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

Section 3 OF 15

Document Information			
Document #	0601116		
Title	ECOLOGY APPROVAL OF THE CONSTRUCTION OF THE IN-CONTAINER VITRIFICATION SYSTEM AND THE OFF-GAS TREATMENT SYSTEM OF THE FINAL DANGEROUS AND/OR MIXED WASTE RESEARCH AND DEVELOPMENT AND DEMONSTRATION PERMIT (RD&D PERMIT) WA789000/8967		
DATE	07/24/2006		
Originator	J. A. HEDGES	Originator Co.	DOEC
Recipient	R. J. SCHEPENS, M.S. SPEARS	Recipient Co.	DOE-ORP, CH2M
References			
Keywords			
Projects			
Other Information			

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:**

$$\Sigma\vec{\tau} = 0 \text{ about any point} \quad \text{(second condition for equilibrium)} \tag{11-2}$$

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.

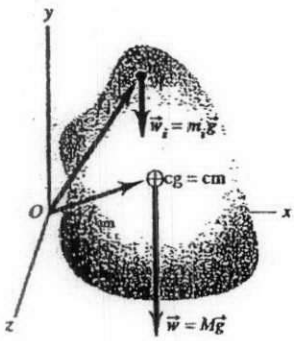
First let's review the definition of the center of mass. For a collection of particles with masses $m_1, m_2, \ldots$ and coordinates $(x_1, y_1, z_1), (x_2, y_2, z_2), \ldots$, the coordinates x_{cm}, y_{cm}, and z_{cm} of the center of mass are given by

$$x_{cm} = \frac{m_1x_1 + m_2x_2 + m_3x_3 + \cdots}{m_1 + m_2 + m_3 + \cdots} = \frac{\sum_i m_ix_i}{\sum_i m_i}$$
$$y_{cm} = \frac{m_1y_1 + m_2y_2 + m_3y_3 + \cdots}{m_1 + m_2 + m_3 + \cdots} = \frac{\sum_i m_iy_i}{\sum_i m_i} \quad \text{(center of mass)} \tag{11-3}$$
$$z_{cm} = \frac{m_1z_1 + m_2z_2 + m_3z_3 + \cdots}{m_1 + m_2 + m_3 + \cdots} = \frac{\sum_i m_iz_i}{\sum_i m_i}$$

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

$$\vec{r}_{cm} = \frac{m_1\vec{r}_1 + m_2\vec{r}_2 + \cdots}{m_1 + m_2 + \cdots} = \frac{\sum_i m_i\vec{r}_i}{\sum_i m_i}. \tag{11-4}$$

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



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.

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Attachment 5

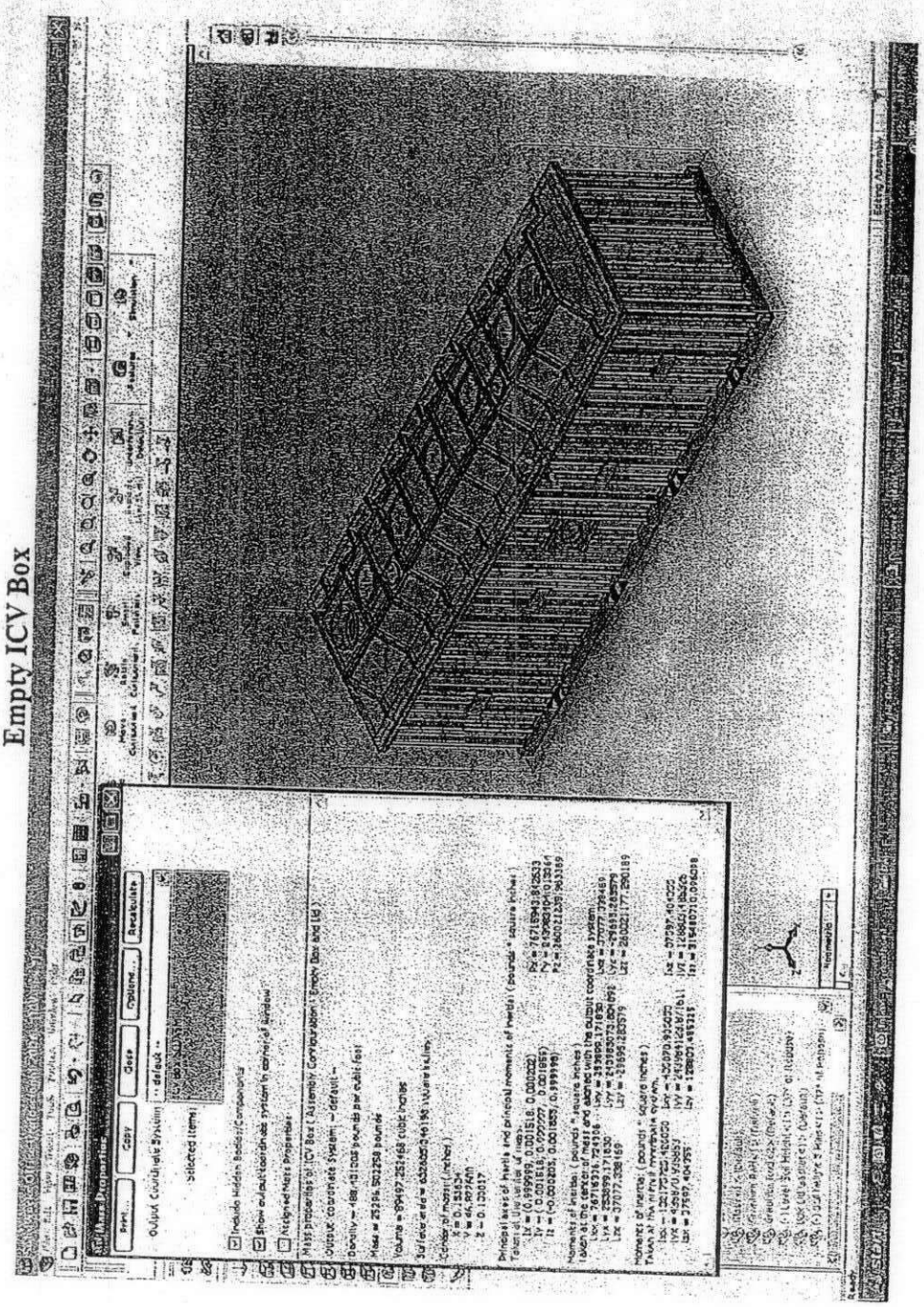
SolidWorks Model Pictures

Attachment: 5

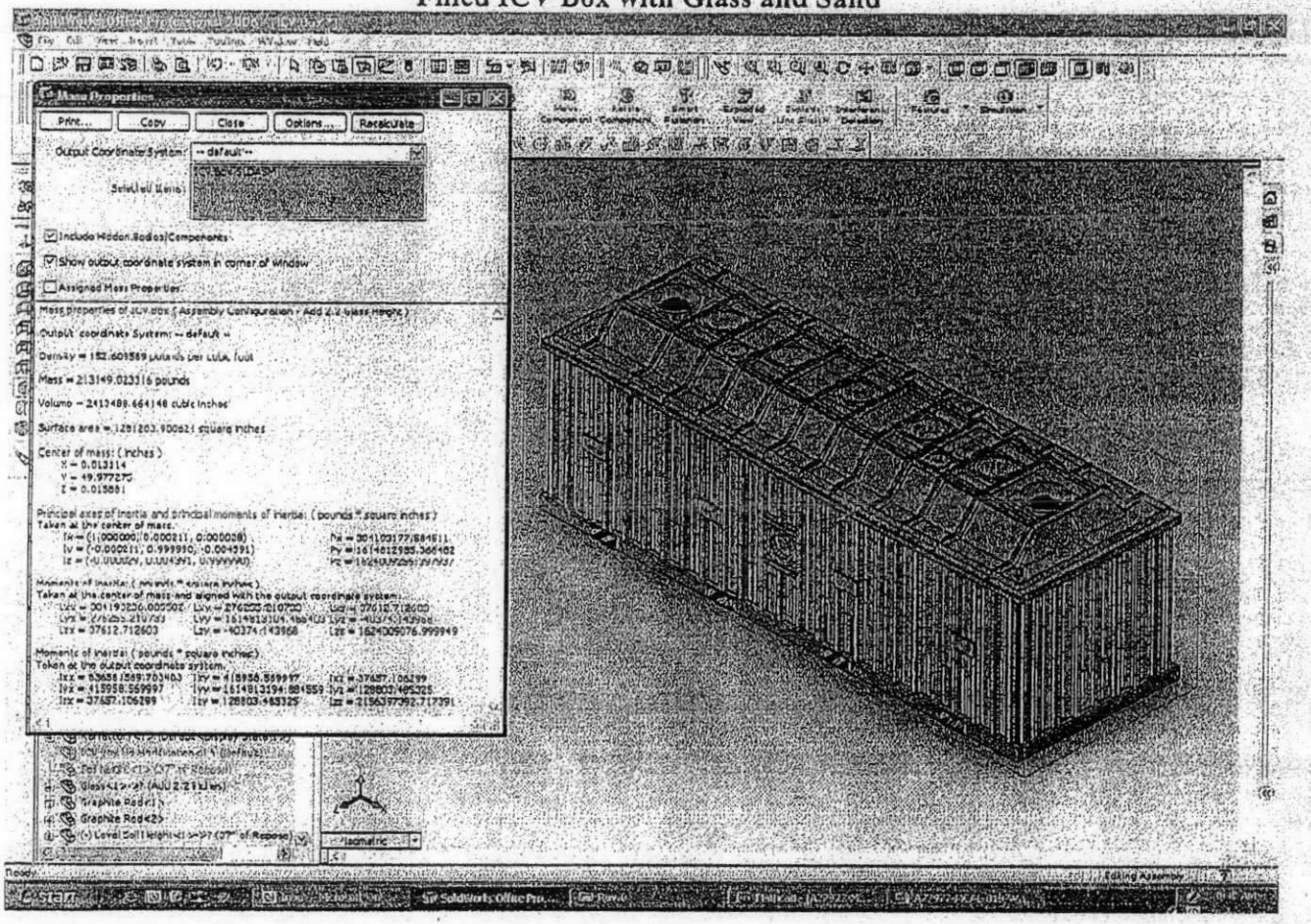
Calc No: 145579-D-CA-028

Rev.0
1 of 2

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

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

Form EP 3.10-1F, March 2001 1 of 2

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

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:	Ja-Kael Luey 2/21/06		
Checked By:	Kurt McCracken 2/21/06		
Approved By:	Kurt McCracken 2/21/06		
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 Lue 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: Ja-Kael Luey DATE 2/21/06
Rev. No. A	CHECKER: Kurt McCracken DATE 2/21/06
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.

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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)

ARES CORPORATION	CALCULATION COVER SHEET	Page No. 1 of 252 Calculation No: 0509206.01-M-002

Project No.	Project Title:	Client:
0509206.01	DBVS Thermal Analysis Authorization	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 PS Lowery 2/17/06	S.R. Pierce 2/19/06	S.R. Pierce 2/19/06

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

ARES CORPORATION

CALCULATION REVIEW CHECKLIST

Project No.	Calculation No.	Rev.	Page No.
0509206.01	0509206.01-M-002	1	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):	Date:
S.R. Pierce	2/19/06
Originator (Print Name and Sign):	**Date:**
P.S. Lowery	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

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3.0 ANALYSIS FOR DESIGN CONDITIONS 9
4.0 ANALYSIS FOR INSULATED AWTE FLOOR CONDITIONS 10
5.0 ANALYSIS FOR "OPEN AIR" OPERATING CONDITIONS 11
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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™

ARES CORPORATION	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

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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

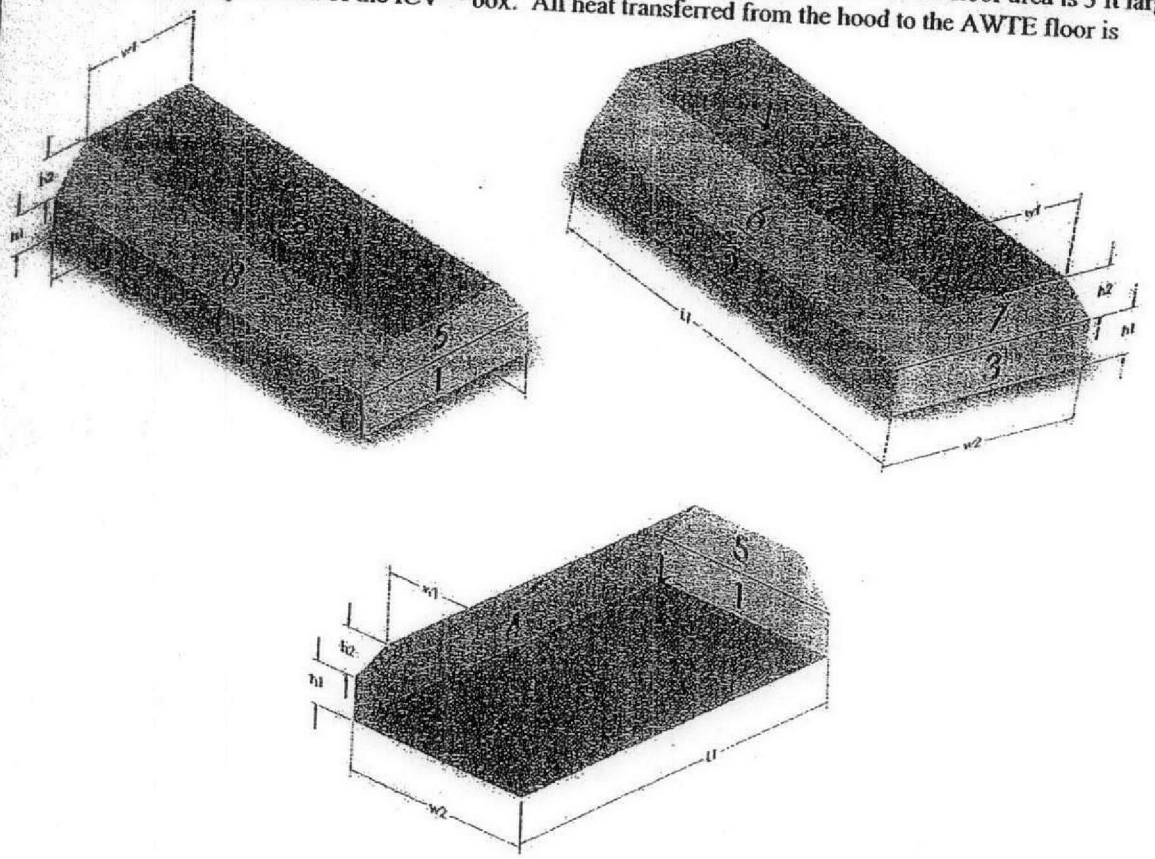

Figure 1. Model Schematic.

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/m^2)
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

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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.

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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

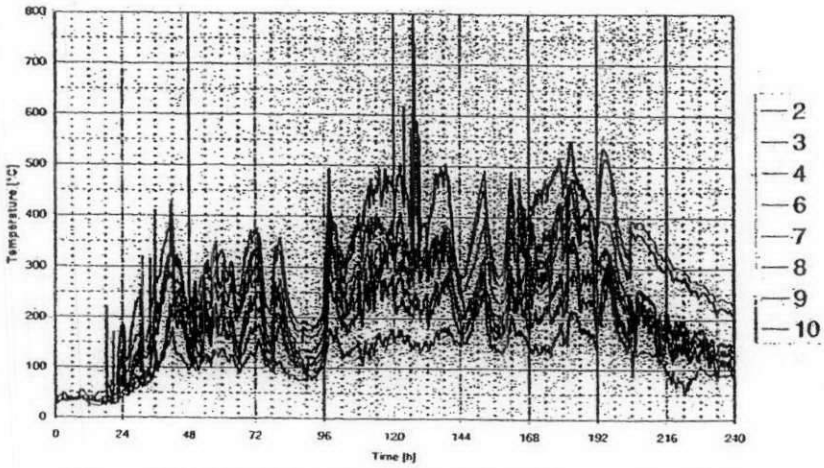

Figure 2. BulkVit Test 38A-1 Hood Skin Temperature Data.

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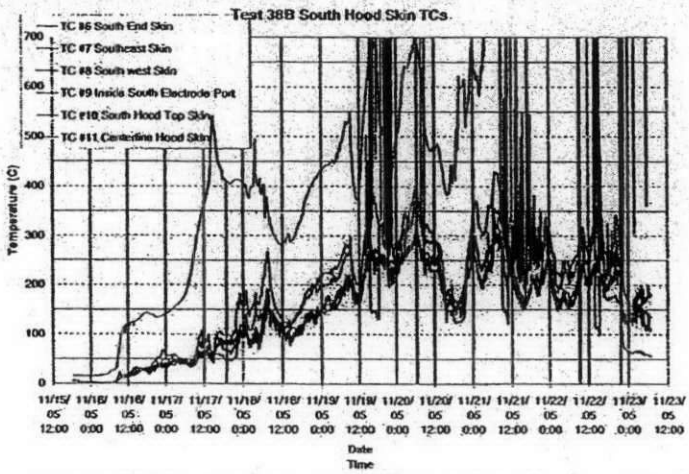

Figure 3. BulkVit Test 38B South-Side Hood Skin Temperature Data.

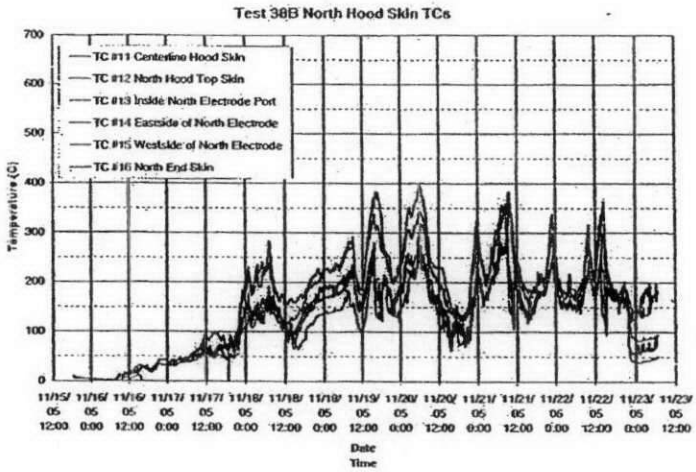

Figure 4. BulkVit Test 38B North-Side Hood Skin Temperature Data.

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.

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

1. Email, Ja-Kael Luey to P.S. Lowery, dated November 23, 2005 @ 13:51, "Outline of Work Scope for the ICV Box Lid Calculation."
2. AMEC calculation number 145579-D-CA-007, Rev. B, October 24, 2005, "Final DBVS Design Heat Transfer Analysis."
3. Siegel, Robert and J.R. Howell, Thermal Radiation Heat Transfer, 3rd Edition, 1992, Hemisphere Publishing Corporation.
4. MathCad 2001i, Mathsoft Engineering & Education, Inc., 2001.
5. MEIER Enterprises, Inc. letter from Mike C. Lippis to Mr. Jason Martin (Thompson Mechanical Contractors, Inc., January 5, 2006. RE: ANCILLARY WASTE TRANSFER ENCLOSURE (AWTE) DESIGN TEMPERATURES FOR AWTE ROOM.
6. Buelt, J.L, et al., In Situ Vitrification of Transuranic Waste: An Updated Systems Evaluation and Applications Assessment, PNL-4800, Supp. 1 – UC-70. Pacific Northwest Laboratory, March 1987.
7. Email, Jerid Mauss to Pat Lowery, "ICV Box Lid Analysis Values", dated February 10, 2006 @ 4:11 PM.

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APPENDIX A

MATHCAD MODEL FOR THE DESIGN CONDITIONS

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DBVS Off-Gas Hood Thermal Model

$°F = 1$

$°C = 1$

$CtoF(x) := \left(\frac{9}{5}\frac{x}{°C} + 32\right)°F$ $CtoK(x) := \left(\frac{x}{°C} + 273.15\right)K$ $KtoC(x) := \left(\frac{x}{K} - 273.15\right)°C$

$FtoC(x) := \frac{5}{9}\left(\frac{x}{°F} - 32\right)°C$ $FtoR(x) := \left(\frac{x}{°F} + 459.67\right)R$

$w_1 := 5.5ft$ $w_2 := 3.5ft$ $L_1 := 22ft$ $h_1 := 14in$ $h_2 := 16in$ $\theta := 52deg$ $N_{ribs} := 12$ $w_{ribs} := 2in$ $h_{ribs} := 4in$

$\delta_{hood} := 0.3125in$ $\theta := 52deg$ $\delta_{floor} := 3.5in$ $\delta_{CR} := 6in$ $\delta_{sand} := 6in$

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

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$$F := \begin{pmatrix} 0 & .021 & .091 & .021 & .091 & .028 & .177 & .028 & .177 & .366 & 0 \\ .397 & 0 & .026 & .004 & .026 & 0 & .129 & .021 & .129 & .265 & 0 \\ .428 & .006 & 0 & .006 & .052 & .019 & .039 & .019 & .077 & .354 & 0 \\ .400 & .004 & .026 & 0 & .026 & .021 & .129 & 0 & .129 & .265 & 0 \\ .428 & .006 & .052 & .006 & 0 & .019 & .077 & .019 & .039 & .354 & 0 \\ .565 & 0 & .081 & .022 & .081 & 0 & .081 & .003 & .081 & .086 & 0 \\ .575 & .022 & .027 & .022 & .053 & .013 & 0 & .013 & .015 & .125 & .616 \\ .565 & .022 & .081 & 0 & .081 & .003 & .081 & 0 & .081 & .086 & 0 \\ .575 & .022 & .053 & .022 & .027 & .013 & .150 & .013 & 0 & .125 & .616 \\ .574 & .022 & .118 & .022 & .118 & .013 & .060 & .013 & .060 & 0 & 1 \end{pmatrix}$$

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

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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 ...

$T_0 := T_{melt}$ $\quad T_0 = 1323.15\,K$

$T_1 := 773K$ $\quad T_3 := 773K$ $\quad T_5 := 773K$ $\quad T_7 := 773K$ $\quad T_9 := 773K$

$T_2 := 773K$ $\quad T_4 := 773K$ $\quad T_6 := 773K$ $\quad T_8 := 773K$ $\quad T_{10} := 773K$

$T_{11} := 473K$ $\quad T_{13} := 473K$

$T_{12} := 473K$ $\quad T_{14} := 473K$ $\quad T_{15} := T_{OG}$

Material properties ...

$\varepsilon_{melt} := 0.7$ $\quad \sigma := 5.67 \cdot 10^{-8} \cdot \frac{W}{m^2 \cdot K^4}$

$\varepsilon_{stl} := .85$ $\quad k_{stl} := 60.5 \frac{W}{m \cdot K}$

$\varepsilon_{CR} := 0.66$ $\quad k_{CR} := 1.44 \frac{W}{m \cdot K}$ $\quad k_{sand} := 2 \frac{W}{m \cdot K}$

$\alpha_{OG} := 0$ $\quad \tau_{OG} := 1 - \alpha_{OG}$ $\quad \tau_{OG} = 1$

Convective heat transfer coefficients ...

$n := \frac{1}{3}$ $\quad \xi_V := 1.32 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$ $\quad \xi_{HD} := 0.691 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$ $\quad \xi_{HU} := 1.52 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$

$T_{amb} = 328.1\,K$ $\quad T_{OG} = 741.5\,K$

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Given

j=1

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{1,0}\cdot\left(\left|T_1-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_1-T_{OG}\right)\cdots$$

$$+\frac{A_{1,0}\cdot\left(T_1-T_{11}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_1^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}}}$$

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j=2

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\xi_V\cdot A_{2,0}\cdot\left(\left|T_2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_2-T_{OG}\right)+\frac{A_{2,0}\cdot\left(T_2-T_{12}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_2^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

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$j=3$

$$\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{3,0}\cdot\left(\left|T_3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_3-T_{OG}\right)\ldots$$

$$+\frac{A_{3,0}\cdot\left(T_3-T_{13}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T_3^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}$$

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j=4

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{A_{4,0}\cdot\left(T_4-T_{14}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V\cdot A_{4,0}\cdot\left(\left|T_4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_4-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_4^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}\ldots$$

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j=5

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,6}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_5^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\cdot\left[\left|T_5-\left(\frac{T_5+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_5-\left(\frac{T_5+T_{10}}{2}\right)\right]+\xi_V\cdot A_{5,0}\cdot\left(\left|T_5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_5-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_5^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}=0$$

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j=6

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_6^{\,4}-T_{10}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T_6^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot\left(1-F_{6,10}\right)}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\cdot\left[\left|T_6-\left(\frac{T_6+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_6-\left(\frac{T_6+T_{10}}{2}\right)\right]\cdots$$

$$+\xi_{HU}\cdot A_{6,1}\cdot\left[\left|T_6-\left(\frac{T_6+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_6-\left(\frac{T_6+T_{10}}{2}\right)\right]+\xi_V\cdot A_{6,0}\cdot\left(\left|T_6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_6^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

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$j=7$

$$\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_7^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\cdot\left[\left|T_7-\left(\frac{T_7+T_{10}}{2}\right)\right|\right]^{\frac{1}{5}}\cdot\left[T_7-\left(\frac{T_7+T_{10}}{2}\right)\right]+\xi_V\cdot A_{7,0}\cdot\left(\left|T_7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_7-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_7^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}$$

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j=8

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+$$

$$+\frac{\sigma\cdot\left(T_8^4-T_{10}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T_8^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot\left(1-F_{8,10}\right)}}+\xi_V\cdot\left(A_{8,0}+A_{8,2}\right)\cdot\left[\left|T_8-\left(\frac{T_8+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_8-\left(\frac{T_8+T_{10}}{2}\right)\right]+$$

$$+\xi_{HU}\cdot A_{8,1}\cdot\left[\left|T_8-\left(\frac{T_8+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_8-\left(\frac{T_8+T_{10}}{2}\right)\right]+\xi_V\cdot A_{8,0}\cdot\left(\left|T_8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_8^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}=0$$

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$i=9$

DBVS Off-Gas Hood Thermal Model

$$\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\ldots$$

$$+\frac{\sigma\left(T_9^{\,4}-T_{10}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\xi_V\left(A_{9,0}+A_{9,2}\right)\left[\left|T_9-\left(\frac{T_9+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_9-\left(\frac{T_9+T_{10}}{2}\right)\right]\ldots$$

$$+\xi_{HD}\cdot A_{9,1}\left[\left|T_9-\left(\frac{T_9+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_9-\left(\frac{T_9+T_{10}}{2}\right)\right]+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T_9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_9^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

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j=10

$$\frac{\sigma\cdot\left(T_{10}^{4}-T_{6}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\left(T_{10}^{4}-T_{8}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\left(T_{10}^{4}-T_{9}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\frac{\sigma\cdot\left(T_{10}^{4}-T_{amb}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{10,0}\left(1-\frac{A_{6,0}\cdot F_{6,10}}{A_{10,0}}-\frac{A_{8,0}\cdot F_{8,10}}{A_{10,0}}-\frac{A_{9,0}\cdot F_{9,10}}{A_{10,0}}\right)}}+\xi_{HD}\cdot A_{10,0}\left[\left|T_{10}-\left(\frac{T_{9}+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_{10}-\left(\frac{T_{9}+T_{10}}{2}\right)\right]+\frac{A_{10,0}\cdot\left(T_{10}-T_{AWTE}\right)}{\left(\frac{\delta_{floor}}{k_{stl}}\right)}=0$$

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

$$\frac{A_{12,0}\cdot\left(T_{12}-T_{2}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{12}^{4}-T_{amb}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right)+\frac{1}{A_{12,0}}}+\xi_{V}\cdot A_{12,0}\cdot\left(\left|T_{12}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{12}-T_{amb}\right)=0$$

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j=13

DBVS Off-Gas Hood Thermal Model

$$\frac{A_{13,0}\cdot(T_{13}-T_3)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{13}^{\ 4}-T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{13,0}}\right)+\frac{1}{A_{13,0}}}+\xi_V\cdot A_{13,0}\cdot\left(\left|T_{13}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{13}-T_{amb}\right)=0$$

j=14

$$\frac{A_{14,0}\cdot(T_{14}-T_4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{14}^{\ 4}-T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{14,0}}}+\xi_V\cdot A_{14,0}\cdot\left(\left|T_{14}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{14}-T_{amb}\right)=0$$

$$\begin{pmatrix} T1 \\ T2 \\ T3 \\ T4 \\ T5 \\ T6 \\ T7 \\ T8 \\ T9 \\ T10 \\ T11 \\ T12 \\ T13 \\ T14 \end{pmatrix} := \mathrm{Find}\left(T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, T_{13}, T_{14}\right)$$

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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

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Check results ...

$T_0 = 1323.2\,K$

$T1 = 1145.6\,K$ $T2 = 1156.4\,K$ $T3 = 1145.6\,K$ $T4 = 1156.4\,K$ $T5 = 1035.4\,K$ $T6 = 1014.4\,K$

$T7 = 1035.4\,K$ $T8 = 1014.4\,K$ $T9 = 1031.5\,K$ $T10 = 330\,K$ $T11 = 495.3\,K$ $T12 = 497.2\,K$ $T13 = 495.2\,K$

$T14 = 497.2\,K$ $T_{AWTE} = 298.1\,K$ $T_{amb} = 328.1\,K$ $T_{OG} = 741.5\,K$

j=1

$$\frac{\sigma\cdot\tau_{OG}\left(T1^4 - T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\left(T1^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\left(T1^4 - T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} \ldots = 0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T1^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\left(T1^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,6}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\left(T1^4 - T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,7}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}} \ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T1^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,8}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}} + \frac{\sigma\cdot\tau_{OG}\left(T1^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,9}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} + \xi_V\cdot A_{1,0}\cdot\left(\left|T1 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T1 - T_{OG}\right) \ldots$$

$$+\frac{A_{1,0}\cdot(T1 - T11)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\alpha_{OG}\cdot\left(T1^4 - T_{15}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}}}$$

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DBVS Off-Gas Hood Thermal Model

j=2

$$\frac{\sigma\cdot\tau_{OG}\left(T2^4-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots=-0.W$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\varepsilon_V\cdot A_{2,0}\left(\left|T2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T2-T_{OG}\right)+\frac{A_{2,0}\cdot(T2-T12)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\sigma_{OG}\left(T2^4-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

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DBVS Off-Gas Hood Thermal Model

$i=3$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{3,0}\cdot\left(\left|T3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T3-T_{OG}\right)\ldots$$

$$+\frac{A_{3,0}\cdot(T3-T15)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T3^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}$$

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DBVS Off-Gas Hood Thermal Model

j=4

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=-0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{A_{4,0}\cdot(T4-T14)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\zeta_V\cdot A_{4,0}\cdot\left(\left|T4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T4-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T4^4-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}$$

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DBVS Off-Gas Hood Thermal Model

$i=5$

$$\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_{6,0}\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)}+\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}}}+\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}}}+\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}\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}}}=0\,W$$

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DBVS Off-Gas Hood Thermal Model

j=6

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots \quad =-0\cdot W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T6^4-T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T6^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot\left(1-F_{6,10}\right)}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\cdot\left[\left|T6-\left(\frac{T6+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T6-\left(\frac{T6+T10}{2}\right)\right]\cdots$$

$$+\xi_{BU}\cdot A_{6,1}\cdot\left[\left|T6-\left(\frac{T6+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T6-\left(\frac{T6+T10}{2}\right)\right]+\xi_V\cdot A_{6,0}\cdot\left(\left|T6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T6^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

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DBVS Off-Gas Hood Thermal Model

j=7

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{mell}}{\varepsilon_{mell}\cdot A_{0,0}}\right)+\frac{1}{A_{0,9}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T7^4-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\left[\left|T7-\left(\frac{T7+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T7-\left(\frac{T7+T10}{2}\right)\right]+\xi_V\cdot A_{7,0}\cdot\left(\left|T7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T7-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T7^4-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}=0\cdot W$$

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DBVS Off-Gas Hood Thermal Model

j=8

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T8^4-T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T8^4-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot\left(1-F_{8,10}\right)}}+\xi_V\cdot\left(A_{8,0}+A_{8,2}\right)\cdot\left[\left|T8-\left(\frac{T8+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T8-\left(\frac{T8+T10}{2}\right)\right]\cdots$$

$$+\xi_{HU}\cdot A_{8,1}\cdot\left[\left|T8-\left(\frac{T8+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T8-\left(\frac{T8+T10}{2}\right)\right]+\xi_V\cdot A_{8,0}\cdot\left(\left|T8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T8-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T8^4-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}=-0\,W$$

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DBVS Off-Gas Hood Thermal Model

j=9

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T9^4-T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left[\left|T9-\left(\frac{T9+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T9-\left(\frac{T9+T10}{2}\right)\right]\cdots$$

$$+\xi_{HU}\cdot A_{9,1}\cdot\left[\left|T9-\left(\frac{T9+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T9-\left(\frac{T9+T10}{2}\right)\right]+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T9^4-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

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j=10

$$\frac{\sigma\cdot\left(T10^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\left(T10^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}-$$

$$+\frac{\sigma\cdot\left(T10^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\frac{\sigma\cdot\left(T10^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{10,0}\cdot\left(1-\frac{A_{6,0}\cdot F_{6,10}}{A_{10,0}}-\frac{A_{8,0}\cdot F_{8,10}}{A_{10,0}}-\frac{A_{9,0}\cdot F_{9,10}}{A_{10,0}}\right)}}-$$

$$+\xi_{HD}\cdot A_{10,0}\left[\left|T10-\left(\frac{T9+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T10-\left(\frac{T9+T10}{2}\right)\right]+\frac{A_{10,0}\cdot\left(T10-T_{AWTE}\right)}{\left(\frac{\delta_{floor}}{k_{stl}}\right)}=0\,W$$

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

$$\frac{A_{12,0}\cdot(T12-T2)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T12^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right)+\frac{1}{A_{12,0}}}+\xi_V\cdot A_{12,0}\cdot\left(\left|T12-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T12-T_{amb}\right)=0\,W$$

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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

$$\frac{A_{14,0}\cdot(T14 - T4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T14^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right) + \frac{1}{A_{14,0}}} + \xi_V\cdot A_{14,0}\cdot\left(\left|T14 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T14 - T_{amb}\right) = 0\cdot W$$

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Total radiant heat loss from the melt surface ...

$$\frac{\sigma\cdot\left(T1^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\left(T2^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\left(T3^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}=-951.5\,kW$$

$$+\frac{\sigma\cdot\left(T4^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\left(T5^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\left(T6^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}=$$

$$+\frac{\sigma\cdot\left(T7^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\left(T8^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\left(T9^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}$$

$$F_{0,1}+F_{0,2}+F_{0,3}+F_{0,4}+F_{0,5}+F_{0,6}+F_{0,7}+F_{0,8}+F_{0,9}=1$$

Compute the average hood temperature ...

$$T_{HA}:=\frac{A_{5,0}\cdot T5C+A_{6,0}\cdot T6C+A_{7,0}\cdot T7C+A_{8,0}\cdot T8C+A_{9,0}\cdot T9C}{A_{5,0}+A_{6,0}+A_{7,0}+A_{8,0}+A_{9,0}}$$

$T_{HA}=750.8$ $\quad T_{HAF}:=CtoF(T_{HA})$ $\quad T_{HAF}=1383.5$

Heat flux through AWTE floor ...

$$q_{AWTE}:=\frac{T10-T_{AWTE}}{\frac{\delta_{floor}}{k_{sd}}} \qquad q_{AWTE}=21.7\,\frac{kW}{m^2}$$

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APPENDIX B

MATHCAD MODEL FOR THE DESIGN CONDITIONS WITH SOIL OVERBURDEN

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DBVS ICV™ Off-Gas Hood Thermal Analysis

$°F = 1$

$°C = 1$

$CtoF(x) := \left(\frac{9}{5}\frac{x}{°C} + 32\right)°F \quad CtoK(x) := \left(\frac{x}{°C} + 273.15\right)K \quad KtoC(x) := \left(\frac{x}{K} - 273.15\right)°C$

$FtoC(x) := \frac{5}{9}\left(\frac{x}{°F} - 32\right)°C \quad FtoR(x) := \left(\frac{x}{°F} + 459.67\right)R$

$w_1 := 5.5ft \quad w_2 := 3.5ft \quad L_1 := 22ft \quad h_1 := 14in \quad h_2 := 16in \quad \theta := 52deg \quad N_{ribs} := 12 \quad w_{ribs} := 2in \quad h_{ribs} := 4in$

$\delta_{hood} := 0.3125in \quad \theta := 52deg \quad \delta_{floor} := 3.5in \quad \delta_{CR} := 6in \quad \delta_{sand} := 6in \quad \delta_{soil} := \frac{1}{2}in$

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 =

	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

ft^2

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DBVS ICV™ Off-Gas Hood Thermal Analysis

$$F_{ij}=\begin{pmatrix} 0 & .021 & .091 & .021 & .091 & .028 & .177 & .028 & .177 & .366 & 0 \\ .397 & 0 & .026 & .004 & .026 & 0 & .129 & .021 & .129 & .265 & 0 \\ .428 & .006 & 0 & .006 & .052 & .019 & .039 & .019 & .077 & .354 & 0 \\ .400 & .004 & .026 & 0 & .026 & .021 & .129 & 0 & .129 & .265 & 0 \\ .428 & .006 & .052 & .006 & 0 & .019 & .077 & .019 & .039 & .354 & 0 \\ .565 & 0 & .081 & .022 & .081 & 0 & .081 & .003 & .081 & .086 & 0 \\ .575 & .022 & .027 & .022 & .053 & .013 & 0 & .013 & .015 & .125 & .616 \\ .565 & .022 & .081 & 0 & .081 & .003 & .081 & 0 & .081 & .086 & 0 \\ .575 & .022 & .053 & .022 & .027 & .013 & .150 & .013 & 0 & .125 & .616 \\ .574 & .022 & .118 & .022 & .118 & .013 & .060 & .013 & .060 & 0 & 1 \end{pmatrix}$$

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

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DBVS ICV™ Off-Gas Hood Thermal Analysis

Temperature Boundary Conditions ...

$Tmelt := 2282°F$	$TmC := FtoC(Tmelt)$	$T_{melt} := CtoK(TmC)$	$T_{melt} = 1523.15\,K$
$TAWTE := 77°F$	$TAC := FtoC(TAWTE)$	$T_{AWTE} := CtoK(TAC)$	$T_{AWTE} = 298.1\,K$
$TOG := 875°F$	$Tog := FtoC(TOG)$	$T_{OG} := CtoK(Tog)$	$T_{OG} = 741.483\,K$
	$Tamb := 55°C$	$T_{amb} := CtoK(Tamb)$	$T_{amb} = 328.1\,K$

Initial guess for temperatures ...

$T_0 := 973K$

$T_1 := 773K$ $T_3 := 773K$ $T_5 := 773K$ $T_7 := 773K$ $T_9 := 773K$

$T_2 := 773K$ $T_4 := 773K$ $T_6 := 773K$ $T_8 := 773K$ $T_{10} := 773K$

$T_{11} := 473K$ $T_{13} := 473K$

$T_{12} := 473K$ $T_{14} := 473K$

Material properties ...

$\sigma := 5.67 \cdot 10^{-8} \cdot \frac{W}{m^2 \cdot K^4}$

$\varepsilon_{melt} := 0.7$

$\varepsilon_{stl} := .85$ $k_{stl} := 60.5 \cdot \frac{W}{m \cdot K}$

$\varepsilon_{CR} := 0.66$ $k_{CR} := 1.44 \cdot \frac{W}{m \cdot K}$ $k_{sand} := 2 \cdot \frac{W}{m \cdot K}$

$\alpha_{OG} := 0$ $\tau_{OG} := 1 - \alpha_{OG}$ $\tau_{OG} = 1$

Convective heat transfer coefficients ... $n := \frac{1}{3}$ $\xi_V := 1.32 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$ $\xi_{HD} := 0.691 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$ $\xi_{HU} := 1.52 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

$T_{amb} = 328.1\,K$ $\quad T_{OG} = 741.5\,K$

Given

$j=0$

$$\frac{k_{sand} \cdot A_{0,0} \cdot (T_0 - T_{melt})}{\delta_{soil}} + \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_1^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_2^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{2,0}}\right)} - \qquad = 0$$

$$+ \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_3^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_4^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{4,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_5^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,5}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{5,0}}\right)} -$$

$$+ \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_6^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,6}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{6,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_7^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,7}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{7,6}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_8^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,8}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{8,0}}\right)} -$$

$$+ \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_9^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,9}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{9,0}}\right)} + \frac{\sigma \cdot \alpha_{OG} \cdot (T_0^4 - T_{OG}^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0}}} + \xi_{HU} \cdot A_{0,0} \cdot \left(|T_0 - T_{OG}|\right)^{\frac{1}{3}} \cdot (T_0 - T_{OG})$$

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j=1

$$\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_1^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{1,0}\cdot\left(\left|T_1-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_1-T_{OG}\right)\cdots$$

$$+\frac{A_{1,0}\cdot\left(T_1-T_{11}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_1^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}}}$$

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j=2

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_2^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\xi_V\cdot A_{2,0}\cdot\left(\left|T_2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_2-T_{OG}\right)+\frac{A_{2,0}\cdot\left(T_2-T_{12}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_2^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

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j=3

$$\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_3^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{3,0}\cdot\left(\left|T_3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_3-T_{OG}\right)\ldots$$

$$+\frac{A_{3,0}\cdot\left(T_3-T_{13}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_3^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}$$

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j=4

$$\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{A_{4,0}\cdot\left(T_4-T_{14}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V\cdot A_{4,0}\cdot\left(\left|T_4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_4-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_4^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}\cdots$$

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j=5

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}$$

$$+\frac{\sigma\cdot\left(T_5^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\cdot\left[\left|T_5-\left(\frac{T_5+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_5-\left(\frac{T_5+T_{10}}{2}\right)\right]+\xi_V\cdot A_{5,0}\cdot\left(\left|T_5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_5-T_{OG}\right)+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}=0$$

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j=6

$$\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}A_{0,0}}\right)+\frac{1}{A_{0,0}F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{6,0}}\right)+\frac{1}{A_{6,0}F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{6,0}}\right)+\frac{1}{A_{6,0}F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}A_{2,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{6,0}}\right)+\frac{1}{A_{6,0}F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{6,0}}\right)+\frac{1}{A_{6,0}F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{6,0}}\right)+\frac{1}{A_{6,0}F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{6,0}}\right)+\frac{1}{A_{6,0}F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{6,0}}\right)+\frac{1}{A_{6,0}F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_6^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{6,0}}\right)+\frac{1}{A_{6,0}F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_6^4-T_{10}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{6,0}}\right)+\frac{1}{A_{6,0}F_{6,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{10,0}}\right)}+\frac{\sigma\cdot\left(T_6^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{6,0}}\right)+\frac{1}{A_{6,0}\left(1-F_{6,10}\right)}}+\xi_V\left(A_{6,0}+A_{6,2}\right)\left[\left|T_6-\left(\frac{T_6+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_6-\left(\frac{T_6+T_{10}}{2}\right)\right]\cdots$$

$$+\xi_{HU}A_{6,1}\left[\left|T_6-\left(\frac{T_6+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_6-\left(\frac{T_6+T_{10}}{2}\right)\right]+\xi_V A_{6,0}\left(\left|T_6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_6^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

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$i=7$

$$\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_7^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_7^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\cdot\left[\left|T_7-\left(\frac{T_7+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_7-\left(\frac{T_7+T_{10}}{2}\right)\right]+\xi_V\cdot A_{7,0}\cdot\left(\left|T_7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_7-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_7^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}$$

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j=8

$$\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{mell}}{\varepsilon_{mell}A_{0,0}}\right)+\frac{1}{A_{0,0}F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{8,0}}\right)+\frac{1}{A_{8,0}F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{8,0}}\right)+\frac{1}{A_{8,0}F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}A_{2,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{8,0}}\right)+\frac{1}{A_{8,0}F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{8,0}}\right)+\frac{1}{A_{8,0}F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{8,0}}\right)+\frac{1}{A_{8,0}F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{8,0}}\right)+\frac{1}{A_{8,0}F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{8,0}}\right)+\frac{1}{A_{8,0}F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{8,0}}\right)+\frac{1}{A_{8,0}F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_8^{\,4}-T_{10}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{8,0}}\right)+\frac{1}{A_{8,0}F_{8,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{10,0}}\right)}+\frac{\sigma\cdot\left(T_8^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{8,0}}\right)+\frac{1}{A_{8,0}\left(1-F_{8,10}\right)}}+\xi_V\left(A_{8,0}+A_{8,2}\right)\left[\left|T_8-\left(\frac{T_8+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_8-\left(\frac{T_8+T_{10}}{2}\right)\right]\cdots$$

$$+\xi_{HU}A_{8,1}\left[\left|T_8-\left(\frac{T_8+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_8-\left(\frac{T_8+T_{10}}{2}\right)\right]+\xi_V A_{8,0}\left(\left|T_8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{OG}\right)+\frac{\sigma\cdot\tau_{OG}\left(T_8^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{8,0}}\right)+\frac{1}{A_{8,0}}}$$

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j=9

$$\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_9^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T_9^{\,4}-T_{10}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left[\left|T_9-\left(\frac{T_9+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_9-\left(\frac{T_9+T_{10}}{2}\right)\right]\ldots$$

$$+\xi_{HU}\cdot A_{9,1}\cdot\left[\left|T_9-\left(\frac{T_9+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_9-\left(\frac{T_9+T_{10}}{2}\right)\right]+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T_9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_9^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

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j=10

$$\frac{\sigma\cdot\left(T_{10}^{4}-T_{6}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\left(T_{10}^{4}-T_{8}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\left(T_{10}^{4}-T_{9}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\frac{\sigma\cdot\left(T_{10}^{4}-T_{amb}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{10,0}\cdot\left(1-\frac{A_{6,0}\cdot F_{6,10}}{A_{10,0}}-\frac{A_{8,0}\cdot F_{8,10}}{A_{10,0}}-\frac{A_{9,0}\cdot F_{9,10}}{A_{10,0}}\right)}}+\xi_{HD}\cdot A_{10,0}\cdot\left[\left|T_{10}-\left(\frac{T_{9}+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_{10}-\left(\frac{T_{9}+T_{10}}{2}\right)\right]+\frac{k_{stl}\cdot A_{10,0}\cdot\left(T_{10}-T_{AWTE}\right)}{\delta_{floor}}=0$$

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

$$\frac{A_{12,0}\cdot\left(T_{12}-T_{2}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{12}^{4}-T_{amb}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right)+\frac{1}{A_{12,0}}}+\xi_{V}\cdot A_{12,0}\cdot\left(\left|T_{12}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{12}-T_{amb}\right)=0$$

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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

$$\frac{A_{14,0}\cdot(T_{14}-T_4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{14}^{4}-T_{amb}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{14,0}}}+\xi_V\cdot A_{14,0}\cdot\left(\left|T_{14}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot(T_{14}-T_{amb})=0$$

$$\begin{pmatrix} T0 \\ T1 \\ T2 \\ T3 \\ T4 \\ T5 \\ T6 \\ T7 \\ T8 \\ T9 \\ T10 \\ T11 \\ T12 \\ T13 \\ T14 \end{pmatrix} := \mathrm{Find}(T_0, T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, T_{13}, T_{14})$$

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T0 = 1165.7 K	T0C := KtoC(T0)	T0C = 892.6
T1 = 1005 K	T1C := KtoC(T1)	T1C = 731.8
T2 = 1014.2 K	T2C := KtoC(T2)	T2C = 741.1
T3 = 1005 K	T3C := KtoC(T3)	T3C = 731.8
T4 = 1014.2 K	T4C := KtoC(T4)	T4C = 741.1
T5 = 911 K	T5C := KtoC(T5)	T5C = 637.8
T6 = 891.7 K	T6C := KtoC(T6)	T6C = 618.6
T7 = 911 K	T7C := KtoC(T7)	T7C = 637.8
T8 = 891.7 K	T8C := KtoC(T8)	T8C = 618.6
T9 = 905.6 K	T9C := KtoC(T9)	T9C = 632.5
T10 = 317.6 K	T10C := KtoC(T10)	T10C = 44.5
T11 = 474.8 K	T11C := KtoC(T11)	T11C = 201.7
T12 = 476.3 K	T12C := KtoC(T12)	T12C = 203.1
T13 = 474.8 K	T13C := KtoC(T13)	T13C = 201.7
T14 = 476.3 K	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

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Check results ...

$T0 = 1165.7K$ $T1 = 1005K$ $T2 = 1014.2K$ $T3 = 1005K$ $T4 = 1014.2K$ $T5 = 911K$ $T6 = 891.7K$

$T7 = 911K$ $T8 = 891.7K$ $T9 = 905.6K$ $T10 = 317.6K$ $T11 = 474.8K$ $T12 = 476.3K$ $T13 = 474.8K$

$T14 = 476.3K$ $T_{AWIE} = 298.1K$ $T_{amb} = 328.1K$ $T_{OG} = 741.5K$

j=1

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots=0W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{1,0}\cdot\left(\left|T1-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T1-T_{OG}\right)\ldots$$

$$+\frac{A_{1,0}\cdot(T1-T11)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T1^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}}}$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

j=2

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\varepsilon_V\cdot A_{2,0}\cdot\left(\left|T2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T2-T_{OG}\right)+\frac{A_{2,0}\cdot(T2-T12)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T2^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

$j=3$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}-=0\cdot W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}-$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{3,0}\cdot\left(\left|T3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T3-T_{OG}\right)\ldots$$

$$+\frac{A_{3,0}\cdot(T3-T13)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T3^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

$i=4$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{A_{4,0}\cdot(T4-T14)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_v\cdot A_{4,0}\cdot\left(\left|T4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T4-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T4^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

j=5

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}-$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}-$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}-$$

$$+\frac{\sigma\cdot\left(T5^4-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\left[\left|T5-\left(\frac{T5+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T5-\left(\frac{T5+T10}{2}\right)\right]+\xi_V\cdot A_{5,0}\cdot\left(\left|T5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T5-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T5^4-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}=0\,W$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

$i=6$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}-$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}-$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}-$$

$$+\frac{\sigma\cdot\left(T6^4-T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T6^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot\left(1-F_{6,10}\right)}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\cdot\left[\left|T6-\left(\frac{T6+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T6-\left(\frac{T6+T10}{2}\right)\right]-$$

$$+\xi_{HU}\cdot A_{6,1}\cdot\left[\left|T6-\left(\frac{T6+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T6-\left(\frac{T6+T10}{2}\right)\right]+\xi_V\cdot A_{6,0}\cdot\left(\left|T6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T6^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}=0\cdot W$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

j=7

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T7^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\cdot\left[\left|T7-\left(\frac{T7+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T7-\left(\frac{T7+T10}{2}\right)\right]+\xi_V\cdot A_{7,0}\cdot\left(\left|T7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T7-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T7^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}=0\,W$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

j=8

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T8^4-T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T8^4-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot\left(1-F_{8,10}\right)}}+\xi_V\cdot\left(A_{8,0}+A_{8,2}\right)\cdot\left[\left|T8-\left(\frac{T8+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T8-\left(\frac{T8+T10}{2}\right)\right]\cdots$$

$$+\xi_{HU}\cdot A_{8,1}\cdot\left[\left|T8-\left(\frac{T8+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T8-\left(\frac{T8+T10}{2}\right)\right]+\xi_V\cdot A_{8,0}\cdot\left(\left|T8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T8-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T8^4-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}$$

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$i=9$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T9^4-T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left[\left|T9-\left(\frac{T9+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T9-\left(\frac{T9+T10}{2}\right)\right]\ldots$$

$$+\xi_{HU}\cdot A_{9,1}\cdot\left[\left|T9-\left(\frac{T9+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T9-\left(\frac{T9+T10}{2}\right)\right]+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T9^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

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j=10

$$\frac{\sigma\cdot\left(T10^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right) + \frac{1}{A_{6,0}\cdot F_{6,10}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}} + \frac{\sigma\cdot\left(T10^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,10}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}} \ldots = 0\,W$$

$$+ \frac{\sigma\cdot\left(T10^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right) + \frac{1}{A_{9,0}\cdot F_{9,10}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} + \frac{\sigma\cdot\left(T10^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right) + \frac{1}{A_{10,0}\cdot\left(1 - \frac{A_{6,0}\cdot F_{6,10}}{A_{10,0}} - \frac{A_{8,0}\cdot F_{8,10}}{A_{10,0}} - \frac{A_{9,0}\cdot F_{9,10}}{A_{10,0}}\right)}} \ldots$$

$$+ \xi_{HD}\cdot A_{10,0}\cdot\left[\left|T10 - \left(\frac{T9 + T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T10 - \left(\frac{T9 + T10}{2}\right)\right] + \frac{k_{stl}\cdot A_{10,0}\cdot\left(T10 - T_{AWTE}\right)}{\delta_{Door}}$$

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

$$\frac{A_{12,0}\cdot(T12 - T2)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T12^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right) + \frac{1}{A_{12,0}}} + \xi_V\cdot A_{12,0}\cdot\left(\left|T12 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T12 - T_{amb}\right) = 0\,W$$

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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

$$\frac{A_{14,0}\cdot(T14-T4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T14^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{14,0}}}+\xi_V\cdot A_{14,0}\cdot\left(\left|T14-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T14-T_{amb}\right)=0\,W$$

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Total radiant heat loss from the melt surface ...

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T1^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}=-578.3\,kW$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T5^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T7^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T8^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}}}$$

$$F_{0,1}+F_{0,2}+F_{0,3}+F_{0,4}+F_{0,5}+F_{0,6}+F_{0,7}+F_{0,8}+F_{0,9}=1$$

Compute the average hood temperature ...

$$T_{HA}:=\frac{A_{5,0}\cdot T5C+A_{6,0}\cdot T6C+A_{7,0}\cdot T7C+A_{8,0}\cdot T8C+A_{9,0}\cdot T9C}{A_{5,0}+A_{6,0}+A_{7,0}+A_{8,0}+A_{9,0}}$$

$T_{HA}=626.5$ $\quad T_{HAF}:=CtoF(T_{HA})$ $\quad T_{HAF}=1159.8$

Heat flux through AWTE floor ...

$$q_{AWTE}:=\frac{k_{stl}\left(T10-T_{AWTE}\right)}{\delta_{floor}} \qquad q_{AWTE}=13.2\,\frac{1}{m^2}\,kW$$

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APPENDIX C

MATHCAD MODEL FOR THE INSULATED FLOOR CONDITIONS

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DBVS Off-Gas Hood Thermal Model

$°F := 1$

$°C := 1$

$CtoF(x) := \left(\frac{9}{5}\cdot\frac{x}{°C} + 32\right)°F \quad CtoK(x) := \left(\frac{x}{°C} + 273.15\right)K \quad KtoC(x) := \left(\frac{x}{K} - 273.15\right)°C$

$FtoC(x) := \frac{5}{9}\left(\frac{x}{°F} - 32\right)°C \quad FtoR(x) := \left(\frac{x}{°F} + 459.67\right)R$

$w_1 := 5.5ft \quad w_2 := 3.5ft \quad L_1 := 22ft \quad h_1 := 14in \quad h_2 := 16in \quad \theta := 52deg \quad N_{ribs} := 12 \quad w_{ribs} := 2in \quad h_{ribs} := 4in$

$\delta_{hood} := 0.3125in \quad \theta := 52deg \quad \delta_{floor} := 3.5in \quad \delta_{CR} := 6in \quad \delta_{sand} := 6in \quad \delta_{CaSi} := 1.5in$

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 dal 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 fibs 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

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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

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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 tempeiatures ...

$T_0 := T_{melt}$ $\quad T_0 = 1323.15\,K$

$T_1 := 773K$ $\quad T_3 := 773K$ $\quad T_5 := 773K$ $\quad T_7 := 773K$ $\quad T_9 := 773K$

$T_2 := 773K$ $\quad T_4 := 773K$ $\quad T_6 := 773K$ $\quad T_8 := 773K$ $\quad T_{10} := 773K$

$T_{11} := 473K$ $\quad T_{13} := 473K$

$T_{12} := 473K$ $\quad T_{14} := 473K$ $\quad T_{15} := T_{OG}$

Material properties ...

$\varepsilon_{melt} := 0.7$ $\quad \sigma := 5.67 \cdot 10^{-8} \cdot \frac{W}{m^2 \cdot K^4}$

$\varepsilon_{stl} := .85$ $\quad k_{stl} := 60.5 \frac{W}{m \cdot K}$

$\varepsilon_{CR} := 0.66$ $\quad k_{CR} := 1.44 \frac{W}{m \cdot K}$ $\quad k_{sand} := 2 \cdot \frac{W}{m \cdot K}$

$\varepsilon_{Al} := 0.04$ $\quad k_{CaSi} := 0.0655 \frac{W}{m \cdot K}$

$\alpha_{OG} := 0$ $\quad \tau_{OG} := 1 - \alpha_{OG}$ $\quad \tau_{OG} = 1$

Convective heat transfer coefficients ...

$n := \frac{1}{3}$ $\quad \zeta_V := 1.32\, W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$ $\quad \zeta_{HD} := 0.691 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$ $\quad \zeta_{HU} := 1.52 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$

$T_{amb} = 328.1\,K$ $\quad T_{OG} = 741.5\,K$

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Given

j=1

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{1,0}\cdot\left(\left|T_1-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_1-T_{OG}\right)+$$

$$+\frac{A_{1,0}\cdot\left(T_1-T_{11}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_1^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}}}$$

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DBVS Off-Gas Hood Thermal Model

j=2

$$\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}$$

$$+\xi_V\cdot A_{2,0}\cdot\left(\left|T_2-T_{OG}\right|\right)^{\frac{1}{5}}\cdot\left(T_2-T_{OG}\right)+\frac{A_{2,0}\cdot\left(T_2-T_{12}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T_2^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

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DBVS Off-Gas Hood Thermal Model

$j=3$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{3,0}\cdot\left(\left|T_3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_3-T_{OG}\right)$$

$$+\frac{A_{3,0}\cdot\left(T_3-T_{13}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_3^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}$$

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DBVS Off-Gas Hood Thermal Model

j=4

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}$$

$$+\frac{A_{4,0}\cdot\left(T_4-T_{14}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V\cdot A_{4,0}\cdot\left(\left|T_4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_4-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_4^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}$$

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DBVS Off-Gas Hood Thermal Model

j=5

$$\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}$$

$$+\frac{\sigma\cdot\left(T_5^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\cdot\left[\left|T_5-\left(\frac{T_5+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_5-\left(\frac{T_5+T_{10}}{2}\right)\right]+\xi_V\cdot A_{5,6}\cdot\left(\left|T_5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_5-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_5^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}=0$$

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DBVS Off-Gas Hood Thermal Model

$i=6$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}$$

$$+\frac{\sigma\cdot\left(T_6^4-T_{10}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T_6^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot\left(1-F_{6,10}\right)}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\cdot\left[\left|T_6-\left(\frac{T_6+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_6-\left(\frac{T_6+T_{10}}{2}\right)\right]+$$

$$+\xi_{HU}\cdot A_{6,1}\cdot\left[\left|T_6-\left(\frac{T_6+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_6-\left(\frac{T_6+T_{10}}{2}\right)\right]+\xi_V\cdot A_{6,0}\cdot\left(\left|T_6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_6^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

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DBVS Off-Gas Hood Thermal Model

$j=7$

$$\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}A_{0,0}}\right)+\frac{1}{A_{0,0}F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{7,0}}\right)+\frac{1}{A_{7,0}F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{7,0}}\right)+\frac{1}{A_{7,0}F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}A_{2,0}}\right)}=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{7,0}}\right)+\frac{1}{A_{7,0}F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{7,0}}\right)+\frac{1}{A_{7,0}F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{7,0}}\right)+\frac{1}{A_{7,0}F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{6,0}}}$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{7,0}}\right)+\frac{1}{A_{7,0}F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{7,0}}\right)+\frac{1}{A_{7,0}F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{9,0}}}$$

$$+\frac{\sigma\cdot\left(T_7^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\left[\left|T_7-\left(\frac{T_7+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_7-\left(\frac{T_7+T_{10}}{2}\right)\right]+\xi_V\cdot A_{7,0}\cdot\left(\left|T_7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_7-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_7^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}A_{7,0}}\right)+\frac{1}{A_{7,0}}}$$

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DBVS Off-Gas Hood Thermal Model

$j=8$

$$\frac{\sigma\cdot\tau_{OG}\left(T_8^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_8^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_8^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_8^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_8^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_8^4-T_{10}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T_8^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot\left(1-F_{8,10}\right)}}+\xi_V\cdot\left(A_{8,0}+A_{8,2}\right)\left[\left|T_8-\left(\frac{T_8+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_8-\left(\frac{T_8+T_{10}}{2}\right)\right]\cdots$$

$$+\xi_{HU}\cdot A_{8,1}\left[\left|T_8-\left(\frac{T_8+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_8-\left(\frac{T_8+T_{10}}{2}\right)\right]+\xi_V\cdot A_{8,0}\cdot\left(\left|T_8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_8^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}=0$$

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DBVS Off-Gas Hood Thermal Model

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T_9^{\,4}-T_{10}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\left(\frac{1-\varepsilon_{Al}}{\varepsilon_{Al}\cdot A_{10,0}}\right)}+\xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left[\left|T_9-\left(\frac{T_9+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_9-\left(\frac{T_9+T_{10}}{2}\right)\right]\ldots$$

$$+\xi_{HU}\cdot A_{9,1}\cdot\left[\left|T_9-\left(\frac{T_9+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_9-\left(\frac{T_9+T_{10}}{2}\right)\right]+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T_9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_9^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

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DBVS Off-Gas Hood Thermal Model

j=10

$$\frac{\sigma\cdot\left(T_{10}^{4}-T_{6}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\left(T_{10}^{4}-T_{8}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}-$$

$$+\frac{\sigma\cdot\left(T_{10}^{4}-T_{9}^{4}\right)}{\left(\frac{1-\varepsilon_{Al}}{\varepsilon_{Al}\cdot A_{10,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\frac{\sigma\cdot\left(T_{10}^{4}-T_{amb}^{4}\right)}{\left(\frac{1-\varepsilon_{Al}}{\varepsilon_{Al}\cdot A_{10,0}}\right)+\frac{1}{A_{10,0}\cdot\left(1-\frac{A_{6,0}\cdot F_{6,10}}{A_{10,0}}-\frac{A_{8,0}\cdot F_{8,10}}{A_{10,0}}-\frac{A_{9,0}\cdot F_{9,10}}{A_{10,0}}\right)}}=0$$

$$+\varepsilon_{HD}\cdot A_{10,0}\cdot\left[\left|T_{10}-\left(\frac{T_{9}+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_{10}-\left(\frac{T_{9}+T_{10}}{2}\right)\right]+\frac{A_{10,0}\cdot\left(T_{10}-T_{AWTE}\right)}{\left(\frac{\delta_{floor}}{k_{stl}}\right)+\left(\frac{\delta_{CaSi}}{k_{CaSi}}\right)}$$

j=11

$$\frac{A_{11,0}\cdot\left(T_{11}-T_{1}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{11}^{4}-T_{amb}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{11,0}}\right)+\frac{1}{A_{11,0}}}+\varepsilon_{V}\cdot A_{11,0}\cdot\left(\left|T_{11}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{11}-T_{amb}\right)=0$$

j=12

$$\frac{A_{12,0}\cdot\left(T_{12}-T_{2}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{12}^{4}-T_{amb}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right)+\frac{1}{A_{12,0}}}+\varepsilon_{V}\cdot A_{12,0}\cdot\left(\left|T_{12}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{12}-T_{amb}\right)=0$$

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$i := 13$

$$\frac{A_{13,0}\cdot(T_{13}-T_3)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{13}^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{13,0}}\right)+\frac{1}{A_{13,0}}}+\xi_V\cdot A_{13,0}\cdot\left(\left|T_{13}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{13}-T_{amb}\right)=0$$

$i := 14$

$$\frac{A_{14,0}\cdot(T_{14}-T_4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{14}^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{14,0}}}+\xi_V\cdot A_{14,0}\cdot\left(\left|T_{14}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{14}-T_{amb}\right)=0$$

$$\begin{pmatrix} T1 \\ T2 \\ T3 \\ T4 \\ T5 \\ T6 \\ T7 \\ T8 \\ T9 \\ T10 \\ T11 \\ T12 \\ T13 \\ T14 \end{pmatrix} := \mathrm{Find}(T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, T_{13}, T_{14})$$

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T1 = 1200.2 K	T1C := KtoC(T1)	T1C = 927
T2 = 1232.4 K	T2C := KtoC(T2)	T2C = 959.2
T3 = 1200.2 K	T3C := KtoC(T3)	T3C = 927
T4 = 1232.4 K	T4C := KtoC(T4)	T4C = 959.2
T5 = 1075.8 K	T5C := KtoC(T5)	T5C = 802.6
T6 = 1135.3 K	T6C := KtoC(T6)	T6C = 862.1
T7 = 1075.8 K	T7C := KtoC(T7)	T7C = 802.6
T8 = 1135.3 K	T8C := KtoC(T8)	T8C = 862.1
T9 = 1238.1 K	T9C := KtoC(T9)	T9C = 964.9
T10 = 1080.2 K	T10C := KtoC(T10)	T10C = 807.1
T11 = −880.6 K	T11C := KtoC(T11)	T11C = −1153.8
T12 = 507.7 K	T12C := KtoC(T12)	T12C = 234.6
T13 = −880.6 K	T13C := KtoC(T13)	T13C = −1153.8
T14 = 507.7 K	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 := CtoF(T13C) T14F := CtoF(T14C)

Results in F ...

T1F = 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 T10F = 1484.7 T11F = −2044.8 T12F = 454.2 T13F = −2044.8 T14F = 454.2

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Check results ...

$T_0 = 1323.2\,K$

$T1 = 1200.2\,K$ $T2 = 1232.4\,K$ $T3 = 1200.2\,K$ $T4 = 1232.4\,K$ $T5 = 1075.8\,K$ $T6 = 1135.3\,K$

$T7 = 1075.8\,K$ $T8 = 1135.3\,K$ $T9 = 1238.1\,K$ $T10 = 1080.2\,K$ $T11 = -880.6\,K$ $T12 = 507.7\,K$ $T13 = -880.6\,K$

$T14 = 507.7\,K$ $T_{AWTB} = 298.1\,K$ $T_{amb} = 328.1\,K$ $T_{OG} = 741.5\,K$

$i = 1$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} \ldots = -0.W$$

$$+ \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,6}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,7}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}} \ldots$$

$$+ \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,8}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,9}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} + \xi_V\cdot A_{1,0}\cdot\left(\left|T1 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T1 - T_{OG}\right) \ldots$$

$$+ \frac{A_{1,0}\cdot(T1 - T11)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right) + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T_{13}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}}}}$$

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$j=2$

$$\frac{\sigma\cdot\tau_{OG}\left(T2^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}=0.W$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}$$

$$+\varepsilon_V\cdot A_{2,0}\cdot\left(\left|T2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T2-T_{OG}\right)+\frac{A_{2,0}\cdot(T2-T12)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T2^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

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j=3

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=-QW$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\varepsilon_V\cdot A_{3,0}\cdot\left(\left|T3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T3-T_{OG}\right)\ldots$$

$$+\frac{A_{3,0}\cdot(T3-T13)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T3^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}$$

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DBVS Off-Gas Hood Thermal Model

F4

$$\frac{\sigma\cdot\tau_{OG}\left(T4^4-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T4^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T4^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}=-Q\cdot W$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T4^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T4^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T4^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T4^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T4^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T4^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}=$$

$$+\frac{A_{4,0}\cdot(T4-T14)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V\cdot A_{4,0}\cdot\left(\left|T4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T4-T_{OG}\right)+\frac{\sigma\cdot\tau_{OG}\left(T4^4-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}$$

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DBVS Off-Gas Hood Thermal Model

$i=5$

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T5^4-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T5^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T5^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T5^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T5^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T5^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T5^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T5^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}$$

$$+\frac{\sigma\cdot\left(T5^4-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\left[\left|T5-\left(\frac{T5+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T5-\left(\frac{T5+T10}{2}\right)\right]+\xi_V\cdot A_{5,0}\left(\left|T5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T5-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T5^4-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}=-0\,W$$

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DBVS Off-Gas Hood Thermal Model

j=6

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=-Q\cdot W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T6^4-T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T6^4-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot\left(1-F_{6,10}\right)}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\cdot\left[\left|T6-\left(\frac{T6+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T6-\left(\frac{T6+T10}{2}\right)\right]\cdots$$

$$+\xi_{HU}\cdot A_{6,1}\cdot\left[\left|T6-\left(\frac{T6+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T6-\left(\frac{T6+T10}{2}\right)\right]+\xi_V\cdot A_{6,0}\cdot\left(\left|T6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T6^4-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

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DBVS Off-Gas Hood Thermal Model

$i=7$

$$\frac{\sigma\cdot\tau_{OG}\left(T7^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T5^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T7^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T7^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T7^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T7^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T7^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T7^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T7^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\left[\left|T7-\left(\frac{T7+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T7-\left(\frac{T7+T10}{2}\right)\right]+\xi_V\cdot A_{7,0}\cdot\left(\left|T7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T7-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T7^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}=0\,W$$

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DBVS Off-Gas Hood Thermal Model

F8

$$\frac{\sigma\cdot\varepsilon_{OG}\left(T8^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\left(T8^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\left(T8^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\left(T8^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\left(T8^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\left(T8^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\left(T8^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\left(T8^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\left(T8^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T8^4-T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T8^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot\left(1-F_{8,10}\right)}}+\xi_V\cdot\left(A_{8,0}+A_{8,2}\right)\cdot\left[\left|T8-\left(\frac{T8+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T8-\left(\frac{T8+T10}{2}\right)\right]\cdots$$

$$+\xi_{HU}\cdot A_{8,1}\cdot\left[\left|T8-\left(\frac{T8+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T8-\left(\frac{T8+T10}{2}\right)\right]+\xi_V\cdot A_{8,6}\cdot\left(\left|T8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T8-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T8^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}=-0\,W$$

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DBVS Off-Gas Hood Thermal Model

i=9

$$\frac{\sigma\cdot\tau_{OG}\left(T9^4-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T9^4-T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\left(\frac{1-\varepsilon_{Al}}{\varepsilon_{Al}\cdot A_{10,0}}\right)}+\xi_{VF}\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left[\left|T9-\left(\frac{T9+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T9-\left(\frac{T9+T10}{2}\right)\right]\cdots$$

$$+\xi_{HU}\cdot A_{9,1}\cdot\left[\left|T9-\left(\frac{T9+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T9-\left(\frac{T9+T10}{2}\right)\right]+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T9^4-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

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F10

$$\frac{\sigma\cdot\left(T10^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right) + \frac{1}{A_{6,0}\cdot F_{6,10}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}} + \frac{\sigma\cdot\left(T10^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,10}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}} - \frac{\sigma\cdot\left(T10^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{Al}}{\varepsilon_{Al}\cdot A_{10,0}}\right) + \frac{1}{A_{9,0}\cdot F_{9,10}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} + \frac{\sigma\cdot\left(T10^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{Al}}{\varepsilon_{Al}\cdot A_{10,0}}\right) + \frac{1}{A_{10,0}\left(1 - \frac{A_{6,0}\cdot F_{6,10}}{A_{10,0}} - \frac{A_{8,0}\cdot F_{8,10}}{A_{10,0}} - \frac{A_{9,0}\cdot F_{9,10}}{A_{10,0}}\right)}} - \xi_{HD}\cdot A_{10,0}\left[\left|T10 - \left(\frac{T9+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T10 - \left(\frac{T9+T10}{2}\right)\right] + \frac{A_{10,0}\cdot\left(T10 - T_{AWTE}\right)}{\left(\frac{\delta_{floor}}{k_{stl}}\right) + \left(\frac{\delta_{CaSi}}{k_{CaSi}}\right)} = 0\,W$$

F11

$$\frac{A_{11,0}\cdot(T11 - T1)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T11^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{11,0}}\right) + \frac{1}{A_{11,0}}} + \xi_V\cdot A_{11,0}\cdot\left(\left|T11 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T11 - T_{amb}\right) = 0\,W$$

F12

$$\frac{A_{12,0}\cdot(T12 - T2)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T12^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right) + \frac{1}{A_{12,0}}} + \xi_V\cdot A_{12,0}\cdot\left(\left|T12 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T12 - T_{amb}\right) = 0\,W$$

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i=13

$$\frac{A_{13,0}\cdot(T13-T3)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T13^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{13,0}}\right)+\frac{1}{A_{13,0}}}+\xi_V\cdot A_{13,0}\cdot\left(\left|T13-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T13-T_{amb}\right)=0\cdot W$$

i=14

$$\frac{A_{14,0}\cdot(T14-T4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T14^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{14,0}}}+\xi_V\cdot A_{14,0}\cdot\left(\left|T14-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T14-T_{amb}\right)=0\cdot W$$

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Total radiant heat loss from the melt surface ...

$$\frac{\sigma\cdot\left(T1^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\left(T2^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\left(T3^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}=-548.8\,kW$$

$$+\frac{\sigma\cdot\left(T4^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\left(T5^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\left(T6^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}$$

$$+\frac{\sigma\cdot\left(T7^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\left(T8^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\left(T9^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}$$

$$F_{0,1}+F_{0,2}+F_{0,3}+F_{0,4}+F_{0,5}+F_{0,6}+F_{0,7}+F_{0,8}+F_{0,9}=1$$

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 ...

$$q_{AWTE}:=\frac{T10-T_{AWTE}}{\left(\frac{\delta_{floor}}{k_{stl}}\right)+\left(\frac{\delta_{CaSi}}{k_{CaSi}}\right)}\qquad q_{AWTE}=1.3\,\frac{kW}{m^2}$$

APPENDIX D

MATHCAD MODEL FOR THE "OPEN AIR" CONDITIONS

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$°F \equiv 1$

$°C \equiv 1$

$CtoF(x) := \left(\frac{9}{5}\cdot\frac{x}{°C} + 32\right)°F$ $\quad CtoK(x) := \left(\frac{x}{°C} + 273.15\right)K$ $\quad KtoC(x) := \left(\frac{x}{K} - 273.15\right)°C$

$FtoC(x) := \frac{5}{9}\cdot\left(\frac{x}{°F} - 32\right)°C$ $\quad FtoR(x) := \left(\frac{x}{°F} + 459.67\right)R$

$w_1 := 5.5ft$ $\quad w_2 := 3.5ft$ $\quad L_1 := 22ft$ $\quad h_1 := 14in$ $\quad h_2 := 16in$ $\quad \theta := 52deg$ $\quad N_{ribs} := 12$ $\quad w_{ribs} := 2in$ $\quad h_{ribs} := 4in$

$\delta_{hood} := 0.3125in$ $\quad \theta := 32deg$ $\quad \delta_{floor} := 3.5in$ $\quad \delta_{CR} := 6in$ $\quad \delta_{sand} := 6in$

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

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$$F = \begin{pmatrix} 0 & .021 & .091 & .021 & .091 & .028 & .177 & .028 & .177 & .366 & 0 \\ .397 & 0 & .026 & .004 & .026 & 0 & .129 & .021 & .129 & .265 & 0 \\ .428 & .006 & 0 & .006 & .052 & .019 & .039 & .019 & .077 & .354 & 0 \\ .400 & .004 & .026 & 0 & .026 & .021 & .129 & 0 & .129 & .265 & 0 \\ .428 & .006 & .052 & .006 & 0 & .019 & .077 & .019 & .039 & .354 & 0 \\ .565 & 0 & .081 & .022 & .081 & 0 & .081 & .003 & .081 & .086 & 0 \\ .575 & .022 & .027 & .022 & .053 & .013 & 0 & .013 & .015 & .125 & .616 \\ .565 & .022 & .081 & 0 & .081 & .003 & .081 & 0 & .081 & .086 & 0 \\ .575 & .022 & .053 & .022 & .027 & .013 & .150 & .013 & 0 & .125 & .616 \\ .574 & .022 & .118 & .022 & .118 & .013 & .060 & .013 & .060 & 0 & 1 \end{pmatrix}$$

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

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DBVS ICV™ Off-Gas Hood Thermal Analysis

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 ...

$T_0 := T_{melt}$

$T_1 := 773K$ $T_3 := 773K$ $T_5 := 773K$ $T_7 := 773K$ $T_9 := 773K$

$T_2 := 773K$ $T_4 := 773K$ $T_6 := 773K$ $T_8 := 773K$ $T_{10} := 773K$ (T_{10} not used in this model)

$T_{11} := 473K$ $T_{13} := 473K$

$T_{12} := 473K$ $T_{14} := 473K$

Material properties ...

$\sigma := 5.67 \cdot 10^{-8} \cdot \frac{W}{m^2 \cdot K^4}$

$\varepsilon_{melt} := 0.7$

$\varepsilon_{sil} := .85$ $k_{sil} := 60.5 \cdot \frac{W}{m \cdot K}$

$\varepsilon_{CR} := 0.66$ $k_{CR} := 1.44 \cdot \frac{W}{m \cdot K}$ $k_{sand} := 2 \cdot \frac{W}{m \cdot K}$

$\alpha_{OG} := 0$ $\tau_{OG} := 1 - \alpha_{OG}$ $\tau_{OG} = 1$

Convective heat transfer coefficients ... $n := \frac{1}{3}$ $\xi_V := 1.32 \cdot W \cdot m^{-2} \cdot K^{\frac{-4}{3}}$ $\xi_{HD} := 0.691 \cdot W \cdot m^{-2} \cdot K^{\frac{-4}{3}}$ $\xi_{HU} := 1.52 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$

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$T_{amb} = 328.1K$ $T_{OG} = 741.5K$

Given

j=1

$$\frac{\sigma\cdot\tau_{OG}\left(T_1^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_1^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_1^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_1^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\varepsilon_V\cdot A_{1,0}\cdot\left(\left|T_1-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_1-T_{OG}\right)+$$

$$+\frac{A_{1,0}\cdot\left(T_1-T_{11}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T_1^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}}}$$

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j=2

$$\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_2^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}=0$$

$$+\xi_V\cdot A_{2,0}\cdot\left(\left|T_2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_2-T_{OG}\right)+\frac{A_{2,0}\cdot\left(T_2-T_{12}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T_2^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

j=3

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\zeta_V\cdot A_{3,0}\cdot\left(\left|T_3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_3-T_{OG}\right)+$$

$$+\frac{A_{3,0}\cdot\left(T_3-T_{13}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_3^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}$$

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$i=4$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+$$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+$$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}-$$

$$+\frac{A_{4,0}\cdot\left(T_4-T_{14}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V\cdot A_{4,0}\cdot\left(\left|T_4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_4-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_4^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}=0$$

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j=5

$$\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_5^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_5^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\cdot\left(\left|T_5-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_5-T_{amb}\right)+\xi_V\cdot A_{5,0}\cdot\left(\left|T_5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_5-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_5^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}=0$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

$i=6$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_6^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}+\xi_V\left(A_{6,0}+A_{6,2}\right)\cdot\left(\left|T_6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{amb}\right)\cdots$$

$$+\xi_{HU}\cdot A_{6,1}\cdot\left(\left|T_6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{amb}\right)+\xi_V\cdot A_{6,0}\cdot\left(\left|T_6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_6^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

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j=7

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T_7^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\cdot\left(\left|T_7-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_7-T_{amb}\right)+\xi_V\cdot A_{7,0}\cdot\left(\left|T_7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_7-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_7^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}$$

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$j=8$

$$\frac{\sigma\cdot\tau_{OG}\left(T_8^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_8^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_8^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_8^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_8^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_8^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_8^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}+\xi_V\cdot\left(A_{8,0}+A_{8,2}\right)\cdot\left(\left|T_8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{amb}\right)\cdots$$

$$+\xi_{HO}\cdot A_{8,1}\cdot\left(\left|T_8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{amb}\right)+\xi_V\cdot A_{8,0}\cdot\left(\left|T_8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_8^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}$$

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i=9

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_9^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}+\xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left(\left|T_9-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{amb}\right)\cdots$$

$$+\xi_{HU}\cdot A_{9,1}\cdot\left(\left|T_9-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{amb}\right)+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T_9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_9^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

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$i=10$

$$T_{10}-T_{10}=0$$

$i=11$

$$\frac{A_{11,0}\cdot(T_{11}-T_1)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{11}^{4}-T_{amb}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{11,0}}\right)+\frac{1}{A_{11,0}}}+\xi_V\cdot A_{11,0}\cdot\left(\left|T_{11}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{11}-T_{amb}\right)=0$$

$i=12$

$$\frac{A_{12,0}\cdot(T_{12}-T_2)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{12}^{4}-T_{amb}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right)+\frac{1}{A_{12,0}}}+\xi_V\cdot A_{12,0}\cdot\left(\left|T_{12}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{12}-T_{amb}\right)=0$$

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j=13

$$\frac{A_{13,0}\cdot(T_{13}-T_3)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{13,0}}\right)+\frac{1}{A_{13,0}}}+\frac{\sigma\cdot\left(T_{13}^{4}-T_{amb}^{4}\right)}{}+\xi_V\cdot A_{13,0}\cdot\left(\left|T_{13}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot(T_{13}-T_{amb})=0$$

j=14

$$\frac{A_{14,0}\cdot(T_{14}-T_4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{14,0}}}+\frac{\sigma\cdot\left(T_{14}^{4}-T_{amb}^{4}\right)}{}+\xi_V\cdot A_{14,0}\cdot\left(\left|T_{14}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot(T_{14}-T_{amb})=0$$

$$\begin{pmatrix} T1 \\ T2 \\ T3 \\ T4 \\ T5 \\ T6 \\ T7 \\ T8 \\ T9 \\ T10 \\ T11 \\ T12 \\ T13 \\ T14 \end{pmatrix} := \mathrm{Find}(T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, T_{13}, T_{14})$$

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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)				

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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 ...

$T0 := T_{melt}$ $T0 = 1325.2\,K$

$T1 = 1338.7\,K$ $T2 = 1149.2\,K$ $T3 = 1138.7\,K$ $T4 = 1149.2\,K$ $T5 = 1021.8\,K$ $T6 = 1003\,K$

$T7 = 1021.8\,K$ $T8 = 1003\,K$ $T9 = 1008\,K$ $T10 = 773\,K$ $T11 = 494.7\,K$ $T12 = 496.2\,K$ $T15 = 494.7\,K$

$T14 = 496.2\,K$ $T_{AWTE} = 298.1\,K$ $T_{amb} = 328.1\,K$ $T_{OG} = 741.5\,K$

$j = 1$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} \ldots = 0\,W$$

$$+ \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,6}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,7}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}} \ldots$$

$$+ \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,8}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,9}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} + \xi_V\cdot A_{1,0}\cdot\left(\left|T1 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T1 - T_{OG}\right) \ldots$$

$$+ \frac{A_{1,0}\cdot(T1 - T11)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\alpha_{OG}\cdot\left(T1^4 - T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}}}$$

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j=2

$$\frac{\sigma\cdot\tau_{OG}\left(T2^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\xi_V\cdot A_{2,0}\cdot\left(\left|T2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T2-T_{OG}\right)+\frac{A_{2,0}\cdot(T2-T12)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T2^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

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j=3

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\varepsilon_V\cdot A_{3,0}\cdot\left(\left|T3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T3-T_{OG}\right)\ldots$$

$$+\frac{A_{3,0}\cdot(T3-T13)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}$$

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j=4

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=-0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{A_{4,0}\cdot(T4-Tld)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V\cdot A_{4,0}\cdot\left(\left|T4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T4-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T4^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

$i=5$

$$\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)}+\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}}}+\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}}}+\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$$

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j=6

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0\cdot W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T6^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\cdot\left(\left|T6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{amb}\right)\ldots$$

$$+\xi_{HU}\cdot A_{6,1}\cdot\left(\left|T6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{amb}\right)+\xi_V\cdot A_{6,0}\cdot\left(\left|T6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T6^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

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j=7

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T7^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\cdot\left(\left|T7-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T7-T_{amb}\right)+\xi_V\cdot A_{7,0}\cdot\left(\left|T7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T7-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T7^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}$$

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j=8

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0\cdot W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T8^4-T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}+\xi_V\cdot\left(A_{8,0}+A_{8,2}\right)\cdot\left(\left|T8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T8-T_{amb}\right)\ldots$$

$$+\xi_{HU}\cdot A_{8,1}\cdot\left(\left|T8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T8-T_{amb}\right)+\xi_V\cdot A_{8,0}\cdot\left(\left|T8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T8-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T8^4-T_{OG}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}$$

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j=9

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T9^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}+\xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left(\left|T9-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{amb}\right)\ldots$$

$$+\xi_{HU}\cdot A_{9,1}\cdot\left(\left|T9-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{amb}\right)+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T9^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

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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

$$\frac{A_{12,0}\cdot(T12 - T2)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T12^4 - T_{amb}^4\right)}{\left(\frac{1-\epsilon_{stl}}{\epsilon_{stl}\cdot A_{12,0}}\right) + \frac{1}{A_{12,0}}} + \xi_V\cdot A_{12,0}\cdot\left(\left|T12 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T12 - T_{amb}\right) = 0\,W$$

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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

$$\frac{A_{14,0}\cdot(T14-T4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T14^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{14,0}}}+\xi_V\cdot A_{14,0}\cdot\left(\left|T14-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T14-T_{amb}\right)=-0\,W$$

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Total radiant heat loss from the melt surface ...

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T1^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots=-985.8\,kW$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T5^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T7^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T8^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}}}$$

$$F_{0,1}+F_{0,2}+F_{0,3}+F_{0,4}+F_{0,5}+F_{0,6}+F_{0,7}+F_{0,8}+F_{0,9}=1$$

Compute the average hood temperature ...

$$T_{HA}:=\frac{A_{5,0}\cdot T5C+A_{6,0}\cdot T6C+A_{7,0}\cdot T7C+A_{8,0}\cdot T8C+A_{9,0}\cdot T9C}{A_{5,0}+A_{6,0}+A_{7,0}+A_{8,0}+A_{9,0}}$$

$T_{HA}=733.6$ $\quad T_{HAF}:=CtoF\left(T_{HA}\right)$ $\quad T_{HAF}=1352.4$

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APPENDIX E

MATHCAD MODEL FOR THE "OPEN AIR" CONDITIONS WITH SOIL OVERBURDEN

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°F = 1

°C = 1

DBVS ICV™ Off-Gas Hood Thermal Analysis

$CtoF(x) := \left(\frac{9}{5}\frac{x}{°C} + 32\right)°F$ $CtoK(x) := \left(\frac{x}{°C} + 273.15\right)K$ $KtoC(x) := \left(\frac{x}{K} - 273.15\right)°C$

$FtoC(x) := \frac{5}{9}\left(\frac{x}{°F} - 32\right)°C$ $FtoR(x) := \left(\frac{x}{°F} + 459.67\right)R$

$w_1 := 5.5ft$ $w_2 := 3.5ft$ $L_1 := 22ft$ $h_1 := 34in$ $h_2 := 16in$ $\theta := 52deg$ $N_{ribs} := 12$ $w_{ribs} := 2in$ $h_{ribs} := 4in$

$\delta_{hood} := 0.3125in$ $\theta := 52deg$ $\delta_{floor} := 3.5in$ $\delta_{CR} := 6in$ $\delta_{sand} := 6in$ $\delta_{soil} := 1in$

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

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$$F := \begin{pmatrix} 0 & .021 & .091 & .021 & .091 & .028 & .177 & .028 & .177 & .366 & 0 \\ .397 & 0 & .026 & .004 & .026 & 0 & .129 & .021 & .129 & .265 & 0 \\ .428 & .006 & 0 & .006 & .052 & .019 & .039 & .019 & .077 & .354 & 0 \\ .400 & .004 & .026 & 0 & .026 & .021 & .129 & 0 & .129 & .265 & 0 \\ .428 & .006 & .052 & .006 & 0 & .019 & .077 & .019 & .039 & .354 & 0 \\ .565 & 0 & .081 & .022 & .081 & 0 & .081 & .003 & .081 & .086 & 0 \\ .575 & .022 & .027 & .022 & .053 & .013 & 0 & .013 & .015 & .125 & .616 \\ .565 & .022 & .081 & 0 & .081 & .003 & .081 & 0 & .081 & .086 & 0 \\ .575 & .022 & .053 & .022 & .027 & .013 & .150 & .013 & 0 & .125 & .616 \\ .574 & .022 & .118 & .022 & .118 & .013 & .060 & .013 & .060 & 0 & 1 \end{pmatrix}$$

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

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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)

$T_{11} := 473K$ $T_{13} := 473K$

$T_{12} := 473K$ $T_{14} := 473K$

Material properties ...

$\sigma := 5.67 \cdot 10^{-8} \cdot \frac{W}{m^2 \cdot K^4}$

$\varepsilon_{melt} := 0.7$

$\varepsilon_{stl} := .85$ $k_{stl} := 60.5 \frac{W}{m \cdot K}$

$\varepsilon_{CR} := 0.66$ $k_{CR} := 1.44 \frac{W}{m \cdot K}$ $k_{sand} := 2 \frac{W}{m \cdot K}$

$\alpha_{OG} := 0$ $\tau_{OG} := 1 - \alpha_{OG}$ $\tau_{OG} = 1$

Convective heat transfer coefficients ... $n := \frac{1}{3}$ $\xi_V := 1.32 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$ $\xi_{HD} := 0.691 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$ $\xi_{HU} := 1.52 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$

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$T_{amb} = 298.1\,K$ $\quad T_{OG} = 741.5\,K$

Given

$j=0$

$$\frac{k_{sand} \cdot A_{0,0} \cdot (T_0 - T_{melt})}{\delta_{soil}} + \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_1^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_2^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{2,0}}\right)} \cdots = 0$$

$$+ \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_3^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_4^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{4,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_5^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,5}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{5,0}}\right)} \cdots$$

$$+ \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_6^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,6}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{6,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_7^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,7}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{7,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_8^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,8}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{8,0}}\right)} \cdots$$

$$+ \frac{\sigma \cdot \tau_{OG} \cdot (T_0^4 - T_9^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,9}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{9,0}}\right)} + \frac{\sigma \cdot \alpha_{OG} \cdot (T_0^4 - T_{OG}^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0}}} + \varepsilon_{HU} \cdot A_{0,0} \cdot \left(\left|T_0 - T_{OG}\right|\right)^{\frac{1}{3}} \cdot (T_0 - T_{OG})$$

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j=1

$$\frac{\sigma\cdot\tau_{OG}\left(T_1^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_1^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_1^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_1^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_1^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{1,0}\left(\left|T_1-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_1-T_{OG}\right)=$$

$$+\frac{A_{1,0}\cdot\left(T_1-T_{11}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T_1^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}}}$$

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j=2

$$\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+$$

$$\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+$$

$$\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_2^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}=0$$

$$+\xi_V\cdot A_{2,0}\cdot\left(\left|T_2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_2-T_{OG}\right)+\frac{A_{2,0}\cdot\left(T_2-T_{12}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_2^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

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$j=3$

$$\frac{\sigma\cdot\tau_{OG}\left(T_3^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_3^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{5,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_3^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_3^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_3^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\varepsilon_V\cdot A_{3,0}\cdot\left(\left|T_3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_3-T_{OG}\right)\ldots$$

$$+\frac{A_{3,0}\cdot\left(T_3-T_{13}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T_3^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}$$

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F4

$$\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_4^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{A_{4,0}\left(T_4-T_{14}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V\cdot A_{4,0}\cdot\left(\left|T_4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_4-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_4^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}$$

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j=5

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}$$

$$+\frac{\sigma\cdot\left(T_5^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\varepsilon_V\cdot A_{5,0}\cdot\left(\left|T_5-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_5-T_{amb}\right)+\varepsilon_V\cdot A_{5,0}\cdot\left(\left|T_5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_5-T_{OG}\right)+\frac{\sigma\cdot\sigma_{OG}\cdot\left(T_5^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}=0$$

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j=6

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_6^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\cdot\left(\left|T_6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{amb}\right)\cdots$$

$$+\xi_{HU}\cdot A_{6,1}\cdot\left(\left|T_6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{amb}\right)+\xi_V\cdot A_{6,0}\cdot\left(\left|T_6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_6^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

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$i=7$

$$\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_5^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_7^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}$$

$$+\frac{\sigma\cdot\left(T_7^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\cdot\left(\left|T_7-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_7-T_{amb}\right)+\xi_V\cdot A_{7,0}\cdot\left(\left|T_7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_7-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_7^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}$$

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$i=8$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_8^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}+\xi_V\cdot\left(A_{8,0}+A_{8,2}\right)\cdot\left(\left|T_8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{amb}\right)\cdots$$

$$+\xi_{HU}\cdot A_{8,1}\cdot\left(\left|T_8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{amb}\right)+\xi_V\cdot A_{8,0}\cdot\left(\left|T_8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_8^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}$$

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F9

$$\frac{\sigma\cdot\tau_{OG}\left(T_9^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}=0$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_9^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T_9^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T_9^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_9^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T_9^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}$$

$$+\frac{\sigma\cdot\left(T_9^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}+\xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left(\left|T_9-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{amb}\right)+$$

$$+\xi_{HU}\cdot A_{9,1}\cdot\left(\left|T_9-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{amb}\right)+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T_9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T_9^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

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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

$$\frac{A_{12,0}\cdot(T_{12} - T_2)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T_{12}^{\ 4} - T_{amb}^{\ 4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right) + \frac{1}{A_{12,0}}} + \xi_V\cdot A_{12,0}\cdot\left(\left|T_{12} - T_{amb}\right|\right)^{\frac{1}{3}}\cdot(T_{12} - T_{amb}) = 0$$

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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

$$\frac{A_{14,0}\cdot(T_{14}-T_4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{14}^{4}-T_{amb}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{14,0}}}+\xi_V\cdot A_{14,0}\cdot\left(\left|T_{14}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{14}-T_{amb}\right)=0$$

$$\begin{pmatrix} T0 \\ T1 \\ T2 \\ T3 \\ T4 \\ T5 \\ T6 \\ T7 \\ T8 \\ T9 \\ T10 \\ T11 \\ T12 \\ T13 \\ T14 \end{pmatrix} := \mathrm{Find}\left(T_0, T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, T_{13}, T_{14}\right)$$

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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

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$T7F = 970.364$ $T8F = 935.876$ $T9F = 939.598$ $T10F = 931.7$ $T11F = 334.9$ $T12F = 337.5$ $T13F = 334.9$ $T14F = 337.5$

Check results ...

$T0 = 1041\,K$

$T1 = 885.4\,K$ $T2 = 893.6\,K$ $T3 = 885.4\,K$ $T4 = 893.6\,K$ $T5 = 794.5\,K$ $T6 = 775.3\,K$

$T7 = 794.5\,K$ $T8 = 775.3\,K$ $T9 = 977.4\,K$ $T10 = 773\,K$ $T11 = 441.4\,K$ $T12 = 442.9\,K$ $T13 = 441.4\,K$

$T14 = 442.9\,K$ $T_{AWTE} = 298.1\,K$ $T_{amb} = 298.1\,K$ $T_{OG} = 741.5\,K$

j=0

$$\frac{k_{sand} A_{0,0} (T0 - T_{melt})}{\delta_{soil}} + \frac{\sigma \cdot \tau_{OG} (T0^4 - T1^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} A_{0,0}}\right) + \frac{1}{A_{0,0} F_{0,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} A_{1,0}}\right)} + \frac{\sigma \cdot \tau_{OG} (T0^4 - T2^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} A_{0,0}}\right) + \frac{1}{A_{0,0} F_{0,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} A_{2,0}}\right)} \cdots = -0\,W$$

$$+ \frac{\sigma \cdot \tau_{OG} (T0^4 - T3^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} A_{0,0}}\right) + \frac{1}{A_{0,0} F_{0,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} A_{3,0}}\right)} + \frac{\sigma \cdot \tau_{OG} (T0^4 - T4^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} A_{0,0}}\right) + \frac{1}{A_{0,0} F_{0,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} A_{4,0}}\right)} + \frac{\sigma \cdot \tau_{OG} (T0^4 - T5^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} A_{0,0}}\right) + \frac{1}{A_{0,0} F_{0,5}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} A_{5,0}}\right)} \cdots$$

$$+ \frac{\sigma \cdot \tau_{OG} (T0^4 - T6^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} A_{0,0}}\right) + \frac{1}{A_{0,0} F_{0,6}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} A_{6,0}}\right)} + \frac{\sigma \cdot \tau_{OG} (T0^4 - T7^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} A_{0,0}}\right) + \frac{1}{A_{0,0} F_{0,7}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} A_{7,0}}\right)} + \frac{\sigma \cdot \tau_{OG} (T0^4 - T8^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} A_{0,0}}\right) + \frac{1}{A_{0,0} F_{0,8}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} A_{8,0}}\right)} \cdots$$

$$+ \frac{\sigma \cdot \tau_{OG} (T0^4 - T9^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} A_{0,0}}\right) + \frac{1}{A_{0,0} F_{0,9}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} A_{9,0}}\right)} + \frac{\sigma \cdot \tau_{OG} (T0^4 - T_{OG}^4)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} A_{0,0}}\right) + \frac{1}{A_{0,0}}} + \varepsilon_{HU} A_{0,0} \cdot \left(|T0 - T_{OG}|\right)^{\frac{1}{3}} \cdot (T0 - T_{OG})$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

$i=1$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\ldots=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\zeta_V\cdot A_{1,0}\cdot\left(\left|T1-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T1-T_{OG}\right)\ldots$$

$$+\frac{A_{1,0}\cdot(T1-T11)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T1^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}}}\ldots$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

j=2

$$\frac{\sigma\cdot\tau_{OG}\left(T2^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T2^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\xi_{sv}\cdot A_{2,0}\cdot\left(\left|T2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T2-T_{OG}\right)+\frac{A_{2,0}\cdot\left(T2-T12\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\left(T2^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

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j=3

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0\,W$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{3,0}\cdot\left(\left|T3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T5-T_{OG}\right)\cdots$$

$$+\frac{A_{3,0}\cdot(T3-T13)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T3^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}$$

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j=4

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\cdots=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\cdots$$

$$+\frac{A_{4,0}\cdot(T4-T14)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V\cdot A_{4,0}\cdot\left(\left|T4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T4-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T4^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

j=5

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T5^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\cdot\left(\left|T5-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T5-T_{amb}\right)+\xi_V\cdot A_{5,0}\cdot\left(\left|T5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T5-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T5^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}$$

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j=6

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T6^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\cdot\left(\left|T6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{amb}\right)\ldots$$

$$+\xi_{HU}\cdot A_{6,1}\cdot\left(\left|T6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{amb}\right)+\xi_V\cdot A_{6,0}\cdot\left(\left|T6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{OG}\right)+\frac{\sigma\cdot\sigma_{OG}\cdot\left(T6^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

I=7

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}$$

$$+\frac{\sigma\cdot\left(T7^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\cdot\left(\left|T7-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T7-T_{amb}\right)+\xi_V\cdot A_{7,0}\cdot\left(\left|T7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T7-T_{OG}\right)+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}$$

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j=8

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}$$

$$+\frac{\sigma\cdot\left(T8^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}+\xi_V\cdot\left(A_{8,0}+A_{8,2}\right)\cdot\left(\left|T8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T8-T_{amb}\right)\ldots$$

$$+\xi_{HU}\cdot A_{8,1}\cdot\left(\left|T8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T8-T_{amb}\right)+\xi_V\cdot A_{8,0}\cdot\left(\left|T8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T8-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T8^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}$$

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j=9

$$\frac{\sigma\cdot\tau_{OG}\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0\,W$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\left(T9^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T9^4-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}+\xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left(\left|T9-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{amb}\right)\cdots$$

$$+\xi_{HU}\cdot A_{9,1}\cdot\left(\left|T9-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{amb}\right)+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\left(T9^4-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

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j=10

$T10 - T10 = 0\,K$

j=11

$$\frac{A_{11,0}\cdot(T11 - T1)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T11^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{11,0}}\right) + \frac{1}{A_{11,0}}} + \xi_V\cdot A_{11,0}\cdot\left(\left|T11 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T11 - T_{amb}\right) = 0\,W$$

j=12

$$\frac{A_{12,0}\cdot(T12 - T2)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T12^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right) + \frac{1}{A_{12,0}}} + \xi_V\cdot A_{12,0}\cdot\left(\left|T12 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T12 - T_{amb}\right) = 0\,W$$

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

$$\frac{A_{14,0}\cdot(T14 - T4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T14^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right) + \frac{1}{A_{14,0}}} + \xi_V\cdot A_{14,0}\cdot\left(\left|T14 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T14 - T_{amb}\right) = 0\,W$$

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Total radiant heat loss from the melt surface ...

$$\frac{\sigma\cdot\varepsilon_{.OG}\cdot\left(T1^4-T0^4\right)}{\left(\frac{1-\varepsilon_{.melt}}{\varepsilon_{.melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{.CR}}{\varepsilon_{.CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{.OG}\cdot\left(T2^4-T0^4\right)}{\left(\frac{1-\varepsilon_{.melt}}{\varepsilon_{.melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{.CR}}{\varepsilon_{.CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\varepsilon_{.OG}\cdot\left(T3^4-T0^4\right)}{\left(\frac{1-\varepsilon_{.melt}}{\varepsilon_{.melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{.CR}}{\varepsilon_{.CR}\cdot A_{3,0}}\right)}=-392.5\,kW$$

$$+\frac{\sigma\cdot\varepsilon_{.OG}\cdot\left(T4^4-T0^4\right)}{\left(\frac{1-\varepsilon_{.melt}}{\varepsilon_{.melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{.CR}}{\varepsilon_{.CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{.OG}\cdot\left(T5^4-T0^4\right)}{\left(\frac{1-\varepsilon_{.melt}}{\varepsilon_{.melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{.stl}}{\varepsilon_{.stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{.OG}\cdot\left(T6^4-T0^4\right)}{\left(\frac{1-\varepsilon_{.melt}}{\varepsilon_{.melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{.stl}}{\varepsilon_{.stl}\cdot A_{6,0}}\right)}=$$

$$+\frac{\sigma\cdot\varepsilon_{.OG}\cdot\left(T7^4-T0^4\right)}{\left(\frac{1-\varepsilon_{.melt}}{\varepsilon_{.melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{.stl}}{\varepsilon_{.stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\varepsilon_{.OG}\cdot\left(T8^4-T0^4\right)}{\left(\frac{1-\varepsilon_{.melt}}{\varepsilon_{.melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{.stl}}{\varepsilon_{.stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\varepsilon_{.OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{.melt}}{\varepsilon_{.melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{.stl}}{\varepsilon_{.stl}\cdot A_{9,0}}\right)}=$$

$$+\frac{\sigma\cdot\varepsilon_{.OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{.melt}}{\varepsilon_{.melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}}}$$

$$F_{0,1}+F_{0,2}+F_{0,3}+F_{0,4}+F_{0,5}+F_{0,6}+F_{0,7}+F_{0,8}+F_{0,9}=1$$

Compute the average hood temperature ...

$$T_{HA}=\frac{A_{5,0}\cdot T5C+A_{6,0}\cdot T6C+A_{7,0}\cdot T7C+A_{8,0}\cdot T8C+A_{9,0}\cdot T9C}{A_{5,0}+A_{6,0}+A_{7,0}+A_{8,0}+A_{9,0}}$$

$T_{HA}=504.5$ $\quad T_{HAF}:=CtoF\left(T_{HA}\right)$ $\quad T_{HAF}=940.2$

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APPENDIX F

HRTS BULKVIT TEST 38A-1 & 38B CONDITIONS

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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

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2/17/2006

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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)

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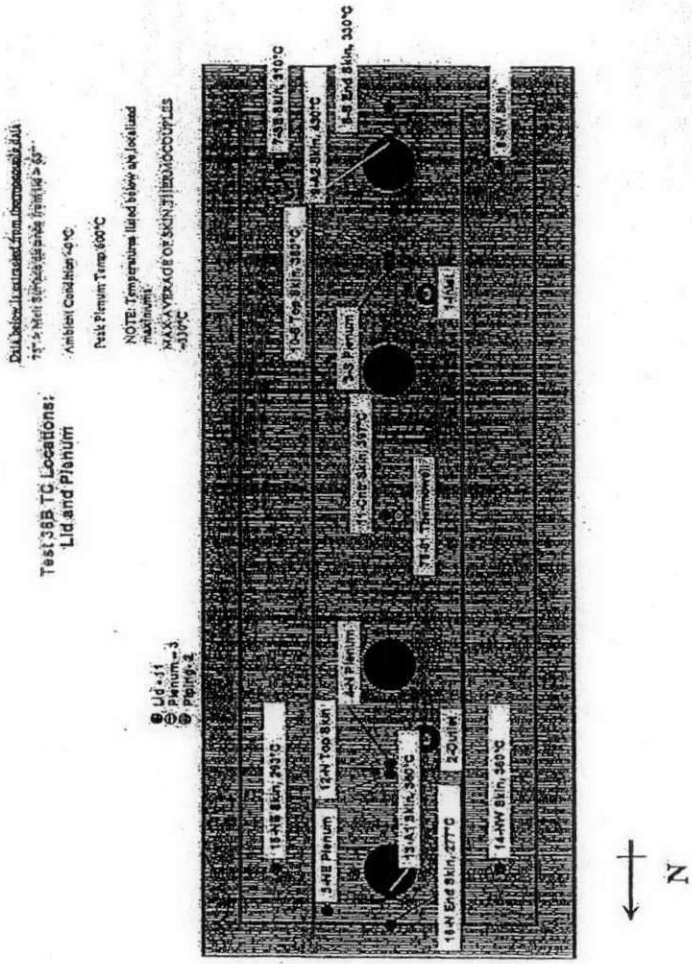

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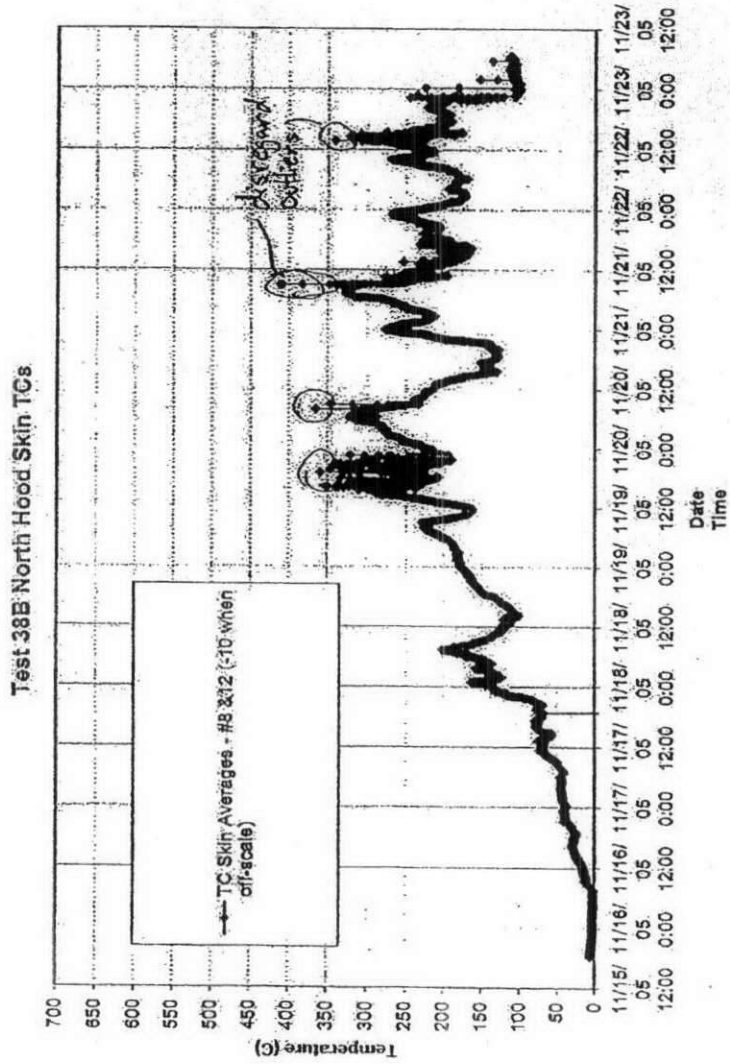

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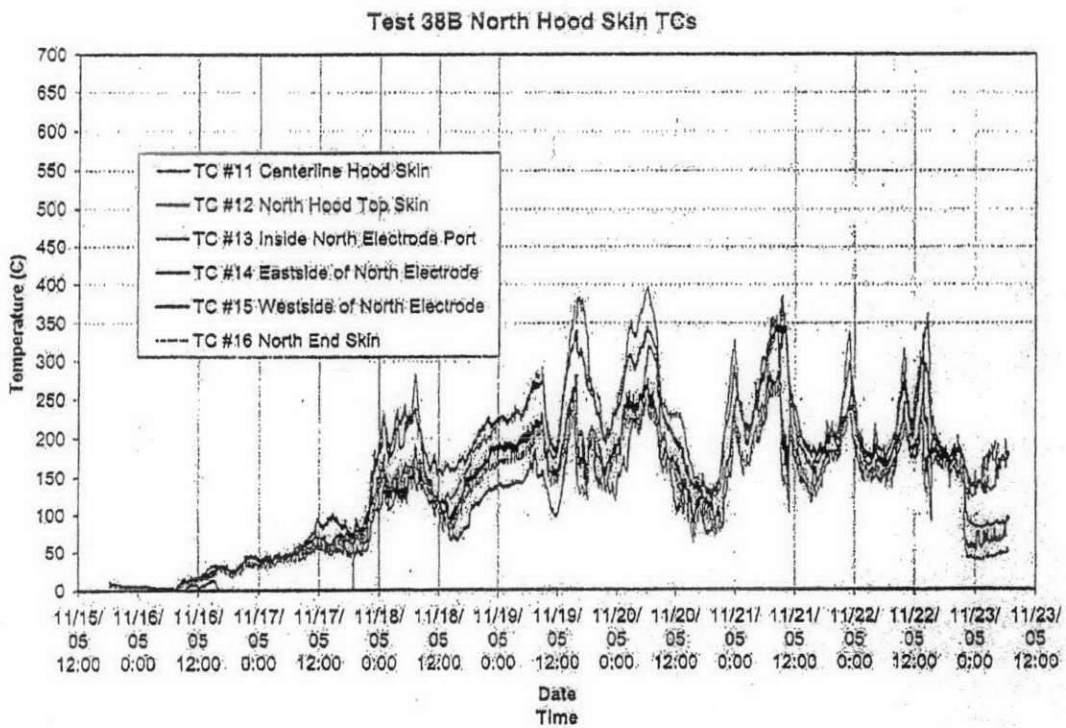

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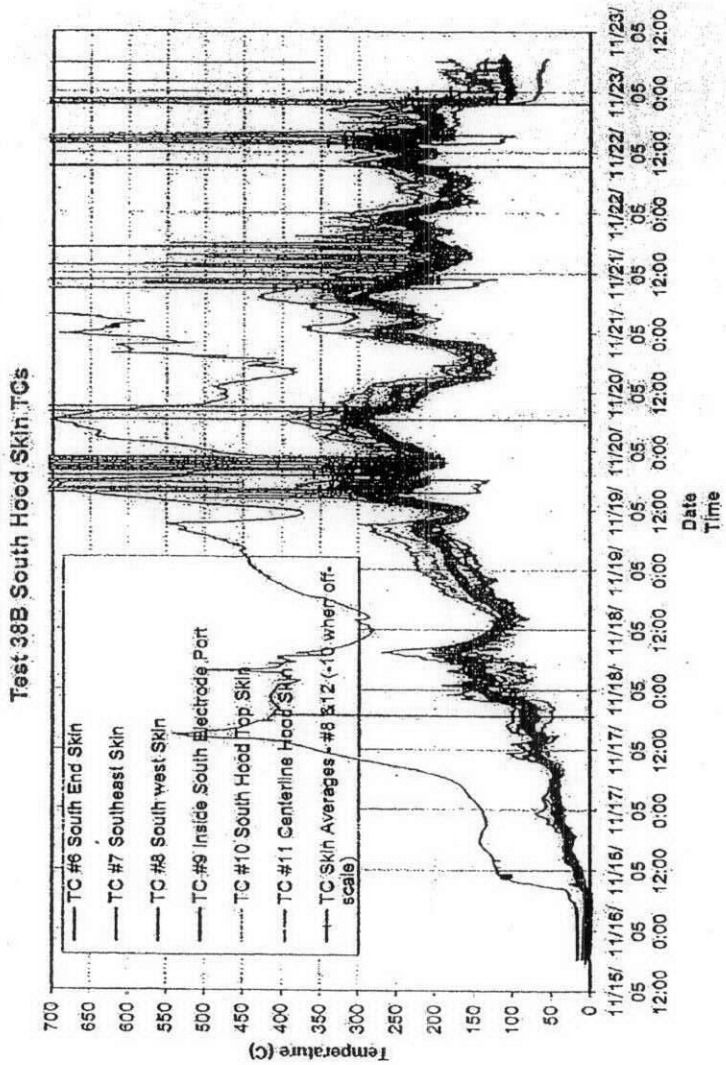

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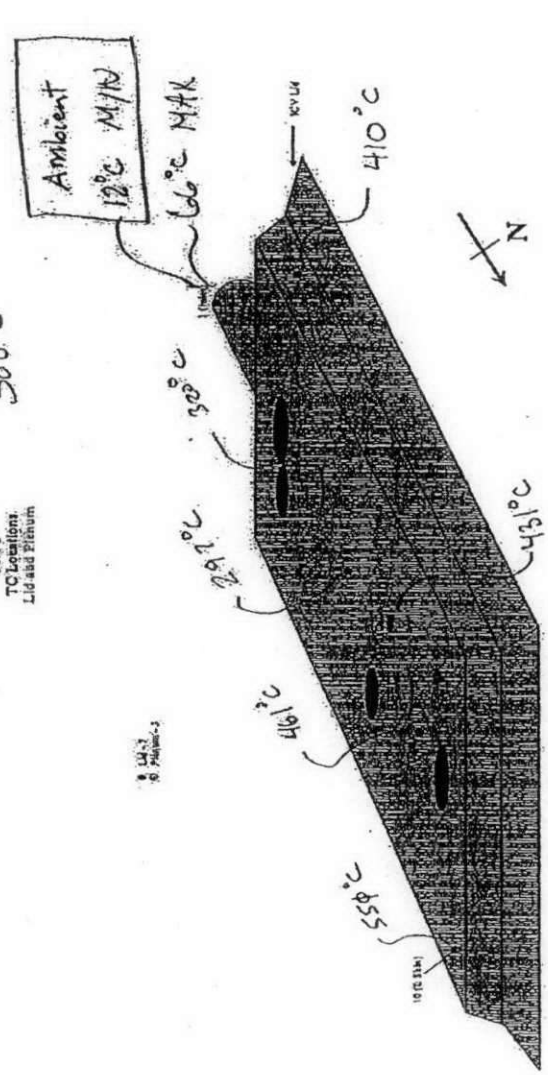
Average Skin Thermocouple Data 375°C

MAX PLENUM TEMP 50.0°C



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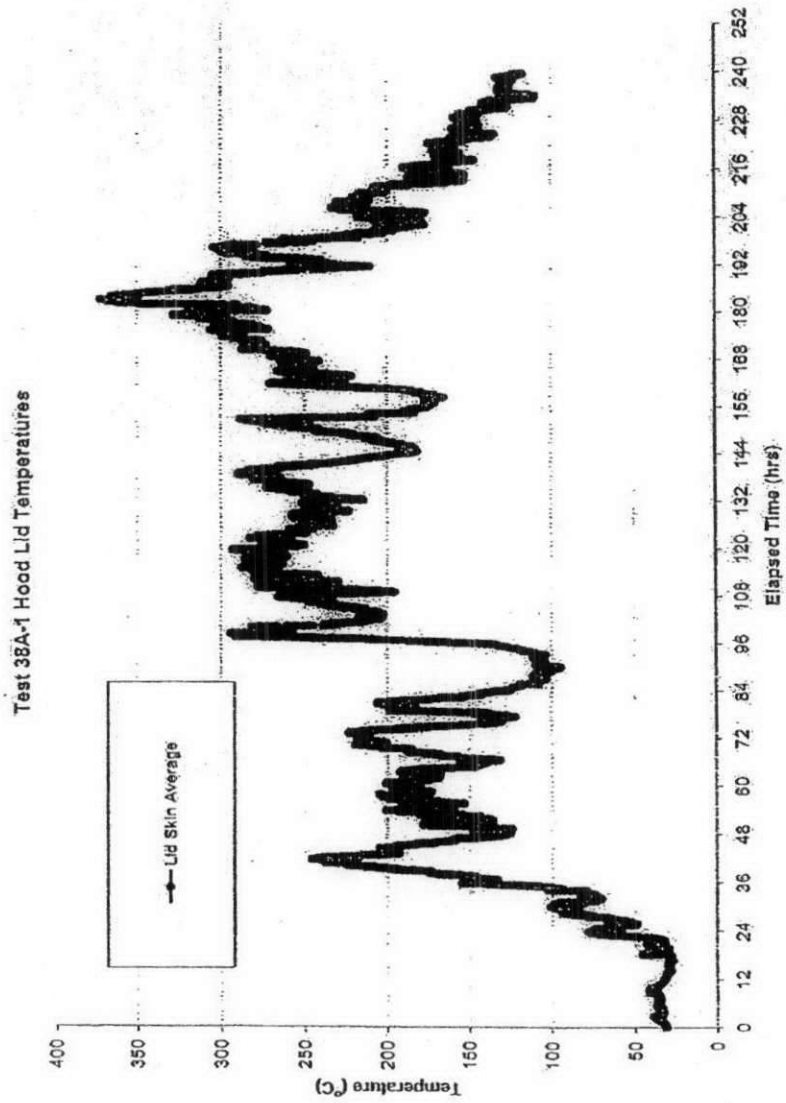

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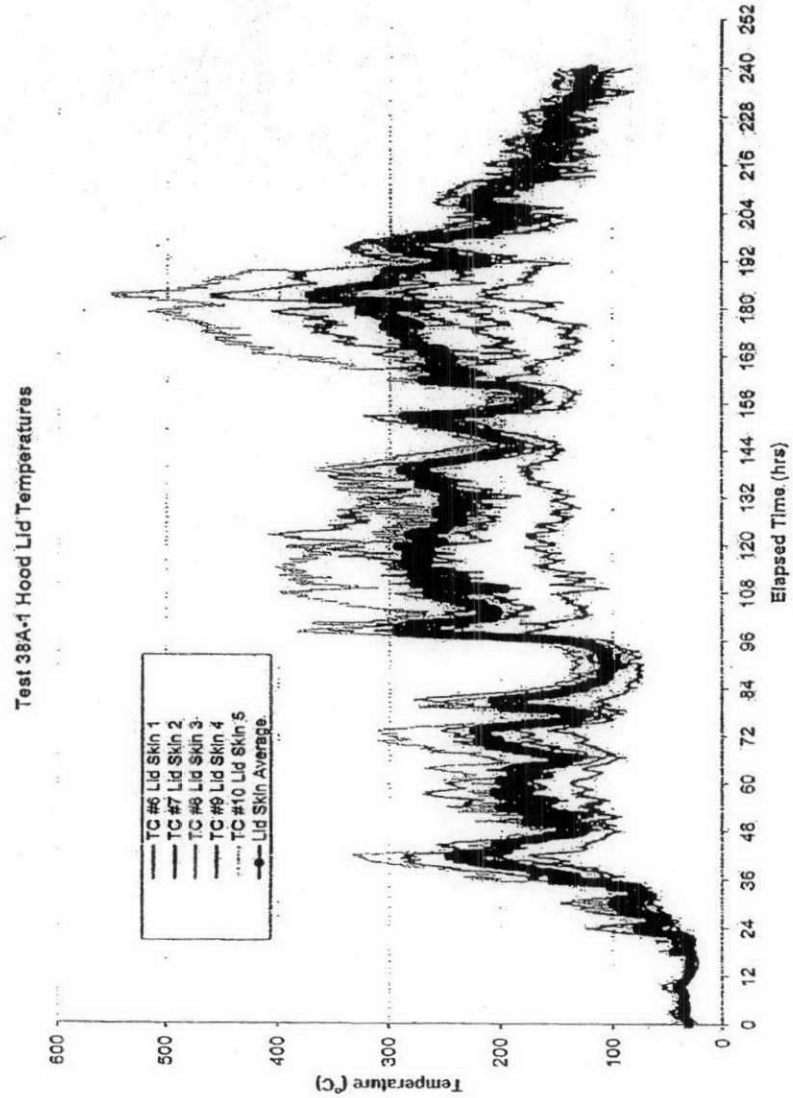

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APPENDIX G

MATHCAD MODEL FOR THE HRTS CONDITIONS WITH ADJUSTED MELT SURFACE TEMPERATURE

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DBVS ICV™ Off-Gas Hood Thermal Analysis

$°F = 1$

$°C = 1$

$CtoF(x) := \left(\frac{9}{5}\frac{x}{°C} + 32\right)°F$ $CtoK(x) := \left(\frac{x}{°C} + 273.15\right)K$ $KtoC(x) := \left(\frac{x}{K} - 273.15\right)°C$

$FtoC(x) := \frac{5}{9}\left(\frac{x}{°F} - 32\right)°C$ $FtoR(x) := \left(\frac{x}{°F} + 459.67\right)R$

$w_1 := 5.5ft$ $w_2 := 3.5ft$ $L_1 := 22ft$ $h_1 := 1\cdot in$ $h_2 := 16in$ $\theta := 52deg$ $N_{ribs} := 12$ $w_{ribs} := 2in$ $h_{ribs} := 4in$

$\delta_{hood} := 0.3125in$ $\theta := 52deg$ $\delta_{floor} := 3.5in$ $\delta_{CR} := 6in$ $\delta_{stand} := 6in$

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.

$A =$

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	13.6
7	6	0	0
8	37.2	3.4	13.6
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

ft^2

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DBVS ICV™ Off-Gas Hood Thermal Analysis

$$F_{i,j} := \begin{pmatrix} 0 & .021 & .091 & .021 & .091 & .028 & .177 & .028 & .177 & .366 & 0 \\ .397 & 0 & .026 & .004 & .026 & 0 & .129 & .021 & .129 & .265 & 0 \\ .428 & .006 & 0 & .006 & .052 & .019 & .039 & .019 & .077 & .354 & 0 \\ .400 & .004 & .026 & 0 & .026 & .021 & .129 & 0 & .129 & .265 & 0 \\ .428 & .006 & .052 & .006 & 0 & .019 & .077 & .019 & .039 & .354 & 0 \\ .565 & 0 & .081 & .022 & .081 & 0 & .081 & .003 & .081 & .086 & 0 \\ .575 & .022 & .027 & .022 & .053 & .013 & 0 & .013 & .015 & .125 & .616 \\ .565 & .022 & .081 & 0 & .081 & .003 & .081 & 0 & .081 & .086 & 0 \\ .575 & .022 & .053 & .022 & .027 & .013 & .150 & .013 & 0 & .125 & .616 \\ .574 & .022 & .118 & .022 & .118 & .013 & .060 & .013 & .060 & 0 & 1 \end{pmatrix}$$

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 salt 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 15, 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

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DBVS ICV™ Off-Gas Hood Thermal Analysis

Temperature Boundary Conditions ...

$T_{melt} := 1157°F$ $\quad T_{mC} := FtoC(T_{melt})$ $\quad T_{melt} := CtoK(T_{mC})$ $\quad T_{melt} = 898.15\,K$

$T_{AWTE} := 77°F$ $\quad T_{AC} := FtoC(T_{AWTE})$ $\quad T_{AWTE} := CtoK(T_{AC})$ $\quad T_{AWTE} = 298.1\,K$

$T_{OG} := 1112°F$ $\quad T_{og} := FtoC(T_{OG})$ $\quad T_{OG} := CtoK(T_{og})$ $\quad T_{OG} = 873.15\,K$

$T_{amb} := 12°C$ $\quad T_{amb} := CtoK(T_{amb})$ $\quad T_{amb} = 285.1\,K$

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 ...

$\sigma := 5.67 \cdot 10^{-8} \cdot \frac{W}{m^2 \cdot K^4}$

$\varepsilon_{melt} := 0.7$

$\varepsilon_{stl} := .85$ $\quad k_{stl} := 60.5 \frac{W}{m \cdot K}$

$\varepsilon_{CR} := 0.66$ $\quad k_{CR} := 1.44 \frac{W}{m \cdot K}$ $\quad k_{sand} := 2 \frac{W}{m \cdot K}$

$\alpha_{OG} := 0$ $\quad \varepsilon_{OG} := 1 - \alpha_{OG}$ $\quad \varepsilon_{OG} = 1$

Convective heat transfer coefficients ... $\quad n := \frac{1}{3}$ $\quad \xi_V := 1.32 \cdot W \cdot m^{-2} \cdot K^{\frac{-4}{3}}$ $\quad \xi_{HD} := 0.691 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$ $\quad \xi_{HU} := 1.52 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$

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$T_{amb} = 285.1\ K$ $\quad T_{OG} = 873.1\ K$

Given

j=1

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_1^4 - T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_1^4 - T_2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_1^4 - T_3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots = 0$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_1^4 - T_4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_1^4 - T_6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_1^4 - T_7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}\ldots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_1^4 - T_8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_1^4 - T_9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\zeta_V\cdot A_{1,0}\cdot\left(\left|T_1 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_1 - T_{OG}\right)\ldots$$

$$+\frac{A_{1,0}\cdot\left(T_1 - T_{11}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_1^4 - T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}}}$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

$j=3$

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_3^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_3^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_3^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_3^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_3^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_3^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_3^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_3^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{3,0}\cdot\left(\left|T_3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_3-T_{OG}\right)\cdots$$

$$+\frac{A_{3,0}\cdot\left(T_3-T_{13}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_3^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

j=4

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_4^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{A_{4,0}\cdot\left(T_4-T_{14}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V\cdot A_{4,0}\cdot\left(\left|T_4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_4-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_4^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

j=5

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_5^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\zeta_V\cdot A_{5,0}\cdot\left(\left|T_5-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_5-T_{amb}\right)+\zeta_V\cdot A_{5,0}\cdot\left(\left|T_5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_5-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_5^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}=0$$

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j=6

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_6^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{6,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_6^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_6^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_6^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_6^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_6^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_6^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_6^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_6^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T_6^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\cdot\left(\left|T_6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{amb}\right)\ldots$$

$$+\xi_{EFU}\cdot A_{6,1}\cdot\left(\left|T_6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{amb}\right)+\xi_V\cdot A_{6,0}\cdot\left(\left|T_6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_6^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

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$j=7$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_7^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\cdot\left(\left|T_7-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_7-T_{amb}\right)+\xi_V\cdot A_{7,0}\cdot\left(\left|T_7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_7-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_7^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}$$

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j=8

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_8^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_8^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_8^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0.$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_8^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_8^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_8^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_8^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_8^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_8^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_8^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}+\xi_V\cdot\left(A_{8,0}+A_{8,2}\right)\cdot\left(\left|T_8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{amb}\right)\cdots$$

$$+\xi_{HU}\cdot A_{8,1}\cdot\left(\left|T_8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{amb}\right)+\xi_V\cdot A_{8,0}\cdot\left(\left|T_8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_8^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}$$

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j=9

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{molt}}{\varepsilon_{molt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T_9^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}+\xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left(\left|T_9-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{amb}\right)\ldots$$

$$+\xi_{HU}\cdot A_{9,1}\cdot\left(\left|T_9-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{amb}\right)+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T_9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_9^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

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j=10

$$T_{10} - T_{10} = 0$$

j=11

$$\frac{A_{11,0}\cdot(T_{11} - T_1)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T_{11}^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{11,0}}\right) + \frac{1}{A_{11,0}}} + \xi_{11}\cdot A_{11,0}\cdot\left(\left|T_{11} - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{11} - T_{amb}\right) = 0$$

j=12

$$\frac{A_{12,0}\cdot(T_{12} - T_2)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T_{12}^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right) + \frac{1}{A_{12,0}}} + \xi_{12}\cdot A_{12,0}\cdot\left(\left|T_{12} - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{12} - T_{amb}\right) = 0$$

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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

$$\frac{A_{14,0}\cdot(T_{14}-T_4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{14}^{4}-T_{amb}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{14,0}}}+\xi_V\cdot A_{14,0}\cdot\left(\left|T_{14}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{14}-T_{amb}\right)=0$$

$$\begin{pmatrix} T1 \\ T2 \\ T3 \\ T4 \\ T5 \\ T6 \\ T7 \\ T8 \\ T9 \\ T10 \\ T11 \\ T12 \\ T13 \\ T14 \end{pmatrix} := \mathrm{Find}(T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, T_{13}, T_{14})$$

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T1 = 771.1 K	T1C := KtoC(T1)	T1C = 497.9
T2 = 777.8 K	T2C := KtoC(T2)	T2C = 504.6
T3 = 771.1 K	T3C := KtoC(T3)	T3C = 497.9
T4 = 777.8 K	T4C := KtoC(T4)	T4C = 504.6
T5 = 690.7 K	T5C := KtoC(T5)	T5C = 417.5
T6 = 672.2 K	T6C := KtoC(T6)	T6C = 399
T7 = 690.7 K	T7C := KtoC(T7)	T7C = 417.5
T8 = 672.2 K	T8C := KtoC(T8)	T8C = 399
T9 = 669 K	T9C := KtoC(T9)	T9C = 395.9
T10 = 386.5 K	T10C := KtoC(T10)	T10C = 113.4
T11 = 414.2 K	T11C := KtoC(T11)	T11C = 141
T12 = 415.5 K	T12C := KtoC(T12)	T12C = 142.3
T13 = 414.2 K	T13C := KtoC(T13)	T13C = 141
T14 = 415.5 K	T14C := KtoC(T14)	T14C = 142.3

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)				

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Results in °F ...

T1F = 928.266 T2F = 940.286 T3F = 928.266 T4F = 940.286 T5F = 783.507 T6F = 750.273

T7F = 783.507 T8F = 750.273 T9F = 144.558 T10F = 236 T11F = 285.9 T12F = 288.2 T13F = 285.9 T14F = 288.2

Check results ...

$T0 := T_{melt}$ $T0 = 898.1\ K$

$T1 = 771.1\ K$ $T2 = 777.8\ K$ $T3 = 771.1\ K$ $T4 = 777.8\ K$ $T5 = 690.7\ K$ $T6 = 672.2\ K$

$T7 = 690.7\ K$ $T8 = 672.2\ K$ $T9 = 669\ K$ $T10 = 386.5\ K$ $T11 = 414.2\ K$ $T12 = 415.5\ K$ $T13 = 414.2\ K$

$T14 = 415.5\ K$ $T_{AWTE} = 298.1\ K$ $T_{amb} = 285.1\ K$ $T_{OG} = 873.1\ K$

$j := 1$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} \ldots = 0\ W$$

$$+ \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,6}} + \left(\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{6,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,7}} + \frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{7,0}}} \ldots$$

$$+ \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,8}} + \frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{8,0}}} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,9}} + \frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{9,0}}} + h_{cv}\cdot A_{1,0}\cdot\left(\left|T1 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T1 - T_{OG}\right) \ldots$$

$$+ \frac{A_{1,0}\cdot(T1 - T11)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\alpha_{OG}\cdot\left(T1^4 - T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}}}$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

j=2

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots=-0\cdot W$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\xi_{v}\cdot A_{2,0}\cdot\left(\left|T2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T2-T_{OG}\right)+\frac{A_{2,0}\cdot(T2-T12)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T2^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

j=3

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=-0\ \mathrm{W}$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_{3,0}\cdot A_{3,0}\cdot\left(\left|T3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T3-T_{OG}\right)\ldots$$

$$+\frac{A_{3,0}\cdot(T3-T13)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T3^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

j=4

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=-0\ W$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{A_{4,0}\cdot\left(T4-T14\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi\cdot A_{4,0}\cdot\left(\left|T4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T4-T_{OG}\right)+\frac{\alpha\cdot\sigma_{OG}\cdot\left(T4^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

j=5

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T5^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\cdot\left(\left|T5-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T5-T_{amb}\right)+\xi_V\cdot A_{5,0}\cdot\left(\left|T5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T5-T_{OG}\right)+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}=0\ W$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

j=6

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T0^4\right)}{\left(\frac{1-\varepsilon_{molt}}{\varepsilon_{molt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=-Q\cdot W$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T6^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\cdot\left(\left|T6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{amb}\right)\cdots$$

$$+\xi_{HU}\cdot A_{6,1}\cdot\left(\left|T6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{amb}\right)+\xi_V\cdot A_{6,0}\cdot\left(\left|T6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T6^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

j=7

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T7^4-T0^4\right)}{\left(\frac{1-\varepsilon_{insolt.}}{\varepsilon_{insolt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T5^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T7^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=-0\ W$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T7^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T7^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T7^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T7^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T7^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T7^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\cdot\left(\left|T7-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T7-T_{amb}\right)+\xi_V\cdot A_{7,0}\cdot\left(\left|T7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T7-T_{OG}\right)+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T7^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}$$

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DBVS1CV™ Off-Gas Hood Thermal Analysis

j=8

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots = -0\ W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T8^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}+\xi_V\cdot\left(A_{8,0}+A_{8,2}\right)\cdot\left(\left|T8 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T8 - T_{amb}\right)\cdots$$

$$+\xi_{HU}\cdot A_{8,1}\cdot\left(\left|T8 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T8 - T_{amb}\right)+\xi_V\cdot A_{8,0}\cdot\left(\left|T8 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T8 - T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T8^4 - T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}$$

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j=9

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T9^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}+\zeta_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left(\left|T9-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{amb}\right)\ldots$$

$$+\zeta_{HU}\cdot A_{9,1}\cdot\left(\left|T9-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{amb}\right)+\zeta_{HD}\cdot A_{9,0}\cdot\left(\left|T9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T9^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

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$j := 10$

$T10 - T10 = 0\ K$

$j := 11$

$$\frac{A_{11,0}\cdot(T11 - T1)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T11^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{11,0}}\right) + \frac{1}{A_{11,0}}} + \xi_V\cdot A_{11,0}\cdot\left(|T11 - T_{amb}|\right)^{\frac{1}{3}}\cdot(T11 - T_{amb}) = 0\ W$$

$j := 12$

$$\frac{A_{12,0}\cdot(T12 - T2)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T12^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{12,0}}\right) + \frac{1}{A_{12,0}}} + \xi_V\cdot A_{12,0}\cdot\left(|T12 - T_{amb}|\right)^{\frac{1}{3}}\cdot(T12 - T_{amb}) = 0\ W$$

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j=13

$$\frac{A_{13,0}\cdot(T13 - T3)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T13^4 - T_{amb}^4\right)}{\left(\frac{1 - \varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{13,0}}\right) + \frac{1}{A_{13,0}}} + k_v\cdot A_{13,0}\cdot\left(\left|T13 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot(T13 - T_{amb}) = -0\ W$$

j=14

$$\frac{A_{14,0}\cdot(T14 - T4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T14^4 - T_{amb}^4\right)}{\left(\frac{1 - \varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right) + \frac{1}{A_{14,0}}} + k_v\cdot A_{14,0}\cdot\left(\left|T14 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot(T14 - T_{amb}) = -0\ W$$

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Total radiant heat loss from the melt surface ...

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T1^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots = -215.4\ \text{kW}$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T5^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T7^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T8^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}}}$$

$$F_{0,1}+F_{0,2}+F_{0,3}+F_{0,4}+F_{0,5}+F_{0,6}+F_{0,7}+F_{0,8}+F_{0,9}=1$$

Compute the average hood temperature ...

$$T_{HA} := \frac{A_{5,0}\cdot T5C+A_{6,0}\cdot T6C+A_{7,0}\cdot T7C+A_{8,0}\cdot T8C+A_{9,0}\cdot T9C}{A_{5,0}+A_{6,0}+A_{7,0}+A_{8,0}+A_{9,0}}$$

$T_{HA} = 398.9$ $\quad T_{HAF} := CtoF(T_{HA})$ $\quad T_{HAF} = 750$

APPENDIX H

MATHCAD MODEL FOR THE HRTS CONDITIONS WITH ADJUSTED MELT SURFACE TEMPERATURE AND LOWER MELT SURFACE LEVEL

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$°F = 1$

$°C = 1$

$CtoF(x) := \left(\frac{9}{5}\cdot\frac{x}{°C} + 32\right)°F$ $\quad CtoK(x) := \left(\frac{x}{°C} + 273.15\right)K$ $\quad KtoC(x) := \left(\frac{x}{K} - 273.15\right)°C$

$FtoC(x) := \frac{5}{9}\left(\frac{x}{°F} - 32\right)°C$ $\quad FtoR(x) := \left(\frac{x}{°F} + 459.67\right)R$

$w_1 := 5.5ft$ $\quad w_2 := 3.5ft$ $\quad L_1 := 22ft$ $\quad h_1 := 59in$ $\quad h_2 := 16in$ $\quad \theta := 52deg$ $\quad N_{ribs} := 12$ $\quad w_{ribs} := 2in$ $\quad h_{ribs} := 4in$

$\delta_{hood} := 0.3125in$ $\quad \Omega := 52deg$ $\quad \delta_{floor} := 3.5in$ $\quad \delta_{CR} := 6in$ $\quad \delta_{skid} := 6in$

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	121	0	0
1	27	0	0
2	108.2	0	0
3	27	0	0
4	108.2	0	0
5	6	0	0
6	37.2	3.4	13.6
7	6	0	0
8	37.2	3.4	13.6
9	77	7	28
10	322	0	0
11	27	0	0
12	108.2	0	0
13	27	0	0
14	108.2	0	0

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$$F_{ij} = \begin{pmatrix} 0 & .058 & .252 & .058 & .252 & .007 & .029 & .007 & .029 & .308 & 0 \\ .251 & 0 & .233 & .017 & .233 & 0 & .051 & .011 & .051 & .153 & 0 \\ .282 & .06 & 0 & .060 & .319 & .015 & .085 & .015 & .055 & .109 & 0 \\ .251 & .017 & .233 & 0 & .233 & .011 & .051 & 0 & .051 & .153 & 0 \\ .282 & .060 & .319 & .060 & 0 & .015 & .055 & .015 & .085 & .109 & 0 \\ .141 & 0 & .270 & .051 & .270 & 0 & .081 & .010 & .081 & .096 & 0 \\ .094 & .038 & .246 & .038 & .139 & .013 & 0 & .013 & .150 & .249 & .616 \\ .141 & .051 & .270 & 0 & .270 & .010 & .081 & 0 & .081 & .096 & 0 \\ .094 & .038 & .159 & .038 & .246 & .013 & .150 & .013 & 0 & .249 & .616 \\ .484 & .056 & .153 & .056 & .153 & .007 & .120 & .007 & .120 & 0 & 1 \end{pmatrix}$$

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 = 14 in) 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_{ij}

	0	1	2	3	4	5	6	7	8	9	10
0	0	0.058	0.252	0.058	0.252	0.007	0.029	0.007	0.029	0.308	0
1	0.251	0	0.233	0.017	0.233	0	0.051	0.011	0.051	0.153	0
2	0.282	0.06	0	0.06	0.319	0.015	0.085	0.015	0.055	0.109	0
3	0.251	0.017	0.233	0	0.233	0.011	0.051	0	0.051	0.153	0
4	0.282	0.06	0.319	0.06	0	0.015	0.055	0.015	0.085	0.109	0
5	0.141	0	0.27	0.051	0.27	0	0.081	0.01	0.081	0.096	0
6	0.094	0.038	0.246	0.038	0.159	0.013	0	0.013	0.15	0.249	0.616
7	0.141	0.051	0.27	0	0.27	0.01	0.081	0	0.081	0.096	0
8	0.094	0.038	0.159	0.038	0.246	0.013	0.15	0.013	0	0.249	0.616
9	0.484	0.056	0.153	0.056	0.153	0.007	0.12	0.007	0.12	0	1

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DBVS ICV™ Off-Gas Hood Thermal Analysis

Temperature Boundary Conditions ...

Tmelt := 1121°F	TmC := FtoC(Tmelt)	$T_{melt} := CtoK(TmC)$	$T_{melt} = 878.15\ K$
TAWTE := 77°F	TAC := FtoC(TAWTE)	$T_{AWTE} := CtoK(TAC)$	$T_{AWTE} = 298.1\ K$
TOG := 1112°F	Tog := FtoC(TOG)	$T_{OG} := CtoK(Tog)$	$T_{OG} = 873.15\ K$
	Tamb := 0°C	$T_{amb} := CtoK(Tamb)$	$T_{amb} = 273.1\ K$

Initial guess for temperatures ...

$T_0 := T_{melt}$

$T_1 := 773K$ $T_3 := 773K$ $T_5 := 773K$ $T_7 := 773K$ $T_9 := 773K$

$T_2 := 773K$ $T_4 := 773K$ $T_6 := 773K$ $T_8 := 773K$ $T_{10} := 773K$ (T_{10} not used in this model)

$T_{11} := 473K$ $T_{12} := 473K$ $T_{13} := 473K$ $T_{14} := 473K$

Material properties ...

$\sigma := 5.67 \cdot 10^{-8} \cdot \frac{W}{m^2 \cdot K^4}$

$\varepsilon_{melt} := 0.7$

$\varepsilon_{sil} := .85$ $k_{sil} := 60.5 \frac{W}{m \cdot K}$

$\varepsilon_{CR} := 0.66$ $k_{CR} := 1.44 \frac{W}{m \cdot K}$ $k_{annul} := 2 \frac{W}{m \cdot K}$

$\alpha_{OG} := 0$ $\tau_{OG} := 1 - \alpha_{OG}$ $\tau_{OG} = 1$

Convective heat transfer coefficients... $n := \frac{1}{3}$ $\xi_V := 1.32 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$ $\xi_{HD} := 0.691 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$ $\xi_{HU} := 1.52 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$

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$T_{amb} = 273.1\ K \qquad T_{OG} = 873.1\ K$

Given

$j = 1$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4} - T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4} - T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4} - T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} \ldots = 0$$

$$+ \frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4} - T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4} - T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,6}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4} - T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,7}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}} \ldots$$

$$+ \frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4} - T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,8}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T_1^{\,4} - T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,9}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} + \xi_V\cdot A_{1,0}\cdot\left(\left|T_1 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_1 - T_{OG}\right) \ldots$$

$$+ \frac{A_{1,0}\cdot\left(T_1 - T_{11}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{anxl}}{k_{anxl}}\right)} + \frac{\sigma\cdot\alpha_{OG}\cdot\left(T_1^{\,4} - T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}}}$$

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$j=2$

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_2^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_2^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_2^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_2^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_2^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_2^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}\cdots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_2^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_2^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_2^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\xi_V\cdot A_{2,0}\cdot\left(\left|T_2-T_{\infty}\right|\right)^{\frac{1}{3}}\cdot\left(T_2-T_{\infty}\right)+\frac{A_{2,0}\cdot\left(T_2-T_{12}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_2^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

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j=3

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_3^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_3^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_3^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_3^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_3^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_3^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_3^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_3^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{3,0}\cdot\left(\left|T_3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_3-T_{OG}\right)\cdots$$

$$+\frac{A_{3,0}\cdot\left(T_3-T_{13}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_3^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}$$

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j=4

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_4^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_4^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_4^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_4^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_4^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_4^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_4^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_4^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_4^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{A_{4,0}\cdot\left(T_4-T_{14}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V\cdot A_{4,0}\cdot\left(\left|T_4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_4-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_4^{\,4}-T_{OG}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}$$

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$j=5$

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_5^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\cdot\left(\left|T_5-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_5-T_{amb}\right)+\xi_V\cdot A_{5,0}\cdot\left(\left|T_5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_5-T_{OG}\right)+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}=0$$

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$j=6$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_6^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\cdot\left(\left|T_6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{amb}\right)\cdots$$

$$+\xi_{HU}\cdot A_{6,1}\cdot\left(\left|T_6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{amb}\right)+\xi_V\cdot A_{6,0}\cdot\left(\left|T_6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{OG}\right)+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

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j=7

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_5^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_7^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_7^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\cdot\left(\left|T_7-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_7-T_{amb}\right)+\xi_V\cdot A_{7,0}\cdot\left(\left|T_7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_7-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_7^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

j=8

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T_8^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}+\xi_V\cdot\left(A_{8,0}+A_{8,2}\right)\cdot\left(\left|T_8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{amb}\right)\ldots$$

$$+\xi_{HU}\cdot A_{8,1}\cdot\left(\left|T_8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{amb}\right)+\xi_V\cdot A_{8,0}\cdot\left(\left|T_8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_8-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_8^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}$$

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j=9

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_9^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{9,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_9^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_9^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_9^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_9^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_9^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_9^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_9^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_9^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_9^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}+\xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left(\left|T_9-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{amb}\right)\cdots$$

$$+\xi_{HU}\cdot A_{9,1}\cdot\left(\left|T_9-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{amb}\right)+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T_9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_9^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

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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

$$\frac{A_{12,0}\cdot(T_{12} - T_2)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T_{12}^4 - T_{amb}^4\right)}{\left(\frac{1 - \varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right) + \frac{1}{A_{12,0}}} + \xi_V\cdot A_{12,0}\cdot\left(\left|T_{12} - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{12} - T_{amb}\right) = 0$$

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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

$$\frac{A_{14,0}\cdot(T_{14}-T_4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{14}^{\,4}-T_{amb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{14,0}}}+\xi_V\cdot A_{14,0}\cdot\left(\left|T_{14}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot(T_{14}-T_{amb})=0$$

$$\begin{pmatrix} T1 \\ T2 \\ T3 \\ T4 \\ T5 \\ T6 \\ T7 \\ T8 \\ T9 \\ T10 \\ T11 \\ T12 \\ T13 \\ T14 \end{pmatrix} := \mathrm{Find}(T_1,T_2,T_3,T_4,T_5,T_6,T_7,T_8,T_9,T_{10},T_{11},T_{12},T_{13},T_{14})$$

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T1 = 751.3 K	T1C := KtoC(T1)	T1C = 478.1
T2 = 749.8 K	T2C := KtoC(T2)	T2C = 476.7
T3 = 751.3 K	T3C := KtoC(T3)	T3C = 478.1
T4 = 749.8 K	T4C := KtoC(T4)	T4C = 476.7
T5 = 626.8 K	T5C := KtoC(T5)	T5C = 353.6
T6 = 597.9 K	T6C := KtoC(T6)	T6C = 324.8
T7 = 626.9 K	T7C := KtoC(T7)	T7C = 353.7
T8 = 597.9 K	T8C := KtoC(T8)	T8C = 324.8
T9 = 643.2 K	T9C := KtoC(T9)	T9C = 370.1
T10 = 386.5 K	T10C := KtoC(T10)	T10C = 113.4
T11 = 404.6 K	T11C := KtoC(T11)	T11C = 131.4
T12 = 404.3 K	T12C := KtoC(T12)	T12C = 131.1
T13 = 404.6 K	T13C := KtoC(T13)	T13C = 131.4
T14 = 404.3 K	T14C := KtoC(T14)	T14C = 131.1

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)

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Results in °F ...

T1F = 892.634 T2F = 890.051 T3F = 892.634 T4F = 890.051 T5F = 668.543 T6F = 616.625

T7F = 668.678 T8F = 616.625 T9F = 698.141 T10F = 236 T11F = 268.5 T12F = 268 T13F = 268.5 T14F = 268

Check results ...

$T0 := T_{melt}$ T0 = 878.1 K

T1 = 751.3 K T2 = 749.8 K T3 = 751.3 K T4 = 749.8 K T5 = 626.8 K T6 = 597.9 K

T7 = 626.9 K T8 = 597.9 K T9 = 643.2 K T10 = 386.5 K T11 = 404.6 K T12 = 404.3 K T13 = 404.6 K

T14 = 404.3 K T_{AWTE} = 298.1 K T_{amb} = 273.1 K T_{OG} = 873.1 K

j=1

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots = 0\ W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}\cdot F_{1,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\zeta_V\cdot A_{1,0}\cdot\left(\left|T1 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T1 - T_{OG}\right)\ldots$$

$$+\frac{A_{1,0}\cdot(T1 - T11)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4 - T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)+\frac{1}{A_{1,0}}}$$

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j=2

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots=-0\ W$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\xi_v\cdot A_{2,0}\cdot\left(\left|T2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T2-T_{OG}\right)+\frac{A_{2,0}\cdot(T2-T12)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{stand}}{k_{stand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T2^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

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j=3

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4 - T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4 - T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots = -Q\ W$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4 - T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{3,0}\cdot\left(\left|T3 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T3 - T_{OG}\right)\ldots$$

$$+\frac{A_{3,0}\cdot(T3 - T13)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{mnd}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T3^4 - T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}$$

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j=4

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots \approx -0\ W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{A_{4,0}\cdot(T4-T14)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V\cdot A_{4,0}\cdot\left(\left|T4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T4-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T4^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

j=5

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T0^4\right)}{\left(\frac{1-\varepsilon_{molt}}{\varepsilon_{molt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T5^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\cdot\left(\left|T5-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T5-T_{amb}\right)+\xi_V\cdot A_{5,0}\cdot\left(\left|T5-T_{OO}\right|\right)^{\frac{1}{3}}\cdot\left(T5-T_{OO}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T5^4-T_{OO}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}=0\ W$$

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j=6

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T0^4\right)}{\left(\frac{1-\varepsilon_{molt}}{\varepsilon_{molt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots = -0\ W$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T6^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T6^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\cdot\left(\left|T6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{amb}\right)\ldots$$

$$+\xi_{HU}\cdot A_{6,1}\cdot\left(\left|T6-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{amb}\right)+\xi_V\cdot A_{6,0}\cdot\left(\left|T6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T6^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}$$

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j=7

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots = -0\ W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T7^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\cdot\left(\left|T7-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T7-T_{amb}\right)+\xi_V\cdot A_{7,0}\cdot\left(\left|T7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T7-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T7^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}$$

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j=8

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots = -0\ W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T8^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}+\zeta_V\cdot\left(A_{8,0}+A_{8,2}\right)\cdot\left(\left|T8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T8-T_{amb}\right)\cdots$$

$$+\zeta_{HTJ}\cdot A_{8,1}\cdot\left(\left|T8-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T8-T_{amb}\right)+\zeta_V\cdot A_{8,0}\cdot\left(\left|T8-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T8-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T8^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)+\frac{1}{A_{8,0}}}$$

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$j=9$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{mult}}{\varepsilon_{mult}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots = -0.1V$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T9^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}+\xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left(\left|T9-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{amb}\right)\ldots$$

$$+\xi_{HU}\cdot A_{9,1}\cdot\left(\left|T9-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{amb}\right)+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{OG}\right)+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T_{OG}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

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j=10

$$T10 - T10 = 0\ K$$

j=11

$$\frac{A_{11,0}\cdot(T11 - T1)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T11^4 - T_{amb}^4\right)}{\left(\frac{1 - \varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{11,0}}\right) + \frac{1}{A_{11,0}}} + \xi_V\cdot A_{11,0}\cdot\left(\left|T11 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T11 - T_{amb}\right) = 0\ W$$

j=12

$$\frac{A_{12,0}\cdot(T12 - T2)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T12^4 - T_{amb}^4\right)}{\left(\frac{1 - \varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right) + \frac{1}{A_{12,0}}} + \xi_V\cdot A_{12,0}\cdot\left(\left|T12 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T12 - T_{amb}\right) = -0\ W$$

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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

$$\frac{A_{14,0}\cdot(T14 - T4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T14^4 - T_{amb}^4\right)}{\left(\frac{1 - \varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right) + \frac{1}{A_{14,0}}} + \xi_V\cdot A_{14,0}\cdot\left(\left|T14 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T14 - T_{amb}\right) = -0\ W$$

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DBVS ICV™ Off-Gas Hood Thermal Analysis

Total radiant heat loss from the melt surface ...

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T1^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T2^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots \approx -177.9\,KW$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T4^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T5^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{6,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T7^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{9,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}}}$$

$$F_{0,1}+F_{0,2}+F_{0,3}+F_{0,4}+F_{0,5}+F_{0,6}+F_{0,7}+F_{0,8}+F_{0,9}=1$$

Compute the average hood temperature ...

$$T_{HA}:=\frac{A_{5,0}\cdot T5C+A_{6,0}\cdot T6C+A_{7,0}\cdot T7C+A_{8,0}\cdot T8C+A_{9,0}\cdot T9C}{A_{5,0}+A_{6,0}+A_{7,0}+A_{8,0}+A_{9,0}}$$

$T_{HA}\approx 348.2$ $\quad T_{HAF}:=CtoF(T_{HA})$ $\quad T_{HAF}=658.8$

APPENDIX I

MATHCAD MODEL FOR THE DBVS CONDITIONS WITH ADJUSTED MELT SURFACE TEMPERATURE

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DBVS Off-Gas Hood Thermal Model

°F := 1

°C := 1

$CtoF(x) := \left(\frac{9}{5}\frac{x}{°C} + 32\right)°F$ $CtoK(x) := \left(\frac{x}{°C} + 273.15\right)K$ $KtoC(x) := \left(\frac{x}{K} - 273.15\right)°C$

$FtoC(x) := \frac{5}{9}\left(\frac{x}{°F} - 32\right)°C$ $FtoR(x) := \left(\frac{x}{°F} + 459.67\right)R$

$w_1 := 5.5ft$ $w_2 := 3.5ft$ $L_1 := 22ft$ $h_1 := 14in$ $h_2 := 16in$ $\theta := 52deg$ $N_{ribs} := 12$ $w_{ribs} := 2in$ $h_{ribs} := 4in$

$\delta_{hood} := 0.31.25in$ $\Omega := 52deg$ $\delta_{floor} := 3.3in$ $\delta_{CR} := 6in$ $\delta_{sand} := 6in$

Matrix of surface areas ... $A := \begin{bmatrix} w_1 \cdot L_1 & 0 & 0 \\ w_1 \cdot h_1 & 0 & 0 \\ L_1 \cdot h_1 & 0 & 0 \\ w_1 \cdot h_1 & 0 & 0 \\ L_1 \cdot h_1 & 0 & 0 \\ \frac{(w_1 + w_2) \cdot h_2}{2} & 0 & 0 \\ L_1 \cdot \frac{h_2}{\sin(\theta)} & N_{ribs} \cdot w_{ribs} \cdot \frac{h_2}{\sin(\theta)} & 2N_{ribs} \cdot h_{ribs} \cdot \frac{h_2}{\sin(\theta)} \\ \frac{(w_1 + w_2) \cdot h_2}{2} & 0 & 0 \\ L_1 \cdot \frac{h_2}{\sin(\theta)} & N_{ribs} \cdot w_{ribs} \cdot \frac{h_2}{\sin(\theta)} & 2N_{ribs} \cdot h_{ribs} \cdot \frac{h_2}{\sin(\theta)} \\ w_2 \cdot L_1 & N_{rib} \cdot w_{rib} \cdot w_2 & 2N_{rib} \cdot h_{rib} \cdot w_2 \\ (3ft + w_1 + 3ft) \cdot (3ft + L_1 + 3ft) & 0 & 0 \\ w_1 \cdot h_1 & 0 & 0 \\ L_1 \cdot h_1 & 0 & 0 \\ w_1 \cdot h_1 & 0 & 0 \\ L_1 \cdot h_1 & 0 & 0 \end{bmatrix}$

The first column of det 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.

$A =$

0	121	0	0
1	8.4	0	0
2	25.7	0	0
3	8.4	0	0
4	25.7	0	0
5	8	0	0
6	37.2	3.4	13.5
7	8	0	0
8	37.2	3.4	13.6
9	77	7	28
10	322	0	0
11	8.4	0	0
12	25.7	0	0
13	8.4	0	0
14	25.7	0	0

ft^2

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DBVS Off-Gas Hood Thermal Model

$$F_{i,j} = \begin{pmatrix} 0 & .021 & .091 & .021 & .091 & .028 & .177 & .028 & .177 & .366 & 0 \\ .397 & 0 & .026 & .004 & .026 & 0 & .129 & .021 & .129 & .265 & 0 \\ .428 & .006 & 0 & .006 & .052 & .019 & .039 & .019 & .077 & .354 & 0 \\ .400 & .004 & .026 & 0 & .026 & .021 & .129 & 0 & .129 & .265 & 0 \\ .428 & .006 & .052 & .006 & 0 & .019 & .077 & .019 & .039 & .354 & 0 \\ .565 & 0 & .081 & .022 & .081 & 0 & .081 & .003 & .081 & .086 & 0 \\ .575 & .022 & .027 & .022 & .053 & .013 & 0 & .013 & .015 & .125 & .616 \\ .565 & .022 & .081 & 0 & .081 & .003 & .081 & 0 & .081 & .086 & 0 \\ .575 & .022 & .053 & .022 & .027 & .013 & .150 & .013 & 0 & .125 & .616 \\ .574 & .022 & .118 & .022 & .118 & .013 & .060 & .013 & .060 & 0 & 1 \end{pmatrix}$$

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.

$F_{i,j}$

	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

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DBVS Off-Gas Hood Thermal Model

Temperature Boundary Conditions ...

$Tmelt := 1157°F$	$TmC := FtoC(Tmelt)$	$T_{melt} := CtoK(TmC)$	$T_{melt} = 898.15\ K$
$TAWTB := 77°F$	$TAC := FtoC(TAWTB)$	$T_{AWTB} := CtoK(TAC)$	$T_{AWTB} = 298.1\ K$
$TOG := 1112°F$	$Tog := FtoC(TOG)$	$T_{OG} := CtoK(Tog)$	$T_{OG} = 873.15\ K$
	$Tamb := 50°C$	$T_{amb} := CtoK(Tamb)$	$T_{amb} = 323.1\ K$

Initial guess for temperatures ...

$T_0 := T_{melt}$ $\quad T_0 = 898.15\ K$

$T_1 := 773K$ $\quad T_3 := 773K$ $\quad T_5 := 773K$ $\quad T_7 := 773K$ $\quad T_9 := 773K$

$T_2 := 773K$ $\quad T_4 := 773K$ $\quad T_6 := 773K$ $\quad T_8 := 773K$ $\quad T_{10} := 773K$

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$T_{11} := 473K$ $T_{12} := 473K$ $T_{13} := 473K$ DBVS Off-Gas Hood Thermal Model $T_{14} := 473K$ $T_{15} := T_{OG}$

Material properties ...

$\varepsilon_{melt} := .07$ $\sigma := 5.67 \cdot 10^{-8} \cdot \frac{W}{m^2 \cdot K^4}$

$\varepsilon_{stl} := .85$ $k_{stl} := 60.5 \frac{W}{m \cdot K}$

$\varepsilon_{CR} := 0.66$ $k_{CR} := 1.44 \frac{W}{m \cdot K}$ $k_{sand} := 2 \frac{W}{m \cdot K}$

$\alpha_{OG} := 0$ $\tau_{OG} := 1 - \alpha_{OG}$ $\tau_{OG} = 1$

Convective heat transfer coefficients

$n := \frac{1}{3}$ $\xi_V := 1.32 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$ $\xi_{HD} := 0.691 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$ $\xi_{HU} := 1.52 \cdot W \cdot m^{-2} \cdot K^{-\frac{4}{3}}$

$T_{amb} = 323.1\ K$ $T_{OG} = 873.1\ K$

Given

j=1

$$\frac{\sigma \cdot \tau_{OG} \cdot \left(T_1^4 - T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt} \cdot A_{0,0}}\right) + \frac{1}{A_{0,0} \cdot F_{0,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T_1^4 - T_2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0} \cdot F_{1,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{2,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T_1^4 - T_3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0} \cdot F_{1,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{3,0}}\right)} \ldots = 0$$

$$+ \frac{\sigma \cdot \tau_{OG} \cdot \left(T_1^4 - T_4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0} \cdot F_{1,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{4,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T_1^4 - T_6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0} \cdot F_{1,6}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{6,0}}\right)} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T_1^4 - T_7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \frac{1}{A_{1,0} \cdot F_{1,7}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl} \cdot A_{7,0}}} \ldots$$

$$+ \frac{\sigma \cdot \tau_{OG} \cdot \left(T_1^4 - T_8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\ }\right) \cdot \frac{1}{\ } \cdot \frac{1-\varepsilon_{stl}}{\ }} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T_1^4 - T_9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\ }\right) \cdot \frac{1}{\ } \cdot \frac{1-\varepsilon_{stl}}{\ }} + \xi_V \cdot A_{1,0} \cdot \left(\left|T_1 - T_{OG}\right|\right)^{\frac{1}{3}} \cdot \left(T_1 - T_{OG}\right) \ldots$$

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$$\left(\frac{\varepsilon_{CR}\cdot A_{1,0}}{}\right) \cdot \frac{}{A_{1,0}\cdot F_{1,R}} + \frac{}{\varepsilon_{wall}\cdot A_{g,0}} \left(\frac{\varepsilon_{CR}\cdot A_{1,0}}{}\right) \cdot \frac{}{A_{1,0}\cdot F_{1,0}} + \frac{}{\varepsilon_{wall}\cdot A_{g,0}}$$

$$A_{1,0}\left(T_1 - T_{11}\right) = \sigma\cdot\varepsilon_{OG}\cdot\left(T_1^{\,4} - T_{15}^{\,4}\right) \Big/ \left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right) + \left(\frac{1 - \varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}}$$

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DBVS Off-Gas Hood Thermal Model

$j=2$

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_2^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_2^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_2^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_2^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_2^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{sll}}{\varepsilon_{sll}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_2^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{sll}}{\varepsilon_{sll}\cdot A_{6,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_2^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{sll}}{\varepsilon_{sll}\cdot A_{7,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_2^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{sll}}{\varepsilon_{sll}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_2^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{sll}}{\varepsilon_{sll}\cdot A_{9,0}}}\ldots$$

$$+\xi_V\cdot A_{2,0}\cdot\left(\left|T_2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_2-T_{OG}\right)+\frac{A_{2,0}\cdot\left(T_2-T_{12}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k'_{sand}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_2^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

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j=3

DBVS Off-Gas Hood Thermal Model

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_3^{\,4}-T_9^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{3,0}\cdot\left(\left|T_3-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_3-T_{OG}\right)\ldots$$

$$+\frac{A_{3,0}\cdot\left(T_3-T_{13}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{wind}}{k_{wind}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_3^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}$$

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DBVS Off-Gas Hood Thermal Model

$j = 4$

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_4^4 - T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_4^4 - T_1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_4^4 - T_2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots = 0$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_4^4 - T_3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_4^4 - T_5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_4^4 - T_6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\ldots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_4^4 - T_7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_4^4 - T_8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_4^4 - T_9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\frac{A_{4,0}\cdot\left(T_4 - T_{1,4}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_V\cdot A_{4,0}\cdot\left(\left|T_4 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_4 - T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_4^4 - T_{1.5}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}$$

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DBVS Off-Gas Hood Thermal Model

$j=5$

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}\cdot F_{5,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_5^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}+\xi_V\cdot A_{5,0}\cdot\left[\left|T_5-\left(\frac{T_5+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_5-\left(\frac{T_5+T_{10}}{2}\right)\right]+\xi_V\cdot A_{5,0}\cdot\left(\left|T_5-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_5-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_5^4-T_{1,5}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)+\frac{1}{A_{5,0}}}=0$$

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DBVS Off-Gas Hood Thermal Model

$j=6$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{molt}}{\varepsilon_{molt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_6^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_6^4-T_{10}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T_6^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot\left(1-F_{6,10}\right)}}+\xi_V\cdot\left(A_{8,0}+A_{6,2}\right)\cdot\left[\left[T_6-\left(\frac{T_6+T_{10}}{2}\right)\right]\right]^{\frac{1}{3}}\cdot\left[T_6-\left(\frac{T_6+T_{10}}{2}\right)\right]\cdots$$

$$+\xi_{HT}\cdot A_{6,1}\cdot\left[\left[T_6-\left(\frac{T_6+T_{10}}{2}\right)\right]\right]^{\frac{1}{3}}\cdot\left[T_6-\left(\frac{T_6+T_{10}}{2}\right)\right]+\xi_V\cdot A_{6,0}\cdot\left(\left|T_6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_6^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}=0$$

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DBVS Off-Gas Hood Thermal Model

$i=7$

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_7^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_5^4-T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_7^4-T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_7^4-T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_7^4-T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_7^4-T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_7^4-T_8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T_7^4-T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}\cdot F_{7,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T_7^4-T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}+\xi_V\cdot A_{7,0}\cdot\left[\left|T_7-\left(\frac{T_7+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_7-\left(\frac{T_7+T_{10}}{2}\right)\right]+\xi_V\cdot A_{7,0}\cdot\left(\left|T_7-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_7-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_7^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}\right)+\frac{1}{A_{7,0}}}=0$$

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DBVS Off-Gas Hood Thermal Model

$i = 8$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4 - T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,8}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4 - T_1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4 - T_2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \ldots$$

$$+ \frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4 - T_3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4 - T_4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4 - T_5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,5}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}} \ldots$$

$$+ \frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4 - T_6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,6}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4 - T_7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,7}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T_8^4 - T_9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,9}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} \ldots$$

$$+ \frac{\sigma\cdot\left(T_8^4 - T_{10}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,10}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)} + \frac{\sigma\cdot\left(T_8^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot\left(1-F_{8,10}\right)}} + \zeta_V\cdot\left(A_{8,0} + A_{8,2}\right)\cdot\left[\left|T_8 - \left(\frac{T_8 + T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_8 - \left(\frac{T_8 + T_{10}}{2}\right)\right] \ldots$$

$$+ \zeta_{TTU}\cdot A_{8,1}\cdot\left[\left|T_8 - \left(\frac{T_8 + T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_8 - \left(\frac{T_8 + T_{10}}{2}\right)\right] + \zeta_V\cdot A_{8,0}\cdot\left(\left|T_8 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_8 - T_{OG}\right) + \frac{\sigma\cdot\alpha_{OG}\cdot\left(T_8^4 - T_{15}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}}} = 0$$

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DBVS Off-Gas Hood Thermal Model

$i=9$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_1^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_2^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\ldots=0$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_3^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_4^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_5^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\ldots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_6^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_7^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T_9^{\,4}-T_8^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T_9^{\,4}-T_{10}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\xi_{VT}\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left[\left|T_9-\left(\frac{T_9+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_9-\left(\frac{T_9+T_{10}}{2}\right)\right]\ldots$$

$$+\xi_{HU}\cdot A_{9,1}\cdot\left[\left|T_9-\left(\frac{T_9+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_9-\left(\frac{T_9+T_{10}}{2}\right)\right]+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T_9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T_9-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T_9^{\,4}-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

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DBVS Off-Gas Hood Thermal Model

j=10

$$\frac{\sigma\cdot\left(T_{10}^{4}-T_{6}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\left(T_{10}^{4}-T_{8}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{8,0}\cdot F_{8,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\ldots$$

$$+\frac{\sigma\cdot\left(T_{10}^{4}-T_{9}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\frac{\sigma\cdot\left(T_{10}^{4}-T_{amb}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)+\frac{1}{A_{10,0}\cdot\left(1-\frac{A_{6,0}\cdot F_{6,10}}{A_{10,0}}-\frac{A_{8,0}\cdot F_{8,10}}{A_{10,0}}-\frac{A_{9,0}\cdot F_{9,10}}{A_{10,0}}\right)}}\ldots$$

$$+\zeta_{HD}\cdot A_{10,0}\cdot\left[\left|T_{10}-\left(\frac{T_9+T_{10}}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T_{10}-\left(\frac{T_9+T_{10}}{2}\right)\right]+\frac{A_{10,0}\cdot\left(T_{10}-T_{AWTB}\right)}{\frac{\delta_{floor}}{k_{stl}}}=0$$

j=11

$$\frac{A_{11,0}\cdot\left(T_{11}-T_{1}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{11}^{4}-T_{amb}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{11,0}}\right)+\frac{1}{A_{11,0}}}+\zeta_{V}\cdot A_{11,0}\cdot\left(\left|T_{11}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{11}-T_{amb}\right)=0$$

j=12

$$\frac{A_{12,0}\cdot\left(T_{12}-T_{2}\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{12}^{4}-T_{amb}^{4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right)+\frac{1}{A_{12,0}}}+\zeta_{V}\cdot A_{12,0}\cdot\left(\left|T_{12}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{12}-T_{amb}\right)=0$$

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j=13

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$$\frac{A_{13,0}\cdot(T_{13}-T_3)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{13}^4-T_{amb.}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{13,0}}\right)+\frac{1}{A_{13,0}}}+\xi_V\cdot A_{13,0}\cdot\left(\left|T_{13}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{13}-T_{amb}\right)=0$$

j=14

$$\frac{A_{14,0}\cdot(T_{14}-T_4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\left(T_{14}^4-T_{amb.}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right)+\frac{1}{A_{14,0}}}+\xi_V\cdot A_{14,0}\cdot\left(\left|T_{14}-T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T_{14}-T_{amb}\right)=0$$

$$\begin{pmatrix} T1 \\ T2 \\ T3 \\ T4 \\ T5 \\ T6 \\ T7 \\ T8 \\ T9 \\ T10 \\ T11 \\ T12 \\ T13 \\ T14 \end{pmatrix} := Find(T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{12}, T_{13}, T_{14})$$

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T1 = 782.4 K	T1C := KtoC(T1)	T1C = 509.2
T2 = 788.7 K	T2C := KtoC(T2)	T2C = 515.5
T3 = 782.4 K	T3C := KtoC(T3)	T3C = 509.2
T4 = 788.7 K	T4C := KtoC(T4)	T4C = 515.5
T5 = 712.7 K	T5C := KtoC(T5)	T5C = 439.5
T6 = 696.9 K	T6C := KtoC(T6)	T6C = 423.7
T7 = 712.7 K	T7C := KtoC(T7)	T7C = 439.5
T8 = 696.9 K	T8C := KtoC(T8)	T8C = 423.7
T9 = 701.7 K	T9C := KtoC(T9)	T9C = 428.6
T10 = 305.6 K	T10C := KtoC(T10)	T10C = 32.5
T11 = 434.9 K	T11C := KtoC(T11)	T11C = 161.7
T12 = 436.1 K	T12C := KtoC(T12)	T12C = 162.9
T13 = 434.9 K	T13C := KtoC(T13)	T13C = 161.7
T14 = 436.1 K	T14C := KtoC(T14)	T14C = 162.9

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 = 948.574 T2F = 959.978 T3F = 948.574 T4F = 959.978 T5F = 823.158 T6F = 794.676

T7F = 823.158 T8F = 794.676 T9F = 803.426 T10F = 90.5 T11F = 323.1 T12F = 325.2 T13F = 323.1 T14F = 325.2

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Check results...

$T_0 = 898.1$ K

$T1 = 782.4$ K $T2 = 788.7$ K $T3 = 782.4$ K $T4 = 788.7$ K $T5 = 712.7$ K $T6 = 696.9$ K

$T7 = 712.7$ K $T8 = 696.9$ K $T9 = 701.7$ K $T10 = 305.6$ K $T11 = 434.9$ K $T12 = 436.1$ K $T13 = 434.9$ K

$T14 = 436.1$ K $T_{AWTR} = 298.1$ K $T_{amb} = 323.1$ K $T_{OG} = 873.1$ K

j=1

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T1^4 - T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)} + \frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T1^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} + \frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T1^4 - T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} \ldots = 0\ \mathrm{W}$$

$$+ \frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T1^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)} + \frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T1^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,6}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)} + \frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T1^4 - T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,7}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}} \ldots$$

$$+ \frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T1^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,8}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}} + \frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T1^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}\cdot F_{1,9}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} + \xi_V\cdot A_{1,0}\cdot\left(\left|T1 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T1 - T_{OG}\right) \ldots$$

$$+ \frac{A_{1,0}\cdot(T1 - T11)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\alpha_{OG}\cdot\left(T1^4 - T_{15}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right) + \frac{1}{A_{1,0}}}$$

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j=2

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}\ldots = 0\ W$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}\ldots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T2^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}\cdot F_{2,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\ldots$$

$$+\xi\cdot A_{2,0}\cdot\left(\left|T2-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T2-T_{OG}\right)+\frac{A_{2,0}\cdot\left(T2-T12\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T2^4-T_{15}^4\right)}{\left(\frac{1-\alpha_{CR}}{\alpha_{CR}\cdot A_{2,0}}\right)+\frac{1}{A_{2,0}}}$$

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DBVS Off-Gas Hood Thermal Model

j=3

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4 - T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4 - T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots = -0\ W$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4 - T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,5}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T3^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}\cdot F_{3,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}+\xi_V\cdot A_{3,0}\cdot\left(\left|T3 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T3 - T_{OG}\right)\cdots$$

$$+\frac{A_{3,0}\cdot(T3 - T13)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T3^4 - T_{15}^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)+\frac{1}{A_{3,0}}}$$

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$i=4$

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T1^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T2^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=0\ W$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T3^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T5^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,5}}+\left(\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T6^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,6}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{6,0}}}\cdots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T7^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,7}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{7,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T8^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,8}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{8,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T9^4\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}\cdot F_{4,9}}+\frac{1-\varepsilon_{sil}}{\varepsilon_{sil}\cdot A_{9,0}}}\cdots$$

$$+\frac{A_{4,0}\cdot\left(T4-T14\right)}{\left(\frac{\delta_{CR}}{k_{CR}}\right)+\left(\frac{\delta_{sand}}{k_{sand}}\right)}+\xi_{OG}\cdot A_{4,0}\cdot\left(\left|T4-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T4-T_{OG}\right)+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T4^4-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)+\frac{1}{A_{4,0}}}$$

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j=5

$$= -0\ W$$

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T5^4 - T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,5}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right)} + \frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T5^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right) + \frac{1}{A_{5,0}\cdot F_{5,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \cdots$$

$$+ \frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T5^4 - T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right) + \frac{1}{A_{5,0}\cdot F_{5,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} + \frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T5^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right) + \frac{1}{A_{5,0}\cdot F_{5,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)} + \frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T5^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right) + \frac{1}{A_{5,0}\cdot F_{5,6}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}} \cdots$$

$$+ \frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T5^4 - T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right) + \frac{1}{A_{5,0}\cdot F_{5,7}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}} + \frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T5^4 - T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right) + \frac{1}{A_{5,0}\cdot F_{5,8}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}} + \frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T5^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right) + \frac{1}{A_{5,0}\cdot F_{5,9}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} \cdots$$

$$+ \frac{\sigma\cdot\left(T5^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right) + \frac{1}{A_{5,0}}} + \xi_V\cdot A_{5,0}\cdot\left[T5 - \left(\frac{T5+T10}{2}\right)\right]\cdot\left[T5 - \left(\frac{T5+T10}{2}\right)\right]^{\frac{1}{3}} + \xi_V\cdot A_{5,0}\cdot\left(\left|T5 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T5 - T_{OG}\right) + \frac{\sigma\cdot\alpha_{OG}\cdot\left(T5^4 - T_{15}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}\right) + \frac{1}{A_{5,0}}}$$

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DBVS Off-Gas Hood Thermal Model

$$i=6$$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T_0^{\,4}\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}+\frac{\sigma\cdot\tau_{OG}\cdot\left(T6^4-T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,9}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T6^4-T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot F_{6,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\frac{\sigma\cdot\left(T6^4-T_{runb}^{\,4}\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}\cdot\left(1-F_{6,10}\right)}}+\xi_V\cdot\left(A_{6,0}+A_{6,2}\right)\cdot\left[\left|T6-\left(\frac{T6+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T6-\left(\frac{T6+T10}{2}\right)\right]\cdots$$

$$+\xi_H\cdot F\cdot A_{6,1}\cdot\left[\left|T6-\left(\frac{T6+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T6-\left(\frac{T6+T10}{2}\right)\right]+\xi_V\cdot A_{6,0}\cdot\left(\left|T6-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T6-T_{OG}\right)+\frac{\sigma\cdot\alpha_{OG}\cdot\left(T6^4-T_{15}^{\,4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{stl}\cdot A_{6,0}}\right)+\frac{1}{A_{6,0}}}=0\ W$$

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$$\frac{\sigma \cdot \tau_{OG} \cdot \left(T_{17}^{4} - T_{12}^{4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{2,0}}\right) + \left(\frac{1-\varepsilon_{ill}}{\varepsilon_{ill} \cdot A_{7,0}}\right) + \frac{1}{A_{7,0} \cdot F_{7,2}}} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T_{17}^{4} - T_{16}^{4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \left(\frac{1-\varepsilon_{ill}}{\varepsilon_{ill} \cdot A_{7,0}}\right) + \frac{1}{A_{7,0} \cdot F_{7,1}}} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T_{17}^{4} - T_{15}^{4}\right)}{\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR} \cdot A_{1,0}}\right) + \left(\frac{1-\varepsilon_{ill}}{\varepsilon_{ill} \cdot A_{7,0}}\right) + \frac{1}{A_{7,0} \cdot F_{7,6}}} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T_{17}^{4} - T_{14}^{4}\right)}{\left(\frac{1-\varepsilon_{ill}}{\varepsilon_{ill} \cdot A_{7,0}}\right) + \left(\frac{1-\varepsilon_{ill}}{\varepsilon_{ill} \cdot A_{7,0}}\right) + \frac{1}{A_{7,0} \cdot F_{7,4}}} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T_{17}^{4} - T_{13}^{4}\right)}{\left(\frac{1-\varepsilon_{ill}}{\varepsilon_{ill} \cdot A_{7,0}}\right) + \left(\frac{1-\varepsilon_{ill}}{\varepsilon_{ill} \cdot A_{7,0}}\right) + \frac{1}{A_{7,0} \cdot F_{7,8}}} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T_{17}^{4} - T_{9}^{4}\right)}{\left(\frac{1-\varepsilon_{ill}}{\varepsilon_{ill} \cdot A_{7,0}}\right) + \frac{1}{A_{7,0} \cdot F_{7,9}} + \frac{1-\varepsilon_{ill}}{\varepsilon_{ill} \cdot A_{9,0}}} + \frac{\sigma \cdot \tau_{OG} \cdot \left(T_{17}^{4} - T_{15}^{4}\right)}{\left(\frac{1-\varepsilon_{ill}}{\varepsilon_{ill} \cdot A_{7,0}}\right) + \frac{1}{A_{7,0}}}$$

$$+ \frac{\sigma \cdot \left(T_{17}^{4} - T_{amb}^{4}\right)}{\left(\frac{1-\varepsilon_{ill}}{\varepsilon_{ill} \cdot A_{7,0}}\right) + \frac{1}{A_{7,0}}} + \xi_{V} \cdot A_{7,0} \cdot \left[T_{17} - \left(\frac{T_{17} + T_{10}}{2}\right)\right] + \xi_{V} \cdot A_{7,0} \cdot \left(\left|T_{17} - T_{OG}\right|\right)^{\frac{1}{3}} \cdot \left[T_{17} - \left(\frac{T_{17} + T_{10}}{2}\right)\right]^{\frac{1}{3}} \cdot \left(T_{17} - T_{OG}\right) + \frac{\sigma \cdot \varepsilon_{OG} \cdot \left(T_{17}^{4} - T_{15}^{4}\right)}{\left(\frac{1-\varepsilon_{ill}}{\varepsilon_{ill} \cdot A_{7,0}}\right) + \frac{1}{A_{7,0}}}$$

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DBVS Off-Gas Hood Thermal Model

$i = 8$

$$\frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T_0^4\right)}{\left(\frac{1-\varepsilon_{melt}}{\varepsilon_{melt}\cdot A_{0,0}}\right) + \frac{1}{A_{0,0}\cdot F_{0,8}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,1}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,2}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)} \ldots$$

$$+ \frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,3}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,4}} + \left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,5}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}} \ldots$$

$$+ \frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,6}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,7}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}} + \frac{\sigma\cdot\tau_{OG}\cdot\left(T8^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,9}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} \ldots$$

$$+ \frac{\sigma\cdot\left(T8^4 - T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,10}} + \left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)} + \frac{\sigma\cdot\left(T8^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}\cdot\left(1 - F_{8,10}\right)}} + \xi_V\cdot\left(A_{8,0} + A_{8,2}\right)\cdot\left[T8 - \left(\frac{T8 + T10}{2}\right)\right]^{\frac{1}{3}}\cdot\left[T8 - \left(\frac{T8 + T10}{2}\right)\right] \ldots$$

$$+ \xi_{HU}\cdot A_{8,1}\cdot\left[T8 - \left(\frac{T8 + T10}{2}\right)\right]^{\frac{1}{3}}\cdot\left[T8 - \left(\frac{T8 + T10}{2}\right)\right] + \xi_V\cdot A_{8,0}\cdot\left(\left|T8 - T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T8 - T_{OG}\right) + \frac{\sigma\cdot\alpha_{OG}\cdot\left(T8^4 - T_{15}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}\right) + \frac{1}{A_{8,0}}} = 0.W$$

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DBVS Off-Gas Hood Thermal Model

$$j=9$$

$$\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T9^4-T0^4\right)}{\left(\frac{1-\varepsilon_{mult}}{\varepsilon_{mult}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T9^4-T1^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,1}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T9^4-T2^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,2}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{2,0}}\right)}\cdots=-0\ \mathrm{W}$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T9^4-T3^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,3}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{3,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T9^4-T4^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,4}}+\left(\frac{1-\varepsilon_{CR}}{\varepsilon_{CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T9^4-T5^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,5}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{5,0}}}\cdots$$

$$+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T9^4-T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,6}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T9^4-T7^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,7}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{7,0}}}+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T9^4-T8^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,8}}+\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}}\cdots$$

$$+\frac{\sigma\cdot\left(T9^4-T10^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}\cdot F_{9,10}}+\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right)}+\xi_V\cdot\left(A_{9,0}+A_{9,2}\right)\cdot\left[T9-\left(\frac{T9+T10}{2}\right)\right]^{\frac{1}{3}}\cdot\left[T9-\left(\frac{T9+T10}{2}\right)\right]\cdots$$

$$+\xi_{FTU}\cdot A_{9,1}\cdot\left[T9-\left(\frac{T9+T10}{2}\right)\right]^{\frac{1}{3}}\cdot\left[T9-\left(\frac{T9+T10}{2}\right)\right]+\xi_{HD}\cdot A_{9,0}\cdot\left(\left|T9-T_{OG}\right|\right)^{\frac{1}{3}}\cdot\left(T9-T_{OG}\right)+\frac{\sigma\cdot\varepsilon_{OG}\cdot\left(T9^4-T_{15}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}\right)+\frac{1}{A_{9,0}}}$$

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DBVS Off-Gas Hood Thermal Model

j=10

$$\frac{\sigma\cdot\left(T10^4 - T6^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right) + \frac{1}{A_{6,0}\cdot F_{6,10}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{6,0}}} + \frac{\sigma\cdot\left(T10^4 - TR^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right) + \frac{1}{A_{8,0}\cdot F_{8,10}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{8,0}}} \ldots = 0\ W$$

$$+ \frac{\sigma\cdot\left(T10^4 - T9^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right) + \frac{1}{A_{9,0}\cdot F_{9,10}} + \frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{9,0}}} + \frac{\sigma\cdot\left(T10^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{10,0}}\right) + \frac{1}{A_{10,0}\cdot\left(1 - \frac{A_{6,0}\cdot F_{6,10}}{A_{10,0}} - \frac{A_{8,0}\cdot F_{8,10}}{A_{10,0}} - \frac{A_{9,0}\cdot F_{9,10}}{A_{10,0}}\right)}} \ldots$$

$$+ \xi_{HD}\cdot A_{10,0}\cdot\left[\left|T10 - \left(\frac{T9+T10}{2}\right)\right|\right]^{\frac{1}{3}}\cdot\left[T10 - \left(\frac{T9+T10}{2}\right)\right] + \frac{A_{10,0}\cdot\left(T10 - T_{AWTB}\right)}{\frac{\delta_{floor}}{k_{stl}}}$$

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

$$\frac{A_{12,0}\cdot(T12 - T2)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T12^4 - T_{amb}^4\right)}{\left(\frac{1-\varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{12,0}}\right) + \frac{1}{A_{12,0}}} + \xi_V\cdot A_{12,0}\cdot\left(\left|T12 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T12 - T_{amb}\right) = -0\ W$$

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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

$$\frac{A_{14,0}\cdot(T14 - T4)}{\left(\frac{\delta_{CR}}{k_{CR}}\right) + \left(\frac{\delta_{sand}}{k_{sand}}\right)} + \frac{\sigma\cdot\left(T14^4 - T_{amb}^4\right)}{\left(\frac{1 - \varepsilon_{stl}}{\varepsilon_{stl}\cdot A_{14,0}}\right) + \frac{1}{A_{14,0}}} + \xi_V\cdot A_{14,0}\cdot\left(\left|T14 - T_{amb}\right|\right)^{\frac{1}{3}}\cdot\left(T14 - T_{amb}\right) = -0\ W$$

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DBVS Off-Gas Hood Thermal Model

Total radiant heat loss from the melt surface ...

$$\frac{\sigma\cdot\left(T1^4 - T_{,0}^4\right)}{\left(\frac{1-\varepsilon_{,melt}}{\varepsilon_{,melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,1}}+\left(\frac{1-\varepsilon_{,CR}}{\varepsilon_{,CR}\cdot A_{1,0}}\right)}+\frac{\sigma\cdot\left(T2^4 - T_{,0}^4\right)}{\left(\frac{1-\varepsilon_{,melt}}{\varepsilon_{,melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,2}}+\left(\frac{1-\varepsilon_{,CR}}{\varepsilon_{,CR}\cdot A_{2,0}}\right)}+\frac{\sigma\cdot\left(T3^4 - T_{,0}^4\right)}{\left(\frac{1-\varepsilon_{,melt}}{\varepsilon_{,melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,3}}+\left(\frac{1-\varepsilon_{,CR}}{\varepsilon_{,CR}\cdot A_{3,0}}\right)} \ldots = -198.0\,kW$$

$$+\frac{\sigma\cdot\left(T4^4 - T_{,0}^4\right)}{\left(\frac{1-\varepsilon_{,melt}}{\varepsilon_{,melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,4}}+\left(\frac{1-\varepsilon_{,CR}}{\varepsilon_{,CR}\cdot A_{4,0}}\right)}+\frac{\sigma\cdot\left(T5^4 - T_{,0}^4\right)}{\left(\frac{1-\varepsilon_{,melt}}{\varepsilon_{,melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,5}}+\left(\frac{1-\varepsilon_{,stl}}{\varepsilon_{,stl}\cdot A_{5,0}}\right)}+\frac{\sigma\cdot\left(T6^4 - T_{,0}^4\right)}{\left(\frac{1-\varepsilon_{,melt}}{\varepsilon_{,melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,6}}+\left(\frac{1-\varepsilon_{,stl}}{\varepsilon_{,stl}\cdot A_{6,0}}\right)} \ldots$$

$$+\frac{\sigma\cdot\left(T7^4 - T_{,0}^4\right)}{\left(\frac{1-\varepsilon_{,melt}}{\varepsilon_{,melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,7}}+\left(\frac{1-\varepsilon_{,stl}}{\varepsilon_{,stl}\cdot A_{7,0}}\right)}+\frac{\sigma\cdot\left(T8^4 - T_{,0}^4\right)}{\left(\frac{1-\varepsilon_{,melt}}{\varepsilon_{,melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,8}}+\left(\frac{1-\varepsilon_{,stl}}{\varepsilon_{,stl}\cdot A_{8,0}}\right)}+\frac{\sigma\cdot\left(T9^4 - T_{,0}^4\right)}{\left(\frac{1-\varepsilon_{,melt}}{\varepsilon_{,melt}\cdot A_{0,0}}\right)+\frac{1}{A_{0,0}\cdot F_{0,9}}+\left(\frac{1-\varepsilon_{,stl}}{\varepsilon_{,stl}\cdot A_{9,0}}\right)}$$

$$F_{0,1}+F_{0,2}+F_{0,3}+F_{0,4}+F_{0,5}+F_{0,6}+F_{0,7}+F_{0,8}+F_{0,9}=1$$

Compute the average hood temperature ...

$$T_{HA} := \frac{A_{3,0}\cdot T3C + A_{6,0}\cdot T6C + A_{7,0}\cdot T7C + A_{8,0}\cdot T8C + A_{9,0}\cdot T9C}{A_{3,0}+A_{6,0}+A_{7,0}+A_{8,0}+A_{9,0}}$$

$T_{HA} = 427.2$ $\quad T_{HAF} := CtoF(T_{HA})$ $\quad T_{HAF} = 800.9$

Heat flux through AWTE floor ...

$$q_{AWTE} := \frac{T10 - T_{AWTE}}{\frac{\delta_{floor}}{k_{stl}}}$$

$q_{AWTE} = 5.1\,\frac{kW}{m^2}$ $\quad Q_{AWTE} := A_{10,0}\cdot q_{AWTE}$ $\quad Q_{AWTE} = 152.6\,kW$

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Subcontractor Calculation Review Checklist.

Subject: **Heat Transfer Analysis – ICV™ Lid**

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

Documents Reviewed: **145579-D-CA-060, Rev. A**

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 3/27/06

Organizational Manager (printed name, signature and date): **D. H. Shuford** David H. Shuford 4/5/06

Permit Attachment LL DBVS

Appendix 6 In Container Vitrification System

Section 2 Independent Qualified Registered Professional Engineer Design Assessment Reports

DR-013, Rev. 1, Demonstration Bulk Vitrification System IQRPE/RCRA Design Review Package, RPP-24544, Rev. D, 2.6 In-Container Vitrification System (90% Design)

Independent Qualified Registered Professional Engineer Support to Demonstration Bulk Vitrification Project

CH2M Hill Requisition # 114648

IQRPE Design Assessment Report No. DR-013, Rev. 1

Review of

Demonstration Bulk Vitrification System IQRPE/RCRA Design Review Package, RPP-24544, Revision D

Section 2.6, In-Container Vitrification (ICV™) System (90 Percent Design)

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1.0 INTRODUCTION

The Washington State Department of Ecology (Ecology) has issued a permit for the Demonstration Bulk Vitrification System (DBVS) that mandates the use of an Independent Qualified Registered Professional Engineer (IQRPE) to perform a third-party independent review of the design of Washington Department of Ecology sensitive portions of the DBVS project. TechnoGeneral Services Company (TGS) has prepared this IQRPE Design Assessment Report in conjunction with Dana Engineering, Inc. (DEI), at the request of CH2M Hill Hanford Group, Inc. (CH2M HILL), the project co-operator. TGS is the IQRPE of record for this project.

1.1 Project Description

The DBVS is a demonstration waste treatment plant operated under a Research, Development and Demonstration (RD&D) Permit issued by Ecology. The RD&D Permit is issued to the U.S. Department of Energy, Office of River Protection (DOE-ORP) and CH2M HILL. The DBVS plant will be located at the 200 West Area of the Hanford Site. The DBVS is being designed, constructed, and operated by AMEC, an engineering/services company from Vancouver, British Columbia, under contract to CH2M HILL. AMEC is tasked to comply with the RD&D Permit. Figure 1 is a three-dimensional graphic view of the DBVS project.

The DBVS is designed to process a liquid salt solution of low-activity mixed waste (LAW) originating from Tank 241-S-109. Tank 241-S-109 is located adjacent to the DBVS facility. The LAW is to be converted into solid glass form by drying the LAW, mixing the LAW in dried form with soil, and melting it with an electric current. The project is intended to demonstrate the viability of immobilizing LAW from the tank farm utilizing a proprietary AMEC vitrification system. The demonstration is to involve treating up to 600,000 gal of waste (5M Na solution) in 24 months, producing up to 50 In-Container Vitrification (ICV™) melt boxes of stabilized vitrified waste.

About 13,000 gal of S-109 waste (5M Na solution) is to be processed in each melt box.. A detailed description of the process is provided in Attachments AA and BB of the RD&D Permit.

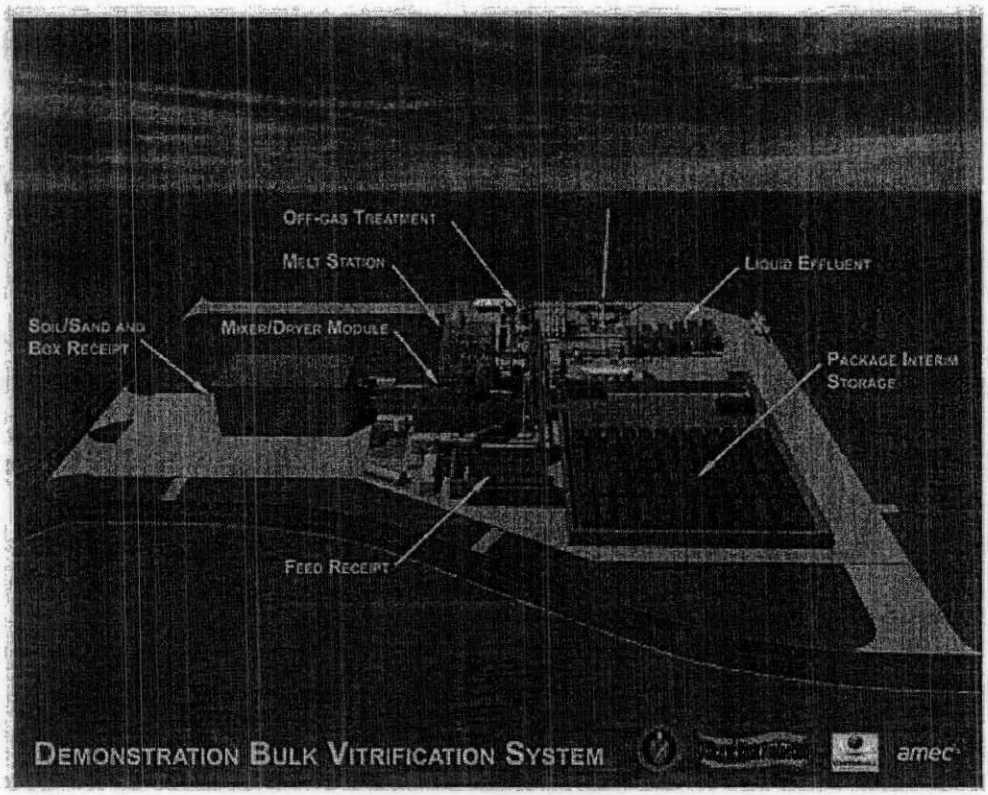

Figure 1. Demonstration Bulk Vitrification System Site Three-Dimensional View

1.2 Design Review Requirements

Many of the components of the DBVS will handle dangerous or mixed waste and are regulated by Washington Department of Ecology in the RD&D Permit. The RD&D Permit requires an IQRPE review of the design of these components prior to installation.

The Compliance Schedules, Sections IV.A.8 and V.I of the RD&D Permit, define the design documents to include drawings, specifications, calculations, and other information as deemed necessary to support the design. The RD&D Permit identifies seven systems, including the foundations system that will have design packages prepared for IQRPE review. CH2M HILL is providing the IQRPE with design review packages as AMEC completes the design.

As a basis for the IQRPE certification, a review is performed on a final version of the document "Demonstration Bulk Vitrification System IQRPE/RCRA Design Review Package", RPP-24544 as prepared by AMEC and reviewed and approved by CH2M HILL. Each design review package includes a body of text that explains the purpose and scope of the DBVS and describes the overall process as well as the specific system addressed in the design package. Included as supporting

information (appendices) are calculations, site maps, drawings, sketches, piping and instrumentation drawings (P&ID), process flow diagrams (PFD), waste characteristics, technical specifications for materials and equipment, and miscellaneous supporting data. Each design review package will be a revision of the RPP-24544 specific to the system addressed in the package. CH2M HILL is not requiring AMEC to seal/stamp final design documents per WAC standards for any DBVS work, other than the Site Improvements work (foundations and site work). Documents such as drawings, calculations, and specifications included in the design review package that are marked as final and have signatures for the preparer, checker, and approver, will be reviewed by the IQRPE as a complete document. All other documents will be reviewed as preliminary or supportive information. Preliminary design data was submitted and reviewed by the IQRPE reviewer as part of this certification, but only in an effort to familiarize the reviewer with the design until receipt of the final version.

The sixth system identified for IQRPE design review is the In-Container Vitrification (ICV™) System, Section 2.6 of RPP-24544, Rev. D, hereafter known as Design Package 2.6. The primary functions of the ICV™ System are:

- Preparation of the ICV™ box in the ICV Box Assembly Building,
- Receipt of the dried waste feed from the Dried Waste Handling System,
- Vitrification of the mixture through joule heating,
- Receipt of top-off soil from the Process Additive Handling System,
- ICV Box Sealing, and
- ICV™ Box transport from the melt area to the storage and sampling area.

1.3 In-Container Vitrification (ICV™) System Design Overview

This certification of the In-Container Vitrification (ICV™) System is based on the information presented in Design Package 2.6. This design package includes multiple calculations, specifications, and drawings, as summarized in Attachment A. TGS is providing one IQRPE design review report for the ICV™ System.

Figure 2 is a three dimensional view of the ICV™ system. White arrows in Figure 2 show the ICV™ System process path boundary. Major components of the ICV™ System are as follows:

- ICV™ Box Preparation Building
- ICV™ Box (prepared and assembled)
- Air Pallets for movement of ICV™ boxes
- Box Cooling, Sampling and Storage Area
- ICV™ Core Sampling

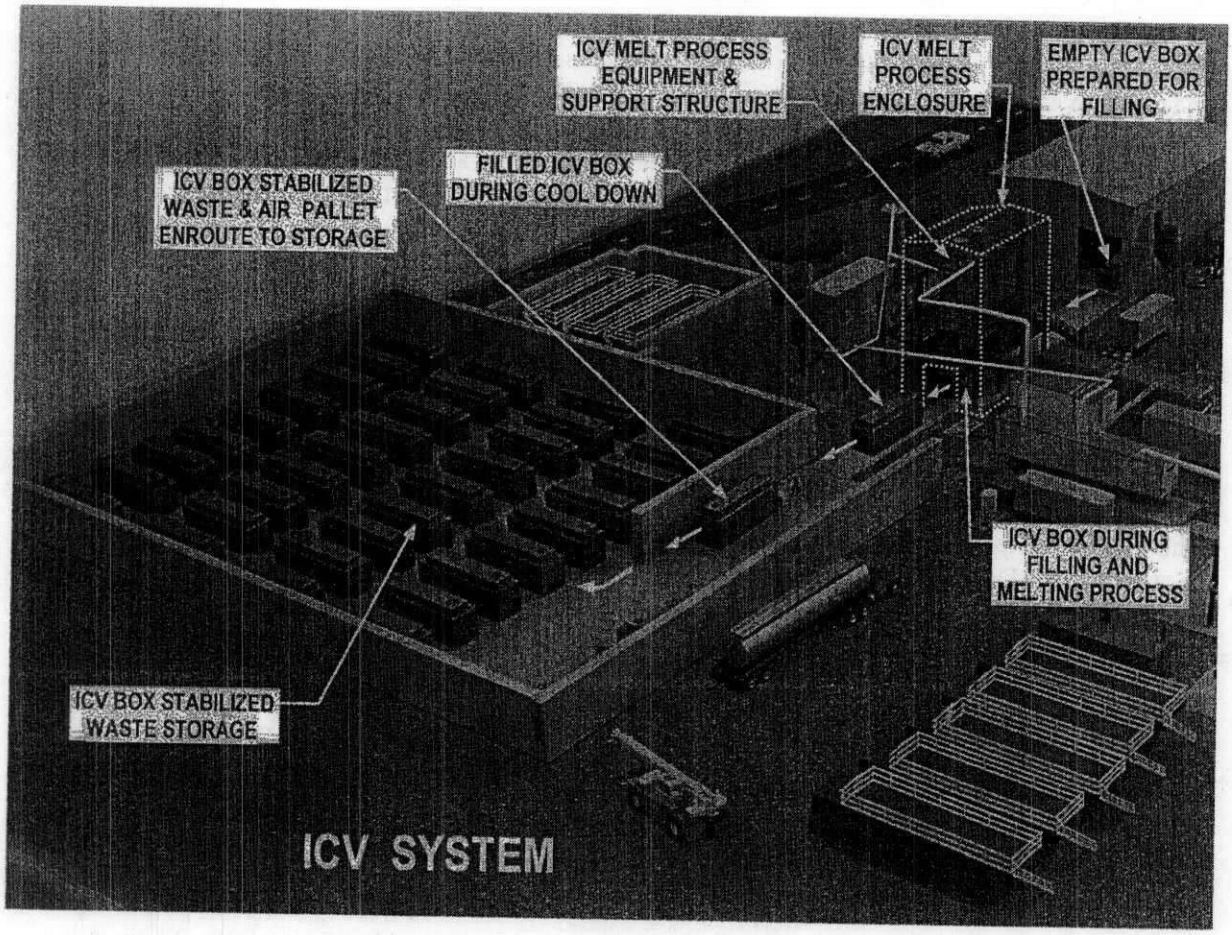

Figure 2. In-Container Vitrification (ICV™) Three Dimensional View

ICV™ boxes are prepared in the box assembly building (ICV™ Container Preparation and Assembly Enclosure). Backing bricks are added to the bottom ends and sides by positioning them on the inside of the ICV™ box, and mortared as required. Six rows of support ribs are spaced with sand fill between ribs as required, and run the length of the ICV™ box bottom. Box sand and refractory panels (container liners), mortar sealant between installed refractory panel half moon joints, seals, box instrumentation (thermocouples) and electrodes are added to each box. Starter path is then added. Plate glass is added to protect the starter path (conductive electrical path) from displacement during the initial loading process.

Once properly prepared, the ICV™ boxes are moved by the ICV™ Box Transporter (ICV-BT) to the melt area beneath the Ancillary Waste Transfer Enclosure (AWTE), with box position determined by box positioning pins. Power supply electrode stubs, designed to be reusable, are lowered and screwed at the ICV™ box lid to the top of the disposable electrodes. The ICV™ Box is also connected to the feed chutes and the Off-Gas Treatment System (OGTS) for venting. The instrumentation wiring harness is also connected to the ICV™ box.

The ICV™ System receives dried waste mixture in sequential batches from the Waste Dryer System via the Dried Waste handling System. The dried waste is then vitrified in an ICV™ box. Approximately two batches of dried waste are fed from the Dried Waste Handling System to the ICV™ box before starting the melt. The power supply to the ICV™ box is then turned on and melting of the soil/waste mixture starts from the bottom (at the starter path location) and progresses in an upward direction Once these initial batches are melted, approximately 6 batches of dried product are added sequentially. A total of approximately 8 batches of dried waste product are melted. Gases produced during the vitrification process are vented to the Offgas Treatment System. Loading of each batch of material from the dryer to the ICV™ box takes several hours. Once all required dryer loads have been placed in the ICV™ box, the melt is allowed to continue to complete the vitrification process.

After all batches of material have been processed, top-off soil is added through the 2 blended dried waste and 3 top-off soil feed chutes. Soil added through the top-off soil feed chutes is fed by gravity from the 3 top-off soil impingement tanks and is controlled by using the airlock assemblies (34-D88-035,036,and 037 on Drawing F-145579-34-A-0101). Soil added through the dried waste feed chutes is added via the mixer/dryer and is controlled by the Dried Waste Handling Equipment. Shielding in the form of top off soil is added through the top-off soil chutes and controlled using the top-off soil feed chute airlock assemblies (34-D88-035, 036, 037 on Drawing F-145579-34-A-0101). Sufficient top-off soil is added such that the interior of the box is approximately 90 percent full and dose rates at the top of the box are as low as reasonably achievable. The chute airlock assemblies allow material to be metered into a given chute. The material feed ports will be capped, which seal to the ICV box lid.

Following initial cool-down, the ICV™ box is manually disconnected from the AWTE, caps are placed onto the open ports and electrode wells for storage/burial after all the chutes and electrode extensions have been disconnected and are clear of the ports and wells. The ICV™ box is then transferred to the Storage and Sampling Area to continue cooling. Following initial cooling, the filled ICV™ box is moved again by the ICV-BT to the designated storage location.

Figure 3 is the ICV™ system elevation arrangement diagrams, depicting the Dried Waste Handling System (above the ICV™) which feeds blended dried waste and top-off soil to the ICV™ box. The ICV Box ICV™ Box Transporter (ICV-BT) floats heavy loads on a film of compressed air. The ICV-BT is positioned below the ICV™ and used to transfer the ICV™ box from the box preparation building to the melting station and then to the cooling/sampling station after addition and vitrification of the waste product batch is completed.

Figure 4 shows an extract from the ICV™ system P&ID, depicting interfaces with other systems for the following process steps:

- Addition of blended waste;
- Melting blended waste
- Addition of clean top off soil added after melting.

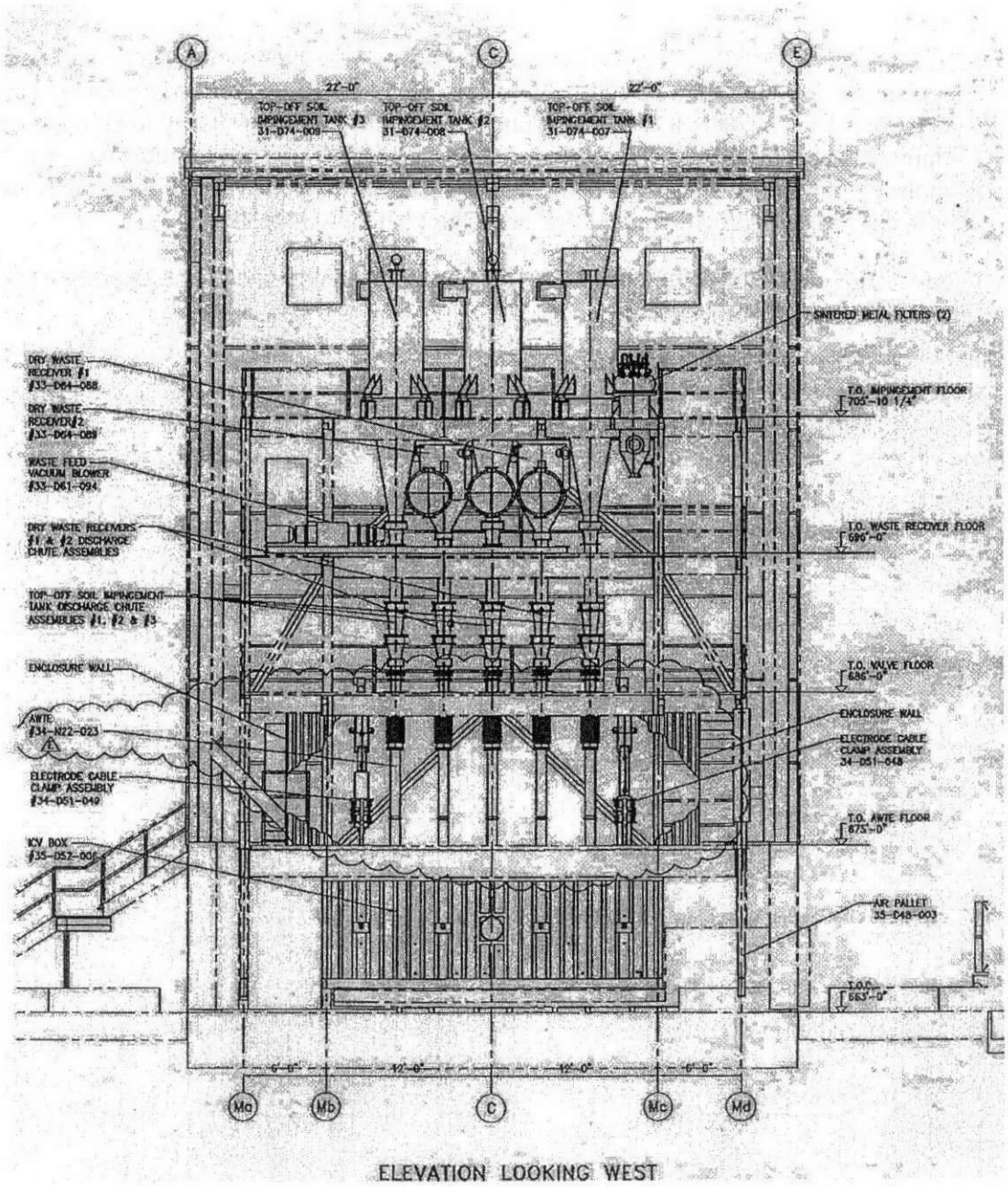

Figure 3. In-Container Vitrification (ICV™) System Elevation Arrangement Diagram

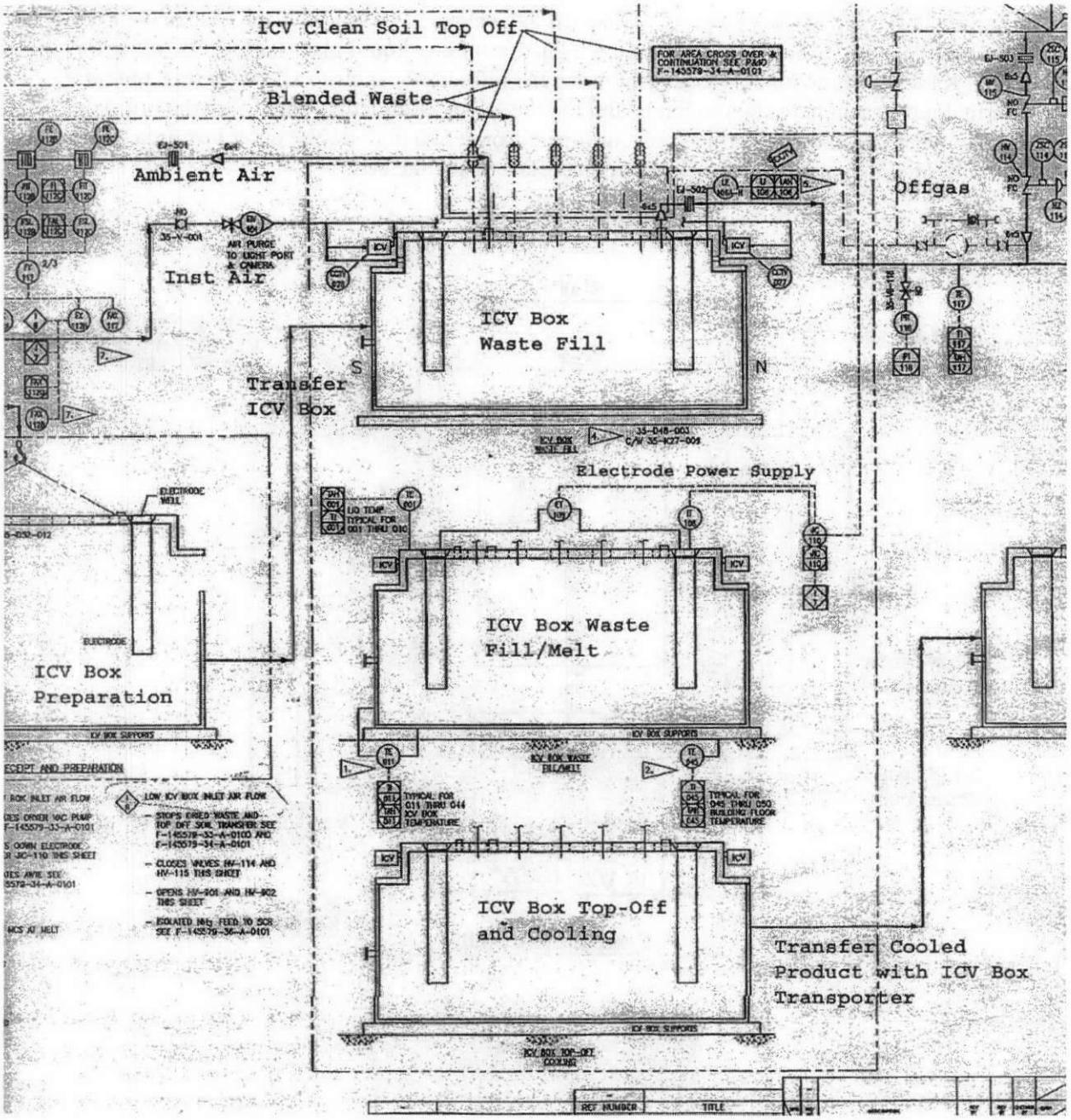

Figure 4. In-Container Vitrification (ICV™) System Interfaces

Figure 5 below, shows the layers contained in the welded steel ICV™ box, sand and castable refractory panels. Silica sand acts as a melt barrier for any liquid glass leaks if the refractory fails. Kaowool M board acts as a cushion for the refractory panels to allow for differential thermal movement between the lining and the metal box. Refractory panels are the primary containment of the melt, but also prevent fumes from escaping into the outer box area. They also provide shielding against the radioactive materials inside the box.

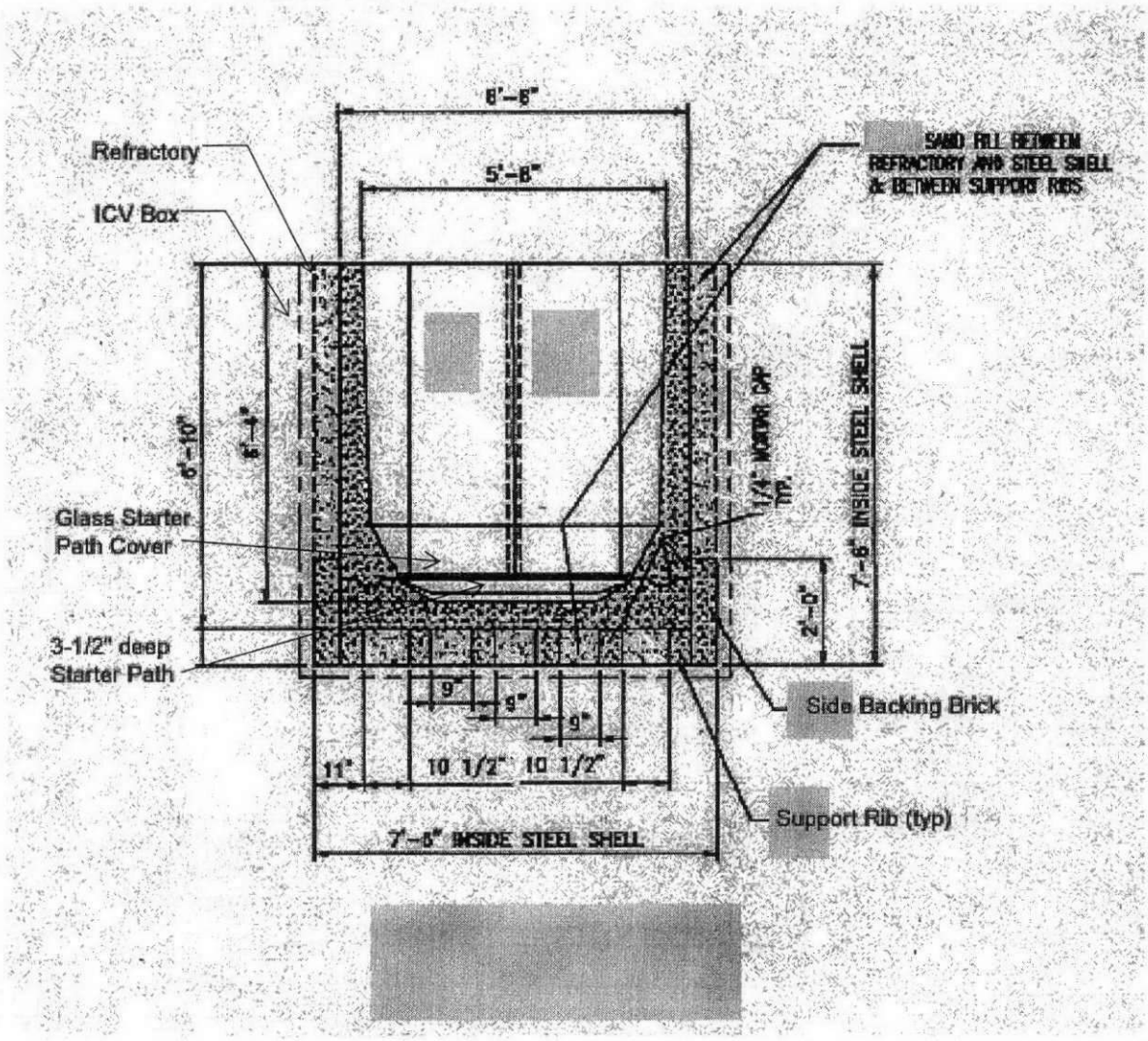

Figure 5. In-Container Vitrification (ICV™) Cross-Section

Finally, the following drawings further help to describe the ICV™ process and arrangement:

- F-145579-35-A-0100 Bulk Vitrification ICV™ Box P&ID
- F-145579-35-D-0004 ICV™ Box Data Sheet
- F-145579-35-D-0005 ICV™ Box Lid Assembly
- F-145579-00-A-0021 Full DBVS Feed Preparation & Melt Process Flow Diagram
- F-145579-00-D-0051 Bulk Vitrification Melt Area G.A. Plan Views
- F-145579-00-D-0041 Bulk Vitrification Melt Area G.A. Sections
- F-145579-35-D-0014 Bulk Vitrification ICV™ Shell Starter Path Details
- F-145579-35-D-0016 Bulk Vitrification ICV™ Box Refractory Assembly
- F-145579-35-D-0020 Bulk Vitrification ICV™ Box Electrode Details
- F-145579-00-F-0014 Bulk Vitrification ICV™ Box Instrument Locations

Note that Design Package 2.6 of the ICV™ System package also includes the "Bulk Vitrification Waste Feed Dryer to Box" P&ID (Drawing F-145579-33-A-0106) which interfaces with, but is not a part of the ICV™ System.

1.4 Scope of IQRPE Design Assessment

This IQRPE design report number is DR-013. This IQRPE design assessment includes a comprehensive review of Design Package 2.6, in accordance with the requirements of the DBVS RD&D Permit IV.A.8.b.i through IV.A.8.b.viii, IV.A.8.c.i, and V.I.2.a through V.I.2.f, and V.I.3.a through V.I.3.e, and WAC 173-303-630(4), (7). For this IQRPE review, the ICV™ system is treated with the same rigor and general format of review as a tank system, since the ICV™ box does contain liquid glass during the melting process; however, since the glass quickly turns to a solid during cooling, the ICV™ box is treated as a "container". A "container" is described in WAC 173-303-040 as any portable device in which a material is stored, transported, treated, disposed of, or otherwise handled. Much of the ICV™ system as provided in Design Package 2.6 was determined to be "Out of Scope" to the WAC requirements for IQRPE review and certification. Further discussion of the scope of the IQRPE design assessment is provided below. Any exceptions taken by the IQRPE to incomplete or unavailable items in Design Package 2.6 are listed in Section 2.2 at the end of each subsection. The documents included in this review and the level of each document review is summarized in Attachment A.

1.4.1 Portions of the ICV™ System Included "In Scope" for IQRPE Certification

ICV™ System processes which were determined to be in-scope for IQRPE review, include the following:

- Receipt of the dried waste feed from the Dried Waste Handling System
- Receipt of top off soil from the Process Additive Handling System
- Vitrification of the mixture through joule heating
- ICV™ Box Sealing
- ICV™ Box transport from the melt area to the storage and sampling area.

In-scope IQRPE reviews include structural assessments of the ICV™ Box and lid design, and melt area steel curbs, to confirm that required strength ICV™ box and strength supporting a fully loaded ICV™ box, especially during elevated temperatures or during full ICV™ box movement, is adequate. IQRPE scope includes review of the fully assembled and loaded ICV™ box design against specified waste stream properties at elevated temperatures, for overall configuration, materials, refractory, sand and insulation. Pressure controls of the ICV™ box during processing are also to be reviewed.

Although the ICV™ Box Transporter (ICV-BT) does not specifically fall under definitions of Tank or Container, as referenced in applicable RD&D Permit and WAC regulations, failure of the ICV-BT during hazardous waste transport of the ICV™ box could challenge structural aspects of the ICV™ box. IQRPE design certification of the ICV-BT which may otherwise affect unsafe drop or ICV™ box structural integrity is recommended when design details of the ICV-BT become available.

The IQRPE scope includes review of the fully assembled and loaded ICV™ box design against specified waste stream properties at elevated temperatures to consider overall configuration, materials, refractory, sand and insulation. Waste compatibility aspects in-scope to be reviewed by the IQRPE include ICV™ box and equipment material selection, melting points, structural strength at temperature, corrosion allowance.

IQRPE Ancillary Equipment considered in-scope includes any equipment which affects pressure control, overfill control, containment, piping, fittings, flanges, valves, instrumentation, valves, Ancillary Waste Transfer Enclosure design which may affect safe containment of hazardous waste in the ICV™ box.

Recommended factory and construction inspections (prior to operation) are considered in-scope for IQRPE review.

Assembly procedures for sand, refractory, and electrode installation inside the ICV™ box, as performed in the ICV™ Box Assembly Building, are considered "In-Scope" where the sand and

refractory shall form the containment barrier during melting of solids forming hazardous waste radioactive liquid glass.

1.4.2 Portions of the ICV™ System "Not-In-Scope" for IQRPE Certification

The following systems interface with the ICV™ System but are outside the scope of this IQRPE review:

- ICV™ box and lid positioning, hoisting and rigging in Preparation Building prior to ICV™ box assembly of sand and refractory,
- Dried Waste Handling system,
- Process Additive Handling system,
- Electrical Power Supply,
- Main Off-Gas Treatment system,
- Waste Sampling, and
- Waste Dryer system.

The following items are not covered by the WAC dangerous waste regulations or the RD&D Permit for the facility, and are therefore outside of the scope of this certification:

- Plant utilities, including instrument and plant air supply lines and electrical power beyond the first upstream valve or uninterruptible power supply systems.
- Structural features not related to hazardous waste secondary containment.
- Architectural features not related to hazardous waste containment.
- Lighting systems.
- System design features related to protection of the system due to vehicular traffic.
- Electrical or signal lines beyond the first upstream field termination box (FTB), motor control center (MCC), or instrument control panel (ICS).
- Radiation monitoring or detection components that may be mounted at various locations throughout the system.
- Verification of functional logic for operation and control of the In-Container Vitrification (ICV™) System.

This certification also excludes the review of the Design Package 2.6 to the following design standards included in RPP-17403 because the Design Review Package does not address these issues:

- Section 3.1.2.1.1.3 and Table 3-3 requirements regarding waste feed radionuclide properties, including all radioactive and radionuclide property considerations.

  Section 3.1 requirements for the DBVS that the design:

  - Ensure that all process byproducts are safe for long-term storage or release into the environment.

- Section 3.3.1.6 requirements for the DBVS that the design include the capability for flushing components for decontamination.

- Section 3.3.6 requirements for the DBVS that the design related to the following:

  - Personnel Safety

  - Fire Protection

  - Non-Radioactive Airborne Emissions (Section 3.3.6.3.4)

  - Radioactive Airborne Emissions (Section 3.3.6.3.6)

- Section 3.3.8 (Decontamination and Deactivation) or Section 3.3.9 (Nuclear Safety) requirements for the DBVS.

Because portions of the 90 percent design of the ICV™ Box Transporter has been developed as purchase specifications, some of the 'design' activities have been designated as the responsibility of the equipment vendor or Seller. Therefore, this information will not be available until fabrication of the equipment is underway and will require further IQRPE review as part of the construction certification package. Documentation to be reviewed by the IQRPE for inclusion with the installation certification package includes the deliverables listed in Attachment B.

2.0 ASSESSMENT

Section 1.4.1 of this report identifies portions of the ICV™ System included "In-Scope" for IQRPE review and certification. The following subsections identify the basis and methods used to complete this IQRPE design certification.

2.1 Codes, Standards and Regulations

The codes, standards, and regulations specifically used during the preparation of this certification are referenced as necessary throughout this report. A complete list of codes, standards, and regulations that have been incorporated into the Technical Specification packages is included as Attachment C.

The IQRPE concurs with the use of the codes, standards, and regulations that have been designated in the Technical Specifications.

2.2 Basis of Design

The ICV™ System is anticipated to operate for a minimum service life of 24 months while handling LAW from Tank S-109. Equipment has been specified with a design life of 5 years to handle the physical properties of low level radioactive hazardous waste identified below. ICVS tank waste feed dangerous waste constituents mean chemical composition of analytes are listed in Table 1. Physical property requirements of treated glass waste product are outside the scope of this certification.

ARES calculated for the box sidewall, in the extremely off-normal condition of a melt interface temperature of 1700° C, the maximum box sidewall skin temperature increases to 421 deg C and the leading edge of the leaking glass approaches to within 5/8" of the ICV box steel skin. Even under these extremely severe assumptions, the molten material is still contained within the refractory and sand layer. Even if the heat transfer coefficients are reduced by a factor of two, the ICV box sidewall temperature increases to 557° C and the "leaking glass" front approaches to within ½" of the ICV box steel skin. These conditions are still within the design limits of the box (Design package 2.6, Calculation CA-001 Rev. 2).

Similarly in this calculation, with the same conditions for the box bottom, even if the heat transfer coefficients are reduced by a factor of two, the ICV box bottom temperature increases to 391° C and the "leaking glass" front approaches to within 1-5/8" of the ICV box steel skin. Even under these extremely severe assumptions, the molten material is still contained within the refractory and sand layer. Even if the heat transfer coefficients are reduced by a factor of two, the ICV box bottom temperature increases to 517° C and the "leaking glass" front approaches to within 1-1/8" of the ICV box steel skin. These conditions are still within the design limits of the box.

The final vitrified waste will be sampled to provide data for waste form qualification, risk assessment, performance assessment and regulatory compliance. The vitrified waste will be analyzed for the dangerous waste constituents that were detected in the tank waste feed to determine compliance with Land Disposal Restrictions (LDR) requirements.

Ecology Publication 94-114, June 1994, "Guidance for Assessing and Certifying Tank Systems that Store and Treat Dangerous Waste" provides the format to assess and certify the In-Container Vitrification (ICV™) System. The ICV™ box is classified as a "container" and not a "tank" (section 1.4 of this report); therefore, this report format is adjusted as appropriate to the certification of hazardous waste ICV™ box containers. The IQRPE assessment focuses on the "process" of adding and vitrifying hazardous waste in the ICV™ box, followed by transport of the loaded ICV™ Boxes to the Storage and Sampling Area.

The following sections highlight the recommendations for the ICV™ System IQRPE assessment:

- Structural design assessment
- Waste compatibility
- Pressure control system
- Secondary containment system
- Ancillary equipment design
- Corrosion assessment
- Inspection schedule

Table 1. ICVS Tank Waste Feed Dangerous Waste Constituents Mean Chemical Composition of Analytes *

Analyte	Average Analyte to Na Mole Ratio
Waste Al^{+3}	9.32E-03
Waste CA^{+2}	2.43E-04
Waste Cl^{-1}	1.5E-03
Waste Cr (total)	2.96E-03
Waste F^{-1}	1.13E-03
Waste Fe^{+3}	9.57E-04
Waste K+	8.73E-04
Waste Mn^{+4}	2.85E-05
Waste Ni^{+2}	2.13E-05
Waste $NO2^{-1}$	1.31E-02
Waste $NO3^{-1}$	9.29E-01
Waste Pb^{+2}	2.78E-05
Waste $PO4^{-3}$	1.16E02
Waste Si^{+4}	1.13E-03
Waste $SO4^{-2}$	7.79E-03
Waste Sr^{+2}	6.53E-06
Waste TIC as $CO3^{-2}$	3.58E-02
Total Organic Carbon (TOC)	5.26E-03
U (Total)	2.34E-05
* RPP-17403, Rev 2 "Functional and System Design Requirements to DBVS, Table 3-2	

2.2.1 Structural Design Standards

Structural assessment of the ICV™ Box was performed to confirm that the required strength of all members in the ICV™ Box and lid are adequate. The plate thickness and stiffeners are sized using an allowable stress at an elevated temperature of 1058° F (570°C). The assessment included a review of each section of the box (i.e. sides, ends and floor) and a review of the calculated lifting requirements. Attachment A provides a summary of calculations, specifications, drawings and comments applicable to structural related matters relevant to the IQRPE scope of review.

Other structures in the ICV™ System are not designated to store or treat dangerous waste, and therefore did not receive an IQRPE review in compliance with WAC standards. For example, the ICV™ Box Assembly Building structure did not receive IQRPE structural reviews.

Where possible, the IQRPE reviewed the ICV™ System report to ensure that the following activities were incorporated into the Technical Specifications as part of the design basis:

- Design parameters used in structural calculations are clearly indicated and labeled on clarifying sketches.

- Seismic considerations, which are appropriate to the seismic risk zone (UBC 1997, Seismic Zone 2B) are accounted for in the structural calculations.

- The foundation underlying the ICV™ System will support the load of a full In-Container Vitrification (ICV™) Box. The foundation underlying the ICV™ system was certified by the IQRPE as part of IQRPE Design Assessment Report No DR-002 (see Section 4.0 References).

- The foundation underlying the ICV™ System has been designed to prevent failure due to settlement, compression, and uplift per the requirements of WAC 173-303-640(4)(c)(II). This was certified by the IQRPE as part of DR-002.

- The foundation supporting the ICV™ System has been designed to withstand the effects of frost heave per the requirements of WAC 173-303-640(3)(a)(v)(C). This was certified by the IQRPE as part of DR-002. This requirement is conservative, since the ICV™ box is classified as a "container", whereby requirements of WAC 173-303-630(4),(7) are applicable.

2.2.1.1 ICV™ Box and Lid Specification (SP-023, Rev 0)

The ICV™ Box and Lid Specification 145579-D-SP-023, Rev 0 was reviewed to ensure that provisions for the proper loads, supports, and design basis had been specified. The appropriate structural considerations have been made in this specification.

The ICV™ Box is based on a standard 50 yd^3 roll-off box with modifications and designed to be water tight; withstand the hydraulic and thermal loads of the molten glass and the weight of the total contents of sand, refractory, glass and top-off soil.

The ICV™ Box Lid is an integral lid and vent hood that is installed on the ICV™ box at assembly and remains on the box through processing and ultimately goes to the disposal site. It will be fastened to the top flange of the ICV™ box and is sealed to it with bolts, nuts, and a refractory gasket. The ICV™ Box Lid is specified to have ports in wells for electrodes that will be hung in electrical insulating bushings that seal to the lid as well as to the electrodes. The design includes 5 ports for material charge into the ICV™ box (three for top-off soil and two for waste feed). The material feed ports have caps which seal to the ICV™ box with refractory seals. These caps will be removed to allow the material feed chutes to extend into the box during filling.

2.2.1.2 ICV™ Box Transporter Data Sheet (D-DS-012.1 Rev 2)

ICV™ Box Transporter (ICV-BT) mechanical, electrical and controls details were not reviewed by the IQRPE, since D-DS-012.1 is a procurement data sheet, and actual equipment has not been designed at the time of this report. Although the ICV-BT does not specifically fall under definitions of Tank or Container, as referenced in applicable RD&D Permit and WAC regulations, failure of the ICV-BT during hazardous waste transport of the ICV™ box could

challenge structural aspects of the ICV™ Box. The ICV™ box design receives IQRPE certification and the ICV-BT supporting the ICV™ box is also critical to the ICV™ Box maintaining structural shape and containment of radioactive hazardous waste during transport from the vitrification station to the storage and sampling station. The Seller must account for temperature increases and weight, when selecting and sizing the ICV-BT per the data sheet. IQRPE design certification of the ICV-BT is recommended as it relates to "safe drop", when structural design aspects of the ICV-BT become available.

Effects of heat transferred to the ICV-BT from the loaded hot ICV™ box should also receive IQRPE evaluation when the ICV-BT design becomes available, to ensure that heat from the box may not detrimentally affect structural aspects of the design to safely transport the loaded ICV™ box.

2.2.1.3 Structural Data Sheets Applicable to Structural Review

The ICV™ Electrodes, Ceramic Sleeve and Collar form part of the pressure boundary of the operating ICV™ box. This pressure boundary is considered structural in nature and intended to be confirmed during pressure testing or during preoperational air flow testing of the ICV™ Box. The following specification sections are required to receive follow-up IQRPE review during or following ICV™ box pressure leak testing or air flow testing:

Specification No.	Specification Structural Sections Applicable to Future IQRPE Review
145579-D-DS-029.1, Rev 0 & TECN-D-DS-029.1.R00.1	ICV™ Electrodes and Accessories
145579-D-DS-047.1, Rev 0 & TECN-D-DS-047.1.R00.1	Ceramic Sleeve and Collar

2.2.1.4 Structural Design Exceptions

The IQRPE reviewed the structural design aspects of the applicable ICV™ System specifications, drawings and calculations as indicated. Structural review certification concurrence and exceptions to the AMEC design package calculations are as follows:

1. Calculation 145579-D-CA-010 Rev 0, ICV™ Box Weight Calculations, Final DBVS Design. IQRPE reviewed and concurs with the calculations.

2. Calculation 145579-D-CA-011 Rev 4, ICV™ Box Structural Analysis, Final DBVS Design. IQRPE reviewed and concurs with the analysis.

3. Calculation 145579-D-CA-028 Rev 0, ICV™ Box Center of Gravity Calculation, Final DBVS Design. IQRPE reviewed and concurs with the calculations.

4. Calculation 145579-D-CA-004 Rev 3, ICV™ Box Support Curbs Type 'C' and 'D' and 'E', Final DBVS Design. IQRPE reviewed and concurs with the calculations.

Heat transfer calculations have been included in the structural review section since high temperatures associated with vitrification may affect structural strength:

5. Calculation 145579-D-CA-001 Rev 2, Area 35- Transient Heat Transfer Calculations of ICV™ Box (includes calculation 0509206.01-M-001 Rev 1, "DBVS ICV™ Box Thermal Analysis"). IQRPE reviewed and concurs with the calculations.

6. Calculation 145579-D-CA-060 Rev A, "Heat Transfer Analysis- ICV Lid" (includes calculation 0509206.01-M-002 Rev 1, "DBVS ICV™ Off-Gas Hood Thermal Analysis"). IQRPE reviewed and concurs with the calculations.

7. IQRPE design certification of the ICV-BT is recommended as it relates to "safe drop", when structural design aspects of the ICV-BT become available.

8. Effects of heat transferred to the ICV-BT from the loaded hot ICV™ box should also receive IQRPE evaluation when the ICV-BT design becomes available, to ensure that heat from the box may not detrimentally affect structural aspects of the design to safely transport the loaded ICV™ box.

2.2.2 Waste Compatibility

RD& D Permit, Table V.1 classifies the ICV™ Boxes as "Containers". WAC 173-303-630 (4) "Use and Management of Containers" states that the owner or operator must use a container made of or lined with materials which will not react with, and are otherwise compatible with, the dangerous waste to be stored, so that the ability of the container to contain the waste is not impaired. Ecology Publication 95-420 provides guidance for assessing dangerous waste secondary containment systems. WAC 173-303-810 General Permit Conditions is applicable to all permits, requiring IQRPE certification of system design.

The IQRPE has reviewed waste characteristics compatibility with refractory and sand enclosed in the steel constructed ICV™ box, for temperature, chemical and corrosion affects. Chemical and corrosion effects are discussed in more detail in Section 2.2.6, Corrosion Assessment.

The following subsections highlight the IQRPE Waste Compatibility review for each of the major ICV™ System subsystems and specific exceptions to this IQRPE certification report as they relate to the Waste Compatibility review.

2.2.2.1 ICV™ Box and Lid Specification (SP-023, Rev 0)

Full scale testing with non-regulated material have been performed with a representative ICV™ box; observations for waste compatibility have been noted from the full-scale tests, and corrective actions have been taken on box design, as warranted. Testing of materials conducted by the melt vendor has confirmed the final selected material characteristics of the ICV™ box and lid.

The IQRPE reviewed the fully assembled and loaded ICV™ box design against specified waste stream properties at elevated temperatures, for overall configuration, materials, refractory and sand (see Table 1, Section 2.2 of this report). Waste compatibility aspects reviewed by the

IQRPE include ICV™ box and equipment material selection, melting points, structural strength at temperature, and HEPA filtration of potentially contaminated airborne particles. Structural strength at temperature is discussed in more detail in Section 2.2.1 of this report.

The IQRPE concurs that this 90 % design basis meets the requirements of the DBVS RD&D Permit and WAC 173-303-630(4),(7), subject to final IQRPE review of results from the melt Vendor ICV™ box vitrification testing.

2.2.2.2 ICV™ Box Transporter System Specification (SP-012, Rev C)

The ICV™ Box Transporter (ICV-BT) has no contact with the waste. Therefore, waste compatibility review on the ICV-BT is not applicable.

2.2.2.3 Waste Compatibility Exceptions

Prior to final acceptance of the proposed construction materials and design configuration, results of ICV™ box vitrification testing are required to be reviewed by the IQRPE for independent review of product compatibility with materials and configuration of construction.

2.2.3 Pressure Control System

During processing in the ICV™ box, ambient air passes through an inlet HEPA filter, feeds the upper ICV™ box internal cavity, and exhausts dust and air to the Off-Gas Treatment System (OGTS). The ICV™ box is intended to be maintained by the OGTS at a negative pressure with respect to atmospheric conditions as indicated by 35-PIT-118 during the melt and during dried waste or top-off soil feed. Pressure is also is remotely indicated on the main control panel. Pressure is manually controlled through adjustment of the flow through the ICV™ lid by remote actuation of valve 35-HV-114. Flows into and out of the ICV™ box are monitored by 35-FE-112A, B, and C .

Low ICV box inlet air flow activates the following pressure control interlocks:

- Stops dried waste and top off soil transfer;
- Isolates OGTS ICV box exhaust processing valves HV-114, HV-115;
- Opens OGTS bypass valves HV-901, HV-902;
- Isolates ammonia feed to SCR;
- Isolates offgas treatment system inlet air bleed valves;
- Stops the dried waste vacuum blower;
- Isolates the AWTE.

Pressure control of the ICV™ Box is maintained at ambient pressures during cooling and storage through installation of an ICV™ box HEPA breather filter. The ICV™ box HEPA breather filter is installed after top-off soil is introduced into the ICV™ box and just before disconnection from the AWTE. Melted liquid head pressure is accounted for in the design of the ICV™ Box, and no other pressure control system is required.

2.2.3.1 Pressure Control System Exceptions

The IQRPE has reviewed the Pressure Control system for the ICV™ box and has no exceptions. The ICV box is designed to prevent excess pressure buildup through the use of continuous venting to the Off Gas Treatment System while connected to the AWTE, or through atmospheric venting through the breather filter after melt is completed. During processing when ICV box is connected to the OGTS, pressures are intended to be maintained negative relative to atmosphere and the AWTE. ICV™ box negative pressure design values (Ref: F-145579-00-A-0021, Rev 0J), may be difficult to attain unless controllable system resistance is added to the ICV™ box inlet air supply piping. This may be verified during preoperational testing . Gases generated, and any particulate suspended, during the process are directed to the OGTS for treatment.

2.2.4 Secondary Containment System

RD& D Permit, Table V.1 classifies the ICV™ Boxes as "Containers". Ecology Publication 95-420, "Guidance for Assessing Dangerous Waste Secondary Containment Systems" includes guidance for assessing the adequacy of secondary containment, for containers secondary containment. Secondary containment for container systems that store, accumulate, or treat dangerous waste must be designed and installed to meet the requirements of WAC 173-303-630(7). A review of the secondary containment system is normally part of the IQRPE review.

During processing, the ICV box is connected to the OGTS and maintained at a negative pressure relative to atmosphere and the AWTE. Gases generated, and any particulate suspended, during the process are directed to and retreated by the OGTS. The ICV box provides primary containment for the dried, molten and gaseous waste form. WAC-173-303-630(7) section (7)(c) states: *"Storage areas that store containers holding only wastes that do not contain free liquids, do not exhibit either the characteristic of ignitability or reactivity as prescribed in WAC 173-303-090, and are not designated as F020, F021, F022, F023, F026, or F027, need not have a containment system as described in this subsection, provided that: (ii) The containers are elevated or are otherwise protected from contact with accumulated liquids."*

Processed ICV™ boxes hold only waste which does not contain free liquids, do not exhibit characteristics of ignitability nor reactivity and are not designated under F numbers listed above. The ICV™ boxes are elevated at all times and are placed on curbs above the super flat floor, except when being transported by the ICV™ Box Transporter System in an elevated manner. Precipitation will be allowed to run-off the flat surfaces to nearby gravel for natural drainage over ground surfaces.

Based on the above, secondary containment does not apply to ICV™ boxes containing hazardous waste. Nevertheless, attention is directed to thermocouple indications during the melting process as well as visual inspections. A spill or release during the vitrification process is detected by thermocouples in the melt area, directly beneath the ICV box . Visual inspection of the ICV™ box is used in other locations to identify a spill or release of solids, consistent with accessibility limitations.

2.2.5 Ancillary Equipment Design

A review of the ancillary equipment design is normally part of the IQRPE review. Because the Technical Specifications prepared for the ICV™ System IQRPE/RCRA Design Review Package are purchase specifications that place responsibility for the final ancillary configurations and the purchase of all piping, fittings, flanges, valves, instrumentation, valves, and electronics on the Seller, a complete review of the ancillary equipment design cannot be completed until final 100% design information is available for IQRPE review.

The following subsections highlight the IQRPE Ancillary Equipment Design review as applied to the specifications, P&ID's, and data sheets; and also identifies specific exceptions to this IQRPE certification report as they relate to the ancillary equipment design review. Ancillary equipment design information to be submitted by the SELLER and reviewed by the IQRPE at a later date is listed in Attachment B.

2.2.5.1 P&ID Review

P&ID F-145579-35-A-0100 was reviewed for the following basic considerations:

- Appropriate location of pressure, temperature, and flow sensing equipment.
- Necessary piping, valve, and instrumentation labeling.
- Proper positioning of instrumentation to prevent undue influence from upstream equipment.
- Necessary isolation valves to allow instrumentation maintenance.
- Identification of preliminary interlocks.
- Designation of valves as fail-open or fail-close.
- Location of check valves or back-flow preventers, if applicable.
- General designation of appropriate alarms and recorded information.
- Overpressure protection.

2.2.5.2 Data Sheet Review

Data sheets are generally incomplete and are required for the 100% IQRPE design review. This review of the existing data sheets included:

- Appropriate materials of construction.
- Appropriate functionality.
- Hazard classification requirements.

The following miscellaneous ancillary equipment were included as part of package 2.6 and were evaluated by the IQRPE as follows:

- Ceramic Sleeve and Collar (DS-047.1)

  The IQRPE reviewed the Ceramic Sleeve and Collar data sheet and had no comments. See further comments in Section 2.2.2.3 of this report.

- Seals (DS-050.1)

  The IQRPE reviewed the Seals data sheet and had no comments.

- ICV™ Box HEPA Breather Filter

  The ICV™ Box Breather HEPA filter is a filter which is installed after top-off soil is introduced into the ICV™ box, just before the AWTE disconnect, to ensure that pressurization/de-pressurization during cooling and storage is avoided. The IQRPE reviewed the ICV™ Box HEPA Breather Filter data sheet and had no comments.

- ICV™ Box Transporter (Data Sheet D-DS-012.1, Rev 2)

  The ICV™ Transporter Data Sheet D-DS-012.1, Rev 2 received IQRPE review. The ICV-BT uses a variety of "casters" to float heavy loads on a film of air. The air pallet is specified to have a low profile to fit under the ICV™ box when mounted on curbs. The ICV-BT is a self contained unit with an on-board, diesel-driven compressor power unit supplying air for lift and drive/steerage. IQRPE reviews are required after 100% design information is available, in order to examine heat transfer into the air pallet affecting pallet process operability. The 100% review should also include the pallet's overall ability to support the load of the full vitrified waste container to ensure safe processing and transfer.

2.2.5.3 Ancillary Equipment Exceptions

IQRPE Certification exceptions to the ancillary equipment review are as follows:

Technical Specifications prepared for the ICV™ System IQRPE/RCRA Design Review Package are purchase specifications that place the responsibility for the final design of the system components on the Seller; thus a complete review of the ancillary equipment systems has not been completed.

The following have been considered by the IQRPE:

1. Secondary containment does not apply to ICV™ system ancillary equipment supporting vitrification processing. Nevertheless, attention is directed to thermocouple indications during the melting process as well as visual inspections. A spill or release during the vitrification process is detected by thermocouples. Visual inspection of the ICV™ box is used in other locations to identify a spill or release of solids, consistent with accessibility limitations.

2. ICV™ System ancillary equipment is required to be designed to be supported and protected against damage and excessive stress due to excessive settlement, vibration, expansion or contraction. (Note that equipment to be supplied by the Seller is not yet available for IQRPE review).

3. Final design of ICV™ System ancillary equipment is not available at the time of this report, therefore the IQRPE review is required at a later date to verify that equipment is supported and protected against damage and excessive stress due to excessive settlement, vibration, expansion or contraction.

4. IQRPE review is required at a later date to verify ICV™ System overfill prevention equipment (includes high ICV™ box process level sensing with remote indication) has been has been provided, to indicate to operator when ICV™ box design processing levels are reached.

5. For the ICV™ Box Transporter System, IQRPE reviews are required after 100% design information is available, to ensure that the pallet's overall ability to support the load of the full vitrified waste container and to ensure safe processing and transfer.

6. Implement a fully integrated pre-operational acceptance test, conducted by representatives of the Buyer, to verify correct operability of all interlocks, wiring, electrical components, instruments, logic and equipment, for both "normal" and "off-normal" conditions, prior to the start of simulant testing.

Revise P&ID F-145579-35-A-0100 in accordance with P&ID review comments below:

P&ID F-145579-35-A-0100 Rev N has been reviewed by the IQRPE with no comments. Previous P&ID comments provided by the IQRPE have been addressed.

2.2.6 Corrosion Assessment

RD& D Permit, Table V.1 classifies the ICV™ Boxes as "Containers". WAC 173-303-630 (4) "Use and Management of Containers" states that the owner or operator must use a container made of or lined with materials which will not react with, and are otherwise compatible with, the dangerous waste to be stored, so that the ability of the container to contain the waste is not impaired. Ecology Publication 95-420 provides guidance for assessing dangerous waste secondary containment systems. WAC 173-303-810 General Permit Conditions is applicable to all permits, requiring IQRPE certification of system design.

The IQRPE has performed an independent engineering corrosion review of the ICV™ Box. The IQRPE reviewed waste characteristics compatibility with refractory, sand, and insulation enclosed in the steel constructed ICV™ box for temperature, chemical, and corrosion affects. Temperature effects not related to the corrosion assessment are discussed in more detail in Section 2.2.2, Waste Compatibility.

The following sections highlight the IQRPE Corrosion Assessment review for the ICV™ System components, and also identify specific exceptions to this IQRPE certification report as they relate to the corrosion assessment review.

- ICV™ Box and Lid Specification (SP-023, Rev. 0, and DS-023.1, Rev. 0)

  NOTE: *Since the independent corrosion engineer's design review, full scale testing with non-regulated simulant material has been performed with a representative ICV box. The customer stated that "no significant scaling of the ICV container was observed." The independent corrosion engineer has recommended that testing of materials, as conducted by the melt vendor, should be conducted to confirm the final selected material characteristics of the ICV™ box and lid. Alternative vendor recommendations should also be evaluated.*

  An independent review was conducted for corrosion review (Appendix H6). An independent corrosion expert has reviewed the specification and associated data sheet and indicated a concern for scaling of the carbon steel in air at the processing temperatures. Since scaling temperature of carbon steel in air is about 900 deg F and increases rapidly above this temperature, it was suggested that use of carbon steel with chromium and molybdenum would raise the scaling temperature and be more compatible with service conditions. One suggested possible material is A387 (UNS 41545) with about 5% Cr and 0.5% Mo, which has a scaling temperature of approximately 1150 deg F (Appendix H6).

  The specification SP-023 requires the use of Carboline – Thermaline 4700 protective coating to be applied. The data sheet requires that the surface be prepared to an SSPC-SP 10 and that a Silicone Zinc Primer be applied to the blasted surface (dry film thickness is not specified). Care must be taken to ensure that the surface profile does not exceed the coating manufacturer's recommended 0.5 – 1.0 mil range. Provisions should be made to perform 3rd party coating inspection at the application location.

- ICV™ Box Transporter System Specification (SP-012, Rev. C)

  The ICV™ Box Transporter (ICV-BT) has no contact with the waste. Therefore, corrosion assessment for the ICV-BT is not applicable.

2.2.6.3 Corrosion Assessment Exceptions

IQRPE Certification exceptions to the corrosion assessment are as follows:

1. Prior to final acceptance of the proposed construction materials and design configuration, results of ICV™ box vitrification testing are required to be reviewed by the Buyer for corrosion effects with materials and configuration of construction. High temperature scaling of the carbon steel ICV™ box should be evaluated. Lined materials must be observed to be compatible with vitrified product and not to react with the product.

2. All Seller recommended protective coatings, surface preparation procedures, application methods, and environmental constraints should be reviewed and approved prior to fabrication.

2.2.7 Recommended Inspection Schedule

In-Container Vitrification (ICV™) System inspections are recommended during four phases:

1. Factory construction of ICV™ boxes/lids.

2. Factory construction of applicable portions of ICV™ Box Transporter System (see Section 1.4.1).

3. Inspections during assembly of ICV™ boxes and lids in the ICV™ Container Preparation and Assembly Enclosure.

4. Site construction Inspection of ICV™ Ancillary Equipment.

2.2.7.1 Factory Construction of ICV™ Boxes and Lids (SP-023, Rev 0)

As part of the procurement process, the ICV™ box Supplier is required to provide a process to plan and execute inspections to verify conformance of the ICV™ box and lid design and construction requirements (SP-023, 4.1.6). Inspections during fabrication shall be independently conducted, documented, and executed in accordance with an approved inspection or test procedure by a qualified inspector in accordance with the NQA-1 quality assurance program. Data from inspections and tests shall be documented in reports for further evaluation, including references to follow-up actions taken for non-conformances. Items inspected are required to be traceable by number, inspector name and date.

The qualified independent inspector or IQRPE should also review the factory ICV™ boxes/lids inspection and testing reports, as they become available, to include but not limited to the following:

- Evaluation of welding work packages and reports to verify no cracking or lack of fusion.
- Confirmation that no punctures, cracks, corrosion, or other structure damage are present.
- Review of "tightness testing" (hydrostatic or pneumatic leak tests, and results) to verify no leaks are present, and that leak test acceptance criteria specified over the test period has been met.
- Verification of critical dimension through physical inspections within specified tolerances;
- Review of Factory Acceptance Test procedures and test results prior to shipment;
- Verification of proper application of coatings, especially verification of ICV™ box high temperature coatings.

2.2.7.2 Factory Construction of the ICV™ Box Transporter (D-DS-012.1 Rev 2)

IQRPE inspection applies to the ICV-BT only as it relates to prevention of an unsafe drop Sections 2.2.1 and 2.2.2. Specification SP-012 requires that the ICV-BT supplier provide a process to plan and execute inspections to verify conformance of the ICV-BT design and construction requirements (SP-012, 4.1.7). Inspections during fabrication shall be independently conducted and documented in accordance with an approved inspection or test procedure by a

qualified inspector in accordance with the NQA-1 quality assurance program. Data from inspections and tests shall be documented in reports for further evaluation, including reference to follow-up actions taken for non-conformances. Items inspected are required to be traceable by number, inspector name and date.

2.2.7.3 Assembly of ICV™ boxes and lids in the ICV™ Container Preparation & Assembly Enclosure

Proper field assembly of the ICV™ boxes insulation, refractory, sand, starter path, lid and gaskets is critical to maintaining ICV™ box integrity (and thus adequately containing hazardous waste) during vitrification operations. ICV™ box assembly inspections are recommended to be conducted by a qualified inspector in accordance with the NQA-1 quality assurance program, and IQRPE spot checked (approximately 5 spot checks, especially during first assemblies) to ensure that assembly acceptance criteria is being met. IQRPE independent review of assembly of ICV™ boxes/lids is not a substitute for a thorough execution of the Quality Assurance/ Quality Control program.

2.2.7.4 Installation Inspection of ICV™ Ancillary Equipment

Accurate records must be kept and recorded in an IQRPE inspectors' database to properly track Inspections, Findings, Resolutions and Acceptance by the IQRPE and Buyer. The IQRPE is recommended to perform inspection walkdowns and coordinate with IQRPE inspectors to inspect and document ongoing and completed construction. Written statements by the IQRPE should be provided, attesting that the In-Container Vitrification(ICV™) System and interconnecting ancillary systems and components have been constructed in accordance with specified requirements, as per WAC 173-303-810 (13)(a).

Inspections shall be conducted by a qualified inspector in accordance with the NQA-1 quality assurance program. IQRPE construction inspections of ICV™ Ancillary Equipment are recommended to include the following:

- Before placing ICV™ Ancillary equipment into service, the associated equipment should be inspected by an IQRPE for structural damage and proper installation.
- IQRPE review of Construction Acceptance Tests, including equipment functional checkout tests, valve actuation tests, electrical continuity tests, valve limit switch tests, instrumentation functionality tests, interlock and control circuit loop tests.
- Verification of the protection of ancillary equipment against physical damage and stress.
- Installation inspection that conforms to consensus-recognized standards including the documentation of findings and corrective actions documented in a post-inspection report;
- Review of non-destructive testing results, including: visual weld examinations, radiography, liquid dye penetrant tests, ultrasonic inspections.
- Review of pre-operational acceptance test results, for testing conducted by representatives of the Buyer. This is an independent review to verify correct operability

of all interlocks, wiring, electrical components, instruments, logic, valves and equipment, for both "normal" and "off-normal" conditions, prior to the start of simulant.

2.2.7.5 Recommended Inspection Schedule Exceptions

The majority of recommended inspections in this report are provided by the IQRPE based on interpretation of requirements referenced in equipment and system procurement specifications, operations and maintenance manuals, equipment data sheets, WAC 173-303-810, WAC 173-303-630 (4),(7); and the RD&D Permit.

IQRPE Certification exceptions to the recommended inspection schedule assessment review are as follows:

- The recommended inspection activities described in this section are based on the design basis operating life, operating conditions, and waste characteristics outlined in the Design Basis Report. Should any of these parameters change (for example: extended operating life, increased operating temperatures, etc.), the inspection schedule must be re-evaluated by the IQRPE.

3.0 DESIGN REVIEW ASSESSMENT CERTIFICATIONS

The In-Container Vitrification (ICV™) System IQRPE/RCRA Design Review Package, RPP-24544, Revision C for System 2.6 has been reviewed by the IQRPE, and, with the exceptions listed herein, was assessed to be in compliance with the applicable sections of WAC 173-303-630, and the RD&D Permit for the DBVS as stated in Section 1.4 of this report. These results are based on a review of the applicable codes, standards, and documents. The certifications below are in accordance with the requirements of WAC 173-303-630 (4),(7)and WAC 173-303-810(13)(a).

Report Lead IQRPE:

I certify under penalty of the law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine or imprisonment for knowing violations.

WILLIAM P. DANA
STATE OF WASHINGTON
29383
REGISTERED PROFESSIONAL ENGINEER
William P. Dana 4-21-07
EXPIRES 7-5-2007

Report Reviewed by:

Robert S. Goodman, P.E. 20 Apr 06.

Karl M. Walterskirchen, P.E. Date

Chief Engineer, TGS

4.0 REFERENCES

WAC 173-303-630, Use and Management of Containers, April, 2005

WAC 173-303-640, Tank Systems, Washington Administrative Code, as amended

WAC 173-303-810 General Permit Conditions, February, 2005

WA Dept of Ecology Publication 94-114, Guidance for Assessing and Certifying Tank Systems that Store and Treat Dangerous Waste, June 1994

WA Dept of Ecology Publication 95-420 Guidance for Assessing Dangerous Waste Secondary Containment Systems, June 1994

RD&D Permit WA7890008967 Permit for Dangerous and or Mixed Waste Research, Development, and Demonstration

CH2M Hill Hanford Group, Inc. Statement of Work, Requisition 114648, "Independent Qualified Registered Professional Engineer support to Demonstration Bulk Vitrification System Project"

RPP-24544, DRAFT Demonstration Bulk Vitrification System IQRPE/RCRA Design Review Package, Revision E. March 21, 2006

WA Dept of Ecology Permit No. WA 7890008967, Permit for Dangerous and/or Mixed Waste Research, development and Demonstration

RPP-17403, Rev 2 "Function and System Design Requirements for the Demonstration Bulk Vitrification System." CH2M Hill Hanford Group, Inc.

HNF-SD-GN-ER-501, Rev. 1B, "Natural Phenomena Hazards, Hanford Site, South Central Washington." (As revised by ECN 672877, May 15, 2002)

DOE-STD-1020-2002, Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities, January 2002

RD&D Permit DOE/ORP-2003-23, Rev 1 May 2004 Section 6 "Waste Analysis Plan"

Principals of Heat Transfer, 5th edition, 1997, Frank Kreith

1997 Uniform Building Code (International Building Code)

AISC Manual of Steel Construction- Allowable Stress Design, 9th edition

ACI Manual of Concrete Practice, 1997, American concrete Institute, Farmington Hills, MI

Design of Welded Structures, O.W. Blodgett, 1996, James F. Lincoln Arc Welding Foundation

Mechanics of Materials, 4th Edition, R.C. Hibbeler

ASME N510, Testing of Air Treatment Systems

ASNT SNT-TC-1A, Recommended Practice for Nondestructive Testing

IQRPE Design Assessment Report No. DR-002, Rev. 0, *Foundations Systems, Review of Calculation 145579-CA-011, Revision 3, Melt Area Support Structure & Foundation (Fdn #1)*

Drawing F-145579-00-A-0021, Rev 0J, Full DBVS Feed Preparation & Melt Process Flow Diagram

Cengel, Y.A. & R.H. Turner, *Fundamentals of Thermal-Fluid Sciences*, McGraw-Hill Co., 2001

Hollman, J.P., *Heat Transfer*, 3rd Edition, McGraw-Hill Co., 1972