2. To: (Receiving Organization) Distribution S. Prol./Prog./Dept./Div.: SM720 8. Originator Remarks: Approval/Release 11. Receiver Remarks: 11. Receiver Remarks: 12. DATA TRANSMITTED 13. Densign Baseline Document? 14. Required Response Data 15. DATA TRANSMITTED 16. Receiver Remarks: 16. DATA TRANSMITTED 11. WHC-SD-WM-ER-619 12. Required Response Data 13. Dermit/Draving No. 14. Required Response Data 14. Required Response Data 15. DATA TRANSMITTED 16. KEV Approval Designator (F) Resent Control (J) Approval 16. Receiver (F) Reason for Transmitted (G) 16. Approval Designator (F) 16. KEV Approval Designator (F) 16. Receiver (K) Signature (L) Design (G) (K) Signature (L) Determined 17. SIGNATURE/DISTRICT 11. Design Agent (L) Date (M) MSIN 11. Design Authority 12. SIGNATURE/DISTRICT 14. Cog. Mgr. J. Greenborg), Junkary (D) SIGNATURE/DISTRICT) 14. Cog. Mgr. J. Greenborg), Junkary (D) SIGNATURE/DISTRICT) 15. SIGNATURE/DISTRICT) 15. Signature (L) Date Markey (L) Date MARK MARK MARK MARK MARK MARK MARK MARK	₀•1∘f_ 19216	Page T 619	1. ED	<u> </u>		AL	SMITTA	RANS	3 DATA 1	INEERING	ENG	1996 27 X	22	OC St	
Distribution (12 Criticality and Shielding (12 Cigradian Shielding (12 Cigradi		:	d EDT No.	4. Relate	on)	anizat	ating Org	(Origina	3. From:		nization)	eiving Orga	(Rec	2. To	
P. Proj. /Prog. //Prog.		619216				eldi	and Sh	lity a	Critica		tribution				
BM/20 W. D. Wittekind NA . Originator Remarks: Approval/Release 9. Equip./Component No.: NA 1. Receiver Remarks: 11A. Design Baseline Document? Yes [] No 1. Receiver Remarks: 11A. Design Baseline Document? Yes [] No 1. Receiver Remarks: 11A. Design Baseline Document? Yes [] No 1. Receiver Remarks: 11A. Design Baseline Document? Yes [] No 1. Receiver Remarks: 11A. Design Baseline Document? Yes [] No 1. Receiver Remarks: 11A. Design Baseline Document? Yes [] No 1. Receiver Remarks: 11A. Design Baseline Document? Yes [] No 1. Receiver Remarks: 11A. Design Baseline Document? Yes [] No 1. Required Response Da 11A. TRANSHITED (E) Title or Description of Data Approval 1. WHC-SD-WM-ER-619 0 Surface Moisture NA [] /2 1. WHC-SD-WM-ER-619 0 Surface Irregularity Induction Probe NA 1. Approval Designator (P) Resson for Transmittal (G) Induction Surface Irregularity I. Approval A Reviewed Molon 5. O. Do TNA 1. Approval Designator (P) Resson for Transmittal (G) I. Deposition (H) & (H) S. Brediewed Molon		No.:	se Ørder	/Cog.	in Agent	ty/ Desig	Authorit	 Design / Engr.: 		v.:	g./Dept./D1	ol./Prog	. Pro		
J. Originator Remarks: Approval/Release 9. Equip./Component No.: NA Approval/Release 11. Receiver Remarks: 11. Design Baseline Document? Yes [] No I. Receiver Remarks: 11A. Design Baseline Document? Yes [] No 12. Major Assm. Dwg. No. S. DATA TRANSMITTED (C) (G) (H) NA 14. Required Response Da Sheet No. (E) Title or Description of Data Description Description of Data Description Descript		NA					ind	itteki	W. D. W			20	8M/2		
Approval / Ke ledse 10. system/8ldg./Facilit 11. Receiver Remarks: 11A. Design Baseline Document? (Yes [] No (C) NA 13. Permit/Permit Applic NA 14. Required Response Da 5. DATA TRANSHITED 5. DATA TRANSHITED 5. DATA TRANSHITED 5. DATA TRANSHITED 5. DATA TRANSHITED 6. (C) (D) 5. Seet No. 14. Required Response Da 7 ana. (E) Title or Description of Data 7 ana. (E) Transmitted 10. system/8ldg./Facilit NA 14. Required Response Da 14. Required Response Da 15. No. 16. No. 11. WHC-SD-WM-ER-619 11. WHC-SD-WM-ER-619 12. Second Comparison 13. Second Comparison 14. Second Comparison 14. Second Comparison 15. Reviewed Accomparison 16. Reason for Transmittal (G) 16. Desponded Woomment 17. SiGNAU Comparison 11. Approval 4. Review 11. Second Comparison 11. Second Comparison 11. Approval 4. Review 11. Second Comparison 12. Second Comparison 13. Information 14. Approval 4. Review 14. Reviewed Accomparison 15. Reviewed Accomparison 16. Reason for Transmittal (G) 16. Reason for Transmittal (G) 17. SiGNAU 18. Reviewed Accomparison 18. Reviewed Accomparison 19. Second Comparison 10. Second Comparison 11. Second Comparison 12. Second Comparison 13. Disponded Woomment 14. Cog.Eng. W. D. Witteking 14. Cog.Eng. W. D. Witteking 15. Second Comparison 15. Second Comparison 16. Second Comparison 17. SiGNAU 18. Second Comparison 18. Reviewed Accomparison 19. Second Comparison 10. Second Comparison		t No.: ł	Originator Remarks: 9. Equip./Component No.:						. Or						
11. Receiver Remarks: 11A. Design Baseline Document? Yes [] No 12. Major Assm. Dwg. No. 13. Permit/Permit Applic NA 14. Required Response Data NA 15. DATA TRANSHITTED (F) (G) (H) 16. (B) Document/Drawing No. Sneet No. (E) Transmitted Approval 1. WHC-SD-WM-ER-619 0 Surface Moisture NA 1/.2 1. WHC-SD-WM-ER-619 0 Surface Moisture NA 1/.2 1. WHC-SD-WM-ER-619 0 Surface Moisture NA 1/.2 1. Approval Designator (F) Reason for Transmittal (G) Disposition (H) & (I) Approved 1. Approval Designator (F) Reason for Transmittal (G) Disposition (H) & (I) A. Reviewed no/con 1.5. G.Q. D or N/A 1. Approval 4. Review S. Reviewed v/comment 5. Reviewed v/com 16. KEY Disposition (H) & (I) 5. Reviewed v/com 3. Disapproved w/comment 6. Reasing acknowle 17. Proval Designator (F) Reason for Transmittal (G) 1. Approved 8. Reviewed no/con	/:	acility:	m/Bldg./F	10. System	. [ease	iva i / Re i	Appro		
13. Permit/Permit Applic NA 14. Required Response Da (C) (C) (D) (A) (B) Document/Drawing No. (C) (D) (E) Title or Description of Data Design nator Origi Document/Drawing No. 1. (B) Document/Drawing No. (C) (D) Strett Rev. (E) Title or Description of Data Design nator Transmitted Origi Document/Drawing No. 1. WHC-SD-WM-ER-619 0 Surface Moisture NA 1/2 Induction Probe 1. WHC-SD-WM-ER-619 0 Surface Irregularity Induction Probe Induction Probe Surface Irregularity Tests Induction Probe Induction Probe Induction Probe Surface Irregularity I. Approval Designator (F) Reason for Transmittal (G) Disposition (H) & (I) (S, O. D or N/A 1. Approval 4. Review 5. Post-Review 3. Disported wicomment 5. Reviewed moloon (S, O. D or N/A 1. Approval Designator (F) Reason for Transmittal (G) Disposition (H) & (I) 1. Reviewed noloon Submorand Designator for required signatures)		g. No.:	Assm. Dw NA	12. Major	10	[]	V Yes WPW	ent?	∍line Docum	Design Base	11A. I	Remarks:	eceiver	11. R	
14. Required Response Da 15. DATA TRANSMITTED (F) (G) (H) (A) Item (B) Document/Drawing No. Sheet Rev. (E) Title or Description of Data Design nator Transmitted Design nator Transmitted Design nator Reason Disp. 1. WHC-SD-WM-ER-619 0 Surface Moisture Measurement System NA 1/2 I/2 1. WHC-SD-WM-ER-619 0 Surface Irregularity I/2 I/2 I. WHC-SD-WM-ER-619 0 Surface Irregularity I/2 I/2 I. Induction Probe Surface Irregularity I/2 I/2 I/2 I. Medasurement System I.	ation No.:	Applicati	t/Permit NA	13. Permi											
DATA TRANSMITTED (F) (G) (H) (A) (B) Document/Drawing No. Sheet Rev. (E) Title or Description of Data Approval Design ator Transmitted Nator Transmitted Transmitted Nator Transmitted Nator Transmitted Nator Transmitted Nator Transmitted Nator Transmitted Transmitted Transmitted Transmited Transmitted	(e:	nse Date:	red Respo	14. Requi											
(A) Item (B) Document/Drawing No. (C) Sheet No. (C) No. (E) Title or Description of Data Transmitted Approval Design nator Approval for Trans- mittal Reson Disp. eittor 1. WHC-SD-WM-ER-619 0 Surface Moisture Measurement System Electromagnetic Induction Probe Surface Irregularity NA 1/2 1. WHC-SD-WM-ER-619 0 Surface Irregularity Tests NA 1/2 1. Indextantial (SD Disposition (H) & (I) Surface Irregularity Tests Indextantial (SD Indextantial (SD 6. KEY Information 6. Dist. (Reseipt Acknow. Required) I. Approved 2. Approved w/comment 5. Reviewed no/com Surface Approval Designator for required signatures) (G) Rea (H) Disp. (J) Name (K) Signature (I) Date (I) Design Agent <	(1)	(#)	(G)	(F))	TRANSMITTE	DATA				15.	
Item No. (B) Document/Drawing No. Sheet No. Hev. No. (B) No. Transmitted Design for nator Transmitted nator Transmitted 1. WHC-SD-WM-ER-619 0 Surface Moisture Measurement System NA 1/2 I. WHC-SD-WM-ER-619 0 Surface Irregularity NA 1/2 I. WHC-SD-WM-ER-619 0 Surface Irregularity Induction Probe Surface Irregularity Tests Induction Probe Induction Probe Surface Irregularity Tests Induction Probe Surface Irregularity Tests Induction Probe Surface Irregularity Induction Probe Surface Irregularity Induction Probe Surface Irregularity Tests Induction Probe Induction Probe Surface Irregularity Induction Probe Inductio	Receiv-	Origi-	Reason	Approval	of Data	ecrintion	Title or D	(E)	(D)	(C)			Γ	(A)	
1. WHC-SD-WM-ER-619 0 Surface Moisture Measurement System Electromagnetic Induction Probe Surface Irregularity Tests NA 1/2 8. KEY Approval Designator (F) Reason for Transmittal (G) Disposition (H) & (I) 1. Approval 4. Review 2. Approval Designator (F) Reason for Transmittal (G) Disposition (H) & (I) 3. Information 6. Dist. (Receipt Acknow. Required) 3. Disapproved w(comment 6. Receipt acknowle 12. Signature (L) Date (M) MSIN (G) (H) 1 Design Agent (L) Date (M) MSIN (G) (J) Name (K) Signature 1 L Cog. Eng. W. D. Wittekind (D) Wittaking (I) I I 1 L Cog. Eng. W. D. Wittekind (D) Wittaking (I) I I 1 L Cog. Mgr. J. Greenborg July (I) (I) I I 1 G Mgr. I I I I I I	er Dispo-	nator Dispo-	for Trans-	Desig- nator	or Data	smitted	Tran	,	No.	No.	wing No.	Document/Dra	(B) (item No.	
1. WHC-SD-WM-ER-619 0 Surface Moisture Measurement System Electromagnetic Induction Probe Surface Irregularity Tests NA 1/2 6. KEY Approval Designator (F) Reason for Transmittal (G) Disposition (H) & (f) 5. KEY Approval Designator (F) Reason for Transmittal (G) Disposition (H) & (f) 5. Release 5. Post-Review 3. Information 6. Dist. (Receipt Acknow. Required) 1. Approved w/comment 6. KEY Approval Designator (F) Reason for Transmittal (G) Disposition (H) & (f) 1. Approval 4. Reviewed w/com 2. Release 5. Post-Review 3. Information 6. Dist. (Receipt Acknow. Required) 1. Approved w/comment 6. Receipt acknow/e 1. Approval Designator for required signatures) 6. Receipt acknow/e 11. Approval Designator for required signatures) 6. Receipt acknow/e 12. Information 10/21/96 1 1 13. Information 10/21/96 1 1 14. Design Agent 1 1 <t< td=""><td>sition</td><td>sition</td><td>mittal</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>	sition	sition	mittal												
Measurement System Electromagnetic Induction Probe Surface Irregularity Tests Image: Stress in the stress in th		ļ	1/2	NA	e	oistu	face Mo	Surf	0		R-619	·SD-WM-E	WHC-	1.	
Electromagnetic Induction Probe Surface Irregularity Tests Approval Designator (F) Reason for Transmittal (G) S. Q. D or N/A see WHC-CM-3-5, B. Information 6. Dist. (Receipt Acknow. Required) 1. Approval 4. Review 2. Release 5. O.D or N/A see WHC-CM-3-5, 3. Information 6. Dist. (Receipt Acknow. Required) 13. Information 6. Dist. (Receipt Acknow. Required) 14. Design Author ity 14. Design Agent 1 1			1		tem	nt Sys	suremen	Meas]		
Induction Probe Surface Irregularity Tests Surface Irregularity Tests Approval Designator (F) Reason for Transmittal (G) S. Q. D or N/A S. Release S. Post-Review J. Information B. Dist. (Recspit Acknow. Required) J. Information Release See Approval Designator for required signatures) (G) (H) Disp. (J) Name (K) Signature (L) Date son Disp. (J) Name (K) Signature (L) Date son						metio	ctromag	Elec							
Surrace Irregularity Tests Surrace Irregularity Tests Surrace Irregularity Tests Surrace Irregularity Tests Surrace Irregularity Tests Surrace Irregularity Tests Approval Designator (F) Reason for Transmittal (6) Suproval Designator (F) Reason for Transmittal (6) I. Approval A. Review I. Approved S. Rolease S. Post-Review S. Information Boist, Receipt Acknow, Required) I. Signature (L) Date Missingatures) (6) (H) (14) Disp. (J) Name (K) Signature (L) Date (M) NSIN Rea- son Disp. 1 Design Agent 1 Cog. Eng. W. D. Witteking UP/24/96 1 1 Cog. Mgr. J. Greenborg 1 Cog. Mgr. J. Greenborg 0a Jamburg (PIS/M)						Prob	iction	Indu							
16. KEY Approval Designator (F) Reason for Transmittal (G) Disposition (H) & (I) 16. KEY Approval Designator (F) Reason for Transmittal (G) Disposition (H) & (I) 17. SIGNATURE/DISTRIBUTION (See Approval Designator for required) 1. Approved 4. Reviewed no/com 17. SIGNATURE/DISTRIBUTION (See Approval Designator for required) 1. Approved w/comment 5. Reviewed w/com 18. (H) (J) Name (K) Signature (L) Date (M) MSIN (B) 11. Design Agent (J) Name (K) Signature (L) Date (M) MSIN (B) 11. Design Agent 1. 1. 1. 1. 1. 11. Cog.Eng. W. D. Wittekind U.D.Wittah					arity	rregu	race In	Surt							
16. KEY Approval Designator (F) Reason for Transmittal (G) Disposition (H) & (I) 1. Approval Designator (F) Reason for Transmittal (G) Disposition (H) & (I) 2. Release 5. Post-Review 1. Approved w/comment 4. Reviewed no/com 2. Release 5. Post-Review 1. Approved w/comment 5. Reviewed w/com 3. Information 6. Dist. (Receipt Acknow. Required) 1. Approved w/comment 6. Receipt acknowle 17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures) (B) (H) (J) Name (K) Signature (L) Date (10) (H) (J) Name (K) Signature (L) Date (M) MSIN Reason (G) (H) (J) Name (K) Signature (L) Date (10) L Design Authority ZHL/24 (96) (L I D.K. 425557 Quittal II (1) Cog. Eng. N. W. D. Witteking (M) (M)<			<u>├</u>				.5	Test	<u> </u>				<u> </u>		
IS. KEY Approval Designator (F) Reason for Transmittal (G) Disposition (H) & (I) E, S, Q, D or N/A see WHC-CM-3-5, See (H-C-CM-3-5, See (H-C-CM-		<u> </u>						<u> </u>					┠───		
6. KEY Approval Designator (F) Reason for Transmittal (G) Approval Designator (F) Reason for Transmittal (G) Disposition (H) & (I) Reason for Transmittal (G) Disposition (H) & (I) Reason for Transmittal (G) Release S. Post-Review Required I. Approved w/comment S. Reviewed no/com									 				<u> </u>		
6. KEY Approval Designator (F) Approval Designator (F) (S, Q, D or N/A (S,				·					 				I		
KEY Approval Designator (F) Reason for Transmittal (G) Disposition (H) & (I) S, O, D or N/A 1. Approval 4. Reviewed no/con see WHC-CM-3-5, 2. Release 5. Post-Review 1. Approved 4. Reviewed no/con see WHC-CM-3-5, 3. Information 6. Dist. (Receipt Acknow. Required) 3. Disapproved w/comment 5. Reviewed w/com 17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures) 16. (H) (J) Name (K) Signature (L) Date 10 Design Authority JULY (J) Line (M) MSIN (G) (H) (J) Name (K) Signature (L) Date 1 Design Agent 1 1 D. Cog. Eng. W. D. Witteking (M) Witteking (M) 1 I Cog. Eng. W. D. Witteking (M) (M) (M) 1 I Cog. Mgr. J. Greenborg July (C) (C) (M) (C) 1 I Cog. Mgr. J. Greenborg July (C) (C) (C) (C) 1 I Go I I I I															
Approval Designator (F) Reason for Transmittal (G) Disposition (H) & (I) (i, S, Q, D or N/A 1. Approval 4. Review (i, S, Q, D or N/A 1. Approval 4. Review (i, S, Q, D or N/A 1. Approval 4. Review (i, S, Q, D or N/A 1. Approval 4. Review (i, S, Q, D or N/A 1. Approval 4. Review (i, S, Q, D or N/A 1. Approval 4. Reviewed no/con (i, S, Q, D or N/A 1. Approval 4. Reviewed no/con (i, Recase 5. Post-Review 3. Disapproved w/comment 6. Receipt acknowle (i, 1, 2.1) 3. Information 6. Dist. (Receipt Acknow. Required) 3. Disapproved w/comment 6. Receipt acknowle 17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures) 6. Receipt acknowle 6. Receipt acknowle 16) (H) (J) Name (K) Signature (L) Date (M) MSIN (G) (H) 1 Design Authority (H) Action 10/21/96 1 1 D. (J) Name (K) Signature (L) Date 1 1 Cog. Eng. W. D. Wittekind 20 Witteking 1 1 D. (J) Name							EY	K						6.	
1. Approval 1. Approval 4. Reviewed no/con 1. Approval 1. Approval 4. Reviewed no/con 2. Rejease 5. Post Review 1. Approval 3. Information 6. Dist. (Receipt Acknow. Required) 3. Disapproved w/comment 5. Receipt acknowle 17. SIGNATURE/DISTRIBUTION 17. SIGNATURE/DISTRIBUTION 6. Receipt acknowle 160 (H) (J) Name (K) Signature (L) Date 18a Disp. (J) Name (K) Signature (L) Date 1 Design Agent 1 1 D. C. 42507 Quint P. Lucen 1 Cog. Eng. W. D. Wittekind Wittekind (G) 1 1 Cog. Eng. W. D. Wittekind (G) 1 1 1 Cog. Eng. W. D. Wittekind (G) 1 1 1 Cog. Eng. W. D. Wittekind (G) 1 1 1 Cog. Eng. W. D. Wittekind (G) 1 1 1 Cog. Eng. J. Greenborg (G) 1 1 1 Cog. Eng. J. Greenborg (G) 1 1			on (H) & (I)	Dispositio		+		(G)	lor Transmitta	Reason	1	gnator (F)	oval Desi	Appr	
3. Information 6. Dist. (Receipt Acknow. Required) 3. Disapproved w/comment 6. Receipt acknowle 17. SiGNATURE/DISTRIBUTION (See Approval Designator for required signatures) (G) (H) (J) Name (K) Signature (L) Date (M) MSIN (G) (H) (J) Name (K) Signature (L) Date 10 Design Authority ////////////////////////////////////	ment nent	no/comme w/commer	4. Reviewed 5. Reviewed	mment t	proved proved w/cor	2. A			ew Review	5. Post	2. Release	-5,	HC-CM-3	see W	
17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures) (6) (H) (J) Name (K) Signature (L) Date (M) MSIN (G) (H) Rea- son Disp. (J) Name (K) Signature (L) Date (M) MSIN (G) (H) 1 I Design Agent I I D. 4. 45507 Quint P. Luum 10-1 1 I Cog. Eng. W. D. Wittekind W. Wittekind W. Wittekind V. Wittekind	dged	cknowledge	6. Receipt a	comment 6	approved w/o	3. D	quired)	now. Req	. (Receipt Ack	ion 6. Dist	3. Informat	_	.7)	Sec.12	
IG) (H) (J) Name (K) Signature (L) Date (M) MSIN (G) (H) (J) Name (K) Signature (L) Date Son 1 Design Authority ////////////////////////////////////					ures)	JTION red signat	E/DISTRIB	IGNATUR Designato	17. See Approval	(
Rea- son Disp. (J) Name (K) Signature (L) Date (M) MSIN Rea- son Disp. (J) Name (K) Signature (L) Date 1 1 Design Authority Ifficial 10/22/96 1 1 D. 4.4550 Dullut P. Luun 10-1 1 1 Cog. Eng. W. D. Wittekind Wittekind Wittekind 1 1 1 1 Cog. Mgr. J. Greenborg Juntary 10-15 1 1 2 0A 1 Safety 1 1 1						E CHU	(G)			'			(H)	(G)	
1 Design Authority Jeffed 10/22/96 1 1 D. L. Lesson Dullet P. Lunn, 10-1 1 Design Agent 1 1 D. L. Lesson Dullet P. Lunn, 10-1 1 1 Cog. Eng. W. D. Wittekind WD Wittekind WD 10/14/1976 1 1 Cog. Mgr. J. Greenborg Junbry 10/15/92 0A 0A	(M) MSIN	.)Date (M	gnature (l.	e (K)Si	(J) Name	Disp.	Rea- son	ISIN)Date (M)N	Signature (L	18 (K) 5	(J) Narr	Disp.	Rea- son	
1 Cog. Eng. W. D. Wittekind & D. Wittekind b 1 Cog. Mgr. J. Greenborg . July 10/5/96 0A Safety	5-96	2 10-15-9	C. Lun	or Delhu	D.L. 4854	1	1	6	D 10/22/9	XEL	ithority Jent	Design AL Design Ag	_	1	
1 Cog. Mgr. J. Greenborg QA Safety							6	1411196	DIT	tekind 2/-	W. D. Wit	Cog.Eng.	T	1	
QA Safety							2	10/15/0	-wmak	borg	J. Green	Cog. Mar.		1	
Safety							— —)	morz			04		1	
						-	-					Safety			
												Salety			
						L					1	Env.			
18. W. D. Wittekind W. D. Wittekind W. D. Wittekind W. D. Wittekind W. D. Wittekind W. D. Wittekind W. D. Wittekind Maproved Authorized Representative Markovicki (I req Ctrl. No. Approved Approved Maproved Markovicki (I req Ctrl. No. Ctrl. No. Ct	ired)	if requir ments	PPROVAL (No. ed ed w/comm	21. DOE A Ctrl. [] Approv [] Approv	10/13/76	enbry	. Greenbor		ngh	Arran Jr	τ. G. F. 96	tekind 19	Wittekind کر کر are of FDT	18. W. D. J L. S	

BD-7400-172-2 (05/96) GEF097

Surface Moisture Measurement System Electromagnetic Induction Probe Surface Irregularity Tests

W. D. Wittekind Westinghouse Hanford Company, Richland, WA 99352 U.S. Department of Energy Contract DE-AC06-87RL10930

EDT/ECN: 619216 UC: 606 Org Code: 403 8M720 Charge Code: N2210 B&R Code: 1N23E40501 Total Pages: 30 EW3120072

Key Words: EMI, electromagnetic induction, moisture measurements, HLW tanks

Abstract: Surface irregularities cause the EMI moisture measurement to infer too low of a free water content in the HLW tank.

TRADEMARK DISCLAIMER. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

Printed in the United States of America. To obtain copies of this document, contact: WHC/BCS Document Control Services, P.O. Box 1970, Mailstop H6-08, Richland WA 99352, Phone (509) 372-2420; Fax (509) 376-4989.

ママーク elease Approval



Approved for Public Release

SURFACE MOISTURE MEASUREMENT SYSTEM ELECTROMAGNETIC INDUCTION PROBE SURFACE IRREGULARITY TESTS

Warren D. Wittekind

Westinghouse Hanford Company Richland, Washington

ABSTRACT

Surface Irregularity Tests

The surface of waste tank contents is irregular; the salt cake may have cracks, voids, humps and dips, etc. These surface irregularities have some effect on the free water content of the waste medium inferred from the electromagnetic induction (EMI) signal.

Several experimental tests were performed on liquids of known electrical conductivity with a wide side-to-side not electrically conducting void centered directly underneath the EMI test coil. This inhomogeneity geometry was chosen because it was believed to be the worst case void for the EMI technique in that the greatest fraction of the circular induced currents would be disrupted by this shape.

The inhomogeneity test results are consistent with the electrically non-conducting voids reducing the effective medium conductivity. The EMI signal reduction and hence the reduction in the inferred conductivity is almost linear with the void fraction from inhomogeneities uniform in depth.

The consequence of reducing the effective medium conductivity is that the EMI inferred free water content represents a lower limit for the free water content. Greater void inhomogeneities would cause a greater EMI underestimate of the free water content actually present. The effect of reducing medium conductivity on EMI inferred free water content is non-linear. A uniform 5% void inhomogeneity would cause an EMI underestimate of the free water content by approximately 2%, a uniform 10% void inhomogeneity would cause an EMI underestimate of the free water content by approximately 4%, a uniform 25% void inhomogeneity would cause an EMI underestimate of the free water content by approximately 12%, and a uniform 50% void inhomogeneity would cause an EMI underestimate of the free water content by approximately 31%.

Void inhomogeneities that are not uniform in depth but that are concentrated in regions of higher electromagnetic fields, that is closer to the EMI coils, will cause a disproportionately greater EMI underestimate of the free water content.

CONTENTS

1.0	INTRODUCTION	1
2.0	SUMMARY	$\begin{array}{c} 1 \\ 1 \\ 1 \end{array}$
3.0	EMI MEASUREMENT SYSTEM DESCRIPTION 3.1 EMI Operating Hardware 3.2 Components 3.3 Configuration 3.3.1 EMI Coil Configuration 3.3.2 EMI Probe Configuration 3.3.3 EMI Probe Configuration 3.3.4 EMI Probe Medium Conductivity Response	222222233 3
4.0	SURFACE INHOMOGENEITY TESTING	7
5.0	INTERPRETATION OF RESULTS 5.1 Surface Inhomogeneity Measurement Prediction 5.1.1 Surface Inhomogeneity Theoretical Calculation 5.1.2 Surface Inhomogeneity Theoretical Discussion 5.2 Surface Inhomogeneity Measurement Interpretation	7 7 8 9 10
6.0	REFERENCES	12
APPEI Figu Figu Figu Figu Figu Figu Figu Figu	NDIX Irregularity Effect 0 mS/cm Amplitude ////////////////////////////////////	4-1 4-2 A-3 A-4 A-5 A-6 A-7 A-8 A-9 -10 -11 -12

LIST OF FIGURES

Figure 1.	Surface Moisture Monitor EMI Probe				4
Figure 2.	EMI Surface Irregularity Attachment				5
Figure 3.	EMI Surface Irregularity Test Pieces				6
Figure 4.	Electrical Conductivity versus Moisture Content				14

LIST OF TABLES

Table 1.	EMI Surface Inhomogeneity Test Results	11
Table 2.	Calculated EMI Moisture Content with Known Voids	13
Table 3.	Void Effect on EMI Inferred Moisture Content	13

1.0 INTRODUCTION

This report documents laboratory measurements to infer the effect of surface inhomogeneities on EMI determined moisture content.

The electromagnetic induction (EMI) probe is being developed by WHC (Crowe and Wittekind 1995) to measure the amount of water remaining in waste stored in the high-level waste tanks on the Hanford Site. A previous report (Wittekind and Crowe, 1996) considered the medium moisture content relationship to medium electrical conductivity. Another report (Wittekind and Crowe, et.al. 1996) considered the EMI signal relationship to medium electrical conductivity.

The electromagnetic probe uses a magnetic field to induce electrical current in the surrounding waste proportional to the waste conductivity. The moisture content of the waste is estimated based on the measured waste conductivity. The EMI coil measured signal amplitude is proportional to the waste electrical conductivity.

2.0 SUMMARY

2.1 Purpose

This report provides details about EMI work in progress. Descriptions are given of:

- EMI operating hardware, and
- Experimental EMI measurements on the effect of surface inhomogeneities.

The EMI probe response was measured with medium conductivities of 0 mS/cm, 5 mS/cm, 10 mS/cm, 20 mS/cm, and 40 mS/cm. The inhomogeneity test pieces consisted of the "W" part of standard length and width, the "X" piece with a greater depth, and the "Y" piece with a narrower width. This allowed one variation in inhomogeneity depth and one variation in inhomogeneity width.

EMI measurements were performed on conductivity test standards with the solution electrical conductivity determined using the standard techniques of an electrical conductivity meter and purchased standard solutions.

2.2 Conclusion

Inhomogeneity data is consistent with reduction of EMI signal amplitude proportional to the reduction of the effective volume contributing to the sample electrical conductivity. It is assumed that inhomogeneities are nonconducting inhomogeneities and diminish the total electrically conducting volume. There was not adequate data to define the depth effect, but this is expected to be consistent with EMI depth sensitivity.

Another way to state this conclusion is that the EMI signal amplitude is proportional to the effective volume fraction of the medium available to contribute to electrical conductivity. That is in the solid medium volume with the void inhomogeneities, the space occupied by voids does not contribute to sample electrical conductivity. The final effect is that the EMI inferred moisture content will be lower than the actual moisture content due to the presence of void inhomogeneities.

3.0 EMI MEASUREMENT SYSTEM DESCRIPTION

3.1 EMI Operating Hardware

An EMI moisture monitor for assaying the effective average free water moisture content in solid salt cake material has been assembled and tested. The two main components are: (1) an eddy current tester (Model MIZ-40A manufactured by ZETEC of Issaquah, Washington), and (2) a custom designed coil pair for this application. There is an electrical intrinsic safety barrier between the MIZ-40A and the EMI coils for safe operation in a hazardous atmosphere. Additional components necessary to record EMI data on archival medium include analog-to-digital converters, and position encoders.

3.2 Components

The EMI probe circuit, starting at the MIZ-40A, has the successive components of 1) MIZ-40A eddy current tester, 2) coaxial cables approximately 100 ft long (two RG 174/U or equivalent), 3) dual channel intrinsic safety barrier (ISB) for ± 9 volts (167 Ω ISB number 9002/22-240-160-00), alternating current. 4) coaxial cables for deployment into a hazardous environment, 5) two EMI coils for electrical conductivity sensing.

3.3 Configuration

3.3.1 EMI Coil Configuration

The EMI coil has the pancake geometry. The pancake geometry puts the coils into a plane of relatively small thickness with significant difference between the inside diameter and the outside diameter. The coil, with associated coaxial cables and intrinsic safety barrier (ISB) is designed to operate at 400 khz. Approximately 85 feet of additional coaxial cable between the van and the ISB has reduced the effective resonance to approximately 360 khz. The 400 khz coil housing has an outside diameter of 3 inches. The coil has an inside diameter of 2.10 inches. There are 23 turns of AWG 20 gauge wire. The reported inductance of this coil is 55μ H.

3.3.2 EMI Probe Configuration

The EMI probe length is 12 3/8 in. and the EMI probe diameter, 3.5 in., is consistent with the requirements for entering the HLW tank vapor space through a 4 inch carbon steel pipe used for a riser.

The EMI coil configuration uses two coils separated by 5 in. The 5 inch coil spacing allows a tungsten weight to be placed approximately 4 inches away within the EMI probe housing. The tungsten weight will bring the total weight of the EMI probe up to 25 lbs. This weight was found to be necessary for the probe to pull the electrical cable from the take up reel when being deployed.

The EMI probe housing is an electrically conducting high density polyethylene. The polyethylene was made electrically conducting by adding graphite into the polyethylene by the plastic supplier. It is believed that the semi-conducting plastic will dissipate static electrical charges.

The two EMI coils were designed for a resonant frequency of 400 khz, and operate in the test/reference mode, with the frequencies of operation expected to be between 200 and 500 khz

The EMI probe size and total weight is not much different than neutron moisture monitoring probe. The EMI probe is electrically simpler than the neutron moisture monitoring probe and does not require an explosion proof housing.

3.3.3 EMI Probe Circuit

The EMI probe circuit, beginning at the MIZ-40A includes coaxial cable connections to the intrinsic safety barrier (ISB), the intrinsic safety barrier, and additional coaxial cable connections inside the HLW tank that connect to the EMI coils, and finally the 400 khz coils.

There is a mercury-wetted slip ring in the circuit between the ISB and the coaxial cable to the EMI coil. This allows an electrical connection while a spool with the coaxial cable turns to lower the coil to the electrically conductive surface.

The ISB is R. Stahl Inc.'s INTRINSPAK 9002/22-240-160-00. This is a dual channel ISB designed for alternating current ± 9 V. There is a 167 Ω resistor, which permits intrinsically safe operation in a Class I, Group B (hydrogen atmosphere or equal) with an inductor as large as 6.5 mH.

The coaxial cable shields are grounded at the ISB. Since the center conductor of the coaxial cable was connected through the ISB, it would be redundant to connect the shield of the coaxial cable through the ISB also.

There is approximately 100 feet of SMMS cable (equivalent to RG 174 coaxial cable) between the EMI coil and the ISB. There is approximately another 85 feet of SMMS cable between the ISB and the MIZ-40A eddy current tester.

The MIZ-40A is an eddy current tester designed for use around nuclear plants for balance of plant operation. The MIZ-40A can sample EMI coil signal response at four frequencies simultaneously. There are analog electrical outputs available that allow connection to an analog to digital convertor and eventual long term storage media.

3.4 EMI Probe Medium Conductivity Response

The EMI probe operates on an inductive effect. There are two EMI coils, 5 inches apart, the absolute is on the bottom while the reference coil is on the top and remote from the medium being interrogated. There is a change in inductance in one coil when it is close to an electrically conductive medium. The MIZ-40A eddy current tester subtracts the EMI response of the reference coil from the EMI response of the absolute coil, the difference is the EMI signal. The greater the electrical conductivity of the medium being interrogated, the greater will be the induced electrical current in the conducting and consequently the greater will be the change in magnetic field at the absolute coil location.

Figure 1., Surface Moisture Monitor EMI Probe, shows the arrangement of the two EMI coils inside the EMI probe housing.



Surface Moisture Monitor EMI Probe

Matched coils on separate spool pieces with 8" to 10" of coaxial cable and BNC connector.

Spacer with center clearance for BNC connector.

Semiconducting polyethylene cylinder with 0.050" thickness at tip.

CW3399

Figure 2. EMI Surface Irregularity Attachment



Side View

Front View

EMI Surface Irregularity Attachment





6

Figure 3. EMI Surface Irregularity Test Pieces

WHC-SD-WM-ER-619 REV 0

WOW35

.394"

->| |+

3.94"

4.0 SURFACE INHOMOGENEITY TESTING

The surface inhomogeneity was created in the electrically conducting liquid by attaching nonconducting plastic forms to the EMI probe. Figure 2., EMI Surface Irregularity Attachment, shows the attachment of the plastic form to the EMI probe housing. Figure 3, EMI Surface Irregularity Test Pieces shows three different plastic forms used to create surface irregularities. The three forms allow for one standard surface inhomogeneity, one variation in thickness, and one variation in depth.

EMI Probe Laboratory Surface Inhomogeneity Test Performed:

Date:	12 Ai	ugust	1996
Series:	Surfa	ače I	nhomogeneity Tests
Probe:	400 k	khz Z	etec Čoils, 5 inch coil spacing
Probe:	Polye	ethy1	ene with graphite (under 10° Ohm-cm resistivity)
Values:	320 k	khz,	340 khz, and 360 khz.
Values:	0 mS/	/cm,	05 mS/cm, 10 mS/cm, 20 mS/cm, and 40 mS/cm.
Values:	Three	e sur	face inhomogeneities (W, X and Y) and none.
Values:	W and	dΧh	ave same widths, X part is twice depth of W.
Values:	W and	dΥh	ave same depths, Y part is half width of W.
Results:	EMI	signa	1 variation with inhomogeneity.
Observatio	ons :	1)	0 mS/cm: none & X similar, W & Y lower.
Observatio	ons:	2)	5 mS/cm: none & X similar, W & Y lower.
Observatio	ons :	3)	10 mS/cm: none, W & X similar, Y lower.
Observatio	ons :	4)	20 mS/cm: none is highest, Y, X & W lower.
Observatio	ons:	5)	40 mS/cm: none is highest, Y, X & W lower.
CONCLUSION	NS:	A)	EMI amplitude trend is consistent that greater width of
			inhomogeneity causes a lower EMI signal.
		B)	EMI amplitude trend is not definitive that depth of
			inhomogeneity causes a lower EMI signal.
		C)	EMI amplitude is consistent with the inhomogeneity causing
			a lower EMI signal,
		D)	EMI amplitude is most consistent with the scan starting
			distance causing a variation in EMI signal amplitude.
			This is the same as saying that just where the EMI probe
			is "zeroed" for a reference point is significant and that
			it should be remote from the surface being interrogated.

5.0 INTERPRETATION OF RESULTS

5.1 Surface Inhomogeneity Measurement Prediction

The sensitivity region of the pancake shape of the EMI coil with a 0.075 inch thickness and diameters of 3.0 inches 0.D. and 2.1 inches I.D. can be expected to be focussed down, with reduced sensitivity off to the side.

Because of the homogeneous shape of the coil with approximately 2 layers of turns between the coil bottom and coil top, EMI signal from samples with inhomogeneities can be expected to depend more on total sample volume and less on the specific arrangement of the surface inhomogeneity. This statement must be qualified because volumes closer to the EMI coils are where electromagnetic fields are stronger and count more heavily than volumes that are more remote from the EMI coils and where electromagnetic fields are weaker.

The quantitative reduction of EMI signal amplitude from non-conducting inhomogeneities could be estimated by the ratio of sample volume without inhomogeneities to the total volume of the sample volume with the void inhomogeneities.

The quantitative effect on EMI signal phase of the surface inhomogeneity is expected to be zero. A phase shift could be introduced by a change in EMI probe capacitance, but the electrically conducting EMI coil housing short circuits the probe capacitance, eliminating the cause of phase shift.

EMI depth of penetration with 90% of the signal coming from approximately the first 3 inches of depth, was not expected to show much variation between the 1.97 inch depth test pieces (W and Y parts), and the 3.94 inch depth test piece (X part).

5.1.1 Surface Inhomogeneity Theoretical Calculation

A theoretical calculations of the effect of electrically conducting flaws on the signal amplitude was performed by Burrows (Burrows, 1964). There were four cases considered.

- 1) prolate spheroid, field parallel long axis.
- 2) prolate spheroid, field perpendicular long axis,
 3) oblate spheroid, field parallel short axis, and
 4) oblate spheroid, field perpendicular short axis.

A prolate spheroid is a shape between a sphere and a rod; one axis is long and the two equal axes are short. An oblate spheroid is a shape between a sphere and a circular disk; one axis is short and the two equal axes are long.

The base case is the non-conducting sphere, where P_0 , induced dipole moment, (Burroughs, 1964, Equations 5.5, 5.10 and 7.14) is:

$$\overline{P_0} = -\frac{3}{2} V \overline{j_i}$$

where

V is the volume of the sphere, and j, is the average current density.

For the special case of a non-conducting long rod in a parallel field, the induced dipole approaches the limiting value:

$$\overline{P_L} = \boldsymbol{\alpha}_L \ \overline{P_0} = \frac{2}{3} \ \overline{P_0}$$

For the special case of a non-conducting long rod in a transverse field. the induced dipole approaches the limiting value:

$$\overline{P_T} = \boldsymbol{\alpha}_T \ \overline{P_0} = \frac{4}{3} \ \overline{P_0}$$

For the special case of a non-conducting flat disk in a parallel field, the induced dipole approaches the limiting value:

$$\overline{P_L} = \alpha_L \ \overline{P_0} = \frac{4 \ b}{3 \ \pi \ a} \ \overline{P_0}$$

where

a is the length of the short axis, and

b is the length of the two long axes.

For the special case of a non-conducting flat disk in a transverse field, the induced dipole approaches the limiting value:

$$\overline{P_T} = \alpha_T \overline{P_0} = \frac{2}{3} \overline{P_0}$$

5.1.2 Surface Inhomogeneity Theoretical Discussion

The calculations from Burrows (Burrows, 1964) had assumed a constant electrical field with different shapes of nonconducting voids introduced in the path of this constant electrical field. The magnetic field produced by the pancake geometry EMI coil leads to an circular or azimuthal current flow. When nonconducting obstacles are placed in this current flow, the current simply deviates around the obstacle and flows according to the path of least resistance. This situation leads to an electrical current flow that would be parallel the void inhomogeneity surface instead of perpendicular to it. Electrical current flow perpendicular to the nonconducting obstacle would be a path of greater resistance. The coefficient for the prolate spheroid with an electrical field parallel the oblate spheroid surface has the limiting value of $\alpha_{\rm r}$ = 2/3. The coefficient for the oblate spheroid with an electrical field parallel the oblate spheroid surface has the limiting value of $\alpha_{\rm r}$ = 2/3. This 3/2 factor, leads to EMI signal reduction, $P_{\rm F}$, directly proportional to the product of volume and current for density:

$$\overline{P_F} = \alpha \ \overline{P_0} = \frac{2}{3} \ \overline{P_0} = \frac{2}{3} \left(-\frac{3}{2} \ V \ \overline{j_i} \right) = -V \ \overline{j_i}$$

where

V is the inhomogeneity volume with current parallel the surface, and \mathbf{j}_i is the average current density.

There is the assumption that the void inhomogeneity was subject to the same current field that the bulk volume was subject to. This means that the current term can be canceled out. The fractional diminishment of EMI signal amplitude for a nonconducting void inhomogeneity with current flow parallel the surface is calculated from

EMI Signal Fraction =
$$\frac{\overline{P} - \overline{P_F}}{\overline{P}} = \frac{(\pi/4) a^2 L - taL}{(\pi/4) a^2 L} = \frac{(\pi/4) a - t}{(\pi/4) a}$$

where

a is the diameter of a cylinder of sample below EMI coil,

L is the effective depth of EMI penetration, and

t is the thickness of the nonconducting flaw.

For the test situation, a=3 inches, the coil diameter is reasonable, 1=3 inches for the effective depth of penetration is reasonable, and t= 0.125 inches or t= 0.394 inches depending on void inhomogeneity test piece thickness.

5.2 Surface Inhomogeneity Measurement Interpretation

The interpretation of the EMI signal will depend on the amplitude of the EMI signal. The amplitude can be compared to predictions. The lower conductivity tests were dominated by the distance from the surface that the MIZ-40A was 'zeroed.' The higher conductivity tests are more strongly affected by the medium electrical conductivity. The 40 mS/cm test is the most sensitive to the surface inhomogeneity effect on EMI signal amplitude because the electrical conductivity is the highest.

Figures in the Appendix portray the measured amplitude and phase for the surface inhomogeneity tests. There is no inhomogeneity effect on EMI signal phase, as expected. The inhomogeneity effect on EMI signal amplitude is compared to inhomogeneity surface area calculations are shown in Table 1.

The data in Table 1. has several items for discussion. First, the EMI probe was "zeroed" at different distances from the electrically conductive medium. This introduced some differences in measured signal amplitudes that were not caused by surface inhomogeneities. The calculated reduction of EMI signal amplitude was simply calculated from the formula given at the end of the previous section for a non-conducting disk inhomogeneity with a transverse EMI field.

W part and X part (dimensions in inches):

Amplitude Reduction $\approx \frac{(Sampled Volume) - (Inhomogeneity Volume)}{Sampled Volume}$ = $\frac{((\pi/4) * (a^2) * h) - (t * a * h)}{(\pi/4) * (a^2) * h} = \frac{(\pi/4) * a - t}{(\pi/4) * a}$ = $\frac{(2.356) - (0.394)}{2.356} = 0.8328$

Table 1. EMI Surface Inhomogeneity Test Results Measured versus Calculated EMI Signal Amplitudes Inhomogeneities: None, W, X and Y 40 mS/cm Electrical Conductivity								
Lift-off	360 khz							
None								
-1.438	0.09756	0.1088	0.1419					
0	4.572	5.344	5.695					
W								
-2.018	0.05629	0.09062	0.09121					
0	3.597	4.220	4.508					
% Measured	0.786745	0.789671	0.791572					
% Calculated	0.832781	0.832781	0.832781					
Ratio	0.94472	0.948233	0.950516	0.947823				
Х								
-4.101	0.1553	0.1525	0.1486					
.0	3.957	4.601	4.854					
% Measured	0.865486	0.860966	0.852327					
% Calculated	0.832781	0.832781	0.832781					
Ratio	1.039271	1.033844	1.02347	1.032195				
Y								
-2.337	0.07718	0.08551	0.08192					
0	4.425	5.191	5.456					
% Measured	0.967848	0.97137	0.958033					
% Calculated	0.946948	0.946948	0.946948					
Ratio	1.02207	1.02579	1.011706	1.019855				

The ratio rows calculated in Table 1 are the ratio of measured to calculated EMI amplitude reduction with volume inhomogeneity. Average ratios tabulated in Table 1 with values close to 1.0 are consistent with EMI signal proportional to the void inhomogeneity fraction not contributing to sampled volume electrical conductivity.

Y part (dimensions in inches):

Amplitude Reduction ≈ (Sampled Volume) - (Inhomogeneity Volume) Sampled Volume

$$= \frac{((\pi/4) * (a^2) *h) - (t*a*h)}{(\pi/4) * (a^2) *h} = \frac{(\pi/4) *a - t}{(\pi/4) *a}$$
$$= \frac{(2.356) - (0.125)}{2.356} = 0.9469$$

This volume calculation assumes that the inhomogeneity depth is at least equal to the EMI depth of interrogation. This was expected because the 90% depth of interrogation is approximately 3 inches and the inhomogeneity test pieces are 1.97 inches and 3.94 inches deep.

There was not adequate data to define the depth effect, but this is expected to be consistent with EMI depth sensitivity, that about 90% of the EMI signal is from the top 3 inches.

Another way to state this conclusion is that the EMI signal is proportional to the effective density of the medium, that is the medium density and inhomogeneities the space occupied by voids. The final effect due to void inhomogeneities under the EMI probe is that the EMI inferred moisture content assuming no void inhomogeneities will be a lower limit for the actual moisture content of the same solid with void inhomogeneities actually present.

Table 2 shows the EMI inferred moisture content for different void fractions that reduces the effective medium density by (1.-void fraction). The actual moisture content necessary to give a certain measured electrical conductivity is tabulated in the column under the void fraction assumed.

Table 3 shows the difference between moisture content with known void fractions and the EMI inferred moisture content assuming zero void fraction. Table 3 also shows the ratio of moisture content with known void fractions to the EMI inferred moisture content assuming zero void fraction. The second part of Table 3 was used to estimate the EMI underestimate of the free water content assuming zero void inhomogeneities. Figure 4, Electrical Conductivity versus Moisture Content and subtilled Inhomogeneity Effect (Void Fractions), shows the Table 2 information in a graph.

6.0 REFERENCES

Burrows, M. L., 1964, A Theory of Eddy-Current Flaw Detection, Doctoral Dissertation, University of Michigan.

Wittekind, W. D., and R. D. Crowe, May 1996, *Electromagnetic Induction Probe Calibration for Electrical Conductivity Measurements and Moisture Content Determination of Hanford High Level Waste*, WHC-SD-ER-531 REV 0, Westinghouse Hanford Company, Richland, Washington.

Wittekind, W. D., R. D. Crowe, D. L. Lessor, and S. D. Tomich, October 1996, Surface Moisture Measurement System Electromagnetic Induction Probe Characterization, WHC-SD-WM-ER-606 REV 0, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WM-ER-619 REV 0

Table 2. Calculated EMI Moisture Content with Known Voids*									
Void Fraction	0.00	0.05	0.10	0.25	0.50				
EMI Measured Electrical Conductivity mS/cm									
80	0.2678	0.2724	0.2772						
60	0.2429	0.2473	0.2519	0.2678					
40	0.2102	0.2142	0.2184	0.2331	0.2678				
20	0.1611	0.1644	0.1680	0.1804	0.2102				
10	0.1212	0.1238	0.1267	0.1367	0.1611				
5	0.0897	0.0917	0.0940	0.1018	0.1212				

*EMI moisture content calculated assuming: Porosity θ = 0.50; Interstitial liquid electrical conductivity $\sigma_{\rm W}$ = 200 mS/cm. Solid density $\rho_{\rm S}$ = 2.20 g/cm³, Liquid density $\rho_{\rm L}$ = 1.177 g/cm³, Proportion of water in interstitial liquid ($\rho_{\rm H20}/\rho_{\rm L}$) = 0.792.

Table 3. Void Effect on EMI Inferred Moisture Content Difference Between EMI Moisture Content With Known Voids And EMI Moisture Content Without Voids									
Void Fraction 0.00 0.05 0.10 0.25 0.50									
EMI Measured Electrical Conductivity mS/cm									
80	0.0000	0.0046	0.0094						
60	0.0000	0.0043	0.0090	0.0249					
40	0.0000	0.0040	0.0082	0.0229	0.0576				
20	0.0000	0.0033	0.0069	0.0193	0.0490				
10	0,0000	0.0027	0.0055	0.0155	0.0400				
5	0.0000	0.0021	0.0043	0.0121	0.0315				
Ratio of EMI To EMI M	Moisture oisture Co	Content Wi Dontent Wit	ith Known hout Voids	Voids S					
80	1.0000	1.0171	1.0352						
60	1.0000	1.0179	1.0369	1.1024					
40	1.0000	1.0190	1.0392	1.1092	1.2742				
20	1.0000	1.0206	1.0426	1.1195	1.3043				
10	1.0000	1.0219	1.0454	1.1280	1.3300				
5	1.0000	1.0230	1.0477	1.1347	1.3509				



Figure innomogeneit. Electrica Conductiv Effect V01d versus Moisture Content Fractions)

14

WHC-SD-WM-ER-619 REV 0

APPENDIX









A-3





A-4

Figure A-4. Irregularity Effect 20 mS/cm - Amplitude





Figure A-5. Irregularity Effect 40 mS/cm - Amplitude





Figure A-6. Irregularity Effect 0 mS/cm - Phase



Figure A-7. Irregularity Effect 5 mS/cm - Phase



A-8

Figure A-8. Irregularity Effect 10 mS/cm - Phase



Figure A-9. Irregularity Effect 20 mS/cm - Phase



A-10



A-11



Electrical Conductivity versus Moisture Content

A-12

WHC-SD-WM-ER-619 REV 0

EMI

moisture

content

g

Porosi

a

ō θ

Su g

0 . ຫ

Solid

density

он

/ater ġ

densi

TUDT

Inters

Figure A-11

Electrical C Hanford

Conductivity Waste ate

versus

Moisture

Content

Tank Model assuming conduct

DISTRIBUTION SHEET										
То	From	From								
Distribution	Criticality a	Criticality and Shielding				Date October 11, 1996				
Project Title/Work Order				EDT	No. 619	216				
Surface Moisture Measurement Sys Probe Surface Irregularity Tests	tem Electromag	netic Indu	ction	ECN	No.					
Name	MSIN	Text With All Attach.	Text Onl	y .	Attach./ Appendix Only	EDT/ECN Only				
R. J. Cash	\$7-14	X								
R. D. Crowe	A3-34	Х								
K. L. Drury	H5-09	х								
G. T. Dukelow	S7-14	х								
J. Greenborg	H0-35	Х								
D. L. Lessor	K7-15	х								
J. E. Meacham	S7-14	Х								
E. R. Siciliano	H0-31	Х								
T. I. Stokes	L6-37	Х								
G. F. Vargo, Jr.	H509	Х								
W. T. Watson	H0-31	Х								
W. D. Wittekind	H0-35	х								
Central Files (Original +1)	A3-88	х								