1}\cdot\left[\left|T9-\left(\frac{T9+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T9-\left(\frac{T9+T10}{2}\right)\right]+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T9^4-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 42 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=10

$$\frac{\sigma\cdot\left(T10^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\left(T10^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\ldots = 0\,W$$

$$+\frac{\sigma\cdot\left(T10^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\frac{\sigma\cdot\left(T10^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{10,0}\cdot\left(1-\frac{A_{6,0}\cdot F_{6,10}}{A_{10,0}}-\frac{A_{8,0}\cdot F_{8,10}}{A_{10,0}}-\frac{A_{9,0}\cdot F_{9,10}}{A_{10,0}}\right)}}\ldots$$

$$+\xi_{HD}\cdot A_{10,0}\left[\left|T10-\left(\frac{T9+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T10-\left(\frac{T9+T10}{2}\right)\right]+\frac{A_{10,0}\cdot\left(T10-T_{AWTE}\right)}{\left(\frac{\delta_{floor}}{k_{stl}}\right)}$$

j=11

$$\frac{A_{11,0}\cdot(T11-T1)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T11^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{11,0}}\right)+\frac{1}{A_{11,0}}}+\xi_V\cdot A_{11,0}\cdot\left(\left|T11-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T11-T_{amb}\right)=0\,W$$

j=12

$$\frac{A_{12,0}\cdot(T12-T2)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T12^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right)+\frac{1}{A_{12,0}}}+\xi_V\cdot A_{12,0}\cdot\left(\left|T12-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T12-T_{amb}\right)=0\,W$$

DBVS Off-Gas Hood Thermal Model

j=13

$$\frac{A_{13,0}\cdot(T13-T3)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T13^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{13,0}}\right)+\frac{1}{A_{13,0}}}+\xi_V\cdot A_{13,0}\cdot\left(\left|T13-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T13-T_{amb}\right)=0\cdot W$$

j=14

$$\frac{A_{14,0}\cdot(T14-T4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T14^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{14,0}}}+\xi_V\cdot A_{14,0}\cdot\left(\left|T14-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T14-T_{amb}\right)=0\cdot W$$

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 44 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

Total radiant heat loss from the melt surface ...

$$\frac{\sigma\cdot(T1^4-T_0^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot(T2^4-T_0^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot(T3^4-T_0^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots = -951.5\,kW$$

$$+\frac{\sigma\cdot(T4^4-T_0^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot(T5^4-T_0^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot(T6^4-T_0^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot(T7^4-T_0^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot(T8^4-T_0^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot(T9^4-T_0^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}$$

$$F_{0,1}+F_{0,2}+F_{0,3}+F_{0,4}+F_{0,5}+F_{0,6}+F_{0,7}+F_{0,8}+F_{0,9}=1$$

Compute the average hood temperature ...

$$T_{HA} := \frac{A_{5,0}\cdot T5C+A_{6,0}\cdot T6C+A_{7,0}\cdot T7C+A_{8,0}\cdot T8C+A_{9,0}\cdot T9C}{A_{5,0}+A_{6,0}+A_{7,0}+A_{8,0}+A_{9,0}}$$

$T_{HA} = 750.8$ $\quad T_{HAF} := CtoF(T_{HA})$ $\quad T_{HAF} = 1383.5$

Heat flux through AWTE floor ...

$$q_{AWTE} := \frac{T10 - T_{AWTE}}{\frac{\delta_{floor}}{k_{st}}} \qquad q_{AWTE} = 21.7\frac{1}{m^2}kW$$

APPENDIX B

MATHCAD MODEL FOR THE DESIGN CONDITIONS WITH SOIL OVERBURDEN

A.R.E.S CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 46 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

$^{\circ}F \equiv 1$

$^{\circ}C \equiv 1$

$CtoF(x) := \left(\frac{9}{5}\cdot\frac{x}{^{\circ}C} + 32\right)^{\circ}F \quad CtoK(x) := \left(\frac{x}{^{\circ}C} + 273.15\right)K \qquad KtoC(x) := \left(\frac{x}{K} - 273.15\right)^{\circ}C$

$FtoC(x) := \frac{5}{9}\left(\frac{x}{^{\circ}F} - 32\right)^{\circ}C \quad FtoR(x) := \left(\frac{x}{^{\circ}F} + 459.67\right)R$

$w_1 := 5.5ft \quad w_2 := 3.5ft \quad L_1 := 22ft \quad h_1 := 14in \quad h_2 := 16in \quad \theta := 52deg \quad N_{ribs} := 12 \quad w_{ribs} := 2in \quad h_{ribs} := 4in$

$\delta_{hood} := 0.3125in \quad \theta := 52deg \quad \delta_{floor} := 3.5in \quad \delta_{CR} := 6in \quad \delta_{sand} := 6in \quad \delta_{soil} := \frac{1}{2}in$

Matrix of surface areas ...

$$A := \begin{bmatrix} w_1\cdot L_1 & 0 & 0 \\ w_1\cdot h_1 & 0 & 0 \\ L_1\cdot h_1 & 0 & 0 \\ w_1\cdot h_1 & 0 & 0 \\ L_1\cdot h_1 & 0 & 0 \\ \frac{(w_1 + w_2)\cdot h_2}{2} & 0 & 0 \\ L_1\cdot\frac{h_2}{\sin(\theta)} & N_{ribs}\cdot w_{ribs}\cdot\frac{h_2}{\sin(\theta)} & 2N_{ribs}\cdot h_{ribs}\cdot\frac{h_2}{\sin(\theta)} \\ \frac{(w_1 + w_2)\cdot h_2}{2} & 0 & 0 \\ L_1\cdot\frac{h_2}{\sin(\theta)} & N_{ribs}\cdot w_{ribs}\cdot\frac{h_2}{\sin(\theta)} & 2N_{ribs}\cdot h_{ribs}\cdot\frac{h_2}{\sin(\theta)} \\ w_2\cdot L_1 & N_{ribs}\cdot w_{ribs}\cdot w_2 & 2N_{ribs}\cdot h_{ribs}\cdot w_2 \\ (3ft + w_1 + 3ft)\cdot(3ft + L_1 + 3ft) & 0 & 0 \\ w_1\cdot h_1 & 0 & 0 \\ L_1\cdot h_1 & 0 & 0 \\ w_1\cdot h_1 & 0 & 0 \\ L_1\cdot h_1 & 0 & 0 \end{bmatrix}$$

The first column of dat contains the area of the element for radiant heat transfer. The second column of data contains the horizontal component of area associated with the 4"x2" steel tubing ribs on that elemental area. The third column of data contains the vertical component of the ribs for that elemental area.

A = (ft^2)

	0	1	2
0	121	0	0
1	6.4	0	0
2	25.7	0	0
3	6.4	0	0
4	25.7	0	0
5	6	0	0
6	37.2	3.4	13.5
7	6	0	0
8	37.2	3.4	13.5
9	77	7	28
10	322	0	0
11	6.4	0	0
12	25.7	0	0
13	6.4	0	0
14	25.7	0	0

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 47 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

$$F=\begin{pmatrix} 0 & .021 & .091 & .021 & .091 & .028 & .177 & .028 & .177 & .366 & 0 \\ .397 & 0 & .026 & .004 & .026 & 0 & .129 & .021 & .129 & .265 & 0 \\ .428 & .006 & 0 & .006 & .052 & .019 & .039 & .019 & .077 & .354 & 0 \\ .400 & .004 & .026 & 0 & .026 & .021 & .129 & 0 & .129 & .265 & 0 \\ .428 & .006 & .052 & .006 & 0 & .019 & .077 & .019 & .039 & .354 & 0 \\ .565 & 0 & .081 & .022 & .081 & 0 & .081 & .003 & .081 & .086 & 0 \\ .575 & .022 & .027 & .022 & .053 & .013 & 0 & .013 & .015 & .125 & .616 \\ .565 & .022 & .081 & 0 & .081 & .003 & .081 & 0 & .081 & .086 & 0 \\ .575 & .022 & .053 & .022 & .027 & .013 & .150 & .013 & 0 & .125 & .616 \\ .574 & .022 & .118 & .022 & .118 & .013 & .060 & .013 & .060 & 0 & 1 \end{pmatrix}$$

Matrix F contains the view factors for radiant heat transfer between surfaces of the model. The first (row) index corresponds to the ID of the source surface; the second to the receiving surface. For example, the top of the soil surface - above the melt has ID=0; the ID of the "short" box wall surface (width = 5.5 ft, height = 14in) has ID = 1. The view factor between these two surfaces is located at F[0,1] = 0.021 (obtained from Configuration 16, p. 1030 in Siegel & Howell's Thermal Radiation Heat Transfer, 3rd Edition). The "reciprocity" view factor for these two surfaces is F[1,0]= A[0,0]*F[0,1]/A[1,0] = 0.397.

F=

	0	1	2	3	4	5	6	7	8	9	10
0	0	0.021	0.091	0.021	0.091	0.028	0.177	0.028	0.177	0.366	0
1	0.397	0	0.026	0.004	0.026	0	0.129	0.021	0.129	0.265	0
2	0.428	0.006	0	0.006	0.052	0.019	0.039	0.019	0.077	0.354	0
3	0.4	0.004	0.026	0	0.026	0.021	0.129	0	0.129	0.265	0
4	0.428	0.006	0.052	0.006	0	0.019	0.077	0.019	0.039	0.354	0
5	0.565	0	0.081	0.022	0.081	0	0.081	0.003	0.081	0.086	0
6	0.575	0.022	0.027	0.022	0.053	0.013	0	0.013	0.015	0.125	0.616
7	0.565	0.022	0.081	0	0.081	0.003	0.081	0	0.081	0.086	0
8	0.575	0.022	0.053	0.022	0.027	0.013	0.15	0.013	0	0.125	0.616
9	0.574	0.022	0.118	0.022	0.118	0.013	0.06	0.013	0.06	0	1

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 48 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

Temperature Boundary Conditions ...

$Tmelt := 2252°F$ $TmC := FtoC(Tmelt)$ $T_{melt} := CtoK(TmC)$ $T_{melt} = 1523.15\,K$

$TAWTE := 77°F$ $TAC := FtoC(TAWTE)$ $T_{AWTE} := CtoK(TAC)$ $T_{AWTE} = 298.1\,K$

$TOG := 875°F$ $Tog := FtoC(TOG)$ $T_{OG} := CtoK(Tog)$ $T_{OG} = 741.483\,K$

$Tamb := 55°C$ $T_{amb} := CtoK(Tamb)$ $T_{amb} = 328.1\,K$

Initial guess for temperatures ...

$T_0 := 973K$

$T_1 := 773K$ $T_3 := 773K$ $T_5 := 773K$ $T_7 := 773K$ $T_9 := 773K$

$T_2 := 773K$ $T_4 := 773K$ $T_6 := 773K$ $T_8 := 773K$ $T_{10} := 773K$

$T_{11} := 473K$ $T_{12} := 473K$ $T_{13} := 473K$ $T_{14} := 473K$

Material properties ...

$\sigma := 5.67 \cdot 10^{-8} \cdot \frac{W}{m^2 \cdot K^4}$

$\varepsilon_{melt} := 0.7$

$\varepsilon_{stl} := .85$ $k_{stl} := 60.5 \cdot \frac{W}{m \cdot K}$

$\varepsilon_{CR} := 0.66$ $k_{CR} := 1.44 \frac{W}{m \cdot K}$ $k_{sand} := 2 \cdot \frac{W}{m \cdot K}$

$\alpha_{OG} := 0$ $\tau_{OG} := 1 - \alpha_{OG}$ $\tau_{OG} = 1$

Convective heat transfer coefficients ... $n := \frac{1}{3}$ $\xi_V := 1.32 \cdot W \cdot m^{-2} \cdot K^{\frac{-4}{3}}$ $\xi_{HD} := 0.691 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$ $\xi_{HU} := 1.52 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 49 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

$T_{amb} = 328.1\,K$ $\qquad T_{OG} = 741.5\,K$

Given

$j = 0$

$$\frac{k_{sand}\cdot A_{0,0}\cdot(T_0 - T_{melt})}{\delta_{soil}} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T_0^{\,4} - T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T_0^{\,4} - T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \ldots = 0$$

$$+ \frac{\sigma\cdot\tau_{OG}\cdot\left(T_0^{\,4} - T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T_0^{\,4} - T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T_0^{\,4} - T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,5}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)} \ldots$$

$$+ \frac{\sigma\cdot\tau_{OG}\cdot\left(T_0^{\,4} - T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,6}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T_0^{\,4} - T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,7}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T_0^{\,4} - T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,8}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)} \ldots$$

$$+ \frac{\sigma\cdot\tau_{OG}\cdot\left(T_0^{\,4} - T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,9}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)} + \frac{\sigma\cdot\alpha_{OG}\cdot\left(T_0^{\,4} - T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}}} + \varepsilon_{HU}\cdot A_{0,0}\cdot\left(\left|T_0 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot(T_0 - T_{OG})$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 50 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=1

$$\frac{\sigma \cdot \tau_{OG}\left(T_1^4 - T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right)} + \frac{\sigma \cdot \tau_{OG}\left(T_1^4 - T_2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0} \cdot F_{1,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{2,0}}\right)} + \frac{\sigma \cdot \tau_{OG}\left(T_1^4 - T_3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0} \cdot F_{1,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right)} \ldots = 0$$

$$+ \frac{\sigma \cdot \tau_{OG}\left(T_1^4 - T_4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0} \cdot F_{1,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{4,0}}\right)} + \frac{\sigma \cdot \tau_{OG}\left(T_1^4 - T_6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0} \cdot F_{1,6}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{6,0}}\right)} + \frac{\sigma \cdot \tau_{OG}\left(T_1^4 - T_7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0} \cdot F_{1,7}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{7,0}}} \ldots$$

$$+ \frac{\sigma \cdot \tau_{OG}\left(T_1^4 - T_8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0} \cdot F_{1,8}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{8,0}}} + \frac{\sigma \cdot \tau_{OG}\left(T_1^4 - T_9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0} \cdot F_{1,9}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{9,0}}} + \xi_V \cdot A_{1,0} \cdot \left(\left|T_1 - T_{OG}\right|\right)^{\frac{1}{3}} \cdot \left(T_1 - T_{OG}\right) \ldots$$

$$+ \frac{A_{1,0} \cdot \left(T_1 - T_{11}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma \cdot \alpha_{OG} \cdot \left(T_1^4 - T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0}}}$$

CALCULATION SHEET

ARES CORPORATION

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 51 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

j=2

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\xi_V\cdot A_{2,0}\cdot\left(\left|T_2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_2-T_{OG}\right)+\frac{A_{2,0}\cdot\left(T_2-T_{12}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_2^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=3

$$\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ ... = 0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ ...$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\varepsilon_V\cdot A_{3,0}\left(\left|T_3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_3-T_{OG}\right)\ ...$$

$$+\frac{A_{3,0}\left(T_3-T_{13}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T_3^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}$$

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 53 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=4

$$\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \ldots = 0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} \ldots$$

$$+\frac{A_{4,0}\left(T_4-T_{14}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V\cdot A_{4,0}\left(\left|T_4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_4-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_4^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}$$

ARES CORPORATION	**CALCULATION SHEET**		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 54 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=5

$$\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\alpha\cdot\tau_{OG}\left(T_5^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \dots = 0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}} \dots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} \dots$$

$$+\frac{\sigma\left(T_5^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\left[\left|T_5-\left(\frac{T_5+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_5-\left(\frac{T_5+T_{10}}{2}\right)\right]+\xi_V\cdot A_{5,0}\cdot\left(\left|T_5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_5-T_{OG}\right)+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}$$

ARES CORPORATION	CALCULATION SHEET				
Project No. 0509206.01	Calculation No. 0509206.01-M-002		Rev. No. 1	Page 55 of 252	
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis					
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce		Date: 2.17.06	

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=6

$$\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots = 0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T_6^{\,4}-T_{10}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T_6^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot\left(1-F_{6,10}\right)}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\cdot\left[\left|T_6-\left(\frac{T_6+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_6-\left(\frac{T_6+T_{10}}{2}\right)\right]\ldots$$

$$+\xi_{HU}\cdot A_{6,1}\cdot\left[\left|T_6-\left(\frac{T_6+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_6-\left(\frac{T_6+T_{10}}{2}\right)\right]+\xi_V\cdot A_{6,0}\cdot\left(\left|T_6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_6^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 56 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

j=7

$$\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T_7^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\left[\left|T_7-\left(\frac{T_7+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_7-\left(\frac{T_7+T_{10}}{2}\right)\right]+\xi_V\cdot A_{7,0}\cdot\left(\left|T_7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_7-T_{OG}\right)+\frac{\sigma\cdot\varepsilon_{OG}\left(T_7^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}=0$$

DBVS ICV™ Off-Gas Hood Thermal Analysis

$j = 8$

$$\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} \ldots$$

$$+\frac{\sigma\cdot\left(T_8^{\,4}-T_{10}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T_8^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot\left(1-F_{8,10}\right)}}+\xi_V\cdot\left(A_{8,0}+A_{8,2}\right)\cdot\left[\left|T_8-\left(\frac{T_8+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_8-\left(\frac{T_8+T_{10}}{2}\right)\right] \ldots$$

$$+\xi_{HU}\cdot A_{8,1}\cdot\left[\left|T_8-\left(\frac{T_8+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_8-\left(\frac{T_8+T_{10}}{2}\right)\right]+\xi_V\cdot A_{8,0}\cdot\left(\left|T_8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_8^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}} = 0$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 58 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=9

$$\frac{\sigma\cdot\tau_{OG}\left(T_9^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_9^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_9^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_9^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_9^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\ldots$$

$$+\frac{\sigma\left(T_9^4-T_{10}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\left[\left|T_9-\left(\frac{T_9+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_9-\left(\frac{T_9+T_{10}}{2}\right)\right]\ldots$$

$$+\xi_{HU}\cdot A_{9,1}\left[\left|T_9-\left(\frac{T_9+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_9-\left(\frac{T_9+T_{10}}{2}\right)\right]+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T_9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_9^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}=0$$

A.R.E.S CORPORATION	**CALCULATION SHEET**			
Project No. 0509206.01	Calculation No. 0509206.01-M-002		Rev. No. 1	Page 59 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis				
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce		Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=10

$$\frac{\sigma\cdot\left(T_{10}^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\left(T_{10}^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\ldots = 0$$

$$+\frac{\sigma\cdot\left(T_{10}^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\frac{\sigma\cdot\left(T_{10}^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{10,0}\cdot\left(1-\frac{A_{6,0}\cdot F_{6,10}}{A_{10,0}}-\frac{A_{8,0}\cdot F_{8,10}}{A_{10,0}}-\frac{A_{9,0}\cdot F_{9,10}}{A_{10,0}}\right)}}\ldots$$

$$+\xi_{HD}\cdot A_{10,0}\cdot\left[\left|T_{10}-\left(\frac{T_9+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_{10}-\left(\frac{T_9+T_{10}}{2}\right)\right]+\frac{k_{stl}\cdot A_{10,0}\cdot\left(T_{10}-T_{AWTE}\right)}{\delta_{floor}}$$

j=11

$$\frac{A_{11,0}\cdot\left(T_{11}-T_1\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{11}^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{11,0}}\right)+\frac{1}{A_{11,0}}}+\xi_V\cdot A_{11,0}\cdot\left(\left|T_{11}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{11}-T_{amb}\right)=0$$

j=12

$$\frac{A_{12,0}\cdot\left(T_{12}-T_2\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{12}^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right)+\frac{1}{A_{12,0}}}+\xi_V\cdot A_{12,0}\cdot\left(\left|T_{12}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{12}-T_{amb}\right)=0$$

j=13

$$\frac{A_{13,0}\cdot(T_{13}-T_3)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{13}^{\ 4}-T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{13,0}}\right)+\frac{1}{A_{13,0}}}+\xi_V\cdot A_{13,0}\cdot\left(\left|T_{13}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{13}-T_{amb}\right)=0$$

j=14

$$\frac{A_{14,0}\cdot(T_{14}-T_4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{14}^{\ 4}-T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{14,0}}}+\xi_V\cdot A_{14,0}\cdot\left(\left|T_{14}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{14}-T_{amb}\right)=0$$

$$\begin{pmatrix} T0 \\ T1 \\ T2 \\ T3 \\ T4 \\ T5 \\ T6 \\ T7 \\ T8 \\ T9 \\ T10 \\ T11 \\ T12 \\ T13 \\ T14 \end{pmatrix} := \mathrm{Find}\left(T_0,T_1,T_2,T_3,T_4,T_5,T_6,T_7,T_8,T_9,T_{10},T_{11},T_{12},T_{13},T_{14}\right)$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 61 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

T0 = 1165.7K	T0C := KtoC(T0)	T0C = 892.6
T1 = 1005K	T1C := KtoC(T1)	T1C = 731.8
T2 = 1014.2K	T2C := KtoC(T2)	T2C = 741.1
T3 = 1005K	T3C := KtoC(T3)	T3C = 731.8
T4 = 1014.2K	T4C := KtoC(T4)	T4C = 741.1
T5 = 911K	T5C := KtoC(T5)	T5C = 637.8
T6 = 891.7K	T6C := KtoC(T6)	T6C = 618.6
T7 = 911K	T7C := KtoC(T7)	T7C = 637.8
T8 = 891.7K	T8C := KtoC(T8)	T8C = 618.6
T9 = 905.6K	T9C := KtoC(T9)	T9C = 632.5
T10 = 317.6K	T10C := KtoC(T10)	T10C = 44.5
T11 = 474.8K	T11C := KtoC(T11)	T11C = 201.7
T12 = 476.3K	T12C := KtoC(T12)	T12C = 203.1
T13 = 474.8K	T13C := KtoC(T13)	T13C = 201.7
T14 = 476.3K	T14C := KtoC(T14)	T14C = 203.1

T0F := CtoF(T0C)

T1F := CtoF(T1C) T2F := CtoF(T2C) T3F := CtoF(T3C) T4F := CtoF(T4C) T5F := CtoF(T5C) T6F := CtoF(T6C)

T7F := CtoF(T7C) T8F := CtoF(T8C) T9F := CtoF(T9C) T10F := CtoF(T10C) T11F := CtoF(T11C) T12F := CtoF(T12C)

T13F := CtoF(T13C) T14F := CtoF(T14C)

Results in F ...

T0F = 1638.6 T1F = 1349.297 T2F = 1365.979 T3F = 1349.297 T4F = 1365.979 T5F = 1180.083 T6F = 1145.447

T7F = 1180.083 T8F = 1145.447 T9F = 1170.418 T10F = 112 T11F = 395 T12F = 397.6 T13F = 395 T14F = 397.6

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 62 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

Check results ...

$T0 = 1165.7K$ $T1 = 1005K$ $T2 = 1014.2K$ $T3 = 1005K$ $T4 = 1014.2K$ $T5 = 931K$ $T6 = 891.7K$

$T7 = 911K$ $T8 = 891.7K$ $T9 = 905.6K$ $T10 = 317.6K$ $T11 = 474.8K$ $T12 = 476.3K$ $T13 = 474.8K$

$T14 = 476.3K$ $T_{AWTE} = 298.1K$ $T_{amb} = 328.1K$ $T_{OG} = 741.5K$

j=1

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} \dots = 0W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}} \dots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{1,0}\cdot\left(\left|T1 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T1 - T_{OG}\right) \dots$$

$$+\frac{A_{1,0}\cdot(T1 - T11)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T1^4 - T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 63 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=2

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\varepsilon_V\cdot A_{2,0}\cdot\left(\left|T2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T2-T_{OG}\right)+\frac{A_{2,0}\cdot(T2-T12)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T2^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 64 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=3

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{3,0}\cdot\left(\left|T3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T3-T_{OG}\right)\ldots$$

$$+\frac{A_{3,0}\cdot(T3-T13)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T3^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}=0\cdot W$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 65 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=4

$$
\begin{aligned}
&\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots = 0W\\
&+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots\\
&+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots\\
&+\frac{A_{4,0}\cdot(T4-T14)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+k_V\cdot A_{4,0}\cdot\left(\left|T4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T4-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T4^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}
\end{aligned}
$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 66 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=5

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots = 0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T5^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\left[\left|T5-\left(\frac{T5+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T5-\left(\frac{T5+T10}{2}\right)\right]+\xi_V\cdot A_{5,0}\left(\left|T5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T5-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T5^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}$$

A.R.E.S CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 67 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=6

$$\frac{\sigma\cdot\tau_{OG}\left(T6^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0W$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T6^4-T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T6^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot\left(1-F_{6,10}\right)}}+\xi_V\cdot\left(A_{6,0}+A_{6,0}\right)\left[\left|T6-\left(\frac{T6+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T6-\left(\frac{T6+T10}{2}\right)\right]\ldots$$

$$+\xi_{HU}\cdot A_{6,1}\left[\left|T6-\left(\frac{T6+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T6-\left(\frac{T6+T10}{2}\right)\right]+\xi_V\cdot A_{6,0}\cdot\left(\left|T6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T6^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=7

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T7^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\cdot\left[\left|T7-\left(\frac{T7+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T7-\left(\frac{T7+T10}{2}\right)\right]+\xi_V\cdot A_{7,0}\cdot\left(\left|T7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T7-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T7^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}=0W$$

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=8

$$\frac{\sigma\cdot\tau_{OG}\left(T8^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T8^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T8^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\dots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T8^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T8^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T8^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\dots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T8^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T8^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T8^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\dots$$

$$+\frac{\sigma\cdot\left(T8^4-T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T8^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot\left(1-F_{8,10}\right)}}+\xi_V\left(A_{8,0}+A_{8,2}\right)\left[\left|T8-\left(\frac{T8+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T8-\left(\frac{T8+T10}{2}\right)\right]\dots$$

$$+\xi_{HU}\cdot A_{8,1}\left[\left|T8-\left(\frac{T8+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T8-\left(\frac{T8+T10}{2}\right)\right]+\xi_V\cdot A_{8,0}\cdot\left(\left|T8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T8-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T8^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}$$

$= 0\,W$

A.R.E.S CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 70 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

j=9

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\dots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\dots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\dots$$

$$+\frac{\sigma\cdot\left(T9^4-T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left[\left|T9-\left(\frac{T9+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T9-\left(\frac{T9+T10}{2}\right)\right]\dots$$

$$+\xi_{HU}\cdot A_{9,1}\cdot\left[\left|T9-\left(\frac{T9+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T9-\left(\frac{T9+T10}{2}\right)\right]+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T9^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}=0W$$

CALCULATION SHEET

ARES CORPORATION			
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 71 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=10

$$\frac{\sigma\cdot\left(T10^4-T6^4\right)}{\left(\frac{1-\epsilon_{stl}}{\epsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\frac{1-\epsilon_{stl}}{\epsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\left(T10^4-T8^4\right)}{\left(\frac{1-\epsilon_{stl}}{\epsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,10}}+\frac{1-\epsilon_{stl}}{\epsilon_{stl}\cdot A_{8,0}}}\ldots = 0\,W$$

$$+\frac{\sigma\cdot\left(T10^4-T9^4\right)}{\left(\frac{1-\epsilon_{stl}}{\epsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\frac{1-\epsilon_{stl}}{\epsilon_{stl}\cdot A_{9,0}}}+\frac{\sigma\cdot\left(T10^4-T_{amb}^4\right)}{\left(\frac{1-\epsilon_{stl}}{\epsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{10,0}\cdot\left(1-\frac{A_{6,0}\cdot F_{6,10}}{A_{10,0}}-\frac{A_{8,0}\cdot F_{8,10}}{A_{10,6}}-\frac{A_{9,0}\cdot F_{9,10}}{A_{10,0}}\right)}}\ldots$$

$$+\xi_{HTF}\cdot A_{10,0}\cdot\left[\left|T10-\left(\frac{T9+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T10-\left(\frac{T9+T10}{2}\right)\right]+\frac{k_{stl}\cdot A_{10,0}\cdot\left(T10-T_{AWTE}\right)}{\delta_{floor}}$$

j=11

$$\frac{A_{11,0}\cdot(T11-T1)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T11^4-T_{amb}^4\right)}{\left(\frac{1-\epsilon_{stl}}{\epsilon_{stl}\cdot A_{11,0}}\right)+\frac{1}{A_{11,0}}}+\xi_V\cdot A_{11,0}\cdot\left(\left|T11-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T11-T_{amb}\right)=0\,W$$

j=12

$$\frac{A_{12,0}\cdot(T12-T2)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T12^4-T_{amb}^4\right)}{\left(\frac{1-\epsilon_{stl}}{\epsilon_{stl}\cdot A_{12,0}}\right)+\frac{1}{A_{12,0}}}+\xi_V\cdot A_{12,0}\cdot\left(\left|T12-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T12-T_{amb}\right)=0\,W$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 72 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=13

$$\frac{A_{13,0}\cdot(T13-T3)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T13^4-T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{13,0}}\right)+\frac{1}{A_{13,0}}}+\xi_V\cdot A_{13,0}\cdot\left(\left|T13-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T13-T_{amb}\right)=0\,W$$

j=14

$$\frac{A_{14,0}\cdot(T14-T4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T14^4-T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{14,0}}}+\xi_V\cdot A_{14,0}\cdot\left(\left|T14-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T14-T_{amb}\right)=0\,W$$

A.R.E.S. CORPORATION

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 73 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

Total radiant heat loss from the melt surface ...

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots = -578.3\,kW$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}}}$$

$$F_{0,1}+F_{0,2}+F_{0,3}+F_{0,4}+F_{0,5}+F_{0,6}+F_{0,7}+F_{0,8}+F_{0,9}=1$$

Compute the average hood temperature ...

$$T_{HA} := \frac{A_{5,0}\cdot T5C + A_{6,0}\cdot T6C + A_{7,0}\cdot T7C + A_{8,0}\cdot T8C + A_{9,0}\cdot T9C}{A_{5,0}+A_{6,0}+A_{7,0}+A_{8,0}+A_{9,0}}$$

$T_{HA} = 626.5$ $\quad T_{HAF} := CtoF\left(T_{HA}\right)$ $\quad T_{HAF} = 1159.8$

Heat flux through AWTE floor ...

$$q_{AWTE} := \frac{k_{stl}\left(T10 - T_{AWTE}\right)}{\delta_{floor}} \qquad q_{AWTE} = 13.2\frac{1}{m^2}kW$$

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 74 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

APPENDIX C

MATHCAD MODEL FOR THE INSULATED FLOOR CONDITIONS

A.R.E.S CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 75 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

$°F \equiv 1$

$°C \equiv 1$

$CtoF(x) := \left(\frac{9}{5} \cdot \frac{x}{°C} + 32\right)°F$ $CtoK(x) := \left(\frac{x}{°C} + 273.15\right)K$ $KtoC(x) := \left(\frac{x}{K} - 273.15\right)°C$

$FtoC(x) := \frac{5}{9}\left(\frac{x}{°F} - 32\right)°C$ $FtoR(x) := \left(\frac{x}{°F} + 459.67\right)R$

$w_1 := 5.5ft$ $w_2 := 3.5ft$ $L_1 := 22ft$ $h_1 := 14in$ $h_2 := 16in$ $\theta := 52deg$ $N_{ribs} := 12$ $w_{ribs} := 2in$ $h_{ribs} := 4in$

$\delta_{hood} := 0.3125in$ $\theta := 52deg$ $\delta_{floor} := 3.5in$ $\delta_{CR} := 6in$ $\delta_{sand} := 6in$ $\delta_{CaSi} := 1.5in$

Matrix of surface areas ...

$$A := \begin{bmatrix} w_1 \cdot L_1 & 0 & 0 \\ w_1 \cdot h_1 & 0 & 0 \\ L_1 \cdot h_1 & 0 & 0 \\ w_1 \cdot h_1 & 0 & 0 \\ L_1 \cdot h_1 & 0 & 0 \\ \frac{(w_1 + w_2) \cdot h_2}{2} & 0 & 0 \\ L_1 \cdot \frac{h_2}{\sin(\theta)} & N_{ribs} \cdot w_{ribs} \cdot \frac{h_2}{\sin(\theta)} & 2N_{ribs} \cdot h_{ribs} \cdot \frac{h_2}{\sin(\theta)} \\ \frac{(w_1 + w_2) \cdot h_2}{2} & 0 & 0 \\ L_1 \cdot \frac{h_2}{\sin(\theta)} & N_{ribs} \cdot w_{ribs} \cdot \frac{h_2}{\sin(\theta)} & 2N_{ribs} \cdot h_{ribs} \cdot \frac{h_2}{\sin(\theta)} \\ w_2 \cdot L_1 & N_{ribs} \cdot w_{ribs} \cdot w_2 & 2N_{ribs} \cdot h_{ribs} \cdot w_2 \\ (3ft + w_1 + 3ft) \cdot (3ft + L_1 + 3ft) & 0 & 0 \\ w_1 \cdot h_1 & 0 & 0 \\ L_1 \cdot h_1 & 0 & 0 \\ w_1 \cdot h_1 & 0 & 0 \\ L_1 \cdot h_1 & 0 & 0 \end{bmatrix}$$

The first column of dat contains the area of the element for radiant heat transfer. The second column of data contains the horizontal component of area associated with the 4"x2" steel tubing ribs on that elemental area. The third column of data contains the vertical component of the ribs for that elemental area.

A = (units: ft^2)

	0	1	2
0	121	0	0
1	6.4	0	0
2	25.7	0	0
3	6.4	0	0
4	25.7	0	0
5	6	0	0
6	37.2	3.4	13.5
7	6	0	0
8	37.2	3.4	13.5
9	77	7	28
10	322	0	0
11	6.4	0	0
12	25.7	0	0
13	6.4	0	0
14	25.7	0	0

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 76 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

$$F = \begin{pmatrix} 0 & .021 & .091 & .021 & .091 & .028 & .177 & .028 & .177 & .366 & 0 \\ .397 & 0 & .026 & .004 & .026 & 0 & .129 & .021 & .129 & .265 & 0 \\ .428 & .006 & 0 & .006 & .052 & .019 & .039 & .019 & .077 & .354 & 0 \\ .400 & .004 & .026 & 0 & .026 & .021 & .129 & 0 & .129 & .265 & 0 \\ .428 & .006 & .052 & .006 & 0 & .019 & .077 & .019 & .039 & .354 & 0 \\ .565 & 0 & .081 & .022 & .081 & 0 & .081 & .003 & .081 & .086 & 0 \\ .575 & .022 & .027 & .022 & .053 & .013 & 0 & .013 & .015 & .125 & .616 \\ .565 & .022 & .081 & 0 & .081 & .003 & .081 & 0 & .081 & .086 & 0 \\ .575 & .022 & .053 & .022 & .027 & .013 & .150 & .013 & 0 & .125 & .616 \\ .574 & .022 & .118 & .022 & .118 & .013 & .060 & .013 & .060 & 0 & 1 \end{pmatrix}$$

Matrix F contains the view factors for radiant heat transfer between surfaces of the model. The first (row) index corresponds to the ID of the source surface; the second to the receiving surface. For example, the top of the soil surface above the melt has ID=0; the ID of the "short" box wall surface (width = 5.5 ft, height = 14in) has ID = 1. The view factor between these two surfaces is located at F[0,1] = 0.021 (obtained from Configuration 16, p. 1030 in Siegel & Howell's Thermal Radiation Heat Transfer, 3rd Edition). The "reciprocity" view factor for these two surfaces is F[1,0]= A[0,0]*F[0,1]/A[1,0] = 0.397.

F =

	0	1	2	3	4	5	6	7	8	9	10
0	0	0.021	0.091	0.021	0.091	0.028	0.177	0.028	0.177	0.366	0
1	0.397	0	0.026	0.004	0.026	0	0.129	0.021	0.129	0.265	0
2	0.428	0.006	0	0.006	0.052	0.019	0.039	0.019	0.077	0.354	0
3	0.4	0.004	0.026	0	0.026	0.021	0.129	0	0.129	0.265	0
4	0.428	0.006	0.052	0.006	0	0.019	0.077	0.019	0.039	0.354	0
5	0.565	0	0.081	0.022	0.081	0	0.081	0.003	0.081	0.086	0
6	0.575	0.022	0.027	0.022	0.053	0.013	0	0.013	0.015	0.125	0.616
7	0.565	0.022	0.081	0	0.081	0.003	0.081	0	0.081	0.086	0
8	0.575	0.022	0.053	0.022	0.027	0.013	0.15	0.013	0	0.125	0.616
9	0.574	0.022	0.118	0.022	0.118	0.013	0.06	0.013	0.06	0	1

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 77 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

Temperature Boundary Conditions ...

$Tmelt := 1922°F$ $TmC := FtoC(Tmelt)$ $T_{melt} := CtoK(TmC)$ $T_{melt} = 1323.15\,K$

$TAWTE := 77°F$ $TAC := FtoC(TAWTE)$ $T_{AWTE} := CtoK(TAC)$ $T_{AWTE} = 298.1\,K$

$TOG := 875°F$ $Tog := FtoC(TOG)$ $T_{OG} := CtoK(Tog)$ $T_{OG} = 741.483\,K$

$Tamb := 55°C$ $T_{amb} := CtoK(Tamb)$ $T_{amb} = 328.1\,K$

Initial guess for temperatures ...

$T_0 := T_{melt}$ $T_0 = 1323.15\,K$

$T_1 := 773K$ $T_3 := 773K$ $T_5 := 773K$ $T_7 := 773K$ $T_9 := 773K$

$T_2 := 773K$ $T_4 := 773K$ $T_6 := 773K$ $T_8 := 773K$ $T_{10} := 773K$

$T_{11} := 473K$ $T_{12} := 473K$ $T_{13} := 473K$ $T_{14} := 473K$ $T_{15} := T_{OG}$

Material properties ...

$\varepsilon_{melt} := 0.7$ $\sigma := 5.67 \cdot 10^{-8} \cdot \frac{W}{m^2 \cdot K^4}$

$\varepsilon_{stl} := .85$ $k_{stl} := 60.5 \cdot \frac{W}{m \cdot K}$

$\varepsilon_{CR} := 0.66$ $k_{CR} := 1.44 \cdot \frac{W}{m \cdot K}$ $k_{sand} := 2 \cdot \frac{W}{m \cdot K}$

$\varepsilon_{Al} := 0.04$ $k_{CaSi} := 0.0655 \cdot \frac{W}{m \cdot K}$

$\alpha_{OG} := 0$ $\tau_{OG} := 1 - \alpha_{OG}$ $\tau_{OG} = 1$

Convective heat transfer coefficients ...

$n := \frac{1}{3}$ $\zeta_V := 1.32 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$ $\zeta_{HD} := 0.691 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$ $\zeta_{HU} := 1.52 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$

$T_{amb} = 328.1\,K$ $T_{OG} = 741.5\,K$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 78 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

Given

j=1

$$\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} \ldots = 0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{1,0}\cdot\left(\left|T_1-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_1-T_{OG}\right) \ldots$$

$$+\frac{A_{1,0}\cdot\left(T_1-T_{11}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T_1^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 79 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=2

$$\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} = 0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}$$

$$+\xi_V\cdot A_{2,0}\cdot\left(\left|T_2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_2-T_{OG}\right)+\frac{A_{2,0}\cdot\left(T_2-T_{12}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T_2^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 80 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=3

$$\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{3,0}\left(\left|T_3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_3-T_{OG}\right)\ldots$$

$$+\frac{A_{3,0}\cdot\left(T_3-T_{13}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T_3^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}$$

CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 81 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=4

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{A_{4,0}\cdot\left(T_4-T_{14}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V\cdot A_{4,0}\cdot\left(\left|T_4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_4-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_4^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}\ldots = 0$$

ARES CORPORATION	CALCULATION SHEET				
Project No. 0509206.01	Calculation No. 0509206.01-M-002		Rev. No. 1	Page 82 of 252	
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis					
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce		Date: 2.17.06	

DBVS Off-Gas Hood Thermal Model

j=5

$$\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\dots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\dots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\dots$$

$$+\frac{\sigma\cdot\left(T_5^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\left[\left|T_5-\left(\frac{T_5+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_5-\left(\frac{T_5+T_{10}}{2}\right)\right]+\xi_V\cdot A_{5,6}\left(\left|T_5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_5-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_5^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}} = 0$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 83 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=6

$$\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots = 0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T_6^{\,4}-T_{10}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T_6^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\left(1-F_{6,10}\right)}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\cdot\left[\left|T_6-\left(\frac{T_6+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_6-\left(\frac{T_6+T_{10}}{2}\right)\right]\ldots$$

$$+\xi_{HU}\cdot A_{6,1}\cdot\left[\left|T_6-\left(\frac{T_6+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_6-\left(\frac{T_6+T_{10}}{2}\right)\right]+\xi_V\cdot A_{6,0}\cdot\left(\left|T_6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_6^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

ARES CORPORATION	CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002		Rev. No. 1	Page 84 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis				
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce		Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

$j=7$

$$\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \;\; =0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}$$

$$+\frac{\sigma\left(T_7^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\left[\left|T_7-\left(\frac{T_7+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\left[T_7-\left(\frac{T_7+T_{10}}{2}\right)\right]+\xi_V\cdot A_{7,0}\left(\left|T_7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_7-T_{OG}\right)+\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}$$

ARES CORPORATION	CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002		Rev. No. 1	Page 85 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis				
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce		Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

$j=8$

$$\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T_8^{\,4}-T_{10}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T_8^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot\left(1-F_{8,10}\right)}}+\xi_V\cdot\left(A_{8,0}+A_{8,2}\right)\left[\left|T_8-\left(\frac{T_8+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_8-\left(\frac{T_8+T_{10}}{2}\right)\right]\ldots$$

$$+\xi_{HU}\cdot A_{8,1}\left[\left|T_8-\left(\frac{T_8+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_8-\left(\frac{T_8+T_{10}}{2}\right)\right]+\xi_V\cdot A_{8,0}\cdot\left(\left|T_8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_8^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}$$

$$=0$$

A.R.E.S. CORPORATION	CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002		Rev. No. 1	Page 86 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis				
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce		Date: 2.17.06

j=9

DBVS Off-Gas Hood Thermal Model

$$\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\ldots$$

$$+\frac{\sigma\left(T_9^{\,4}-T_{10}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\left(\frac{1-\varepsilon_{Al}}{\varepsilon_{Al}\cdot A_{10,0}}\right)}+\xi_V\left(A_{9,0}+A_{9,2}\right)\left[\left|T_9-\left(\frac{T_9+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\left[T_9-\left(\frac{T_9+T_{10}}{2}\right)\right]\ldots$$

$$+\xi_{HU}\cdot A_{9,1}\left[\left|T_9-\left(\frac{T_9+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\left[T_9-\left(\frac{T_9+T_{10}}{2}\right)\right]+\xi_{HD}\cdot A_{9,0}\left(\left|T_9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_9^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 87 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=10

$$\frac{\sigma\left(T_{10}^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{10,0}}\right)+\frac{1}{A_{6,0}F_{6,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{6,0}}}+\frac{\sigma\left(T_{10}^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{10,0}}\right)+\frac{1}{A_{8,0}F_{8,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{8,0}}}\ldots=0$$

$$+\frac{\sigma\left(T_{10}^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{Al}}{\varepsilon_{Al}A_{10,0}}\right)+\frac{1}{A_{9,0}F_{9,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{9,0}}}+\frac{\sigma\left(T_{10}^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{Al}}{\varepsilon_{Al}A_{10,0}}\right)+\frac{1}{A_{10,0}\left(1-\frac{A_{6,0}F_{6,10}}{A_{10,0}}-\frac{A_{8,0}F_{8,10}}{A_{10,0}}-\frac{A_{9,0}F_{9,10}}{A_{10,0}}\right)}}\ldots$$

$$+\xi_{HD}A_{10,0}\left[\left|T_{10}-\left(\frac{T_9+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\left[T_{10}-\left(\frac{T_9+T_{10}}{2}\right)\right]+\frac{A_{10,0}\left(T_{10}-T_{AWTP}\right)}{\left(\frac{\delta_{floor}}{k_{stl}}\right)+\left(\frac{\delta_{CaSi}}{k_{CaSi}}\right)}$$

j=11

$$\frac{A_{11,0}\left(T_{11}-T_1\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\left(T_{11}^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{11,0}}\right)+\frac{1}{A_{11,0}}}+\xi_V A_{11,0}\left(\left|T_{11}-T_{amb}\right|\right)^{\frac{1}{3}}\left(T_{11}-T_{amb}\right)=0$$

j=12

$$\frac{A_{12,0}\left(T_{12}-T_2\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\left(T_{12}^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{12,0}}\right)+\frac{1}{A_{12,0}}}+\xi_V A_{12,0}\left(\left|T_{12}-T_{amb}\right|\right)^{\frac{1}{3}}\left(T_{12}-T_{amb}\right)=0$$

CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 88 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=13

$$\frac{A_{13,0}\cdot(T_{13}-T_3)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{13}^{\ 4}-T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{13,0}}\right)+\frac{1}{A_{13,0}}}+\xi_V\cdot A_{13,0}\cdot\left(\left|T_{13}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot(T_{13}-T_{amb})=0$$

j=14

$$\frac{A_{14,0}\cdot(T_{14}-T_4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{14}^{\ 4}-T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{14,0}}}+\xi_V\cdot A_{14,0}\cdot\left(\left|T_{14}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot(T_{14}-T_{amb})=0$$

$$\begin{pmatrix}T1\\T2\\T3\\T4\\T5\\T6\\T7\\T8\\T9\\T10\\T11\\T12\\T13\\T14\end{pmatrix}:=\text{Find}(T_1,T_2,T_3,T_4,T_5,T_6,T_7,T_8,T_9,T_{10},T_{11},T_{12},T_{13},T_{14})$$

ARES CORPORATION	CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002		Rev. No. 1	Page 89 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis				
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce		Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

T1 = 1200.2K   T1C := KtoC(T1)   T1C = 927

T2 = 1232.4K   T2C := KtoC(T2)   T2C = 959.2

T3 = 1200.2K   T3C := KtoC(T3)   T3C = 927

T4 = 1232.4K   T4C := KtoC(T4)   T4C = 959.2

T5 = 1075.8K   T5C := KtoC(T5)   T5C = 802.6

T6 = 1135.3K   T6C := KtoC(T6)   T6C = 862.1

T7 = 1075.8K   T7C := KtoC(T7)   T7C = 802.6

T8 = 1135.3K   T8C := KtoC(T8)   T8C = 862.1

T9 = 1238.1K   T9C := KtoC(T9)   T9C = 964.9

T10 = 1080.2K   T10C := KtoC(T10)   T10C = 807.1

T11 = −880.6K   T11C := KtoC(T11)   T11C = −1153.8

T12 = 507.7K   T12C := KtoC(T12)   T12C = 234.6

T13 = −880.6K   T15C := KtoC(T13)   T13C = −1153.8

T14 = 507.7K   T14C := KtoC(T14)   T14C = 234.6

T1F := CtoF(T1C)   T2F := CtoF(T2C)   T3F := CtoF(T3C)   T4F := CtoF(T4C)   T5F := CtoF(T5C)   T6F := CtoF(T6C)

T7F := CtoF(T7C)   T8F := CtoF(T8C)   T9F := CtoF(T9C)   T10F := CtoF(T10C)   T11F := CtoF(T11C)   T12F := CtoF(T12C)

T13F := CtoP(T13C)   T14P := CtoF(T14C)

Results in F...

T1P = 1200.673   T2F = 1758.597   T3F = 1700.673   T4F = 1758.597   T5F = 1476.686   T6F = 1583.81

T7F = 1476.686   T8F = 1583.81   T9F = 1768.895   T10P = 1484.7   T11F = −2044.8   T12P = 454.2   T13F = −2044.8   T14F = 454.2

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 90 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

Check results ...

$T_0 = 1393.9\,K$

$T1 = 1200.2\,K$ $T2 = 1232.4\,K$ $T3 = 1200.2\,K$ $T4 = 1232.4\,K$ $T5 = 1075.8\,K$ $T6 = 1135.3\,K$

$T7 = 1075.8\,K$ $T8 = 1135.3\,K$ $T9 = 1238.1\,K$ $T10 = 1080.2\,K$ $T11 = -880.6\,K$ $T12 = 507.7\,K$ $T13 = -880.6\,K$

$T14 = 507.7\,K$ $T_{AWTB} = 298.1\,K$ $T_{amb} = 328.1\,K$ $T_{OG} = 741.5\,K$

j=1

$$\frac{\sigma\cdot\tau_{OG}\left(T1^4 - T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\left(T1^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\left(T1^4 - T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} \ldots = 0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T1^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\left(T1^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,6}}+\left(\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{6,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\left(T1^4 - T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,7}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{7,0}}} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T1^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,8}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{8,0}}} + \frac{\sigma\cdot\tau_{OG}\left(T1^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,9}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{9,0}}} + \xi_V\cdot A_{1,0}\cdot\left(\left|T1 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T1 - T_{OG}\right) \ldots$$

$$+\frac{A_{1,0}\cdot(T1 - T11)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\alpha_{OG}\left(T1^4 - T_{13}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 91 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=2

$$\frac{\sigma\cdot\tau_{OG}\left(T2^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} \ldots = -0W$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} \ldots$$

$$+\xi_V\cdot A_{2,0}\cdot\left(\left|T2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T2-T_{OG}\right)+\frac{A_{2,0}\cdot(T2-T12)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T2^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

A.R.E.S. CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 92 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=3:

$$\frac{\sigma \cdot \tau_{OG} \cdot \left(T3^4 - T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T3^4 - T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right) + \frac{1}{A_{3,0} \cdot F_{3,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T3^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right) + \frac{1}{A_{3,0} \cdot F_{3,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{2,0}}\right)} \ldots = -0W$$

$$+ \frac{\sigma \cdot \tau_{OG} \cdot \left(T3^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right) + \frac{1}{A_{3,0} \cdot F_{3,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{4,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T3^4 - T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right) + \frac{1}{A_{3,0} \cdot F_{3,5}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{5,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T3^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right) + \frac{1}{A_{3,0} \cdot F_{3,6}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{6,0}}} \ldots$$

$$+ \frac{\sigma \cdot \tau_{OG} \cdot \left(T3^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right) + \frac{1}{A_{3,0} \cdot F_{3,8}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{8,0}}} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T3^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right) + \frac{1}{A_{3,0} \cdot F_{3,9}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{9,0}}} + \xi_V \cdot A_{3,0} \cdot \left(\left|T3 - T_{OG}\right|\right)^{\frac{1}{3}} \cdot \left(T3 - T_{OG}\right) -$$

$$+ \frac{A_{3,0} \cdot (T3 - T15)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma \cdot \alpha_{OG} \cdot \left(T3^4 - T_{15}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right) + \frac{1}{A_{3,0}}}$$

A.R.E.S CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 93 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

$j=4$

$$\frac{\sigma\cdot\tau_{OG}\left(T4^4-T_0^{\ 4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T4^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T4^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots = 0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T4^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T4^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T4^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T4^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T4^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T4^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{A_{4,0}\cdot(T4-T14)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V\cdot A_{4,0}\cdot\left(\left|T4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T4-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T4^4-T_{15}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}$$

ARES CORPORATION	CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002		Rev. No. 1	Page 94 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis				
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce		Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=5

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots = -0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T5^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\cdot\left[\left|T5-\left(\frac{T5+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T5-\left(\frac{T5+T10}{2}\right)\right]+\xi_V\cdot A_{5,0}\cdot\left(\left|T5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T5-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T5^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 95 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=6

$$\frac{\sigma\cdot\tau_{OG}\left(T6^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots = -0W$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T6^4-T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T6^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot\left(1-F_{6,10}\right)}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\cdot\left[\left|T6-\left(\frac{T6+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T6-\left(\frac{T6+T10}{2}\right)\right]\ldots$$

$$+\xi_{HU}\cdot A_{6,1}\cdot\left[\left|T6-\left(\frac{T6+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T6-\left(\frac{T6+T10}{2}\right)\right]+\xi_V\cdot A_{6,0}\cdot\left(\left|T6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T6^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

A.R.E.S CORPORATION	**CALCULATION SHEET**		
Project No. 0509206.01	**Calculation No. 0509206.01-M-002**	**Rev. No. 1**	**Page 96 of 252**
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	**Date: 2.17.06**	**Checked By: S.R. Pierce**	**Date: 2.17.06**

DBVS Off-Gas Hood Thermal Model

j=7

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots = 0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T7^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\left[\left|T7-\left(\frac{T7+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T7-\left(\frac{T7+T10}{2}\right)\right]+\xi_V\cdot A_{7,0}\cdot\left(\left|T7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T7-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T7^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}$$

DBVS Off-Gas Hood Thermal Model

$i = 8$

$$\frac{\sigma\cdot\varepsilon_{OG}\left(T8^4 - T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,8}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)} + \frac{\sigma\cdot\varepsilon_{OG}\left(T8^4 - T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)} + \frac{\sigma\cdot\varepsilon_{OG}\left(T8^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \ldots = -0\,W$$

$$+ \frac{\sigma\cdot\varepsilon_{OG}\left(T8^4 - T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} + \frac{\sigma\cdot\varepsilon_{OG}\left(T8^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)} + \frac{\sigma\cdot\varepsilon_{OG}\left(T8^4 - T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,5}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}} \ldots$$

$$+ \frac{\sigma\cdot\varepsilon_{OG}\left(T8^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,6}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}} + \frac{\sigma\cdot\varepsilon_{OG}\left(T8^4 - T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,7}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}} + \frac{\sigma\cdot\varepsilon_{OG}\left(T8^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,9}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} \ldots$$

$$+ \frac{\sigma\cdot\left(T8^4 - T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,10}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)} + \frac{\sigma\cdot\left(T8^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot\left(1 - F_{8,10}\right)}} + \xi_V\cdot\left(A_{8,0} + A_{8,2}\right)\cdot\left[\left|T8 - \left(\frac{T8 + T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T8 - \left(\frac{T8 + T10}{2}\right)\right] \ldots$$

$$+ \xi_{HU}\cdot A_{8,1}\left[\left|T8 - \left(\frac{T8 + T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T8 - \left(\frac{T8 + T10}{2}\right)\right] + \xi_V\cdot A_{8,0}\cdot\left(\left|T8 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T8 - T_{OG}\right) + \frac{\sigma\cdot\alpha_{OG}\left(T8^4 - T_{15}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 98 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

i=9

$$\frac{\sigma\cdot\tau_{OG}\left(T9^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \ldots = 0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}} \ldots$$

$$+\frac{\sigma\cdot\left(T9^4-T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\left(\frac{1-\varepsilon_{Al}}{\varepsilon_{Al}\cdot A_{10,0}}\right)}+\xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left[\left|T9-\left(\frac{T9+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T9-\left(\frac{T9+T10}{2}\right)\right] \ldots$$

$$+\xi_{HU}\cdot A_{9,1}\cdot\left[\left|T9-\left(\frac{T9+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T9-\left(\frac{T9+T10}{2}\right)\right]+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T9^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 99 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=10

$$\frac{\sigma\cdot\left(T10^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\left(T10^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}} \ldots = 0\,W$$

$$+\frac{\sigma\cdot\left(T10^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{Al}}{\varepsilon_{Al}\cdot A_{10,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\frac{\sigma\cdot\left(T10^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{Al}}{\varepsilon_{Al}\cdot A_{10,0}}\right)+\frac{1}{A_{10,0}\cdot\left(1-\frac{A_{6,0}\cdot F_{6,10}}{A_{10,0}}-\frac{A_{8,0}\cdot F_{8,10}}{A_{10,0}}-\frac{A_{9,0}\cdot F_{9,10}}{A_{10,0}}\right)}} \ldots$$

$$+\xi_{HD}\cdot A_{10,0}\cdot\left[\left|T10-\left(\frac{T9+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T10-\left(\frac{T9+T10}{2}\right)\right]+\frac{A_{10,0}\cdot\left(T10-T_{AWTE}\right)}{\left(\frac{\delta_{floor}}{k_{stl}}\right)+\left(\frac{\delta_{CaSi}}{k_{CaSi}}\right)}$$

j=11

$$\frac{A_{11,0}\cdot(T11-T1)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T11^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{11,0}}\right)+\frac{1}{A_{11,0}}}+\xi_V\cdot A_{11,0}\cdot\left(\left|T11-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T11-T_{amb}\right)=0\,W$$

j=12

$$\frac{A_{12,0}\cdot(T12-T2)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T12^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right)+\frac{1}{A_{12,0}}}+\xi_V\cdot A_{12,0}\cdot\left(\left|T12-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T12-T_{amb}\right)=0\,W$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 100 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

j=13

$$\frac{A_{13,0}\cdot(T13-T3)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T13^4-T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{13,0}}\right)+\frac{1}{A_{13,0}}}+\xi_V\cdot A_{13,0}\cdot\left(\left|T13-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T13-T_{amb}\right)=0\,W$$

j=14

$$\frac{A_{14,0}\cdot(T14-T4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T14^4-T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{13,0}}}+\xi_V\cdot A_{14,0}\cdot\left(\left|T14-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T14-T_{amb}\right)=0\,W$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 101 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS Off-Gas Hood Thermal Model

Total radiant heat loss from the melt surface ...

$$\frac{\sigma\cdot\left(T1^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\left(T2^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\left(T3^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} \dots = -548.8\,kW$$

$$+\frac{\sigma\cdot\left(T4^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\left(T5^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\left(T6^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)} \dots$$

$$+\frac{\sigma\cdot\left(T7^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\left(T8^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\left(T9^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}$$

$$F_{0,1}+F_{0,2}+F_{0,3}+F_{0,4}+F_{0,5}+F_{0,6}+F_{0,7}+F_{0,8}+F_{0,9}=1$$

Compute the average hood temperature ...

$$T_{HA} := \frac{A_{5,0}\cdot T5C + A_{6,0}\cdot T6C + A_{7,0}\cdot T7C + A_{8,0}\cdot T8C + A_{9,0}\cdot T9C}{A_{5,0}+A_{6,0}+A_{7,0}+A_{8,0}+A_{9,0}}$$

$T_{HA} = 906.2$ $\quad T_{HAF} := CtoF(T_{HA})$ $\quad T_{HAF} = 1663.1$

Heat flux through AWTE floor ...

$$q_{AWTE} := \frac{T10 - T_{AWTE}}{\left(\frac{\delta_{floor}}{k_{stl}}\right)+\left(\frac{\delta_{CaSi}}{k_{CaSi}}\right)} \qquad q_{AWTE} = 1.3\,\frac{1}{m^2}\,kW$$

APPENDIX D

MATHCAD MODEL FOR THE "OPEN AIR" CONDITIONS

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 103 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

$°F \equiv 1$

$°C \equiv 1$

$$CtoF(x) := \left(\frac{9}{5}\cdot\frac{x}{°C} + 32\right)°F \quad CtoK(x) := \left(\frac{x}{°C} + 273.15\right)K \quad KtoC(x) := \left(\frac{x}{K} - 273.15\right)°C$$

$$FtoC(x) := \frac{5}{9}\left(\frac{x}{°F} - 32\right)°C \quad FtoR(x) := \left(\frac{x}{°F} + 459.67\right)R$$

$w_1 := 5.5ft \quad w_2 := 3.5ft \quad L_1 := 22ft \quad h_1 := 14in \quad h_2 := 16in \quad \theta := 52deg \quad N_{ribs} := 12 \quad w_{ribs} := 2in \quad h_{ribs} := 4in$

$\delta_{hood} := 0.3125in \quad \theta := 52deg \quad \delta_{floor} := 3.5in \quad \delta_{CR} := 6in \quad \delta_{sand} := 6in$

Matrix of surface areas....

$$A := \begin{bmatrix} w_1\cdot L_1 & 0 & 0 \\ w_1\cdot h_1 & 0 & 0 \\ L_1\cdot h_1 & 0 & 0 \\ w_1\cdot h_1 & 0 & 0 \\ L_1\cdot h_1 & 0 & 0 \\ \frac{(w_1 + w_2)\cdot h_2}{2} & 0 & 0 \\ L_1\cdot\frac{h_2}{\sin(\theta)} & N_{ribs}\cdot w_{ribs}\cdot\frac{h_2}{\sin(\theta)} & 2N_{ribs}\cdot h_{ribs}\cdot\frac{h_2}{\sin(\theta)} \\ \frac{(w_1 + w_2)\cdot h_2}{2} & 0 & 0 \\ L_1\cdot\frac{h_2}{\sin(\theta)} & N_{ribs}\cdot w_{ribs}\cdot\frac{h_2}{\sin(\theta)} & 2N_{ribs}\cdot h_{ribs}\cdot\frac{h_2}{\sin(\theta)} \\ w_2\cdot L_1 & N_{ribs}\cdot w_{ribs}\cdot w_2 & 2N_{ribs}\cdot h_{ribs}\cdot w_2 \\ (3ft + w_1 + 3ft)\cdot(3ft + L_1 + 3ft) & 0 & 0 \\ w_1\cdot h_1 & 0 & 0 \\ L_1\cdot h_1 & 0 & 0 \\ w_1\cdot h_1 & 0 & 0 \\ L_1\cdot h_1 & 0 & 0 \end{bmatrix}$$

The first column of dat contains the area of the element for radiant heat transfer. The second column of data contains the horizontal component of area associated with the 4"x2" steel tubing ribs on that elemental area. The third column of data contains the vertical component of the ribs for that elemental area.

A = (ft^2)

	0	1	2
0	121	0	0
1	6.4	0	0
2	25.7	0	0
3	6.4	0	0
4	25.7	0	0
5	6	0	0
6	37.2	3.4	13.5
7	6	0	0
8	37.2	3.4	13.5
9	77	7	28
10	322	0	0
11	6.4	0	0
12	25.7	0	0
13	6.4	0	0
14	25.7	0	0

A.R.E.S CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 104 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

$$F := \begin{pmatrix} 0 & .021 & .091 & .021 & .091 & .028 & .177 & .028 & .177 & .366 & 0 \\ .397 & 0 & .026 & .004 & .026 & 0 & .129 & .021 & .129 & .265 & 0 \\ .428 & .006 & 0 & .006 & .052 & .019 & .039 & .019 & .077 & .354 & 0 \\ .400 & .004 & .026 & 0 & .026 & .021 & .129 & 0 & .129 & .265 & 0 \\ .428 & .006 & .052 & .006 & 0 & .019 & .077 & .019 & .039 & .354 & 0 \\ .565 & 0 & .081 & .022 & .081 & 0 & .081 & .003 & .081 & .086 & 0 \\ .575 & .022 & .027 & .022 & .053 & .013 & 0 & .013 & .015 & .125 & .616 \\ .565 & .022 & .081 & 0 & .081 & .003 & .081 & 0 & .081 & .086 & 0 \\ .575 & .022 & .053 & .022 & .027 & .013 & .150 & .013 & 0 & .125 & .616 \\ .574 & .022 & .118 & .022 & .118 & .013 & .060 & .013 & .060 & 0 & 1 \end{pmatrix}$$

Matrix F contains the view factors for radiant heat transfer between surfaces of the model. The first (row) index corresponds to the ID of the source surface; the second to the receiving surface. For example, the top of the soil surface above the melt has ID=0; the ID of the "short" box wall surface (width = 5.5 ft, height = 14in) has ID = 1. The view factor between these two surfaces is located at F[0,1] = 0.021 (obtained from Configuration 16, p. 1030 in Siegel & Howell's Thermal Radiation Heat Transfer, 3rd Edition). The "reciprocity" view factor for these two surfaces is F[1,0]= A[0,0]*F[0,1]/A[1,0] = 0.397.

F =

	0	1	2	3	4	5	6	7	8	9	10
0	0	0.021	0.091	0.021	0.091	0.028	0.177	0.028	0.177	0.366	0
1	0.397	0	0.026	0.004	0.026	0	0.129	0.021	0.129	0.265	0
2	0.428	0.006	0	0.006	0.052	0.019	0.039	0.019	0.077	0.354	0
3	0.4	0.004	0.026	0	0.026	0.021	0.129	0	0.129	0.265	0
4	0.428	0.006	0.052	0.006	0	0.019	0.077	0.019	0.039	0.354	0
5	0.565	0	0.081	0.022	0.081	0	0.081	0.003	0.081	0.086	0
6	0.575	0.022	0.027	0.022	0.053	0.013	0	0.013	0.015	0.125	0.616
7	0.565	0.022	0.081	0	0.081	0.003	0.081	0	0.081	0.086	0
8	0.575	0.022	0.053	0.022	0.027	0.013	0.15	0.013	0	0.125	0.616
9	0.574	0.022	0.118	0.022	0.118	0.013	0.06	0.013	0.06	0	1

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 105 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

Temperature Boundary Conditions ...

$Tmelt := 1922°F$ $\quad TmC := FtoC(Tmelt)$ $\quad T_{melt} := CtoK(TmC)$ $\quad T_{melt} = 1323.15\,K$

$TAWTE := 77°F$ $\quad TAC := FtoC(TAWTE)$ $\quad T_{AWTE} := CtoK(TAC)$ $\quad T_{AWTE} = 298.1\,K$

$TOG := 875°F$ $\quad Tog := FtoC(TOG)$ $\quad T_{OG} := CtoK(Tog)$ $\quad T_{OG} = 741.483\,K$

$Tamb := 55°C$ $\quad T_{amb} := CtoK(Tamb)$ $\quad T_{amb} = 328.1\,K$

Initial guess for temperatures ....

$T_0 := T_{melt}$

$T_1 := 773K$ $\quad T_3 := 773K$ $\quad T_5 := 773K$ $\quad T_7 := 773K$ $\quad T_9 := 773K$

$T_2 := 773K$ $\quad T_4 := 773K$ $\quad T_6 := 773K$ $\quad T_8 := 773K$ $\quad T_{10} := 773K$ **(T_{10} not used in this model)**

$T_{11} := 473K$ $\quad T_{12} := 473K$ $\quad T_{13} := 473K$ $\quad T_{14} := 473K$

Material properties ....

$\sigma := 5.67 \cdot 10^{-8} \cdot \frac{W}{m^2 \cdot K^4}$

$\varepsilon_{melt} := 0.7$

$\varepsilon_{stl} := .85$ $\quad k_{stl} := 60.5 \frac{W}{m \cdot K}$

$\varepsilon_{CR} := 0.66$ $\quad k_{CR} := 1.44 \frac{W}{m \cdot K}$ $\quad k_{sand} := 2 \frac{W}{m \cdot K}$

$\alpha_{OG} := 0$ $\quad \tau_{OG} := 1 - \alpha_{OG}$ $\quad \tau_{OG} = 1$

Convective heat transfer coefficients ... $\quad n := \frac{1}{3}$ $\quad \xi_V := 1.32 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$ $\quad \xi_{HD} := 0.591 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$ $\quad \xi_{HU} := 1.52 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$

CALCULATION SHEET

ARES CORPORATION

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 106 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

$T_{amb} = 328.1\,K$ $\quad T_{OG} = 741.5\,K$

Given

j=1

$$\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} \ldots = 0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,6}}\right)+\frac{1}{A_{1,0}\cdot F_{1,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{1,0}\cdot\left(\left|T_1-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_1-T_{OG}\right) \ldots$$

$$+\frac{A_{1,0}\cdot\left(T_1-T_{11}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T_1^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}}}$$

A.R.E.S CORPORATION	CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002		Rev. No. 1	Page 107 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis				
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce		Date: 2.17.06

j=2

$$\frac{\sigma \cdot \tau_{OG}\left(T_2^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma \cdot \tau_{OG}\left(T_2^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma \cdot \tau_{OG}\left(T_2^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} = 0$$

$$+\frac{\sigma \cdot \tau_{OG}\left(T_2^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma \cdot \tau_{OG}\left(T_2^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{5,0}}\right)}+\frac{\sigma \cdot \tau_{OG}\left(T_2^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{6,0}}\right)}$$

$$+\frac{\sigma \cdot \tau_{OG}\left(T_2^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{7,0}}}+\frac{\sigma \cdot \tau_{OG}\left(T_2^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{8,0}}}+\frac{\sigma \cdot \tau_{OG}\left(T_2^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{9,0}}}$$

$$+\xi_V \cdot A_{2,0}\cdot\left(\left|T_2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_2-T_{OG}\right)+\frac{A_{2,0}\cdot\left(T_2-T_{12}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T_2^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 108 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

$j=3$

$$\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \ldots = 0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{3,0}\cdot\left(\left|T_3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_3-T_{OG}\right) \ldots$$

$$+\frac{A_{3,0}\cdot\left(T_3-T_{13}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T_3^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}$$

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 109 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

F4

$$\frac{\sigma \cdot \tau_{OG}\left(T_4^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma \cdot \tau_{OG}\left(T_4^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma \cdot \tau_{OG}\left(T_4^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \ldots = 0$$

$$+\frac{\sigma \cdot \tau_{OG}\left(T_4^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma \cdot \tau_{OG}\left(T_4^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{5,0}}\right)}+\frac{\sigma \cdot \tau_{OG}\left(T_4^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{6,0}}} \ldots$$

$$+\frac{\sigma \cdot \tau_{OG}\left(T_4^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{7,0}}}+\frac{\sigma \cdot \tau_{OG}\left(T_4^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{8,0}}}+\frac{\sigma \cdot \tau_{OG}\left(T_4^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{9,0}}} \ldots$$

$$+\frac{A_{4,0}\left(T_4-T_{14}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V \cdot A_{4,0}\cdot\left(\left|T_4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_4-T_{OG}\right)+\frac{\sigma \cdot u_{OG}\left(T_4^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 110 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=5

$$
\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots
$$

$$
+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots
$$

$$
+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots
$$

$$
+\frac{\sigma\cdot\left(T_5^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\cdot\left(\left|T_5-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_5-T_{amb}\right)+\xi_V\cdot A_{5,0}\cdot\left(\left|T_5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_5-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_5^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}=0
$$

CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 111 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

i=6

$$\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ \dots = 0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ \dots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_6^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ \dots$$

$$+\frac{\sigma\cdot\left(T_6^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}+\xi_V\left(A_{6,0}+A_{6,2}\right)\cdot\left(\left|T_6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{amb}\right)\ \dots$$

$$+\xi_{HU}\cdot A_{6,1}\cdot\left(\left|T_6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{amb}\right)+\xi_V\cdot A_{6,0}\cdot\left(\left|T_6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_6^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 112 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=7

$$\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\left(T_7^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\cdot\left(\left|T_7-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_7-T_{amb}\right)+\xi_V\cdot A_{7,0}\cdot\left(\left|T_7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_7-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_7^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}$$

A.R.E.S CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 113 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

j=8

$$\begin{aligned}
&\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ \ldots=0\\
&+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ \ldots\\
&+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ \ldots\\
&+\frac{\sigma\cdot\left(T_8^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}+\xi_V\left(A_{8,0}+A_{8,2}\right)\cdot\left(\left|T_8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{amb}\right)\ \ldots\\
&+\xi_{HU}\cdot A_{8,1}\cdot\left(\left|T_8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{amb}\right)+\xi_V\cdot A_{8,0}\cdot\left(\left|T_8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_8^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}
\end{aligned}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 114 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

$i = 9$

$$\frac{\sigma\cdot\tau_{OG}\left(T_9^4 - T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\left(T_9^4 - T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\left(T_9^4 - T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \ldots = 0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_9^4 - T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\left(T_9^4 - T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\left(T_9^4 - T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_9^4 - T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}} + \frac{\sigma\cdot\tau_{OG}\left(T_9^4 - T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}} + \frac{\sigma\cdot\tau_{OG}\left(T_9^4 - T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}} \ldots$$

$$+\frac{\sigma\left(T_9^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}} + \xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left(\left|T_9 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_9 - T_{amb}\right) \ldots$$

$$+\xi_{HU}\cdot A_{9,1}\cdot\left(\left|T_9 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_9 - T_{amb}\right) + \xi_{HD}\cdot A_{9,0}\cdot\left(\left|T_9 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_9 - T_{OG}\right) + \frac{\sigma\cdot\alpha_{OG}\left(T_9^4 - T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 115 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=10

$$T_{10} - T_{10} = 0$$

j=11

$$\frac{A_{11,0}\cdot(T_{11} - T_1)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T_{11}^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{11,0}}\right) + \frac{1}{A_{11,0}}} + \xi_V\cdot A_{11,0}\cdot\left(\left|T_{11} - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{11} - T_{amb}\right) = 0$$

j=12

$$\frac{A_{12,0}\cdot(T_{12} - T_2)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T_{12}^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right) + \frac{1}{A_{12,0}}} + \xi_V\cdot A_{12,0}\cdot\left(\left|T_{12} - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{12} - T_{amb}\right) = 0$$

CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 116 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=13

$$\frac{A_{13,0}\cdot(T_{13}-T_3)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{13}^{\ 4}-T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{13,0}}\right)+\frac{1}{A_{13,0}}}+\xi_V\cdot A_{13,0}\cdot\left(\left|T_{13}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{13}-T_{amb}\right)=0$$

j=14

$$\frac{A_{14,0}\cdot(T_{14}-T_4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{14}^{\ 4}-T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{14,0}}}+\xi_V\cdot A_{14,0}\cdot\left(\left|T_{14}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{14}-T_{amb}\right)=0$$

$$\begin{pmatrix} T1 \\ T2 \\ T3 \\ T4 \\ T5 \\ T6 \\ T7 \\ T8 \\ T9 \\ T10 \\ T11 \\ T12 \\ T13 \\ T14 \end{pmatrix} := \mathrm{Find}(T_1,T_2,T_3,T_4,T_5,T_6,T_7,T_8,T_9,T_{10},T_{11},T_{12},T_{13},T_{14})$$

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 117 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

T1 = 1138.7 K	T1C := KtoC(T1)	T1C = 865.6
T2 = 1149.2 K	T2C := KtoC(T2)	T2C = 876.1
T3 = 1138.7 K	T3C := KtoC(T3)	T3C = 865.6
T4 = 1149.2 K	T4C := KtoC(T4)	T4C = 876.1
T5 = 1021.8 K	T5C := KtoC(T5)	T5C = 748.6
T6 = 1003 K	T6C := KtoC(T6)	T6C = 729.8
T7 = 1021.8 K	T7C := KtoC(T7)	T7C = 748.6
T8 = 1003 K	T8C := KtoC(T8)	T8C = 729.8
T9 = 1008 K	T9C := KtoC(T9)	T9C = 734.8
T10 = 773 K	T10C := KtoC(T10)	T10C = 499.9
T11 = 494.7 K	T11C := KtoC(T11)	T11C = 221.6
T12 = 496.2 K	T12C := KtoC(T12)	T12C = 223.1
T13 = 494.7 K	T13C := KtoC(T13)	T13C = 221.6
T14 = 496.2 K	T14C := KtoC(T14)	T14C = 223.1

T1F := CtoF(T1C) T2F := CtoF(T2C) T3F := CtoF(T3C) T4F := CtoF(T4C) T5F := CtoF(T5C) T6F := CtoF(T6C)

T7F := CtoF(T7C) T8F := CtoF(T8C) T9F := CtoF(T9C) T10F := CtoF(T10C) T11F := CtoF(T11C) T12F := CtoF(T12C)

T13F := CtoF(T13C) T14F := CtoF(T14C)

CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 118 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

Results in F ...

T1F = 1590.067 T2F = 1608.901 T3F = 1590.067 T4F = 1608.901 T5F = 1379.517 T6F = 1345.683

T7F = 1379.517 T8F = 1345.683 T9F = 1354.7 T10F = 931.7 T11F = 430.8 T12F = 433.5 T13F = 430.8 T14F = 433.5

Check results ...

$T0 := T_{melt}$ $T0 = 1325.2K$

$T1 = 1138.7K$ $T2 = 1149.2K$ $T3 = 1138.7K$ $T4 = 1149.2K$ $T5 = 1021.8K$ $T6 = 1003K$

$T7 = 1021.8K$ $T8 = 1003K$ $T9 = 1008K$ $T10 = 773K$ $T11 = 494.7K$ $T12 = 496.2K$ $T13 = 494.7K$

$T14 = 496.2K$ $T_{AWTE} = 298.1K$ $T_{amb} = 328.1K$ $T_{OG} = 741.5K$

j=1

$$\frac{\sigma\cdot\tau_{OG}\left(T1^4 - T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T1^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T1^4 - T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots = 0W$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T1^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T1^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T1^4 - T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T1^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T1^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{1,0}\cdot\left(\left|T1-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T1-T_{OG}\right)\ldots$$

$$+\frac{A_{1,0}\cdot(T1 - T11)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T1^4 - T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 119 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

j=2

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots=0W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\xi_V\cdot A_{2,0}\cdot\left(\left|T2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T2-T_{OG}\right)+\frac{A_{2,0}\cdot(T2-T12)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T2^4-T_{OG}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

j=3

$$
\begin{aligned}
&\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4 - T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4 - T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right) + \frac{1}{A_{3,0}\cdot F_{3,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right) + \frac{1}{A_{3,0}\cdot F_{3,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \ldots \\
&+ \frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right) + \frac{1}{A_{3,0}\cdot F_{3,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4 - T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right) + \frac{1}{A_{3,0}\cdot F_{3,5}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right) + \frac{1}{A_{3,0}\cdot F_{3,6}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}} \ldots \\
&+ \frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right) + \frac{1}{A_{3,0}\cdot F_{3,8}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right) + \frac{1}{A_{3,0}\cdot F_{3,9}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} + \xi_V\cdot A_{3,0}\cdot\left(\left|T3 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T3 - T_{OG}\right) \ldots \\
&+ \frac{A_{3,0}\cdot(T3 - T13)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\alpha_{OG}\cdot\left(T3^4 - T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right) + \frac{1}{A_{3,0}}} = 0\,W
\end{aligned}
$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 121 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=4

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \ldots = -0W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} \ldots$$

$$+\frac{A_{4,0}\cdot(T4-T14)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V\cdot A_{4,0}\cdot\left(\left|T4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T4-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T4^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 122 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

$j = 5$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4 - T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4 - T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4 - T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T5^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\cdot\left(\left|T5 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T5 - T_{amb}\right)+\xi_V\cdot A_{5,0}\cdot\left(\left|T5 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T5 - T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T5^4 - T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}} = 0\,W$$

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 123 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=6

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T6^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\cdot\left(\left|T6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{amb}\right)\ldots$$

$$+\xi_{HU}\cdot A_{6,1}\cdot\left(\left|T6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{amb}\right)+\xi_V\cdot A_{6,0}\cdot\left(\left|T6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T6^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 124 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=7

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ ...=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ ...$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ ...$$

$$+\frac{\sigma\cdot\left(T7^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\cdot\left(\left|T7-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T7-T_{amb}\right)+\xi_V\cdot A_{7,0}\cdot\left(\left|T7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T7-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T7^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}$$

ARES CORPORATION	CALCULATION SHEET				
Project No. 0509206.01	Calculation No. 0509206.01-M-002		Rev. No. 1	Page 125 of 252	
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis					
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce		Date: 2.17.06	

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=8

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \ldots = 0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} \ldots$$

$$+\frac{\sigma\cdot\left(T8^4-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}+\xi_V\cdot\left(A_{8,0}+A_{8,2}\right)\cdot\left(\left|T8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T8-T_{amb}\right) \ldots$$

$$+\xi_{HU}\cdot A_{8,1}\cdot\left(\left|T8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T8-T_{amb}\right)+\xi_V\cdot A_{8,0}\cdot\left(\left|T8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T8-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T8^4-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}$$

$j = 9$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4 - T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4 - T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \ldots = 0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4 - T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4 - T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4 - T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}} \ldots$$

$$+\frac{\sigma\cdot\left(T9^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}} + \xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left(\left|T9 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T9 - T_{amb}\right) \ldots$$

$$+\xi_{HU}\cdot A_{9,1}\cdot\left(\left|T9 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T9 - T_{amb}\right) + \xi_{HD}\cdot A_{9,0}\cdot\left(\left|T9 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T9 - T_{OG}\right) + \frac{\sigma\cdot\alpha_{OG}\cdot\left(T9^4 - T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 127 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

j=10

$$T10 - T10 = 0\,K$$

j=11

$$\frac{A_{11,0}\cdot(T11-T1)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T11^4-T_{amb}^{\ 4}\right)}{\left(\frac{1-\epsilon_{stl}}{\epsilon_{stl}\cdot A_{11,0}}\right)+\frac{1}{A_{11,0}}}+\xi_V\cdot A_{11,0}\cdot\left(\left|T11-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T11-T_{amb}\right)=0\,W$$

j=12

$$\frac{A_{12,0}\cdot(T12-T2)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T12^4-T_{amb}^{\ 4}\right)}{\left(\frac{1-\epsilon_{stl}}{\epsilon_{stl}\cdot A_{12,0}}\right)+\frac{1}{A_{12,0}}}+\xi_V\cdot A_{12,0}\cdot\left(\left|T12-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T12-T_{amb}\right)=0\,W$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 128 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=13

$$\frac{A_{13,0}\cdot(T13-T3)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T13^4-T_{amb}{}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{13,0}}\right)+\frac{1}{A_{13,0}}}+\xi_V\cdot A_{13,0}\cdot\left(\left|T13-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T13-T_{amb}\right)=0\,W$$

j=14

$$\frac{A_{14,0}\cdot(T14-T4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T14^4-T_{amb}{}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{14,0}}}+\xi_V\cdot A_{14,0}\cdot\left(\left|T14-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T14-T_{amb}\right)=-0\,W$$

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 129 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

Total radiant heat loss from the melt surface ...

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4-T0^4\right)}{\left(\frac{1-\epsilon_{melt}}{\epsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\epsilon_{CR}}{\epsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T0^4\right)}{\left(\frac{1-\epsilon_{melt}}{\epsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\epsilon_{CR}}{\epsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T0^4\right)}{\left(\frac{1-\epsilon_{melt}}{\epsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\epsilon_{CR}}{\epsilon_{CR}\cdot A_{3,0}}\right)}\ldots = -965.8\,kW$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T0^4\right)}{\left(\frac{1-\epsilon_{melt}}{\epsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\epsilon_{CR}}{\epsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T0^4\right)}{\left(\frac{1-\epsilon_{melt}}{\epsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\epsilon_{stl}}{\epsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T0^4\right)}{\left(\frac{1-\epsilon_{melt}}{\epsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\epsilon_{stl}}{\epsilon_{stl}\cdot A_{6,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T0^4\right)}{\left(\frac{1-\epsilon_{melt}}{\epsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\epsilon_{stl}}{\epsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T0^4\right)}{\left(\frac{1-\epsilon_{melt}}{\epsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\epsilon_{stl}}{\epsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\epsilon_{melt}}{\epsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\epsilon_{stl}}{\epsilon_{stl}\cdot A_{9,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\epsilon_{melt}}{\epsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}}}$$

$$F_{0,1}+F_{0,2}+F_{0,3}+F_{0,4}+F_{0,5}+F_{0,6}+F_{0,7}+F_{0,8}+F_{0,9}=1$$

Compute the average hood temperature ...

$$T_{HA} := \frac{A_{5,0}\cdot T5C+A_{6,0}\cdot T6C+A_{7,0}\cdot T7C+A_{8,0}\cdot T8C+A_{9,0}\cdot T9C}{A_{5,0}+A_{6,0}+A_{7,0}+A_{8,0}+A_{9,0}}$$

$T_{HA} = 733.6$ $\quad T_{HAF} := CtoF\left(T_{HA}\right)$ $\quad T_{HAF} = 1352.4$

APPENDIX E

MATHCAD MODEL FOR THE "OPEN AIR" CONDITIONS WITH SOIL OVERBURDEN

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 131 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

$°F \equiv 1$

$°C \equiv 1$

$CtoF(x) := \left(\frac{9}{5}\cdot\frac{x}{°C} + 32\right)°F \quad CtoK(x) := \left(\frac{x}{°C} + 273.15\right)K \quad KtoC(x) := \left(\frac{x}{K} - 273.15\right)°C$

$FtoC(x) := \frac{5}{9}\left(\frac{x}{°F} - 32\right)°C \quad FtoR(x) := \left(\frac{x}{°F} + 459.67\right)R$

$w_1 := 5.5ft \quad w_2 := 3.5ft \quad L_1 := 22ft \quad h_1 := 34in \quad h_2 := 16in \quad \theta := 52deg \quad N_{ribs} := 12 \quad w_{ribs} := 2in \quad h_{ribs} := 4in$

$\delta_{hood} := 0.3125in \quad \theta := 52deg \quad \delta_{floor} := 3.5in \quad \delta_{CR} := 6in \quad \delta_{sand} := 6in \quad \delta_{soil} := 1in$

Matrix of surface areas ...

$$A := \begin{bmatrix} w_1\cdot L_1 & 0 & 0 \\ w_1\cdot h_1 & 0 & 0 \\ L_1\cdot h_1 & 0 & 0 \\ w_1\cdot h_1 & 0 & 0 \\ L_1\cdot h_1 & 0 & 0 \\ \frac{(w_1 + w_2)\cdot h_2}{2} & 0 & 0 \\ L_1\cdot\frac{h_2}{\sin(\theta)} & N_{ribs}\cdot w_{ribs}\cdot\frac{h_2}{\sin(\theta)} & 2N_{ribs}\cdot h_{ribs}\cdot\frac{h_2}{\sin(\theta)} \\ \frac{(w_1 + w_2)\cdot h_2}{2} & 0 & 0 \\ L_1\cdot\frac{h_2}{\sin(\theta)} & N_{ribs}\cdot w_{ribs}\cdot\frac{h_2}{\sin(\theta)} & 2N_{ribs}\cdot h_{ribs}\cdot\frac{h_2}{\sin(\theta)} \\ w_2\cdot L_1 & N_{ribs}\cdot w_{ribs}\cdot w_2 & 2N_{ribs}\cdot h_{ribs}\cdot w_2 \\ (3ft + w_1 + 3ft)\cdot(3ft + L_1 + 3ft) & 0 & 0 \\ w_1\cdot h_1 & 0 & 0 \\ L_1\cdot h_1 & 0 & 0 \\ w_1\cdot h_1 & 0 & 0 \\ L_1\cdot h_1 & 0 & 0 \end{bmatrix}$$

The first column of dat contains the area of the element for radiant heat transfer. The second column of data contains the horizontal component of area associated with the 4"x2" steel tubing ribs on that elemental area. The third column of data contains the vertical component of the ribs for that elemental area.

A = (ft^2)

	0	1	2
0	121	0	0
1	6.4	0	0
2	25.7	0	0
3	6.4	0	0
4	25.7	0	0
5	6	0	0
6	37.2	3.4	13.5
7	6	0	0
8	37.2	3.4	13.5
9	77	7	28
10	322	0	0
11	6.4	0	0
12	25.7	0	0
13	6.4	0	0
14	25.7	0	0

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 132 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

$$F := \begin{pmatrix} 0 & .021 & .091 & .021 & .091 & .028 & .177 & .028 & .177 & .366 & 0 \\ .397 & 0 & .026 & .004 & .026 & 0 & .129 & .021 & .129 & .265 & 0 \\ .428 & .006 & 0 & .006 & .052 & .019 & .039 & .019 & .077 & .354 & 0 \\ .400 & .004 & .026 & 0 & .026 & .021 & .129 & 0 & .129 & .265 & 0 \\ .428 & .006 & .052 & .006 & 0 & .019 & .077 & .019 & .039 & .354 & 0 \\ .565 & 0 & .081 & .022 & .081 & 0 & .081 & .003 & .081 & .086 & 0 \\ .575 & .022 & .027 & .022 & .053 & .013 & 0 & .013 & .015 & .125 & .616 \\ .565 & .022 & .081 & 0 & .081 & .003 & .081 & 0 & .081 & .086 & 0 \\ .575 & .022 & .053 & .022 & .027 & .013 & .150 & .013 & 0 & .125 & .616 \\ .574 & .022 & .118 & .022 & .118 & .013 & .060 & .013 & .060 & 0 & 1 \end{pmatrix}$$

Matrix F contains the view factors for radiant heat transfer between surfaces of the model. The first (row) index corresponds to the ID of the source surface; the second to the receiving surface. For example, the top of the soil surface above the melt has ID=0; the ID of the "short" box wall surface (width = 5.5 ft, height = 14in) has ID = 1. The view factor between these two surfaces is located at F[0,1] = 0.021 (obtained from Configuration 16, p. 1030 in Siegel & Howell's Thermal Radiation Heat Transfer, 3rd Edition). The "reciprocity" view factor for these two surfaces is F[1,0]= A[0,0]*F[0,1]/A[1,0] = 0.397.

F =

	0	1	2	3	4	5	6	7	8	9	10
0	0	0.021	0.091	0.021	0.091	0.028	0.177	0.028	0.177	0.366	0
1	0.397	0	0.026	0.004	0.026	0	0.129	0.021	0.129	0.265	0
2	0.428	0.006	0	0.006	0.052	0.019	0.039	0.019	0.077	0.354	0
3	0.4	0.004	0.026	0	0.026	0.021	0.129	0	0.129	0.265	0
4	0.428	0.006	0.052	0.006	0	0.019	0.077	0.019	0.039	0.354	0
5	0.565	0	0.081	0.022	0.081	0	0.081	0.003	0.081	0.086	0
6	0.575	0.022	0.027	0.022	0.053	0.013	0	0.013	0.015	0.125	0.616
7	0.565	0.022	0.081	0	0.081	0.003	0.081	0	0.081	0.086	0
8	0.575	0.022	0.053	0.022	0.027	0.013	0.15	0.013	0	0.125	0.616
9	0.574	0.022	0.118	0.022	0.118	0.013	0.06	0.013	0.06	0	1

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 133 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

Temperature Boundary Conditions ...

$Tmelt := 2282°F$ $TmC := FtoC(Tmelt)$ $T_{melt} := CtoK(TmC)$ $T_{melt} = 1523.15\,K$

$TAWTE := 77°F$ $TAC := FtoC(TAWTE)$ $T_{AWTE} := CtoK(TAC)$ $T_{AWTE} = 298.1\,K$

$TOG := 875°F$ $Tog := FtoC(TOG)$ $T_{OG} := CtoK(Tog)$ $T_{OG} = 741.483\,K$

$Tamb := 25°C$ $T_{amb} := CtoK(Tamb)$ $T_{amb} = 298.1\,K$

Initial guess for temperatures ...

$T_0 := 973K$

$T_1 := 773K$ $T_3 := 773K$ $T_5 := 773K$ $T_7 := 773K$ $T_9 := 773K$

$T_2 := 773K$ $T_4 := 773K$ $T_6 := 773K$ $T_8 := 773K$ $T_{10} := 773K$ (T_{10} not used in this model)

$T_{11} := 473K$ $T_{12} := 473K$ $T_{13} := 473K$ $T_{14} := 473K$

Material properties ...

$\sigma := 5.67 \cdot 10^{-8} \frac{W}{m^2 \cdot K^4}$

$\varepsilon_{melt} := 0.7$

$\varepsilon_{stl} := .85$ $k_{stl} := 60.5 \frac{W}{m \cdot K}$

$\varepsilon_{CR} := 0.66$ $k_{CR} := 1.44 \frac{W}{m \cdot K}$ $k_{sand} := 2 \frac{W}{m \cdot K}$

$\alpha_{OG} := 0$ $\tau_{OG} := 1 - \alpha_{OG}$ $\tau_{OG} = 1$

Convective heat transfer coefficients ... $n := \frac{1}{3}$ $\xi_V := 1.31 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$ $\xi_{HD} := 0.691 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$ $\xi_{HU} := 1.52 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$

CALCULATION SHEET

ARES CORPORATION

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 134 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

$T_{amb} = 298.1\,K$ $\quad T_{OG} = 741.5\,K$

Given

$j = 0$

$$\frac{k_{sand} \cdot A_{0,0} \cdot (T_0 - T_{melt})}{\delta_{soil}} + \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_1^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_2^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{2,0}}\right)} \ldots$$

$$+ \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_3^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_4^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{4,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_5^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,5}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{5,0}}\right)} \ldots$$

$$+ \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_6^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,6}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{6,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_7^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,7}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{7,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_8^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,8}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{8,0}}\right)} \ldots$$

$$+ \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_9^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,9}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{9,0}}\right)} + \frac{\sigma \cdot \alpha_{OG} \cdot (T_0^4 - T_{OG}^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0}}} + \xi_{HU} \cdot A_{0,0} \cdot \left(|T_0 - T_{OG}|\right)^{\frac{1}{3}} \cdot (T_0 - T_{OG}) = 0$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 135 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

j=1

$$\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\;\ldots = 0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}\;\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{1,0}\left(\left|T_1-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_1-T_{OG}\right)\;\ldots$$

$$+\frac{A_{1,0}\left(T_1-T_{11}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T_1^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 136 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

j=2

$$\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} \ldots = 0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,3}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} \ldots$$

$$+\xi_V\cdot A_{2,0}\cdot\left(\left|T_2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_2-T_{OG}\right)+\frac{A_{2,0}\cdot\left(T_2-T_{12}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T_2^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 137 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=3

$$
\begin{aligned}
&\frac{\sigma\cdot\tau_{OG}\left(T_3^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \ldots = 0\\
&+\frac{\sigma\cdot\tau_{OG}\left(T_3^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}} \ldots\\
&+\frac{\sigma\cdot\tau_{OG}\left(T_3^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_3^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{3,0}\left(\left|T_3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_3-T_{OG}\right) \ldots\\
&+\frac{A_{3,0}\left(T_3-T_{13}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T_3^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}
\end{aligned}
$$

CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 138 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

$j=4$

$$
\begin{aligned}
&\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ \ldots = 0\\
&+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ \ldots\\
&+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ \ldots\\
&+\frac{A_{4,0}\left(T_4-T_{14}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V\cdot A_{4,0}\cdot\left(\left|T_4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_4-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_4^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}
\end{aligned}
$$

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=5

$$\frac{\sigma\cdot\tau_{OG}\left(T_5^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_5^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_5^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_5^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_5^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} \ldots$$

$$+\frac{\sigma\cdot\left(T_5^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\cdot\left(\left|T_5-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_5-T_{amb}\right)+\xi_V\cdot A_{5,0}\cdot\left(\left|T_5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_5-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_5^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}} = 0$$

j=6

$$
\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots
$$

$$
+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots
$$

$$
+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots
$$

$$
+\frac{\sigma\cdot\left(T_6^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\cdot\left(\left|T_6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{amb}\right)\ldots
$$

$$
+\xi_{HU}\cdot A_{6,1}\cdot\left(\left|T_6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{amb}\right)+\xi_V\cdot A_{6,0}\cdot\left(\left|T_6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_6^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}=0
$$

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 141 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=7

$$\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\left(T_7^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\cdot\left(\left|T_7-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_7-T_{amb}\right)+\xi_V\cdot A_{7,0}\cdot\left(\left|T_7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_7-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_7^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}$$

j=8

$$\frac{\sigma\cdot\tau_{OG}\left(T_8^{\ 4}-T_0^{\ 4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\ 4}-T_1^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\ 4}-T_2^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+ = 0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\ 4}-T_3^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\ 4}-T_4^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\ 4}-T_5^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\ 4}-T_6^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\ 4}-T_7^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\ 4}-T_9^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+$$

$$+\frac{\sigma\cdot\left(T_8^{\ 4}-T_{amb}^{\ \ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}+\xi_V\cdot\left(A_{8,0}+A_{8,2}\right)\cdot\left(\left|T_8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{amb}\right)+$$

$$+\xi_{HU}\cdot A_{8,1}\cdot\left(\left|T_8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{amb}\right)+\xi_V\cdot A_{8,0}\cdot\left(\left|T_8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_8^{\ 4}-T_{OG}^{\ \ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 143 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=9

$$\frac{\sigma \cdot \tau_{OG}\left(T_9^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma \cdot \tau_{OG}\left(T_9^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma \cdot \tau_{OG}\left(T_9^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0$$

$$+\frac{\sigma \cdot \tau_{OG}\left(T_9^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma \cdot \tau_{OG}\left(T_9^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma \cdot \tau_{OG}\left(T_9^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma \cdot \tau_{OG}\left(T_9^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma \cdot \tau_{OG}\left(T_9^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma \cdot \tau_{OG}\left(T_9^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\ldots$$

$$+\frac{\sigma \cdot \left(T_9^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}+\xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left(\left|T_9-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{amb}\right)\ldots$$

$$+\xi_{HU}\cdot A_{9,1}\cdot\left(\left|T_9-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{amb}\right)+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T_9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{OG}\right)+\frac{\sigma \cdot \alpha_{OG}\left(T_9^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

ARES CORPORATION

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 144 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=10

$$T_{10} - T_{10} = 0$$

j=11

$$\frac{A_{11,0}\cdot(T_{11}-T_1)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{11}^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{11,0}}\right)+\frac{1}{A_{11,0}}}+\xi_V\cdot A_{11,0}\cdot\left(\left|T_{11}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot(T_{11}-T_{amb})=0$$

j=12

$$\frac{A_{12,0}\cdot(T_{12}-T_2)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{12}^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right)+\frac{1}{A_{12,0}}}+\xi_V\cdot A_{12,0}\cdot\left(\left|T_{12}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot(T_{12}-T_{amb})=0$$

ARES CORPORATION	CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002		Rev. No. 1	Page 145 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis				
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce		Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=13

$$\frac{A_{13,0}\cdot(T_{13}-T_3)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{13}^{\ 4}-T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{13,0}}\right)+\frac{1}{A_{13,0}}}+\xi_V\cdot A_{13,0}\cdot\left(\left|T_{13}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{13}-T_{amb}\right)=0$$

j=14

$$\frac{A_{14,0}\cdot(T_{14}-T_4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{14}^{\ 4}-T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{14,0}}}+\xi_V\cdot A_{14,0}\cdot\left(\left|T_{14}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{14}-T_{amb}\right)=0$$

$$\begin{pmatrix} T0 \\ T1 \\ T2 \\ T3 \\ T4 \\ T5 \\ T6 \\ T7 \\ T8 \\ T9 \\ T10 \\ T11 \\ T12 \\ T13 \\ T14 \end{pmatrix} := \mathrm{Find}\left(T_0, T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, T_{13}, T_{14}\right)$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 146 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

T0 = 1041 K	T0C := KtoC(T0)	T0C = 767.9
T1 = 885.4 K	T1C := KtoC(T1)	T1C = 612.2
T2 = 893.6 K	T2C := KtoC(T2)	T2C = 620.5
T3 = 885.4 K	T3C := KtoC(T3)	T3C = 612.2
T4 = 893.6 K	T4C := KtoC(T4)	T4C = 620.5
T5 = 794.5 K	T5C := KtoC(T5)	T5C = 521.3
T6 = 775.3 K	T6C := KtoC(T6)	T6C = 502.2
T7 = 794.5 K	T7C := KtoC(T7)	T7C = 521.3
T8 = 775.3 K	T8C := KtoC(T8)	T8C = 502.2
T9 = 777.4 K	T9C := KtoC(T9)	T9C = 504.2
T10 = 773 K	T10C := KtoC(T10)	T10C = 499.9
T11 = 441.4 K	T11C := KtoC(T11)	T11C = 168.3
T12 = 442.9 K	T12C := KtoC(T12)	T12C = 169.7
T13 = 441.4 K	T13C := KtoC(T13)	T13C = 168.3
T14 = 442.9 K	T14C := KtoC(T14)	T14C = 169.7

T0F := CtoF(T0C)

T1F := CtoF(T1C) T2F := CtoF(T2C) T3F := CtoF(T3C) T4F := CtoF(T4C) T5F := CtoF(T5C) T6F := CtoF(T6C)

T7F := CtoF(T7C) T8F := CtoF(T8C) T9F := CtoF(T9C) T10F := CtoF(T10C) T11F := CtoF(T11C) T12F := CtoF(T12C)

T13F := CtoF(T13C) T14F := CtoF(T14C)

Results in F ...

T0F = 1414.1 T1F = 1133.999 T2F = 1148.862 T3F = 1133.999 T4F = 1148.862 T5F = 970.364 T6F = 935.876

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 147 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

$T7F = 970.364$ $\quad T8F = 935.876$ $\quad T9F = 939.598$ $\quad T10F = 931.7$ $\quad T11F = 334.9$ $\quad T12F = 337.5$ $\quad T13F = 334.9$ $\quad T14F = 337.5$

Check results ...

$T0 = 1041\,K$

$T1 = 885.4K$ $\quad T2 = 893.6K$ $\quad T3 = 885.4K$ $\quad T4 = 893.6K$ $\quad T5 = 794.5K$ $\quad T6 = 775.3K$

$T7 = 794.5K$ $\quad T8 = 775.3K$ $\quad T9 = 772.4K$ $\quad T10 = 773K$ $\quad T11 = 441.4K$ $\quad T12 = 442.9K$ $\quad T13 = 441.4K$

$T14 = 442.9K$ $\quad T_{AWTE} = 298.1K$ $\quad T_{amb} = 298.1K$ $\quad T_{OG} = 741.5K$

$j = 0$

$$\frac{k_{sand}\cdot A_{0,0}\cdot(T0 - T_{melt})}{\delta_{soil}} + \frac{\sigma\cdot\tau_{OG}\cdot(T0^4 - T1^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot(T0^4 - T2^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \ldots = -0\,W$$

$$+ \frac{\sigma\cdot\tau_{OG}\cdot(T0^4 - T3^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot(T0^4 - T4^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot(T0^4 - T5^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,5}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)} \ldots$$

$$+ \frac{\sigma\cdot\tau_{OG}\cdot(T0^4 - T6^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,6}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot(T0^4 - T7^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,7}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot(T0^4 - T8^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,8}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)} \ldots$$

$$+ \frac{\sigma\cdot\tau_{OG}\cdot(T0^4 - T9^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,9}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)} + \frac{\sigma\cdot\alpha_{OG}\cdot(T0^4 - T_{OG}^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}}} + k_{HU}\cdot A_{0,0}\cdot(|T0 - T_{OG}|)^{\frac{1}{3}}\cdot(T0 - T_{OG})$$

ARES CORPORATION	CALCULATION SHEET				
Project No. 0509206.01	Calculation No. 0509206.01-M-002		Rev. No. 1	Page 148 of 252	
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis					
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce		Date: 2.17.06	

DBVS ICV™ Off-Gas Hood Thermal Analysis

$j = 1$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} \ldots = 0\,W$$

$$+ \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,6}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,7}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}} \ldots$$

$$+ \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,8}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,9}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} + \xi_V\cdot A_{1,0}\cdot\left(\left|T1 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T1 - T_{OG}\right) \ldots$$

$$+ \frac{A_{1,0}\cdot(T1 - T11)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\alpha_{OG}\cdot\left(T1^4 - T_{OG}^{\;4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}}} \ldots$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 149 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=2

$$\frac{\sigma\cdot\tau_{OG}\cdot(T2^4-T0^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot(T2^4-T1^4)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot(T2^4-T3^4)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ ... = 0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot(T2^4-T4^4)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot(T2^4-T5^4)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot(T2^4-T6^4)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{6,0}}\right)}\ ...$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot(T2^4-T7^4)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot(T2^4-T8^4)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot(T2^4-T9^4)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{9,0}}}\ ...$$

$$+\xi_V\cdot A_{2,0}\cdot\left(\left|T2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot(T2-T_{OG})+\frac{A_{2,0}\cdot(T2-T12)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T2^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

CALCULATION SHEET

ARES Corporation			
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 150 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=3

$$\frac{\sigma \cdot \tau_{OG} \cdot \left(T3^4 - T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T3^4 - T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right) + \frac{1}{A_{3,0} \cdot F_{3,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T3^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right) + \frac{1}{A_{3,0} \cdot F_{3,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{2,0}}\right)} \ldots = 0\,W$$

$$+ \frac{\sigma \cdot \tau_{OG} \cdot \left(T3^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right) + \frac{1}{A_{3,0} \cdot F_{3,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{4,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T3^4 - T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right) + \frac{1}{A_{3,0} \cdot F_{3,5}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{5,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T3^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right) + \frac{1}{A_{3,0} \cdot F_{3,6}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{6,0}}} \ldots$$

$$+ \frac{\sigma \cdot \tau_{OG} \cdot \left(T5^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right) + \frac{1}{A_{3,0} \cdot F_{3,8}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{8,0}}} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T3^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right) + \frac{1}{A_{3,0} \cdot F_{3,9}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{9,0}}} + \xi_V \cdot A_{3,0} \cdot \left(\left|T3 - T_{OG}\right|\right)^{\frac{1}{3}} \cdot \left(T5 - T_{OG}\right) \ldots$$

$$+ \frac{A_{3,0} \cdot (T3 - T13)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma \cdot \alpha_{OG} \cdot \left(T3^4 - T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right) + \frac{1}{A_{3,0}}}$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 151 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

j:=4

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{9,0}}}\ldots$$

$$+\frac{A_{4,0}\cdot(T4-T14)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V\cdot A_{4,0}\cdot\left(\left|T4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T4-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T4^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}=0\,W$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 152 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=5

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots = 0W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T5^4-T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\cdot\left(\left|T5-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T5-T_{amb}\right)+\xi_V\cdot A_{5,0}\cdot\left(\left|T5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T5-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T5^4-T_{OG}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}$$

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 153 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=6

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T6^4-T_{amb}{}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\cdot\left(\left|T6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{amb}\right)\ldots$$

$$+\xi_{HU}\cdot A_{6,1}\cdot\left(\left|T6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{amb}\right)+\xi_V\cdot A_{6,0}\cdot\left(\left|T6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T6^4-T_{OG}{}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 154 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

i=7

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T7^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\cdot\left(\left|T7-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T7-T_{amb}\right)+\xi_V\cdot A_{7,0}\cdot\left(\left|T7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T7-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T7^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}=0\,W$$

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 155 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=8

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots = 0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T8^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}+\xi_V\cdot\left(A_{8,0}+A_{8,2}\right)\cdot\left(\left|T8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T8-T_{amb}\right)\ldots$$

$$+\xi_{HU}\cdot A_{8,1}\cdot\left(\left|T8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T8-T_{amb}\right)+\xi_V\cdot A_{8,0}\cdot\left(\left|T8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T8-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T8^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}$$

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=9

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots = 0W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T9^4-T_{amb}{}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}+\xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left(\left|T9-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{amb}\right)\ldots$$

$$+\xi_{HU}\cdot A_{9,1}\cdot\left(\left|T9-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{amb}\right)+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T9^4-T_{OG}{}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 157 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

j=10

$$T10 - T10 = 0K$$

j=11

$$\frac{A_{11,0}\cdot(T11 - T1)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T11^4 - T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{11,0}}\right)+\frac{1}{A_{11,0}}} + \xi_V\cdot A_{11,0}\cdot\left(\left|T11 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T11 - T_{amb}\right) = 0W$$

j=12

$$\frac{A_{12,0}\cdot(T12 - T2)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T12^4 - T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right)+\frac{1}{A_{12,0}}} + \xi_V\cdot A_{12,0}\cdot\left(\left|T12 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T12 - T_{amb}\right) = 0W$$

j=13

$$\frac{A_{13,0}\cdot(T13 - T3)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T13^4 - T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{13,0}}\right)+\frac{1}{A_{13,0}}} + \xi_V\cdot A_{13,0}\cdot\left(\left|T13 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T13 - T_{amb}\right) = 0W$$

j=14

$$\frac{A_{14,0}\cdot(T14 - T4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T14^4 - T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{14,0}}} + \xi_V\cdot A_{14,0}\cdot\left(\left|T14 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T14 - T_{amb}\right) = 0W$$

ARES CORPORATION	CALCULATION SHEET		
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 158 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

DBVS ICV™ Off-Gas Hood Thermal Analysis

Total radiant heat loss from the melt surface ...

$$\frac{\sigma\cdot\tau_{OG}\left(T1^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T3^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} \ldots = -392.5\,kW$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T4^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T5^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T6^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T7^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T8^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)} \ldots$$

$$+\frac{\sigma\cdot\alpha_{OG}\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}}}$$

$$F_{0,1}+F_{0,2}+F_{0,3}+F_{0,4}+F_{0,5}+F_{0,6}+F_{0,7}+F_{0,8}+F_{0,9}=1$$

Compute the average hood temperature ...

$$T_{HA}=\frac{A_{5,0}\cdot T5C+A_{6,0}\cdot T6C+A_{7,0}\cdot T7C+A_{8,0}\cdot T8C+A_{9,0}\cdot T9C}{A_{5,0}+A_{6,0}+A_{7,0}+A_{8,0}+A_{9,0}}$$

$T_{HA}=504.5$ $\qquad T_{HAF}:=CtoF\left(T_{HA}\right)$ $\qquad T_{HAF}=940.2$

APPENDIX F

HRTS BULKVIT TEST 38A-1 & 38B CONDITIONS

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 160 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

Pat Lowery

From: Mauss, Jerid [Jerid.Mauss@amec.com]
Sent: Friday, February 10, 2006 4:11 PM
To: Pat Lowery
Cc: David_H_Dave_Shuford@RL.gov; Ja-Kael.Luey@dmjmhn.aecom.com; Frederickson, Jim; Briggs, Stephen; Leonard, Michael W; Jeffers, Wilfred C (Jeff)
Subject: ICV Box Lid Analysis Values
Attachments: _0210160806_001.pdf

BOX LID ANALYSIS INPUT VALUES
(DATA OBTAINED FROM 38A-1 & 38B TC'S)

Calculations for box lid temperature and AWTE cooling load shall utilize the following bounding conditions from the test site.

A box lid temperature of 400°C.
30" distance from the lid to cold cap/molten surface.
Ambient conditions at 12°C.
Plenum temperatures not less than 600°C.

A 350°C box lid skin temperature at 75" from the lid surface with and ambient condition of 0°C should be used if it results in a more conservative approach.

See attached file for support data.
Please do not hesitate to contact me if you have any questions.

Thanks,
Jerid Mauss

2/17/2006

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 161 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

1 of 8

BOX LID ANALYSIS INPUT VALUES
(DATA OBTAINED FROM 38A-1 & 38B TC'S)

Calculations for box lid temperature and AWTE cooling load shall utilize the following bounding conditions from the test site.

A box lid temperature of 400°C.
30" distance from the lid to cold cap/molten surface.
Ambient conditions at 12°C.
Plenum temperatures not less than 600°C.

A 350°C box lid skin temperature at 75" from the lid surface with and ambient condition of 0°C should be used if it results in a more conservative approach.

Summarized Test Site Data for 38B & 38A-1

Conditions encountered in 38B

The average maximum box lid skin temperature during the 38B melt was 330° (Using TC's #6-16 less 8, 12 & 10 when off-scale).
The melt surface corresponding to the data above was ~65-75" from the box lid.
The peak plenum temp during the melt was 600°C.
The ambient conditions for the test were ~0°C

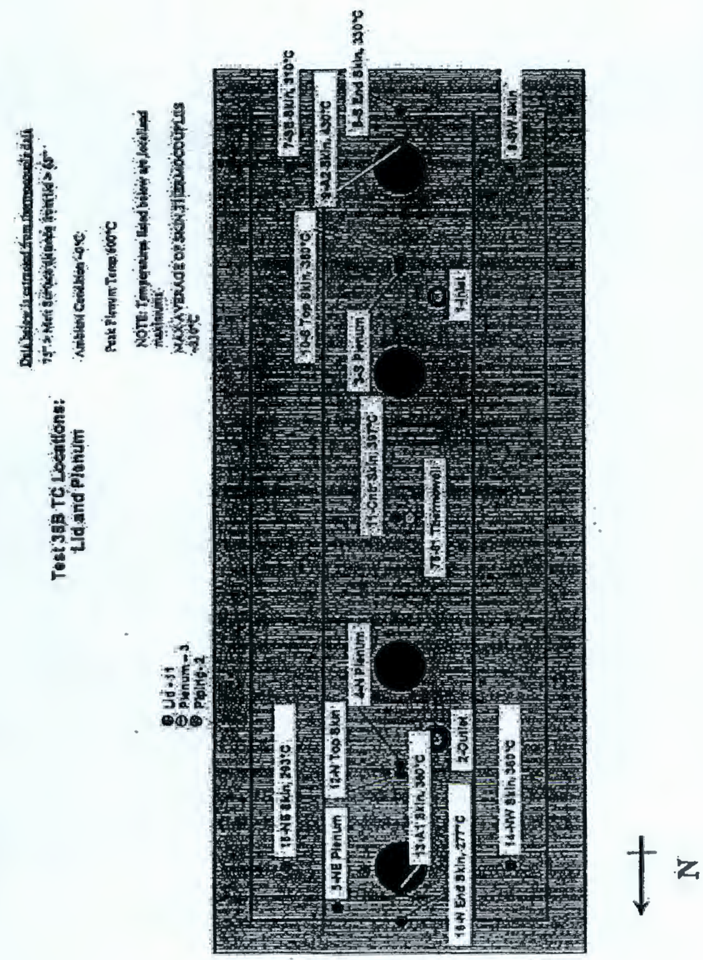
Note: TC #8 is not considered a localized hot spot, but rather a faulty thermocouple (the static temperature was far above the other thermocouples prior to the start of the melt) and was thrown out from the analysis.
TC #12 provided negative readings and was thrown out.
TC #10 was used for the average calculated temperature except when off-scale.

Conditions encountered in 38A-1

The average maximum box lid skin temperature during the 38A-1 melt was 375° (Using TC's 6-10).
The melt surface temps in 38A-1 corresponds to a melt that reached <30" from the box lid.
The last stage of the melt pushed the TC skin temperature average up ~70°C.
The peak plenum temp during the melt was 600°C.
The ambient conditions for the test were ~12°C (minimum record of TC-1)

CALCULATION SHEET			
Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 162 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

2 of 8

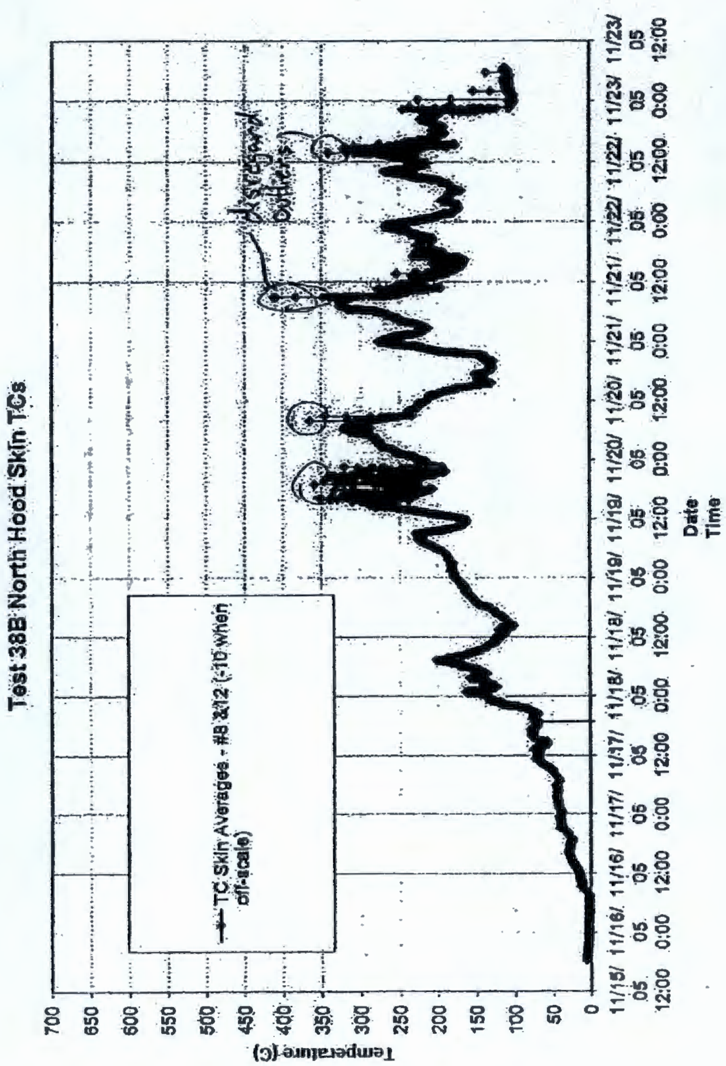


A.R.E.S CORPORATION

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 163 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

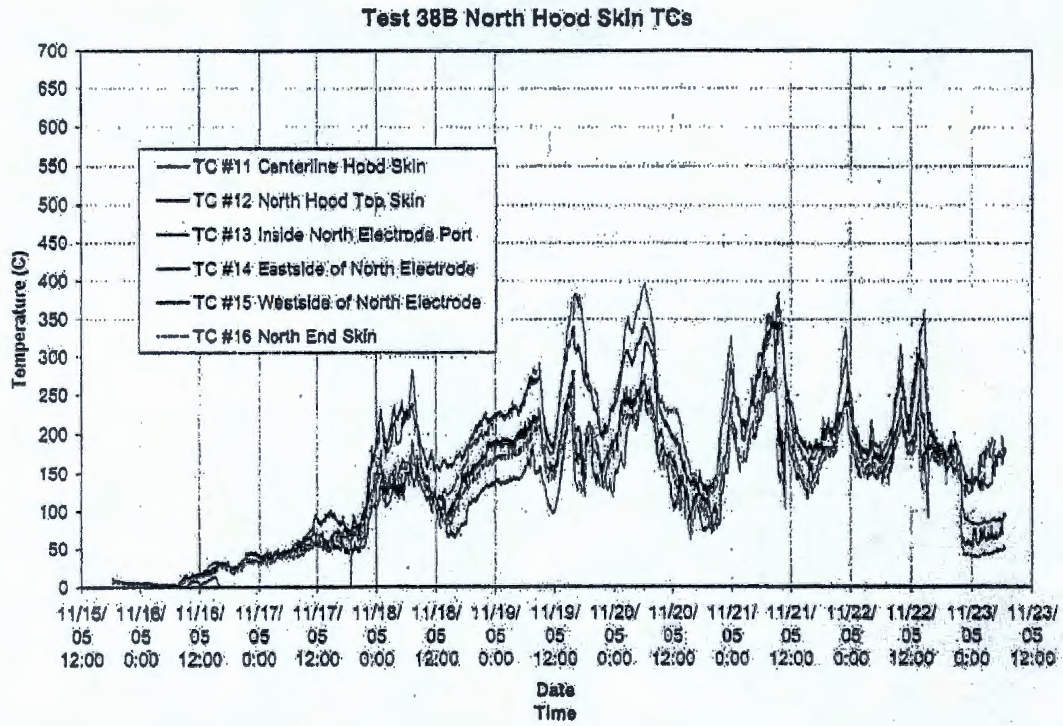
3 of 8



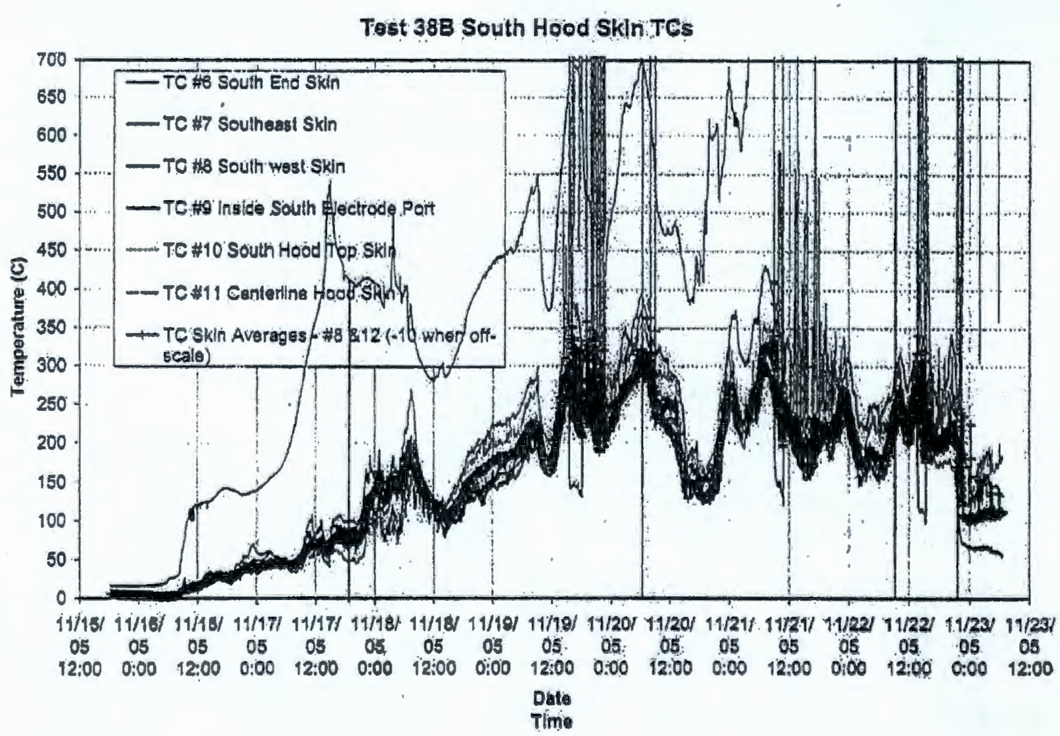
ARES CORPORATION

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 164 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06



4 of 8


Test 38B South Hood Skin TCs
TC #6 South End Skin
TC #7 Southeast Skin
TC #8 South west Skin
TC #9 Inside South Electrode Port
TC #10 South Hood Top Skin
TC #11 Centerline Hood Skin
TC Skin Averages - #8 &12 (-10 when off-scale)
Temperature (C)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
11/15/05 12:00
11/16/05 0:00
11/16/05 12:00
11/17/05 0:00
11/17/05 12:00
11/18/05 0:00
11/18/05 12:00
11/19/05 0:00
11/19/05 12:00
11/20/05 0:00
11/20/05 12:00
11/21/05 0:00
11/21/05 12:00
11/22/05 0:00
11/22/05 12:00
11/23/05 0:00
11/23/05 12:00
Date
Time

5 of 8

CALCULATION SHEET

Project No. 0509206.01	Calculation No. 0509206.01-M-002	Rev. No. 1	Page 166 of 252
Title: DBVS ICV™ Off-Gas Hood Thermal Analysis			
Prepared By: P.S. Lowery	Date: 2.17.06	Checked By: S.R. Pierce	Date: 2.17.06

6 of 6