ENGINEERING CHANGE NOTICE

☒ DM ☐ FM ☐ TM

1a. ECN 720601 R 0

1b. Proj. ECN W- -

2. Request Information Record Information on the ECN-1 Form	3a. Design Inputs -Record Information on the ECN-2 Form	3b. Design References - Record Information on the ECN-3 Form	3c. Engineering Evaluation / Estimate / Approval to Proceed w/ the Design - Record Information on the ECN-4 Form

4. Originator's Name, Organization, MSIN, & Phone No.	5. USQ Number	6. Date
K. G. Carothers, Process/Waste Transfer Engineering, S5-13, 373-4556	No. TF-03-2424-S ☐ N/A Init. ORD Date 5/22/03	5/21/03

7. Title	8. Bldg. / Facility No.	9. Equipment / Component ID	10. Approval Designator
Caustic Volume Calculation for Transfer of C-106 Oxalic Acid Waste to AN-106	241-AN Tank Farm	Tank 241-AN-107	N/A

11. Document Numbers Changed by this ECN (For FM or TM Changes Record Information on the ECN-5 Form) Sheet and Rev.	12. Design Basis Documents?	13. Safety Designation	14. Expedited / Off-Shift ECN?
RPP-13502, Rev. 0	☐ Yes ☒ No	☐ SC ☐ SS ☐ GS ☒ N/A	☐ Yes ☒ No

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

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

This is a complete revision to RPP-13502, *Calculation of the Effect of Tank 241-C-106 retrieval on Chemistry Control of Tank 241-AN-106*. The document is updated to the current planning for retrieval and transfer of C-106 sludge to AN-106. Oxalic acid (a mild acid) will be added to C-106 to dissolve the residual sludge heel stored in the tank. Transfer of the resultant acid waste to tank AN-106 is planned where the waste will undergo in-tank neutralization. Enough hydroxide will have to be available in AN-106 to perform the neutralization step. The revision to RPP-13502 addresses how much hydroxide is required for the neutralization and what the sources of the hydroxide are. The effects of the C-103 saltwell waste transfer to the tank from November 2002 and February 2003 are accounted for in the hydroxide material balance. The contribution to the available hydroxide inventory in AN-106 from the proposed AN-101 transfer is estimated. Given the expected volume of oxalic acid to be used in the C-106 sludge dissolution process, the volume of 25-wt% (8 M) sodium hydroxide needed to supplement the hydroxide inventory in the tank to neutralize the acid waste and keep the final waste mixture within the AC 5.15 chemistry control limits is calculated.

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

Revision 0 of RPP-13502 assumed only alkaline waste from C-106 would be transferred to tank AN-106. The C-106 retrieval plan has changed in order to meet the goal of retrieving enough sludge such that less than 360 ft^3 of waste heel remains. To accomplish this retrieval, the sludge will be dissolved in oxalic acid and transferred to AN-106. A complete revision to RPP-13502 is required to support the new approach to retrieving the C-106 waste.

19. **ECN Category**

☒ Direct Revision

☐ Supplemental

ECN Revision Type

☐ Void/Cancel

☐ Closure

☐ Revision

20. **Distribution** (Name and MSIN)

See Distribution Sheet

Release Stamp

MAY 30 2003

DATE:

STA: 4

HANFORD RELEASE

ID: 8

ENGINEERING CHANGE NOTICE	☒ DM ☐ FM ☐ TM	1a. ECN 720601 R 0
Page 2 of 7		1b. Proj. ECN W- -

21. **Design Check** Record Information on the ECN-6 Form	22. **Design Verification Required?** ☐ Yes ☒ No If Yes, as a minimum attach the one page checklist from TFC-ENG-DESIGN-P-17.	23. **Closeout / Cancel / Void** ☐ Yes ☒ No If Yes, Record Information on the ECN-7 Form and attach form(s).

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

N/A

Note: All Revisions shall have the approvals of the affected organizations as identified in block 9 "Approval Designator," on page 1 of this ECN.

25a. **Commercial Grade Item Dedication Numbers** (associated with this design change) N/A	25b. **Engineering Data Transmittal Numbers** (associated with this design change, e.g., new drawings, new documents) N/A

26a. **Design Cost Estimate** N/A	26b. **Materials / Procurement Costs** N/A	26c. **Estimated Labor Hours** **2 man-weeks**

27. **Field Change Notice(s) Used?** (Used for ECN Revisions only) ☐ Yes ☒ No If Yes, Record Information on the ECN-8 Form attach form(s) and identify permanent changes.	NOTE: ECN Revisions are required to record and approve all FCN's issued during the field modification work process. If the FCN's have not changed the original design media then they are just incorporated into the ECN file via an ECN revision. If the FCN did change the original design media then the ECN Revision will include the necessary engineering changes to the original design media changes.

28. **Approvals**

	Signature	Date
Design Authority		
Team Lead/Lead Engr.		
Resp. Engineer	K.G. Carothers K.G. Carothers	5/21/03
Resp. Manager	T.M. Horner T.M. Horner	5/30/03
Quality Assurance		
IS&H Engineer		
NS&L Engineer		
Environ. Engineer		
Project Engineer		
Design Checker	M.J. Klem M.J. Klem	5/21/03
Design Verifier		
Operations		
Radcon		
Other		
Other		

	Signature	Date
Originator/Design Agent	K.G. Carothers K.G. Carothers	5/21/03
Professional Engineer		
Project Engineer		
Quality Assurance		
Safety		
Designer		
Environ. Engineer		
Other		
Other		

DEPARTMENT OF ENERGY / OFFICE OF RIVER PROTECTION

Signature or a Control Number that tracks the Approval Signature

ADDITIONAL SIGNATURES

ECN - 1 ENGINEERING REQUEST FORM Page 3of 7	☒ DM ☐ FM ☐ TM	1a. ECN 720601 R0 1b. Proj. ECN W- -

Requestor's Name (Print)	Date	REA Reference
K. G. Carothers	5/21/03	N/A

Equipment Name	Estimated Need Date
241-AN-106	5/21/03

Problem/Issue Statement

RPP-13502, Calculation of the Effect of Tank 241-C-106 Retrieval on Chemistry Control in Tank 241-AN-106, needs to be updated to reflect the new plan for retrieval of C-106 sludge using the oxalic acid dissolution process.

Purpose for the Proposed Modification

The RPP-13502 modification will determine the volume of 25-wt% (8 M) sodium hydroxide that needs to be added to AN-106 in preparation for the C-106 oxalic acid waste transfer from C-106.

Basis for the Estimated Need Date

The C-106 retrieval is part of the CH2M HILL mission to accelerate retrieval and closure of tanks.

Requestor's Signature	Date	Requestor's Manager's Signature	Date
KG Carothers	5/21/03	[signature]	5/21/03

Responsible Manager Approval

Work Package Number (If Known)	Estimated Evaluation ROM Cost	CACN
N/A	$N/A	501556
Process as a Simple Modification? ☒ Yes ☐ No	***Assigned to (Team Lead)*** K. G. Carothers	***Date*** 5/5/03
Responsible Manager's Signature [signature] 5/21/03	☒ Approve ☐ Reject	***Date*** 5/21/03

If rejected, explain reason for rejection:

(Once rejected the Responsible Manager returns the request to the Requestor's Manager)

Italicized text items need to be addressed. Standard text items need to be addressed as applicable to the problem/issue described.

ECN - 5 DRAWING / DOCUMENT CHANGE LIST FORM	☒ DM ☐ FM ☐ TM	1a. ECN 720601 R0
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List of Engineering Drawings/Documents to be Modified (Use the attached checklist for guidance)

Dwg./Doc. Number (Sheet/Page, Rev)	Title/Type	Shared	Existing Change Document Nos.
RPP-7917 Rev. 0	Calculation of the Effect of Tank 241-C-106 Retrieval on chemistry Control of Tank 241-AN-106	☐	
		☐	
		☐	
		☐	
		☐	
		☐	
		☐	
		☐	
		☐	
		☐	
		☐	
		☐	

Submitted to Document Service Center Prior to ECN Release?

☐ Yes ☒ No	Team Lead K. G. Carothers K.G. Carothers	Date 5/21/03

List of Non-Engineering Documents Needed to be Modified

Document Number/Revision, Sheet/Page (If Available)	Document Title	Document Owner (Organization)	Individual Notified	Method	Date Notified
Caustic Purchase Requisition	N/A	DST Integrity	M.F. Erhart	email	5/21/03

ECN - 5 DRAWING / DOCUMENT CHANGE LIST FORM	☒ DM ☐ FM ☐ TM	1a. ECN 720601 R0 1b. Proj. ECN W- -

Drawings/Documents to be Modified Checklist			
System Design Description	☐ Yes ☐ No ☒ N/A	Operating Procedure	☐ Yes ☐ No ☒ N/A
Functional Design Criteria	☐ Yes ☐ No ☒ N/A	System/Subsystem Specifications	☐ Yes ☐ No ☒ N/A
Functional Requirements	☐ Yes ☐ No ☒ N/A	Engineering Flow Diagram Drawing	☐ Yes ☐ No ☒ N/A
Operating Specification	☐ Yes ☐ No ☒ N/A	General Arrangement Drawing	☐ Yes ☐ No ☒ N/A
Criticality Specification	☐ Yes ☐ No ☒ N/A	Material Specification	☐ Yes ☐ No ☒ N/A
Conceptual Design Report	☐ Yes ☐ No ☒ N/A	Sampling Plan	☐ Yes ☐ No ☒ N/A
Detailed Design Report	☐ Yes ☐ No ☒ N/A	Inspection Plan	☐ Yes ☐ No ☒ N/A
Equipment Specification	☐ Yes ☐ No ☒ N/A	Radiation Control Procedure	☐ Yes ☐ No ☒ N/A
Procurement Specification	☐ Yes ☐ No ☒ N/A	Spare Parts List	☐ Yes ☐ No ☒ N/A
Construction Specification	☐ Yes ☐ No ☒ N/A	Test Specification	☐ Yes ☐ No ☒ N/A
Vendor Information	☐ Yes ☐ No ☒ N/A	Test Plan	☐ Yes ☐ No ☒ N/A
Operations / Maintenance Manual	☐ Yes ☐ No ☒ N/A	Acceptance Test Procedure	☐ Yes ☐ No ☒ N/A
Safety Analysis / FSAR / SAR / DSA	☐ Yes ☐ No ☒ N/A	Pre-Operational Test Procedure	☐ Yes ☐ No ☒ N/A
Technical Safety Requirement	☐ Yes ☐ No ☒ N/A	Operational Test Procedure	☐ Yes ☐ No ☒ N/A
Master Equipment List	☐ Yes ☐ No ☒ N/A	ASME Coded Item / Vessel	☐ Yes ☐ No ☒ N/A
Safety Equipment List	☐ Yes ☐ No ☒ N/A	Human Factor Consideration	☐ Yes ☐ No ☒ N/A
Radiation Work Permit	☐ Yes ☐ No ☒ N/A	Automated Control Configuration Procedure	☐ Yes ☐ No ☒ N/A
Environmental Requirement	☐ Yes ☐ No ☒ N/A	Computer / Automated Control Software Plan	☐ Yes ☐ No ☒ N/A
Environmental Permit	☐ Yes ☐ No ☒ N/A	Raceway / Cable Schedules	☐ Yes ☐ No ☒ N/A
Seismic / Stress / Structural Analysis	☐ Yes ☐ No ☒ N/A	Work Control Procedure	☐ Yes ☐ No ☒ N/A
Design Report	☐ Yes ☐ No ☒ N/A	Corrective Maintenance Procedure	☐ Yes ☐ No ☒ N/A
Interface Control Drawing	☐ Yes ☐ No ☒ N/A	Process Control Plan	☐ Yes ☐ No ☒ N/A
Calibration Procedure	☐ Yes ☐ No ☒ N/A	Process Control Procedure	☐ Yes ☐ No ☒ N/A
Preventive Maintenance Procedure	☐ Yes ☐ No ☒ N/A	Flow Sheet	☐ Yes ☐ No ☒ N/A
Engineering Procedure	☐ Yes ☐ No ☒ N/A	Purchase Requisition	☒ Yes ☐ No ☐ N/A
Security Plan	☐ Yes ☐ No ☒ N/A	Hazards Analysis	☐ Yes ☐ No ☒ N/A
Emergency Plan	☐ Yes ☐ No ☒ N/A	JCS PM Activity Datasheet	☐ Yes ☐ No ☒ N/A
	☐ Yes ☐ No ☐ N/A		☐ Yes ☐ No ☐ N/A
	☐ Yes ☐ No ☐ N/A		☐ Yes ☐ No ☐ N/A

ECN - 6 DESIGN CHECK LIST	☒ DM ☐ FM ☐ TM	1a. ECN 720601 R 0 1b. Proj. ECN W- -
Sheet 1 of ECN – 6 Page 6 of 7		

Design Details/Attributes (to be filled out by the change originator) identified in the ECN.			
1. Issue/Problem Statement included	☒ Yes ☐ No ☐ N/A	21. Basis for Selected Alternative explained, including assumptions	☐ Yes ☐ No ☒ N/A
2. Safety/Commitment/Programmatic Impacts identified – NEPA Documentation completed	☒ Yes ☐ No ☐ N/A	22. Potential Component/System Impacts identified and resolved	☐ Yes ☐ No ☒ N/A
3. System/Equipment/Personnel Impacts identified	☒ Yes ☐ No ☐ N/A	23. Potential Software Impacts identified and resolved	☐ Yes ☐ No ☒ N/A
4. Technical Evaluation included	☒ Yes ☐ No ☐ N/A	24. Potential Safety Impacts are identified and resolved (e.g., energized electrical equipment)	☐ Yes ☐ No ☒ N/A
5. Compliance w/ Design Basis identified	☐ Yes ☐ No ☒ N/A	25. Modification is Constructible and can be implemented	☐ Yes ☐ No ☒ N/A
6. Assumptions/Sources clearly identified	☒ Yes ☐ No ☐ N/A	26. Design considers Operational Impacts	☐ Yes ☐ No ☒ N/A
7. Affected Documents and Databases clearly identified	☒ Yes ☐ No ☐ N/A	27. Contamination Controls are planned	☐ Yes ☐ No ☒ N/A
8. Inputs Verified	☒ Yes ☐ No ☐ N/A	28. Pre-Installation/Mockup/Prototype Testing planned	☐ Yes ☐ No ☒ N/A
9. Required Function(s) / changes clearly identified	☒ Yes ☐ No ☐ N/A	29. Sketches/Drawings for Tools/Fabricated Components included	☐ Yes ☐ No ☒ N/A
10. Safety Basis/Commitments/Concerns evaluated	☒ Yes ☐ No ☐ N/A	30. Hardware Design described	☐ Yes ☐ No ☒ N/A
11. Application of Industry Standards/Codes explained	☐ Yes ☐ No ☒ N/A	31. Software/Firmware Design described	☐ Yes ☐ No ☒ N/A
12. Proper Analytical Techniques employed	☒ Yes ☐ No ☐ N/A	32. Inspections (per Codes & Standards) / Quality Checks included	☐ Yes ☐ No ☒ N/A
13. Interfaces evaluated and identified	☒ Yes ☐ No ☐ N/A	33. Dimensions and Tolerances included	☐ Yes ☐ No ☒ N/A
14. Material/Component Compatibility evaluated	☐ Yes ☐ No ☒ N/A	34. Sketches/Drawings for Installation included	☐ Yes ☐ No ☒ N/A
15. ALARA/Radiological controls/chemical hazards evaluated	☐ Yes ☐ No ☒ N/A	35. Housekeeping/Personnel Safety Requirements identified	☐ Yes ☐ No ☒ N/A
16. Human/Machine Interface evaluated	☐ Yes ☐ No ☒ N/A	36. Walkdown(s) performed/Labeling Correct	☐ Yes ☐ No ☒ N/A
17. Program impacts evaluated	☒ Yes ☐ No ☐ N/A	37. Acceptance Test generated and Acceptance Criteria included	☐ Yes ☐ No ☒ N/A
18. Design Basis Calculations updated	☐ Yes ☐ No ☒ N/A	38. M&TE Requirements identified	☐ Yes ☐ No ☒ N/A
19. Alternatives described/evaluated and address resolution of problem	☐ Yes ☐ No ☒ N/A	39. Training/Qualification of Test Personnel identified	☐ Yes ☐ No ☒ N/A
20. Impacts on Maintenance and OPS described	☐ Yes ☐ No ☒ N/A	40. Safety and Hazards Analysis assessed	☐ Yes ☐ No ☒ N/A

Design Originator (Print/Sign)	**Date**
K. G. Carothers K.G. Carothers	5/21/03

Italicized text items need to be addressed. Standard text items need to be addressed as applicable to the change as described.

ECN - 6 DESIGN CHECK LIST	☒ DM ☐ FM ☐ TM	1a. ECN 720601 R 0
Sheet 2 of ECN – 6 Page 7 of 7		1b. Proj. ECN W- -

Design Check Method (Select method(s) and provide explanation of how to be performed):

☒ **Peer Check**	☐ **Design Check Team***	☐ **Other** _____

Design Check Explanation:

Check that changes are complete, correct, and technically adequate.

* Design check team members other than the originating organization normally should consist of personnel representing: Operations, Maintenance & Reliability Engineering, Maintenance Management, Maintenance Crafts, Safety, and Projects.

Design Check Details

Design inputs correctly identified?	☒ Yes ☐ No ☐ N/A	*Design changes properly documented?*	☒ Yes ☐ No ☐ N/A
Calculations checked and are correct?	☒ Yes ☐ No ☐ N/A	*Test procedures reviewed and are correct?*	☐ Yes ☐ No ☒ N/A
Design assumptions are stated and verified?	☒ Yes ☐ No ☐ N/A	*Is the design change adequate?*	☒ Yes ☐ No ☐ N/A
Design criteria incorporated into the design?	☒ Yes ☐ No ☐ N/A	*Is the design change complete?*	☒ Yes ☐ No ☐ N/A
Interfaces clearly identified in the design?	☐ Yes ☐ No ☒ N/A	*Is the design change correct?*	☒ Yes ☐ No ☐ N/A
EQRG pre-release review required?	☐ Yes ☒ No	EQRG Pre-release Approval	Date

Comments:

Reference TFC-ENG-DESIGN-P-17, Design Verification

Design Checker (Print/Sign)	***Date***
M. J. Klem M J Klem	5/21/03

Italicized text items need to be addressed. Standard text items need to be addressed as applicable to the problem/issue described.

DISTRIBUTION SHEET

To	From	Page 1 of 1
DISTRIBUTION	PROCESS/WASTE TRANFER ENGINEERING	Date 5/21/03
Project Title/Work Order		EDT No. NA
RPP-13502, Rev. 1 "Calculation of the Effect of Tank 241-C-106 Retrieval on Chemistry Control of Tank 241-AN-106".		ECN No. 720601 RO

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
CH2M Hill Hanford Group, Inc.					
W. B. Barton	R2-12	X			
K. M. Bowen	R2-12	X			
C. A. Burke	S7-65	X			
K. G. Carothers	S5-13	X			
K. E. Carpenter	S7-65	X			
J. M. Conner	S5-13	X			
G. P. Duncan	R3-26	X			
M. F. Erhart	R3-26	X			
T. M. Horner	S5-13	X			
M. A. Knight	R1-14	X			
T. H. May	S7-70	X			
R. S. Nicholson	S5-05	X			
J. G. Propson	S7-65	X			
D. A. Reynolds	S7-70	X			
Office of River Protection					
DOE Reading Room	H2-53	H			
V. L. Callahan	H6-60	X			
JO Ferguson	S0-03	X			
HC-44					

Calculation of the Effect of Tank 241-C-106 Retrieval on Chemistry Control of Tank 241-AN-106

K. G. Carothers
CH2M HILL Hanford Group, Inc.
Richland, WA 99352
U.S. Department of Energy Contract DE-AC27-99RL14047

EDT/ECN: ECN-720601-R0 UC:
Cost Center: 7G230 Charge Code: 16510-018
B&R Code: Total Pages: 33

Key Words: Calculation, Caustic Volume, Tank 241-AN-106, AN-106, Tank 241-C-106, C-106, Retrieval, Oxalic Acid, Chemistry Control

Abstract: In preparation for the retrieval and transfer of the tank 241-C-106 sludge to double-shell tank storage, concentrated caustic (sodium hydroxide) needs to be added to the receiver, tank 241-AN-106, to ensure compliance with the AC 5.15, "Corrosion Mitigation Program," chemistry control limits. The tank 241-C-106 sludge will be retrieved by dissolving the sludge using oxalic acid. The hydroxide content of AN-106 needs to be sufficient to neutralize the incoming acid waste stream.

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5/30/03
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RECORD OF REVISION

(1) Document Number: RPP-13502

Page 1

(2) Title: Calculation of the Effect of Tank 241-C-106 Retrieval on Chemistry Control of Tank 241-AN-106

Change Control Record

(3) Revision	(4) Description of Change - Replace, Add, and Delete Pages	Authorized for Release (5) Cog. Engr.	Authorized for Release (6) Cog. Mgr. Date
0	(7) Initially released on 12/12/02 on EDT-633986	J.M. Conner	M. A. Knight
RS 1	Incorporate per ECN-720601, RO Rev. 0	K. G. Carothers	T. M. Horner

A-7320-005 (10/97)

RPP-13502
Revision 1

CALCULATION OF THE EFFECT OF TANK 241-C-106 RETRIEVAL ON CHEMISTRY CONTROL OF TANK 241-AN-106

K. G. Carothers
CH2M HILL Hanford Group, Inc.

Date Published
May 2003

CH2MHILL
Hanford Group, Inc.

Prepared for the U.S. Department of Energy
Office of River Protection

Approved for public release; distribution unlimited.

Calculation Review Checklist

Calculation Reviewed: RPP-13502, Rev. 1

Scope of Review: Complete document
(e.g., document section or portion of calculation)

Engineer/Analyst: K. G. Carothers K G Carothers Date: 5/28/03

Organizational Mgr: T. M. Horner T. M. Horner Date: 5/30/03

This document consists of ___ pages and the following attachments (if applicable):

Yes	No	NA*		
[X]	[ ]	[ ]	1.	Analytical and technical approaches and results are reasonable and appropriate.
[X]	[ ]	[ ]	2.	Necessary assumptions are reasonable, explicitly stated, and supported.
[ ]	[ ]	[X]	3.	Ensure calculations that use software include a paper printout, microfiche, CD ROM, or other electronic file of the input data and identification to the computer codes and versions used, or provide alternate documentation to uniquely and clearly identify the exact coding and execution process.
[X]	[ ]	[ ]	4.	Input data were checked for consistency with original source information.
[ ]	[ ]	[X]	5.	For both qualitative and quantitative data, uncertainties are recognized and discussed.
[X]	[ ]	[ ]	6.	Mathematical derivations were checked including dimensional consistency of results.
[X]	[ ]	[ ]	7.	Calculations are sufficiently detailed such that a technically qualified person can understand the analysis without requiring outside information.
[ ]	[ ]	[X]	8.	Software verification and validation are addressed adequately.
[X]	[ ]	[ ]	9.	Limits/criteria/guidelines applied to the analysis results are appropriate and referenced. Limits/criteria/guidelines were checked against references.
[X]	[ ]	[ ]	10.	Conclusions are consistent with analytical results and applicable limits.
[X]	[ ]	[ ]	11.	Results and conclusions address all points in the purpose.
[X]	[ ]	[ ]	12.	Referenced documents are retrievable or otherwise available.
[X]	[ ]	[ ]	13.	The version or revision of each reference is cited.
[X]	[ ]	[ ]	14.	The document was prepared in accordance with Attachment A, "Calculation Format and Preparation Instructions."
[X]	[ ]	[ ]	15.	All checker comments have been dispositioned and the design media matches the calculations.

M. J. Klem M J Klem 5/28/03
Checker (Printed Name and Signature) Date

* If No or NA is chosen, an explanation must be provided on or attached to this form.

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1.0 OBJECTIVE/PURPOSE

Sodium hydroxide was added to tank 241-AN-106 (AN-106) in June 2002 in anticipation of receiving waste from tank 241-C-103 (C-103). This transfer occurred between November 2002 and February 2003. A recent effort to accelerate closure of selected single-shell tanks (SSTs) has resulted in a plan to transfer the sludge heel in tank 241-C-106 (C-106) to double-shell tank (DST) AN-106 as well. For this transfer, the C-106 sludge will first be dissolved in a one molar (moles/liter or M) oxalic acid solution. The acid solution will then be transferred to tank AN-106 batch wise where it will undergo in-tank neutralization.

This document calculates the volume of 25-wt% (8 M) sodium hydroxide solution that must be added to tank AN-106 for the waste to remain above the specifications of Administrative Control (AC) 5.15, "Corrosion Mitigation Program" (CH2M HILL 2003a) after the planned C-106 waste transfer.

2.0 BACKGROUND

The DST Integrity Project added 8.1 kgal of 25-wt% caustic in June 2002 (Wood 2002). The goal of the chemical addition was to keep the waste above the AC 5.15 limits for at least 5 years (Conner 2002), accounting for the planned C-103 saltwell pumping transfer. The Corrosion Mitigation Program projects tank chemistry out for a maximum of 5 years (Fort and Klem 2002). A confirmatory sample was taken and analyzed following the chemical addition but before the C-103 transfer (Sosa 2002).

Tank C-103 saltwell pumping began on November 29, 2002, and continued until February 9, 2003. A total of 113.8 kgal of C-103 waste was transferred to tank AN-106. This volume represented approximately 34 kgal more waste than was originally anticipated. Because of the increased volume transferred to AN-106, the C-106 waste buffer will have consumed some of the excess hydroxide from the June 2002 caustic addition. Consequently, not enough hydroxide remains in the waste to meet the 5-year goal and another chemical adjustment was forecast for fiscal year (FY) 2005 to keep the waste above the AC 5.15 chemistry control limits (Fort et al. 2003).

Before the sludge heel in C-106 is retrieved and transferred to AN-106, the supernatant in tank 241-AN-101 (AN-101) will first be transferred to AN-106. This transfer will supply extra waste volume and hydroxide inventory to the tank to support neutralization of the C-106 acid waste stream.

The goal of the C-106 Waste Retrieval and Closure Demonstration Project is to retrieve and transfer the majority of the C-106 waste to DST storage, leaving a residual waste heel of less than 360 ft^3 (or ~2700 gallons). The supernatant in the tank was transferred to tank 241-AY-102 in April 2003. The current estimate of the amount of solids remaining in tank C-106 is approximately 9.1 kgal (Riess 2002). Therefore, at least 6.4 kgal of the remaining sludge heel in tank C-106 would have to be retrieved to meet the objective of the retrieval/closure project. Oxalic acid (a mild acid) has been proposed to achieve the retrieval by dissolving up to 70 percent of the remaining sludge and

transferring the resultant acid waste to tank AN-106. AC 5.15 establishes the chemistry limits for waste stored in DSTs to control corrosion of the primary tank wall to within acceptable levels. Enough caustic needs to be added to AN-106 beforehand to accomplish the in-tank neutralization of the C-106 acid waste transfer and to keep the waste chemistry above the AC 5.15 limits for at least 5 years.

3.0 OPEN ITEMS

The calculation assumes full mixing and neutralization of the C-106 acid waste stream with the caustic adjusted AN-106 waste as it is added to the tank. If the more dilute, high volume, acid stream from tank C-106 does not mix with the waste in tank AN-106, then the surface layer in tank AN-106 would not meet the AC 5.15 specifications. This open item will be addressed in the Process Control Plan for C-106 retrieval.

4.0 METHODS OF ANALYSIS

Calculation methods are common chemical engineering methods such as material (molar) balance, concentration (pH and molarity), and volume calculations, along with routine algebraic manipulations. The depletion of hydroxyl ion (OH^-) from the supernatant via absorption of carbon dioxide from atmospheric air is predicted using the Hobbs equation (Fort et al. 2002).

This calculation generally follows the format (methods, equations, and symbols) established in calculations for recent chemical additions to tank 241-AN-107 (Carothers 2003) and tank AN-106 (Conner 2002).

4.1 Symbols

V_i	initial supernatant volume, AN-106	kgal or L
V_f	final supernatant volume, AN-106	kgal
V_{NaOH}	added caustic solution volume	kgal
$V_{C\text{-}103}$	transferred volume, C-103	kgal
$V_{C\text{-}106}$	transferred volume, C-106	kgal
$V_{AN\text{-}101}$	transferred volume, AN-101	kgal
V_{H2O}	transferred dilution and flush water volume	kgal
C_i	initial supernatant concentration, AN-106	moles/liter (M)
C_f	final supernatant concentration, AN-106	M
C_{i_Hobbs}	initial supernatant concentration for Hobbs depletion calc.	M
C_{f_Hobbs}	final supernatant concentration for Hobbs depletion calc.	M
C_{NaOH}	concentration of added caustic solution	M
$C_{C\text{-}103}$	concentration of transferred C-103 waste	M
$C_{C\text{-}106}$	concentration of transferred C-106 waste	M
$C_{AN\text{-}101}$	concentration of transferred AN-101 waste	M
C_{H2O}	concentration of transferred dilution and flush water	M
M_i	initial amount of chemical specie, AN-106 supernatant	moles
M_f	final amount of chemical specie, AN-106 supernatant	moles
M_{NaOH}	amount of sodium hydroxide added to AN-106	moles
$M_{C\text{-}103}$	amount of chemical specie, C-103	moles
$M_{C\text{-}106}$	amount of chemical specie, C-106	moles
$M_{AN\text{-}101}$	amount of chemical specie, AN-101	moles
M_{H2O}	amount of transferred dilution and flush water	moles
R_v	ventilation rate	ft^3/min
t	reaction or depletion time	days
B	fraction CO_2 absorbed by waste	-
$D_{C\text{-}103}$	caustic demand in C-103 liquid waste	moles OH^-/liter
$D_{C\text{-}106}$	caustic demand in C-106 acid waste	moles OH^-/liter

4.2 Constants and Conversions

1 inch tank elevation	2750 gal
kgal	1000 gal
gal	3.785 liters (L)
kL	1000 L

4.3 Volume and Concentration Calculations

The OH^- concentration is determined through direct analysis or through a pH measurement and conversion to OH^-. The best method is through direct analysis. However, if the OH^- concentration is too low, a direct analysis may be below the detection limit, or may be subject to high uncertainty. Banning (2002) recommends using a converted pH measurement when the pH is below 12.5. The common conversion from pH to OH^- concentration is shown in Equation 1.

$$C_{OH^-} = 10^{(pH-14)} \tag{1}$$

Caustic depletion occurs in tank AN-106 on a continuous basis. Hydroxyl ion in the supernatant reacts with absorbed carbon dioxide from tank ventilation air to produce bicarbonate and carbonate ions and is involved in a complex way with organic degradation reactions. For tank AN-106, the depletion rate is calculated using the Hobbs equation. This equation was developed at Savannah River and is used to predict OH^- depletion for all waste types in the Hanford Site DSTs (Fort et al. 2002). A second equation from Fort et al. (2002), referred to as the Carothers equation, is used to determine the depletion rate in complexant wastes.

Although Hanlon (2003) categorized AN-106 as containing concentrated complexant (CC) waste, the Carothers equation is not utilized in this calculation. With the transfer of C-103 waste, which earlier was categorized as dilute-noncomplexed waste (Hanlon 1999), approximately 80 percent of the current waste volume in AN-106 is comprised of the C-103 waste. Before the C-106 acid waste is transferred to the tank, approximately 206 kgal of AN-101 waste, also dilute-noncomplexed waste, will be transferred into AN-106. Therefore, the potential CC component of the waste will make up less than 10 percent of the AN-106 waste volume. The Carothers equation is not applicable for predicting the OH^- depletion in the AN-106 waste.

Volume and concentration calculations are performed using the conservation of volume and material balance equations. These equations are in common usage in chemical engineering practice and are only listed here.

$$V_i + V_{C\text{-}103} + V_{AN\text{-}101} + V_{C\text{-}106} + V_{H2O} + V_{NaOH} = V_f \quad \text{conservation of volume}$$

$$M_i + M_{C\text{-}103} + M_{AN\text{-}101} + M_{C\text{-}106} + M_{H2O} + M_{NaOH} = M_f \quad \text{material (molar) balance}$$

The mole quantities for chemical species can be expressed in terms of concentration and volume. For example, for the initial supernatant in tank AN-106,

$$M_i = C_i V_i,$$

which for simplicity can be expressed as $(CV)_i$. The chemical species of interest for the Corrosion Mitigation Program are free OH^-, nitrite ion (NO_2^-), and nitrate ion (NO_3^-).

The molar balance can be restated, substituting concentrations and volumes:

$$(CV)_i + (CV)_{C\text{-}103} + (CV)_{AN\text{-}101} + (CV)_{C\text{-}106} + (CV)_{H2O} + (CV)_{NaOH} = (CV)_f \qquad (2)$$

If the volumes are known, then the molar balance equation can be solved for C_f:

$$C_f = \frac{(CV)_i + (CV)_{C-103} + (CV)_{AN-101} + (CV)_{C-106} + (CV)_{H2O} + (CV)_{NaOH}}{V_f}$$

The concentration of chemicals (OH^-, NO_2^-, NO_3^-) in water is zero, so the $(CV)_{H2O}$ term can be dropped from the numerator. In a similar manner, the concentration of chemicals (OH^-, NO_2^-, NO_3^-) in the C-106 acid waste is assumed to be zero, so the $(CV)_{C\text{-}106}$ term can be dropped from the numerator also. Only minor amounts of OH^-, NO_2^-, and NO_3^- remain in the sludge because of the mixing that occurred with dilute sluicing fluid during the first C-106 waste retrieval that occurred in 1988 and 1989. Additionally, before acid is added to tank C-106 to dissolve the residual sludge, the sludge will be sluiced with water and a transfer made to tank 241-AY-102. This sluicing operation will further remove any residual OH^-, NO_2^-, and NO_3^-. Therefore, after substituting from the conservation of volume equation for V_f, the following equation is obtained:

$$C_f = \frac{(CV)_i + (CV)_{C-103} + (CV)_{AN-101} + (CV)_{NaOH}}{V_i + V_{C-103} + V_{AN-101} + V_{C-106} + V_{H2O} + V_{NaOH}} \qquad (3)$$

This molar balance equation for the supernatant does not account for chemical reactions in the waste (i.e., caustic demand).

4.4 Caustic Demand

Caustic demand was not expected to be significant in the AN-106 waste prior to the C-103 transfer because the hydroxide concentration was high (~2 M). Caustic demand was expected to be significant in the C-103 liquid waste that was transferred to the tank because the hydroxide concentration was low (~pH 10). The C-106 acid waste will have a significant caustic demand. Equation 2 can be modified to take into account caustic demand:

$$(CV)_i + (CV)_{C-103} + (CV)_{AN-101} + (CV)_{NaOH} - (DV)_{C-103} - (DV)_{C-106_acid} = (CV)_f$$

Solving for C_f, after substituting from the conservation of volume equation for V_f:

$$C_f = \frac{(CV)_i + (CV)_{C-103} + (CV)_{AN-101} + (CV)_{NaOH} - (DV)_{C-103} - (DV)_{C-106_acid}}{V_i + V_{C-103} + V_{AN-101} + V_{C-106} + V_{H2O} + V_{NaOH}} \qquad (4)$$

If the final volume is not fixed but the final target concentration is known, then the conservation of volume and molar balance equations can be solved simultaneously for the caustic volume.

$$V_{NaOH} = \frac{V_i(C_f - C_i) + V_{C103}(C_f - C_{C103} + D_{C103}) + V_{AN101}(C_f - C_{AN101}) + V_{C106}(C_f + D_{C106}) + C_f V_{H_2O}}{C_{NaOH} - C_f} \quad (5)$$

4.5 Hobbs Equation

The Hobbs equation (Fort et al. 2002) calculates OH^- depletion based on the ventilation rate and supernatant volume. The equation is presented in Equation 6.

$$C_{f_Hobbs} = C_{i_Hobbs} - \frac{1.27BR_V t}{V_f} \quad (6)$$

where C_{i_Hobbs} = initial OH^- concentration (M)
C_{f_Hobbs} = final OH^- concentration (M)
B = fraction CO_2 absorbed by waste
R_V = primary tank ventilation rate (standard ft^3/min)
t = time (days)
V_f = supernatant volume (L)

The B term of the Hobbs equation is defined in Fort et al. (2002):

$$B = 0.165(\log C_{i_Hobbs} + 14) - 1.569 \quad (7)$$

Equation 6 can be rearranged to solve for t:

$$t = \frac{(C_{i_Hobbs} - C_{f_Hobbs})V_f}{1.27BR_V} \quad (8)$$

5.0 INPUT DATA

5.1 Concentration, Level, and Volume Data

Data needed for the calculations are presented in Tables 1 through 7. Data sources are shown in the tables. The solids volume data for AN-101 requires further explanation. Hanlon (2003) shows no sludge or saltcake in the tank. However, a zip cord measurement taken at the time of the October 2002 grab sample event indicated that a 17-inch solids layer exists in the tank. This represents the most current information and is used in determining the AN-101 supernatant volume available for transfer.

Table 1. Tank Level and Volume Data.

Tank	Parameter	Data	Units	Source
Initial AN-106	Surface level[1]	16.78	inches	SACS (CH2M HILL 2002a)
	Waste volume	46	kgal	by conversion (Section 4.2)
	Solids volume	17	kgal	Hanlon (2003)
	Supernatant volume	33.4	kgal	assumption (Section 5.2)
C-103	Transferred waste volume	113.8	kgal	Sasaki (2003)
	Dilution/flush water	4.3	kgal	Sasaki (2003)
AN-101	Surface level[2]	92.05	inches	SACS (CH2M HILL 2003b)
	Waste volume	253	kgal	by conversion (Section 4.2)
	Solids volume	17	inches	CH2M HILL (2002b)
	Solids volume	47	kgal	by conversion (Section 4.2)
	Supernatant volume	206	kgal	by difference
	Dilution/flush water	3	kgal	assumption (Section 5.2)
C-106	Transferred oxalic acid	210	kgal	Rogers (2003)
	Transferred sludge	6.4	kgal	assumption (Section 5.2)
	Dilution/flush water	0.3	kgal	assumption (Section 5.2)

Notes:
[1]Surface level on 7/30/02, the date the tank was sampled following the caustic addition (Sosa 2002a).
[2]Surface level on 10/8/02, the date the tank was sampled (Sosa 2002b).

Table 2. Tank 241-AN-106 Liquid Mean Data from 2002 Grab Samples.

Analyte	Mean	Units	Molecular Weight	Concentration	Units
Hydroxide	3.29E+04	µg /mL	17.0	1.94	M
Nitrate	5.36E+04	µg /mL	62.0	0.86	M
Nitrite	2.15E+04	µg /mL	46.0	0.47	M
Specific Gravity	1.25	unitless	N/A	N/A	N/A

Notes: Mean data for selected constituents from Sosa (2002a). Molecular weights from Perry and Green (1984).
N/A = not applicable

Table 3. Tank 241-C-103 pH Measurements and Conversion to Hydroxide Concentration.

Result Type	Reported pH Value	Reported Units	Lab Sample ID	Sample Number	Converted Hydroxide Value	Units
DUPLICATE_RESULT	9.98	unitless	S01T001466	B0HHL1T	9.55E-05	M
PRIMARY_RESULT	9.93	unitless	S01T001466	B0HHL1T	8.51E-05	M
DUPLICATE_RESULT	9.98	unitless	S01T001467	B0HHL3T	9.55E-05	M
PRIMARY_RESULT	9.96	unitless	S01T001467	B0HHL3T	9.12E-05	M
PRIMARY_RESULT	10.15	unitless	S01T001468	B0HHL5T	1.41E-04	M
DUPLICATE_RESULT	10.14	unitless	S01T001468	B0HHL5T	1.38E-04	M
Simple Average	N/A	N/A	N/A	N/A	1.08E-04	M

Source: CH2M HILL (2002c). Hydroxide conversion according to Equation 1.
N/A = not applicable

Table 4. Tank 241-C-103 Liquid Data from 2001 Grab Samples.

Constituent	Mean	Units	Molecular Weight	Concentration	Units
Nitrate	9.82E+02	µg/mL	62.0	1.58E-02	M
Nitrite	1.77E+04	µg/mL	46.0	3.84E-01	M
Hydroxide	-	-	17.0	1.08E-04	M
Specific Gravity	1.08	unitless	N/A	N/A	N/A

Notes: Mean data for selected constituents from CH2M HILL (2002d). Molecular weights from Perry and Green (1984). Hydroxide data from Table 3.

Table 5. Tank 241-AN-101 Liquid Data from 2002 Grab Samples.

Constituent	Mean	Units	Molecular Weight	Concentration	Units
Nitrate	1.17E+05	µg/mL	62.0	1.89	M
Nitrite	9.65E+04	µg/mL	46.0	2.1	M
Hydroxide	2.71E+04	µg/mL	17.0	1.59	M
Specific Gravity	1.29	unitless	N/A	N/A	N/A

Notes: Mean data for selected constituents from CH2M HILL (2003c). Molecular weights from Perry and Green (1984).

Table 6. Sodium Hydroxide Chemical Data.

Parameter	Value	Units	Source
Concentration	25	wt%	Wood (2002)
Concentration	319.5	g NaOH/L	OxyChem (2001)
Molecular weight	40.0	g/mol	Perry and Green (1984)
Concentration	8.0	M	conversion
Volume	8.1 (June 2002 AN-106 addition)	kgal	Wood 2002

Table 7. 241-AN-Farm Ventilation Data.

Tank	Inlet Orifice Rating[1] (cfm)	Estimated Flow Including Inleakage[2] (cfm)	Estimated Flow Including Inleakage[4] (scfm)
AN-101	35	93	81.3
AN-102	35	93	81.3
AN-103	60	118	106.3
AN-104	60	118	106.3
AN-105	60	118	106.3
AN-106	35	93	81.3
AN-107	90	148	136.3
Total	375	780 (3)	699

Notes:

[1]Information from ECN-668222 (CH2M HILL 2002e).
[2]Calculated by dividing difference between total system flow and total inlet orifice flow evenly between all tanks and adding to each tank's inlet orifice flow.
[3]Stack flow measured on March 19, 2003 (CH2M HILL 2003d).
[4]Standard flow at 1 atmosphere and 32 °F for 241-AN stack pressure and temperature of 29.371 in. Hg and 79 °F, respectively (CH2M HILL 2003d).

The 241-AN Tank Farm ventilation flow data of Table 7 differs from that in Fort et al. (2002), which is used in OH^- depletion rate calculations for various documents that support the Corrosion Mitigation Program. That ventilation flow data was derived from a data collection effort conducted in 2000 (Kufahl and Barker 2000). Since that time, some orifice plates in the air inlet assemblies of the 241-AN tanks have been changed out (CH2M HILL 2002e), which effectively changes the ventilation air flow through the affected tanks. Although the total flow from the tank farm ventilation system remains roughly unchanged, the flow values of Table 7 are considered more representative of current operating condition of the tanks. The Table 7 ventilation flows for tanks AN-101 and AN-106 are used in the Hobbs equation to project OH^- depletion rates in this calculation.

5.2 Key Assumptions

- It is assumed that the contents of AN-106 will be well mixed. If the C-106 acid waste stream and flush water do not mix with the waste in AN-106, then the waste at the surface may not meet the AC 5.15 specifications. This assumption is an open item (Section 3.0) and will be addressed in the Process Control Plan for C-106 retrieval.

- A total tank volume can be determined accurately in a DST with a free liquid surface. However, settled solids volume estimates are much less accurate since they are typically made from a small number of solids level measurements in the tank. Since the saltcake and supernatant volumes of tank AN-106 were both fairly small before making the C-103 transfer, any inaccuracies in the initial volume estimates would be magnified. For example, if the starting supernatant volume were actually 40 kgal instead of 29 kgal (i.e., the difference between the waste volume and solids volume in Table 1), subsequent calculated caustic concentration would be significantly affected.

Another approach to arrive at an initial supernatant volume is by mass balance. It can be assumed that all of the OH^- added in June 2002 was still present when the tank was sampled in July. That is:

$$M_i = M_{NaOH}$$

This seems reasonable because no reactions were expected when the caustic was added (Conner 2002). In addition, the waste in AN-106 had measurable OH^- prior to the June 2002 chemical addition. The OH^- concentration from the sample event on September 4, 2001 was 0.21 M (Bushaw 2001). Hydroxide depletion from carbon dioxide absorption was projected to cause the OH^- concentration of the waste to drop by an order of magnitude to 0.02 M by March 2002 (Fort 2002). The OH^- in the waste at the time of the June 2002 caustic addition is considered insignificant in comparison to the change in OH^- from the 8.1-kgal addition of 8 M caustic.

The material balance (mole) above can then be expressed in terms of concentration and volume, and solved for the AN-106 supernatant volume (V_i):

$$(CV)_i = (CV)_{NaOH}$$

$$V_i = \frac{(CV)_{NaOH}}{C_i}$$

$$V_i = \frac{(8\ \underline{M})(8.1\ kgal)}{1.94\ \underline{M}}$$

V_i = 33.4 kgal
V_i = 1.26E05 L

Because of the uncertainty in the measured solids volume, this calculated value of 33.4 kgal is the best estimate of the initial supernatant volume in AN-106 before the C-103 transfer.

- The volume of flush water that will be used to make the AN-101 transfer is assumed to be 300 gallons. This volume is based on a pipeline flush equal to two transfer line volumes after completing the transfer. The holdup volume for the piping route from tank AN-101 to tank AN-106 is approximately 140 gallons, assuming 360 ft of 3-inch Schedule 40 piping. The assumed route is from the 241-AN-01A central pump pit through transfer line SN-261 to the 241-AN-B valve pit, then trough transfer line SN-268 to the 241-AN-A valve pit, and from there through transfer line SN-266 to the 241-AN-06A central pump pit.

- The volume of C-106 sludge dissolved in the oxalic acid dissolution process and transferred to AN-106 is assumed to be 6.4 kgal. This represents the retrieval of all but 360 ft^3 of sludge currently estimated to remain in tank C-106, which is required in order to interim close the tank. Preliminary process chemistry test results indicate that 50 to 70 percent by weight of the

sludge dissolves when contacted with 1 M oxalic acid (Herting 2003). At 9.1 kgal residual sludge remaining in the tank and an estimated sludge density of 1.7 g/mL, the 6.4 kgal sludge retrieval would require dissolution of 70 percent by weight of the current sludge volume.

- Another assumption is that 3 kgal of water will be required to retrieve tank C-106. This is based on an assumption that the 10 anticipated batch transfers of acid waste to tank AN-106 will require hose-in-hose transfer line (HIHTL) flushes of approximately two transfer line volumes. The HIHTL holdup volume is approximately 140 gallons, assuming 850 ft of 2-inch inside diameter hose.

6.0 RESULTS

6.1 Calculation of AC 5.15 Chemistry Control Limits

The AC 5.15 chemistry limits are variable depending on the OH^-, NO_2^-, and NO_3^- concentrations in the waste. Based on the Table 2 composition of the initial AN-106 waste and the Table 4 composition of the C-103 waste transferred into the tank, the waste currently in tank AN-106 contains less than 1 M NO_3^-. The applicable limits (CH2M HILL 2003a) for waste with a NO_3^- concentration of less than 1.0 M and waste temperature less than 167 °F are:

$$0.010\ \underline{M} \leq [OH^-] \leq 8.0\ \underline{M} \tag{9}$$

$$0.011\ \underline{M} \leq [NO_2^-] \leq 5.5\ \underline{M} \tag{10}$$

$$\frac{[NO_3^-]}{[NO_2^-]+[OH^-]} < 2.5 \tag{11}$$

where the brackets [] denote concentration in molarity.

The applicability of these limits once the tank AN-101 alkaline waste and the C-106 acid waste are transferred to tank AN-106 will be addressed in Section 6.3.

6.2 Current Tank AN-106 Waste Chemistry

Since sampling AN-106 in July 2002, a total of 118 kgal of C-103 saltwell liquid and flush water has been transferred to the tank (see Table 1). This added waste now represents 70 percent of the tank waste volume. The dilute nature of the C-103 waste together with its significant buffer are expected to have causes a substantial reduction in the inventory of hydroxide ion available in the tank. This section calculates a projected waste composition for the current AN-106 waste.

6.2.1 Current Projected Nitrate and Nitrite Concentrations

The average concentration of NO_3^- after the C-103 waste addition can be calculated by a material balance (Equation 3). In this case, only the terms associated with the initial AN-106 waste and the C-103 waste transferred into the tank are applicable. All non-related terms can be dropped.

$$C_f = \frac{(CV)_i + (CV)_{C-103}}{V_i + V_{C-103} + V_{H2O}} \tag{3}$$

AN-106: $C_i = 0.86$ M NO_3^- and 0.47 M NO_2^-
$V_i = 33.4$ kgal

C-103: $C_{C-103} = 0.0158$ M NO_3^- and 0.384 NO_2^-
$V_{C-103} = 113.8$ kgal
$V_{H2O} = 4.3$ kgal

$$C_f = \frac{(0.86)(33.4) + (0.0158)(113.8)}{33.4 + 113.8 + 4.3}$$

C_f = average NO_3^- concentration = 0.201 M.

The concentration of NO_2^- is calculated using Equation 3 in a similar fashion to NO_3^- above, using the data from Sections 5.1 and 5.2. The result is:

Average NO_2^- concentration = 0.392 M

Since this NO_2^- concentration is over an order of magnitude greater than the limit in Section 6.1, a nitrite addition is not necessary. Additionally, based on the Equation 11 ratio, the minimum OH^- concentration limit defaults to that of Equation 9, or 0.010 M.

6.2.2 Current Projected Hydroxide Concentration (Including Caustic Demand)

To estimate the current tank AN-106 waste hydroxide concentration, the hydroxide initially in the tank must first be depleted from the July 2002 sample date until the start of the C-103 transfer in November 2002. The Hobbs equation of Section 4.5 is used in this caustic depletion calculation. Then the final concentration from the C-103 transfer can be determined using Equation 4. Finally, hydroxide depletion using the Hobbs equation is calculated from the end of the C-103 transfer in February 2003 to arrive at the projected AN-106 waste composition in June 2003 before the planned caustic addition.

Depletion of the initial AN-106 hydroxide concentration using the Hobbs equation is calculated using Equations 6 and 7.

$$C_{f_Hobbs} = C_{i_Hobbs} - \frac{1.27 BR_V t}{V_f} \tag{6}$$

$$B = 0.165(\log C_{i_Hobbs} + 14) - 1.569 \quad (7)$$

where C_{i_Hobbs} = 1.94 M OH^- as of the July 30, 2003 sample date
C_{f_Hobbs} = unknown
B = unknown
R_V = 81.3 standard cubic feet per minute (scfm)
t = 122 days (7/30/02 – 11/29/02)
V_i = 33.4 kgal (1.26E+05 L)

Because the hydroxide changes with time from reaction with carbon dioxide in the ventilation air, the fraction absorbed B decreases with time. Therefore, the above equations are solved in 7-day time increments over the period until November 29, 2002 to approximate the affect of the changing absorption fraction on the hydroxide depletion. For each successive calculation, C_{i_Hobbs} is set equal to C_{f_Hobbs} of the previous calculation. The calculation was performed using an Excel[1] spreadsheet titled "AN-106 Hobbs Hydroxide Depletion for C-106 Acid Waste Transfer" (see Appendix A). The projected AN-106 hydroxide concentration before starting the C-103 transfer is

C_{f_Hobbs} = 1.86 M OH^- as of November 29, 2002.

The potential for caustic demand in the AN-106 waste was discounted in Section 4.4. However, caustic demand is a significant factor in the C-103 waste transferred to the tank because the pH is around 10. In that range, reactions such as the conversion of carbonate to bicarbonate and phosphate to biphosphate are expected. Caustic demand of the C-103 waste has been determined (Beck 1996). This reference reports a calculated caustic demand of 0.27 M OH^-, along with an estimate of 0.22 M OH^- from a prior study. Therefore, a caustic demand of 0.27 M OH^- waste will be applied.

$D_{C\text{-}103}$ = 0.27 M OH^-/L

The projected OH^- concentration from the C-103 transfer is calculated according to Equation 4. Again, only the terms associated with the initial AN-106 waste and the C-103 waste transferred into the tank are applicable.

$$C_f = \frac{(CV)_i + (CV)_{C-103} - (DV)_{C-103}}{V_i + V_{C-103} + V_{H2O}} \quad (4)$$

AN-106: C_i = 1.86 M
V_i = 33.4 kgal
V_i = 1.26E+05 L

[1] Microsoft® Excel is a registered trademark of Microsoft Corporation, Redmond, Washington.

C-103: $C_{C\text{-}103} = 0$ M (the OH^- concentration is virtually zero)
$V_{C\text{-}103} = 113.8$ kgal
$V_{C\text{-}103} = 4.31E{+}05$ L
$D_{C\text{-}103} = 0.27$ M

Dilution H_2O: $C_{H2O} = 0$ M
$V_{H2O} = 4.3$ kgal
$V_{H2O} = 1.63E{+}04$ L

$$C_f = \frac{(1.86)(1.26E+05)+(0)(4.31E+05)-(0.27)(4.31E+05)}{(1.26E+05)+(4.31E+05)+(1.63E+04)}$$

$C_f = 0.206$ M OH^- from transferring the C-103 waste.

In a similar manner to that described above, the combined AN-106/C-103 waste initial hydroxide concentration will undergo depletion according to the Hobbs equation from February 2003 until June 2003, after which caustic and AN-101 waste will be transferred into the tank in preparation for receipt of the C-106 acid waste.

In this case, $C_{i_Hobbs} = 0.206$ M
C_{f_Hobbs} = unknown
B = unknown
R_V = 81.3 scfm
t = 120 days (2/10/03 – 6/10/03)
V_i = 151.5 kgal (5.73E+05 L)

As was described above, the Hobbs equation is solved in 7-day time increments over the period until June 10, 2003 to approximate the effect of the changing absorption fraction on the hydroxide depletion. In successive calculation, C_{i_Hobbs} is set equal to C_{f_Hobbs} of the previous calculation. An Excel spreadsheet was used to perform the calculation (see Appendix A). The projected AN-106 hydroxide concentration at the time of the planned caustic transfer is

$C_{f_Hobbs} = 0.193$ M OH^- projected as of June 10, 2003.

6.3 Tank AN-106 Caustic Volume for C-106 Acid Waste Transfer

Controlling the waste chemistry of DSTs is a Technical Safety Requirement (TSR) that was implemented to protect the integrity of the primary tank wall by minimizing its corrosion. AC 5.15, "Corrosion Mitigation Program," sets the acceptable range for OH^-, NO_2^-, and NO_3^- concentrations in waste stored in the DSTs to provide the desired corrosion protection of the primary tank carbon steel wall (CH2M HILL 2003a). An acid transfer would not meet the AC requirements and, therefore, could degrade the level of corrosion protection if complete neutralization and mixing with waste in the DST does not occur. The inventory of hydroxide in tank AN-106 will have to be supplemented before receiving the C-106 acid waste to ensure that complete neutralization is possible (i.e., enough

hydroxide is available in the waste to meet the caustic demand of the acid waste transferred to the tank). Additionally, enough excess caustic needs to be added to keep the resultant waste above the AC 5.15 chemistry control limits for at least 5 years.

6.3.1 Projected AN-106 Chemistry from AN-101 Transfer

Transferring the supernatant from tank AN-101 to AN-106 is planned to provide additional waste volume and supplement the hydroxide inventory in the tank before beginning the C-106 acid waste transfer. With a hydroxide concentration of 1.59 M in October 2002 (see Table 5), transferring the AN-101 waste will increase the AN-106 waste hydroxide concentration substantially above the 0.193-M OH^- projected for the current waste by June 10, 2003.

The most recent sampling of tank AN-101 was on October 8, 2002. The OH^-, NO_2^-, and NO_3^- concentrations as of the sample date are given in Table 5. However, continued absorption of carbon dioxide from the ventilation air by the waste will have caused depletion of the hydroxide concentration. The projected hydroxide concentration of AN-101 waste in June 2003 can be calculated by using the Hobbs equation of Section 4.5.

In this case,
C_{i_Hobbs} = 1.59 M
C_{f_Hobbs} = unknown
B = unknown
R_V = 81.3 scfm
t = 245 days (10/8/02 – 6/10/03)
V_i = 206 kgal (7.81E+05 L)

The Hobbs equation is solved in a manner similar to the solutions in Section 6.2.2. The equations are solved in 7-day time increments over the period until June 10, 2003 to approximate the affect of the changing carbon dioxide absorption fraction on the hydroxide depletion. In successive calculation, C_{i_Hobbs} is set equal to C_{f_Hobbs} of the previous calculation. An Excel spreadsheet was used to perform the calculation (see Appendix A). The projected AN-101 hydroxide concentration is

C_{f_Hobbs} = 1.57 M OH^- as of June 10, 2003.

The projected supernatant composition of the combined AN-106 and AN-101 wastes can be determined using Equation 3. Again, only the terms associated with the current AN-106 projected waste chemistry determined in Section 6.2.2 and the AN-101 waste transferred into the tank are applicable. Substituting using the OH^- concentration and total volume for the current AN-106 waste derived in Sections 6.2.2, and the AN-101 projected OH^- concentration from above together with information from Table 1 and Table 5, Equation 3 is solved to give the projected final AN-106 OH^- concentration from transferring AN-101 waste into the tank.

$$C_f = \frac{(CV)_i + (CV)_{AN-101}}{V_i + V_{AN-101} + V_{H2O}} \quad (4)$$

AN-106: C_i = 0.193 M OH^-, 0.201 M NO_3^-, and 0.392 M NO_2^-
V_i = 151.5 kgal
V_i = 5.73E+05 L

AN-101: $C_{AN\text{-}101}$ = 1.57 M OH^-, 1.89 M NO_3^-, and 2.1 M NO_2^-
$V_{AN\text{-}101}$ = 206 kgal
$V_{AN\text{-}101}$ = 7.81E+05 L

Dilution H_2O: C_{H2O} = 0 M
V_{H2O} = 300 gallons
V_{H2O} = 1.14E+03 L

$$C_f = \frac{(0.193)(5.73E+05)+(1.57)(7.81E+05)}{(5.73E+05)+(7.81E+05)+(1.14E+03)}$$

C_f = 0.986 M OH^- from transferring AN-101 waste.

The concentrations of NO_2^- and NO_3^- are calculated using Equation 3 in a similar fashion to OH^- above, using the data from Sections 6.2.1 for AN-106 and the AN-101 data from Table 1 and Table 5. The results are as follows:

Average NO_2^- = 1.38 M from transferring AN-101 waste.

Average NO_3^- = 1.17 M from transferring AN-101 waste.

Therefore, the projected chemistry of tank AN-106 waste with C-103 and AN-101 wastes transferred into the tank meets the AC 5.15 limits. The applicable limits (CH2M HILL 2003a) for waste with a NO_3^- concentration of greater than 1.0 M but less than or equal to 3 M are:

$$0.1\,([NO_3^-]) \leq [OH^-] \leq 10.0\ \text{M}$$

$$[OH^-] + [NO_2^-] \geq 0.4\,([NO_3^-])$$

where the brackets [] denote concentration in molarity.

6.3.2 C-106 Acid Waste Caustic Demand

The 1 M oxalic acid solution added to tank C-106 to dissolve the sludge heel in the tank will require that sufficient hydroxide be available in tank AN-106 to neutralize the acid waste stream as it is transferred to AN-106. Preliminary laboratory results investigating the acid dissolution process indicated that contacting the C-106 solids with the oxalic acid caused chemical reaction accompanied by significant off gassing (Herting 2003). The amount of acid consumed in this reaction has not been quantified and would be uncertain in any case given the potential non-homogeneity of the C-106 solids.

A conservative assumption is made that all the oxalic acid added to tank C-106 will undergo neutralization when added to tank AN-106. Therefore, the caustic demand of the acid waste stream is estimated from the stoichiometry of the neutralization according to the below reaction.

$$2NaOH + C_2H_2O_4 \rightarrow Na_2C_2O_4 + 2H_2O$$

Therefore, the caustic demand of the C-103 acid waste ($D_{C\text{-}106_acid}$) is 2 mole OH^- per mole of oxalic acid or, because the concentration of oxalic acid used will be 1 M, the caustic demand is equivalent to 2 moles OH^- per liter of oxalic acid.

6.3.3 Caustic Volume Required for AN-106 Chemistry Control

The final OH^- concentration of AN-106 following neutralization of all the C-106 acid waste transferred to the tank must be high enough to keep the combined waste within the AC 5.15 chemistry limits for at least 5 years. This final OH^- concentration, which will deplete over the 5-year period to the chemistry control limit, is calculated using the Hobbs equation (Equations 6 and 7). Because the 210 kgal of oxalic acid to be transferred into tank AN-106 will contribute approximately 50 percent more waste volume than the expected 360 kgal in tank AN-106 after making the AN-101 transfer, the 1.17 M NO_3^- concentration of tank AN-106 calculated in Section 6.3.1 will be diluted by approximately 33 percent to 0.74 M following the C-106 waste transfer. Therefore, the AC 5.15 limits that will apply following completion of the C-106 transfer are those of Section 6.1.

The following relationship exists between the target final concentration from the caustic addition and the Hobbs equation:

$$C_f = C_{i_Hobbs}$$

Equation 6 is rearranged to solve for C_{i_Hobbs}, which is unknown and depends on the volume of caustic transferred. For this calculation C_{f_Hobbs} is the lower AC 5.15 OH^- concentration, or 0.01 M OH^-. The calculation is as follows.

$$C_{i_Hobbs} = C_{f_Hobbs} + \frac{1.27BR_V t}{V_f} \quad (6)$$

$$B = 0.165(\log C_{i_Hobbs} + 14) - 1.569 \quad (7)$$

where C_{i_Hobbs} = unknown
C_{f_Hobbs} = 0.01 M
B = unknown
R_V = 81.3 scfm
t = 1825 days (5 years)
V_f = unknown

The final volume V_f of Equation 6 can be expressed by the conservation of volume relationship from Section 4.3.

$$V_i + V_{C\text{-}106} + V_{H2O} + V_{NaOH} = V_f$$

Similarly, the target final concentration of the caustic addition C_{i_Hobbs} in Equation 6 and Equation 7 above can be expressed using a modified version of Equation 4.

$$C_{i_Hobbs} = \frac{(CV)_i + (CV)_{NaOH} - (DV)_{C-106_acid}}{V_i + V_{C-106} + V_{H2O} + V_{NaOH}} \tag{4}$$

The volume of caustic that needs to be transferred to AN-106 to neutralize the C-106 acid waste and keep the bulk waste within AC 5.15 limits for at least 5 years is calculated using a trial and error approach. The approach follows the following sequence.

1. Assume a volume of caustic, V_{NaOH}.
2. Calculate an initial OH^- concentration C_{i_Hobbs} Using Equation 4.
3. Deplete the OH^- concentration over a 5-year period using the Hobbs equation and the approach described in Sections 6.2.2. For this calculation the equations are solved in 14-day increments over the time period June 2003 to June 2008.
4. Compare the calculated ending OH^- concentration C_{f_Hobbs} with the AC 5.15 limit, 0.01 M.
5. Repeat the steps 1 – 4 until the depleted OH^- concentration at the end of the 5-year period equals the AC 5.15 limit.

The input data to the trial and error calculation are as follows.

AN-106: $C_i = 0.986$ M OH^-
$V_i = 360$ kgal
$V_i = 1.36E+06$ L

C-106: $C_{C\text{-}106} = 0$ M (the waste is acidic)
$V_{C\text{-}106} = 210$ kgal
$V_{C\text{-}106} = 7.95E+05$ L
$D_{C\text{-}106_acid} = 2$ moles OH^-/L

NaOH: $C_{NaOH} = 8$ M
V_{NaOH} = unknown

Flush H_2O: $C_{H2O} = 0$ M
$V_{H2O} = 3$ kgal
$V_{H2O} = 1.14E+04$ L

An Excel spreadsheet was used to perform the calculation (see Appendix A). The volume of 25-wt% caustic that results in an initial OH^- concentration C_{i_Hobbs} following the C-106 acid waste transfer that when depleted over a 5-year period reaches the lower AC 5.15 OH^- concentration limit is

V_{NaOH} = 45,500 L 25-wt% (8 M) NaOH or
V_{NaOH} = 12,000 gallons 25-wt% (8 M) NaOH.

From Equation 4 above, where the total volume V_f is equal to 2.21E+06 L (584 kgal), the target final OH^- concentration of the AN-106 waste following completion of the C-106 acid waste transfer can be calculated.

$$C_f = C_{i_Hobbs} = \frac{(CV)_i + (CV)_{NaOH} - (DV)_{C-106_acid}}{V_i + V_{C-106} + V_{H2O} + V_{NaOH}} \quad (4)$$

$$C_f = \frac{(0.986)(1.36E+06) + (8)(4.55E+04) - (2)(7.95E+05)}{2.21E+06}$$

C_f = 0.052 M OH^-

The final NO_2^- and NO_3^- concentrations are calculated using Equation 3. The concentration and volume of the AN-106 waste prior to the C-106 acid waste transfer includes the contributions from the initial AN-106 waste, the C-103 waste transfer and the AN-101 waste transfer. The NO_2^- and NO_3^- concentrations in the caustic are zero; therefore, the term $C_{NaOH}V_{NaOH}$ can be dropped from the numerator. The revised equation for calculating the final NO_2^- and NO_3^- concentrations is show below.

$$C_f = \frac{C_{AN-106}V_{AN-106}}{V_{AN-106} + V_{C-106} + V_{H2O} + V_{NaOH}}$$

Substituting the volumes for AN-106, C-106, water, and caustic above with the 1.38 M NO_2^- concentration from Section 6.3.1, the final NO_2^- concentration is calculated as follows.

$$C_f = \frac{(1.38)(1.36E+06)}{(1.36E+06) + (7.95E+05) + (4.55E+04) + (1.14E+04)}$$

$$C_{NO_2} = 0.849\ \underline{M}$$

The concentration of NO_3^- is calculated using Equation 3 in a similar fashion to NO_2^- above, using the volume data from above and the 1.17 M NO_3^- concentration from Sections 6.3.1.

$$C_{NO_3} = 0.719\ \underline{M}$$

Therefore, the projected chemistry of tank AN-106 waste with C-103, AN-101, and C-106 wastes transferred into the tank meets the AC 5.15 limits. For a NO_3^- concentration less than 1 M, the applicable limits are the same as those listed in Section 6.1.

When the C-106 acid waste is transferred into tank AN-106 through Riser-015 in the 241-AN-06A central pump pit, neutralization will occur initially in the region near the centerline of the tank. Because the mixing during the C-106 batch transfers may not be uniform throughout the tank, an excess of OH^- is needed to assist in neutralizing the oxalic acid stream near the center of the tank where initial mixing will occur. A 50-percent excess volume of caustic will be added to account for the uncertainty in the mixing during the C-106 transfers. Therefore, the recommended volume of 25-wt% (8 M) caustic to add to tank AN-106 in preparation for the transfer of C-106 oxalic acid waste into the tank is at least

V_{NaOH} = 68,300 L 25-wt% (8 M) NaOH or
V_{NaOH} = 18,000 gallons 25-wt% (8 M) NaOH.

7.0 CONCLUSIONS

To keep the bulk waste in tank AN-106 within the AC 5.15 chemistry control limits after transfers from tanks AN-101 and C-106, a minimum of 18,000 gallons of 25-wt% (8 M) caustic must be added to the tank before receipt of the C-106 oxalic acid waste. With this caustic addition, the waste in tank AN-106 is projected to stay above the OH^- specification for a period of at least 5 years, provided no other waste transfers into the tank exhibit caustic demand.

At least 206 kgal of tank AN-101 supernatant must be transferred to AN-106 prior to the C-106 oxalic acid waste transfer to provide the OH^- inventory needed to completely neutralize the incoming acid waste stream.

The upper limit on the volume of C-106 oxalic acid waste transferred to AN-106 is 210 kgal. Transferring a higher volume of waste will require an additional transfer of caustic to AN-106 beforehand to ensure sufficient OH^- will be available to neutralize the extra waste volume.

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APPENDIX A

VERIFICATION OF SPREADSHEET

SPREADSHEET VERIFICATION FORM (SVF)

A. Name of Spreadsheet Owner: K. G. Carothers

B. Spreadsheet File Number: KGC-01

C. File Name of Spreadsheet: AN-106 Hobbs Hydroxide Depletion for C-106 Acid Waste Transfer.xls

D. Location of Spreadsheet (share drive, personal computer, data system): \\AP012\Chardocs\By All Staff Members\Carothers\RPP-13502 Folder

E. Brief Description of Function and Purpose of Spreadsheet:
The spreadsheet is used to determine the caustic depletion of the supernatant in tanks 241-AN-106 and 241-AN-101, and to calculate the caustic volume needed for tank 241-AN-106 in support of the retrieval of tank 241-C-106 sludge by means of an oxalic acid dissolution process. Three caustic depletion cases are calculated using identical spreadsheet formulas based on the Hobbs equation described in the calculation document. A forth spreadsheet case is used to calculate a caustic volume to add to tank 241-AN-106 in preparation for receiving tank 241-C-106 oxalic acid waste. This calculation uses a trial-and-error approach employing the identical Hobbs caustic depletion formulas used in the other three cases. The outputs from the spreadsheet provide answers to calculations described in the document.

F. Assumptions Important to Spreadsheet Function if Applicable:
Caustic depletion from absorption of carbon dioxide from ventilation airflow through the primary tank headspaces is represented by the Hobbs equation described in this calculation document.

G. Method Used to Perform Verification and Verification Documentation:
The spreadsheet results were verified by checking the inputs, assumptions and results. The inputs were verified by checking the spreadsheet inputs against the input source, either from a reference or the results of intermediate calculations. All the assumptions were checked for reasonableness. Depletion equations were checked to verify the correct output on the specified date. Comparing the equations in the text of the calculation document with the formulas contained in the spreadsheet comprised the equation check.

H. Verification Method Documentation Example:

If this example method is used, the documentation at a minimum must contain:

a. Intended formula function and intended formula expressed in words and in formulaic symbols for each generic formula in the spreadsheet.
b. Cell formula as entered into the spreadsheet cell for each generic formula.
c. Initials by the verifier that the intended function will be performed by the intended formula, that items a and b are the same and that the cell formula as entered will compute the intended calculations as described in step a above.

Worksheet Name	Intended Formula Function and Intended Formula	Cell Formula Entered on Spreadsheet	Checked By (initial)	Date
Initial AN-106 OH Depletion	Index date by the specified time increment.	A14 = A13+$C$9 (repeated in column for increasing row numbers)		
Initial AN-106 OH Depletion	Calculate elapsed time in days between date of previous calculation and current date.	B14 = A14-A13 (repeated in column for increasing row numbers)		
Initial AN-106 OH Depletion	Calculate the fraction CO_2 absorbed by the waste B using Hobbs equation where $B = 0.165(\log C_{i_Hobbs} + 14) - 1.569$	C14 = 0.165*(Log10(D13)+14)-1.569 (repeated in column for increasing row numbers)		
Initial AN-106 OH Depletion	Calculate the depleted OH^- concentration C_{f_Hobbs} for the elapsed time period using Hobbs equation where $C_{f_Hobbs} = C_{i_Hobbs} - \frac{1.27BR_v t}{V_f}$	D14 = D13-((1.27*C14*$H$7*B14)/$I$7) (repeated in column for increasing row numbers)		
Current AN-106 OH Depletion	Same as for worksheet "Initial AN-106 OH Depletion" described above.	Same as for worksheet "Initial AN-106 OH Depletion" described above.		
Current AN-101 OH Depletion	Same as for worksheet "Initial AN-106 OH Depletion" described above.	Same as for worksheet "Initial AN-106 OH Depletion" described above.		
Caustic Volume	Input a trial volume of 25-wt% (8 M) caustic.	Volume input in liters.		
Caustic Volume	Calculate the ending OH^- concentration from transferring C-106 acid waste into AN-106 adjusted with the trial volume of caustic where $C_f = \frac{(CV)_{AN-106} + (CV)_{NaOH} - (DV)_{C-106_acid}}{V_{AN-106} + V_{NaOH} + V_{C-106} + V_{H_2O}}$	C23 = (B13*B16+E13*E16-C17*C16)/(B16+E16+C16+D16)		
Caustic Volume	Calculate the ending NO_2^- concentration from transferring C-106 acid waste into AN-106 adjusted with the trial volume of caustic where $C_f = \frac{(CV)_{AN-106}}{V_{AN-106} + V_{NaOH} + V_{C-106} + V_{H_2O}}$	D23 = (B14*B16)/(B16+E16+C16+D16)		
Caustic Volume	Calculate the ending NO_3^- concentration from transferring C-106 acid waste into AN-106 adjusted with the trial volume of caustic where $C_f = \frac{(CV)_{AN-106}}{V_{AN-106} + V_{NaOH} + V_{C-106} + V_{H_2O}}$	E23 = (B15*B16)/(B16+E16+C16+D16)		

Worksheet Name	Intended Formula Function and Intended Formula	Cell Formula Entered on Spreadsheet	Checked By (initial)	Date
Caustic Volume	Calculate the final volume from transferring C-106 acid waste into AN-106 adjusted with the trial volume of caustic where $V_f = V_{AN-106} + V_{NaOH} + V_{C-106} + V_{H_2O}$	I23 = B16+E16+C16+D16		
Caustic Volume	Index date by the specified time increment.	A30 = A29+$C$25 (repeated in column for increasing row numbers)		
Caustic Volume	Calculate elapsed time in days between date of previous calculation and current date.	B30 = A30-A29 (repeated in column for increasing row numbers)		
Caustic Volume	Calculate the fraction CO_2 absorbed by the waste B using Hobbs equation where $B = 0.165(\log C_{i_Hobbs} + 14) - 1.569$	C30 = 0.165*(Log10(D29)+14)-1.569 (repeated in column for increasing row numbers)		
Caustic Volume	Calculate the depleted OH^- concentration C_{f_Hobbs} for the elapsed time period using Hobbs equation where $C_{f_Hobbs} = C_{i_Hobbs} - \frac{1.27BR_v t}{V_f}$	D30 = D29-((1.27*C30*$H$23*B30)/$I$23) (repeated in column for increasing row numbers)		

I. Approvals:

Owner: K. G. Carothers K G Carothers Date: 5/21/03
Verifier: M. J. Klem M J Klem Date: 5/21/03