

## Appendix E1

### SEM/EDS Data for Test #5, Day-30 Aluminum Coupons

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This appendix shows the SEM/EDS results for the metal aluminum coupons under two categories: (1) unsubmerged and (2) submerged. Unsubmerged refers to coupons located above the water level of the test tank during ICET tests. Unsubmerged coupons were contacted with the solution only during the initial 4-hour spray phase. In addition, the surface of the unsubmerged coupons may be affected during the test by the moist air in the tank gas space. Submerged refers to the coupons submerged in the solution during the test.

The coupon samples were collected on August 25, 2005 (the date Test #5 was shut down), and examined by SEM/EDS on August 30 and September 6, 2005. The aluminum coupon samples were dried in air before coating with Au/Pd for SEM examination. SEM results present the surface condition of the aluminum coupons. In addition, EDS results provide a semi-quantitative elemental analysis of the coupon surface and the corrosion products.

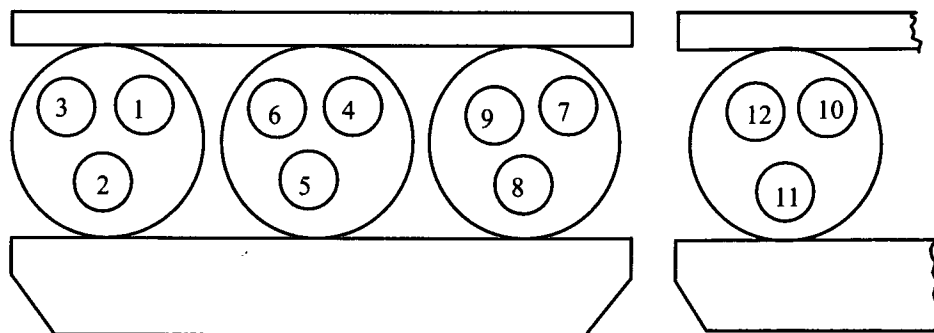


## Transcribed Laboratory Log

Laboratory session from September 6, 2005.

SEM Test #5, Day-30 Aluminum Coupons

Conditions: e=15.0kV, WD=11mm



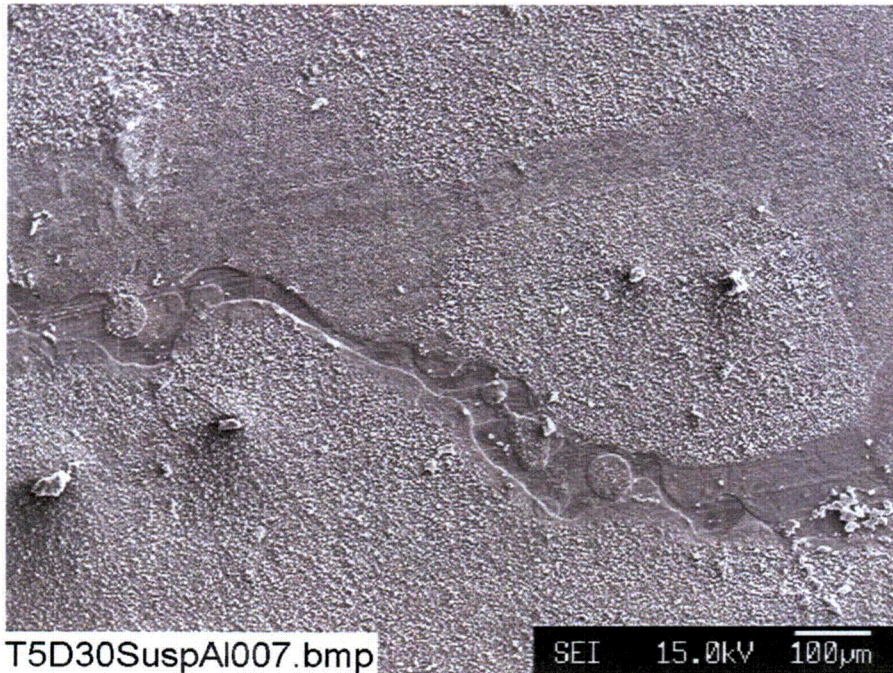
1--Yellow Deposits on Submerged Rack	2--Sediment (T5D30)	3--Al-Unsubmerged
4--Al-Submerged	5--Gal-Steel Unsubmerged	6--Gal-Steel Submerged
7--Cu Unsubmerged	8--Cu-Submerged	9--Steel-Unsubmerged
10--Steel-Submerged	11--Drain Collar Interior	12--Drain Collar Outside Ext.

### Unsubmerged Aluminum Coupons

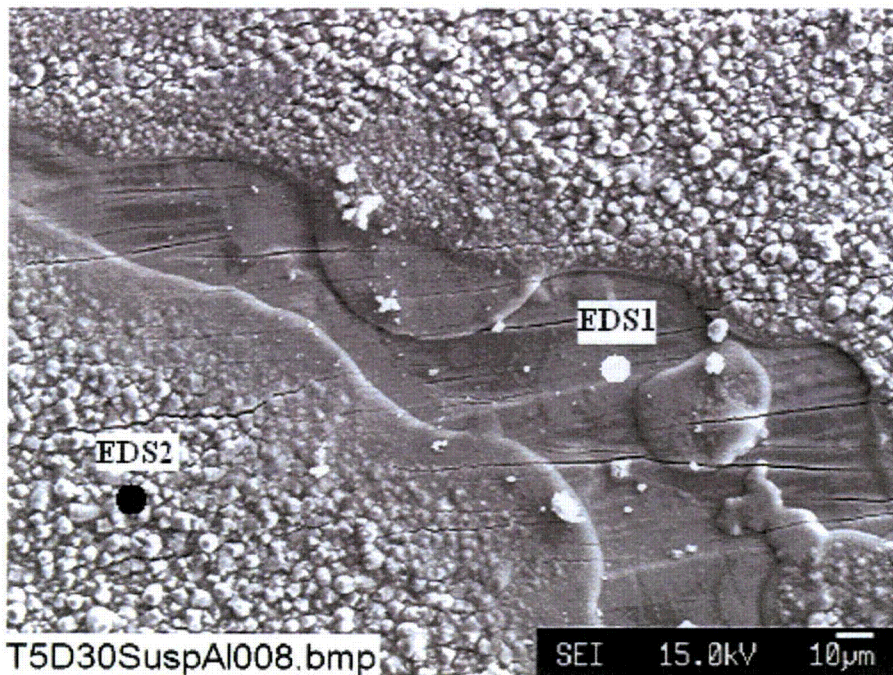
Image:	T5D30SuspAl007	100 ×	SEM image	Figure E1-1
	T5D30SuspAl008	500 ×	SEM image	Figure E1-2
EDS:	T5D30SuspAl_flat		EDS on flat surface in 008	Figure E1-3
	T5D30SuspAl_Granul		EDS on particle in 008	Figure E1-4
Image:	T5D30SuspAl009	1000 ×	SEM image higher magnification	Figure E1-5

### Submerged Al Coupon

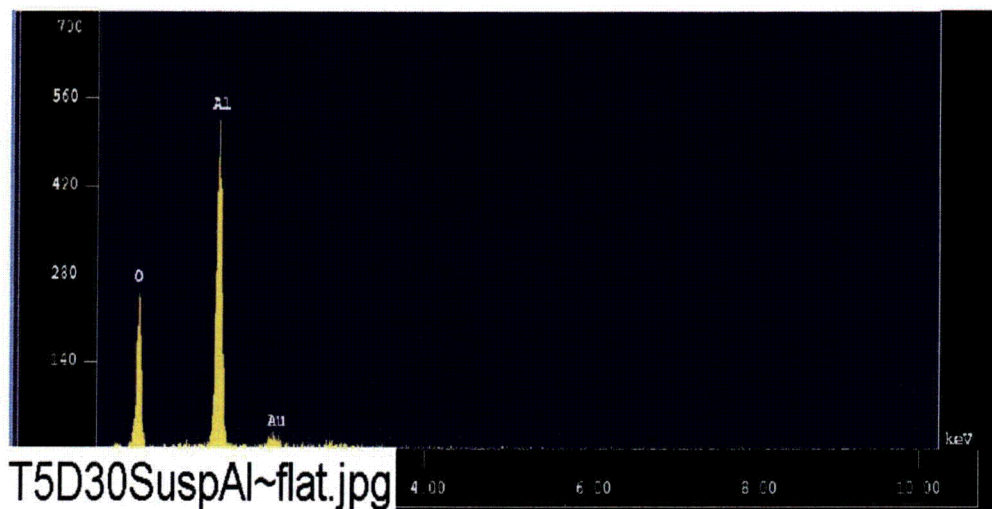
Image:	T5D30SubmAl010	250 ×	SEM image	Figure E1-6
	T5D30SubmAl011	500 ×	SEM image higher magnification	Figure E1-7
	T5D30SubmAl012	1200 ×	SEM annotated	Figure E1-8
EDS:	T5D30SubmAl_dark01		EDS of dark structure in 012	Figure E1-9
	T5D30SubmAl_light02		EDS of light particle in 012	Figure E1-10



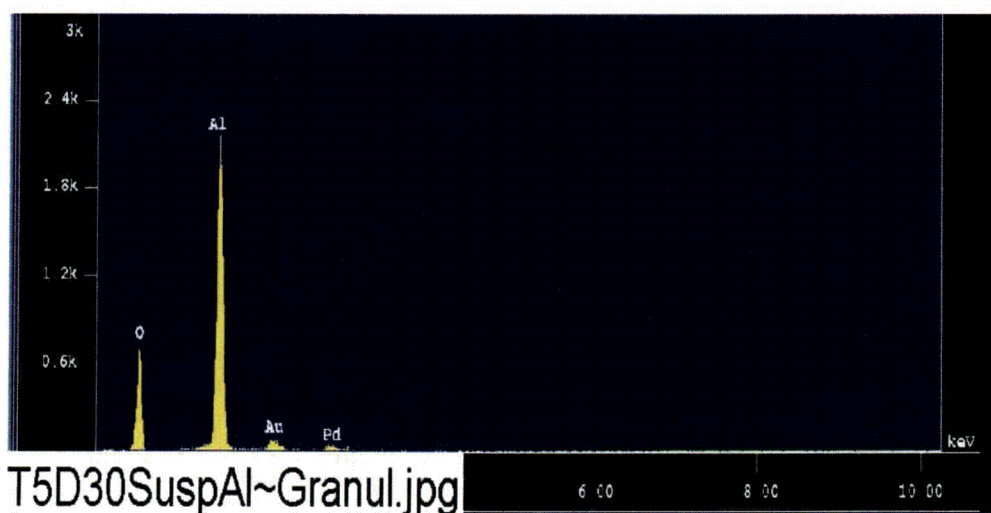
**Figure E1-1.** SEM image magnified 100 times for a Test #5, Day-30 unsubmerged aluminum coupon sample. (T5D30SuspAl007.bmp)



**Figure E1-2.** SEM image magnified 500 times for a Test #5, Day-30 unsubmerged aluminum coupon sample. (T5D30SuspAl008.bmp)



**Figure E1-3.** EDS counting spectrum for the smooth surface (EDS1) of the aluminum coupon shown in Figure E1-2. (T5D30SuspAl~flat.jpg)



**Figure E1-4.** EDS counting spectrum for the granular particles (EDS2) on the aluminum coupon surface shown in Figure E1-2. (T5D30SuspAl~Granul.jpg)



The results from the chemical composition analysis for T5D30SuspAl\_Granul.jpg are given in Table E1-1.

**Table E1-1. Chemical Compositions for T5D30SuspAl~Granul.jpg, Figure E1-4**

```

Group       : NRC
Sample      : T5D30 ID# : 5
Comment     : Granular particles on suspended Al
Condition   : Full Scale : 20KeV(10eV/ch,2Kch)
              Live Time  : 60.000 sec      Aperture #      : 1
              Acc. Volt  : 15.0 KV         Probe Current   : 1.006E-09 A
              Stage Point : X=88.063 Y=64.383 Z=11.848
              Acq. Date  : Tue Aug 30 13:44:34 2005

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Element	Mode	ROI(KeV)	K-ratio(%)	+/-	Net/Background
Al K	Normal	1.26- 1.78	16.5329	0.0023	18452 / 29
O K	Normal	0.31- 0.74	20.9428	0.0107	19756 / 12

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Chi\_square = 45.7092

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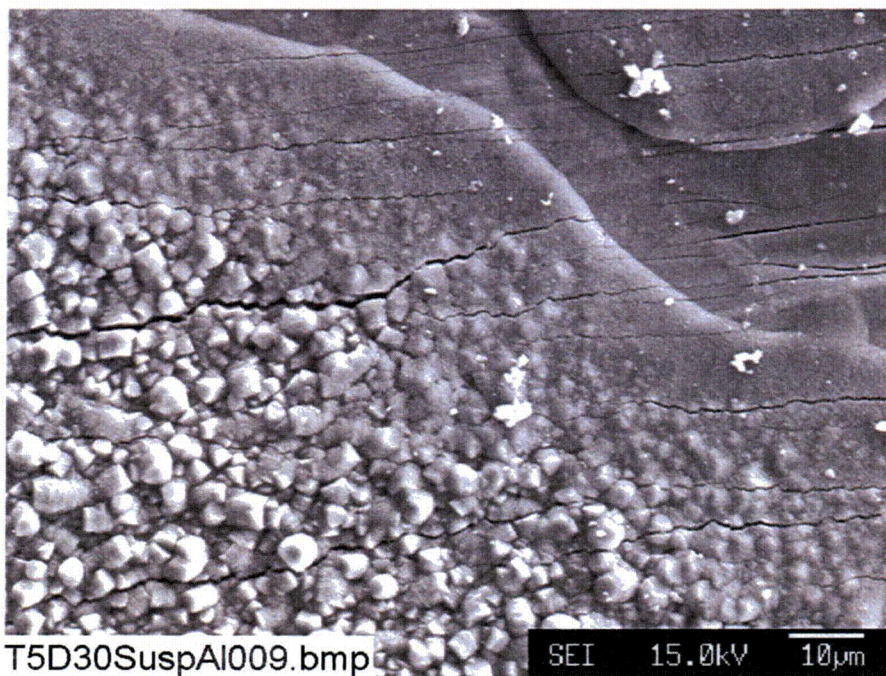
Element	Mass%	Atomic%	ZAF	Z	A	F
Al	46.210	33.7485	1.0224	1.0020	1.0203	1.0000
O	53.790	66.2515	0.9395	1.0018	0.9377	1.0000

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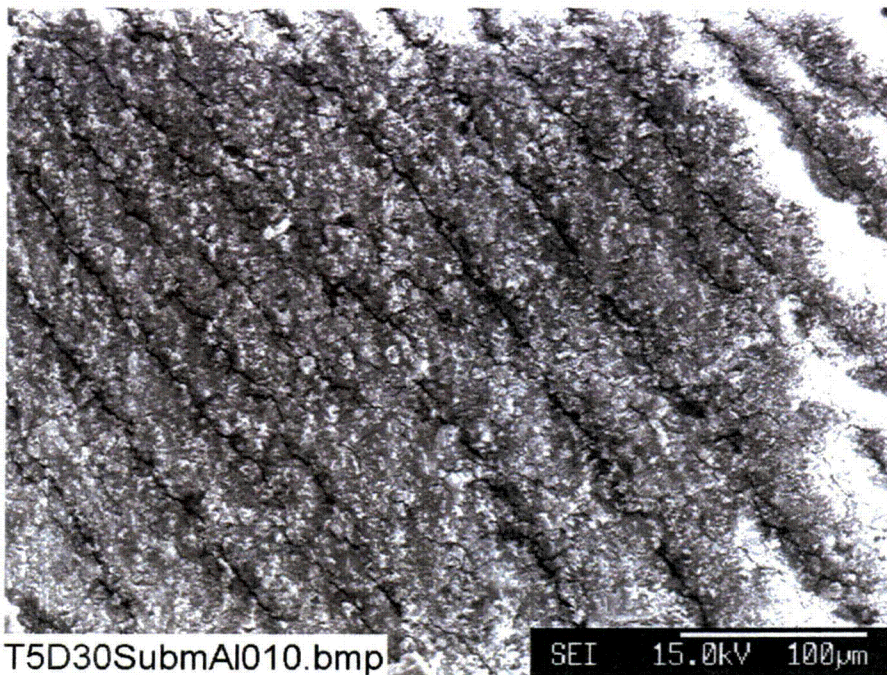
Total    100.000 100.0000

Normalization factor = 2.7339



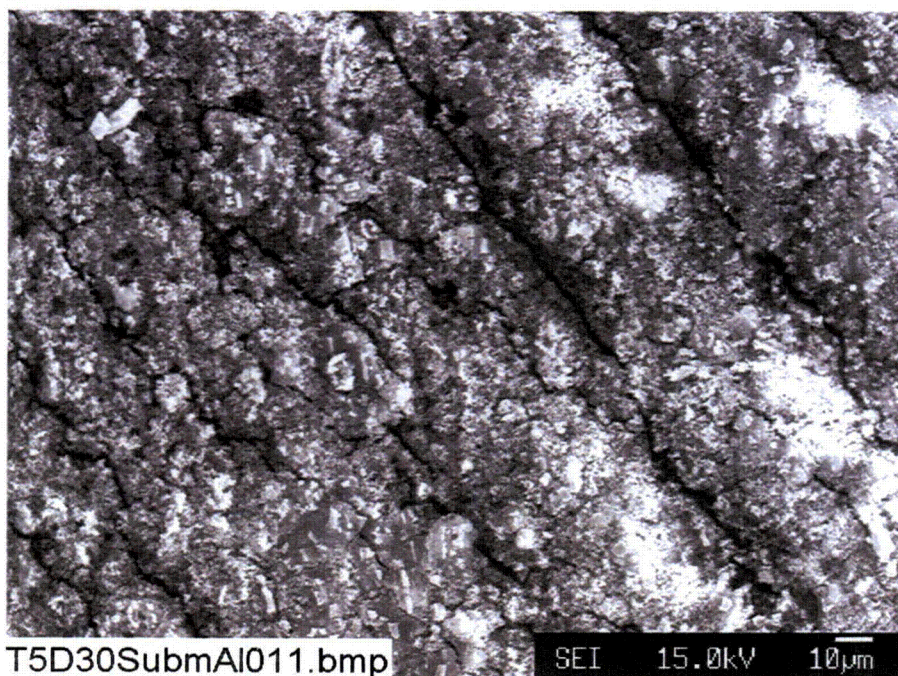


**Figure E1-5.** SEM image magnified 1000 times for a Test #5, Day-30 unsubmerged aluminum coupon sample. (T5D30SuspAl009.bmp)

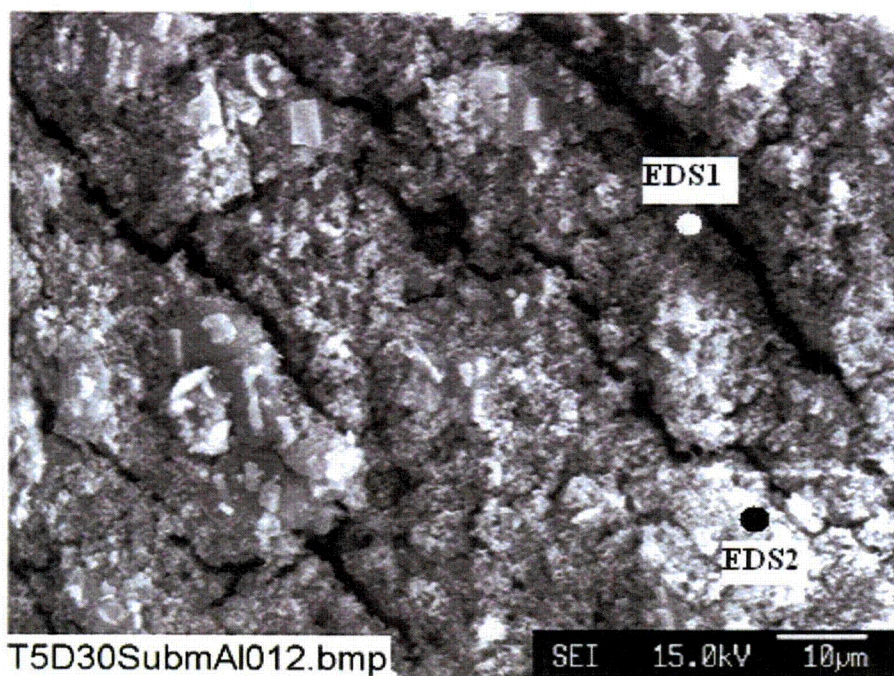


**Figure E1-6.** SEM image magnified 250 times for a Test #5, Day-30 submerged aluminum coupon sample. (T5D30SubmAl010.bmp)

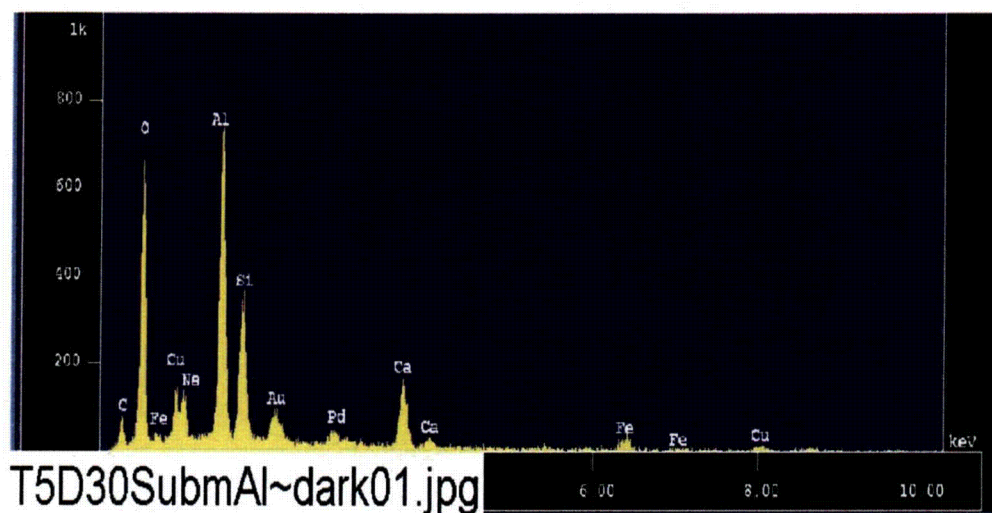




**Figure E1-7.** SEM image magnified 500 times for a Test #5, Day-30 submerged aluminum coupon sample. (T5D30SubmAl011.bmp)



**Figure E1-8.** Annotated SEM image magnified 1200 times for a Test #5, Day-30 submerged aluminum coupon sample. (T5D30SubmAl012.bmp)



**Figure E1-9.** EDS counting spectrum for the dark porous surface (EDS1) of the aluminum coupon shown in Figure E1-8. (T5D30SubmAl~dark01.jpg)



The results from the chemical composition analysis for T5D30SubmAl~dark01.jpg are given in Table E1-2.

**Table E1-2. Chemical Compositions for T5D30SubmAl~dark01.jpg, Figure E1-9**

Group	:	NRC					
Sample	:	T5D30 ID# : 7					
Comment	:	Dark porous layer on submerged Al					
Condition	:	Full Scale : 20KeV(10eV/ch,2Kch)					
	:	Live Time	:	60.000 sec	Aperture #	:	1
	:	Acc. Volt	:	15.0 KV	Probe Current	:	1.006E-09 A
	:	Stage Point	:	X=50.175 Y=52.147 Z=11.848			
	:	Acq. Date	:	Tue Aug 30 14:03:41 2005			

Element	Mode	ROI (KeV)	K-ratio(%)	+/-	Net/Background	
Na K	Normal	0.83- 1.28	0.9587	0.0065	710 /	37
Al K	Normal	1.26- 1.78	5.5632	0.0015	6209 /	133
Si K	Normal	1.50- 2.07	2.4170	0.0006	2961 /	364
Ca K	Normal	3.40- 4.30	3.2624	0.0073	1925 /	13
Fe K	Normal	6.04- 7.40	1.5120	0.0023	402 /	9
C K	Normal	0.11- 0.47	50.6476	0.0123	511 /	98
O K	Normal	0.31- 0.74	21.2659	0.0113	20061 /	35
Cu K	Normal	7.61- 9.28	0.9478	0.0014	138 /	3

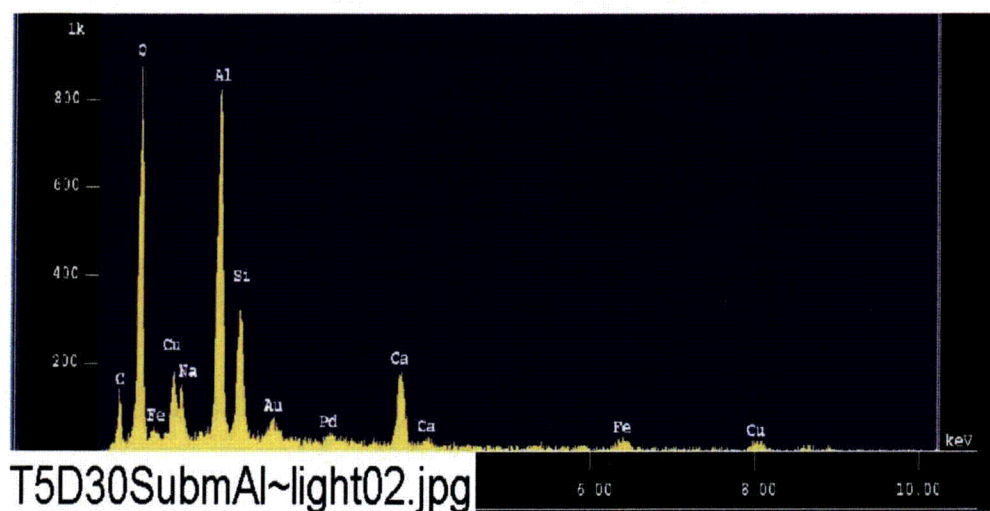
Chi_square = 4.7269						
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Element	Mass%	Atomic%	ZAF	Z	A	F
Na	1.838	1.3545	1.1743	0.9804	1.1967	1.0009
Al	10.097	6.3412	1.1119	0.9887	1.1261	0.9987
Si	4.972	2.9996	1.2602	0.9810	1.2848	0.9999
Ca	5.147	2.1761	0.9665	0.9913	0.9757	0.9992
Fe	2.971	0.9016	1.2039	1.2151	0.9962	0.9946
C	23.844	33.6407	0.2884	0.9910	0.2911	1.0000
O	49.149	52.0575	1.4159	0.9878	1.4334	1.0000
Cu	1.982	0.5287	1.2814	1.2850	0.9972	1.0000

Total	100.000	100.0000				
Normalization factor = 1.6323						



**Figure E1-10.** EDS counting spectrum for the light powder (EDS2) on the aluminum coupon surface shown in Figure E1-8. (T5D30SubmAl~light02.jpg)



The results from the chemical composition analysis for T5D30SubmAl~light02.jpg are given in Table E1-3.

**Table E1-3. Chemical Compositions for T5D30SubmAl~light02.jpg, Figure E1-9**

Group	:	NRC				
Sample	:	T5D30 ID# : 8				
Comment	:	Bright layer on submerged Al				
Condition	:	Full Scale : 20KeV(10eV/ch, 2Kch)				
	:	Live Time : 60.000 sec	Aperture #	:	1	
	:	Acc. Volt : 15.0 KV	Probe Current	:	1.006E-09 A	
	:	Stage Point : X=46.894 Y=50.390 Z=11.848				
	:	Acq. Date : Tue Aug 30 14:12:44 2005				

Element	Mode	ROI(KeV)	K-ratio(%)	+/-	Net/Background	
Na K	Normal	0.83- 1.28	0.9222	0.0067	683 /	43
Al K	Normal	1.26- 1.78	6.2283	0.0015	6951 /	132
Si K	Normal	1.50- 2.07	2.3139	0.0006	2834 /	415
Ca K	Normal	3.40- 4.30	3.6587	0.0078	2159 /	22
O K	Normal	0.31- 0.74	27.0711	0.0128	25537 /	34
C K	Normal	0.11- 0.47	74.5273	0.0149	752 /	144
Fe K	Normal	6.04- 7.40	1.1269	0.0022	299 /	4
Cu K	Normal	7.61- 9.28	2.3661	0.0016	345 /	3

Chi_square = 5.7109						
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Element	Mass%	Atomic%	ZAF	Z	A	F
Na	1.431	1.0376	1.2008	0.9788	1.2256	1.0010
Al	9.046	5.5894	1.1241	0.9871	1.1399	0.9990
Si	3.757	2.2298	1.2564	0.9794	1.2830	0.9999
Ca	4.554	1.8942	0.9633	0.9899	0.9737	0.9994
O	49.656	51.7418	1.4196	0.9861	1.4395	1.0000
C	25.910	35.9628	0.2691	0.9893	0.2720	1.0000
Fe	1.738	0.5188	1.1936	1.2136	0.9954	0.9881
Cu	3.909	1.0256	1.2785	1.2835	0.9962	1.0000

Total	100.000	100.0000				
Normalization factor	=	1.2921				



## Appendix E2

### SEM/EDS Data for Test #5, Day-30 Copper Coupons

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This appendix shows the SEM/EDS results for the metal copper coupons under two categories: (1) unsubmerged and (2) submerged. Unsubmerged coupons were contacted with the solution only during the initial 4-hour spray phase. In addition, the surface of the unsubmerged coupons may be affected during the test by the moist air in the tank gas space. Submerged refers to the coupons submerged in the solution during the test.

The coupon samples were collected on August 25, 2005 (the date Test #5 was shut down), and examined by SEM/EDS on August 30 and September 6, 2005. The copper coupon samples were dried in air before being coated with Au/Pd for SEM examination. SEM results present the surface condition of the copper coupons. In addition, EDS results provide a semi-quantitative elemental analysis of the coupon surface and the corrosion products.

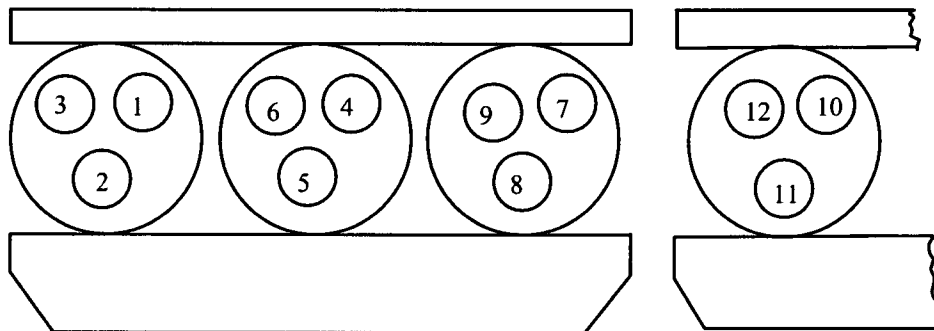


## Transcribed Laboratory Log

Laboratory session from September 6, 2005.

SEM Test #5, Day-30 Copper Coupons

Conditions: e=15.0kV, WD=11mm



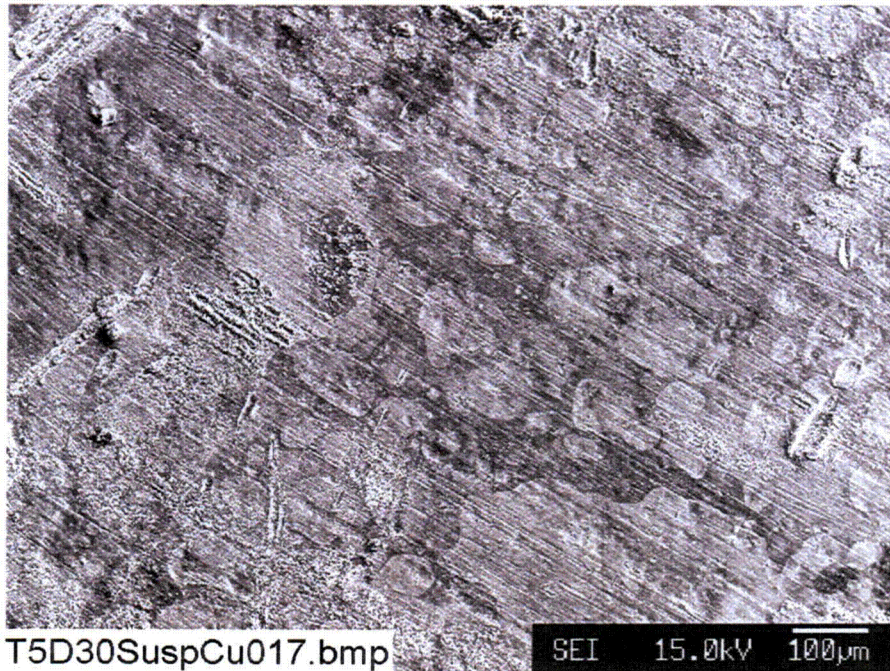
1--Yellow Deposits on Submerged Rack	2--Sediment (T5D30)	3--Al-Unsubmerged
4--Al-Submerged	5--Gal-Steel Unsubmerged	6--Gal-Steel Submerged
7--Cu Unsubmerged	8--Cu-Submerged	9--Steel-Unsubmerged
10--Steel-Submerged	11--Drain Collar Interior	12--Drain Collar Outside Ext.

### Unsubmerged Copper Coupons

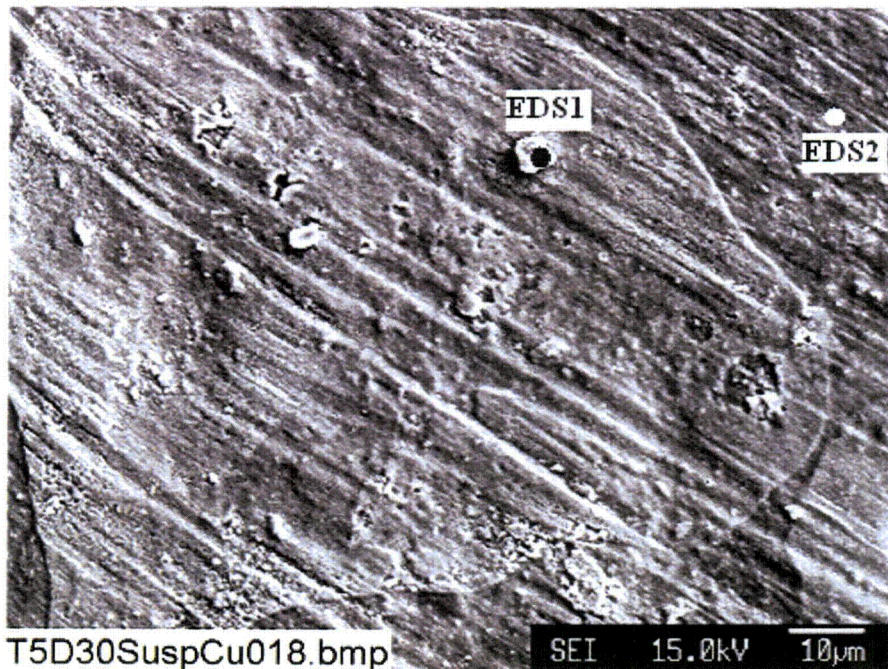
Image:	T5D30SuspCu017	100 ×	SEM image	Figure E2-1
	T5D30SuspCu018	1000 ×	SEM Annotated image higher magnification	Figure E2-2
EDS:	T5D30SuspCu particle07		On light particles shown in 018	Figure E2-3
	T5D30SuspCu Surface08		On coupon surface shown in 018	Figure E2-4

### **Submerged Copper Coupon**

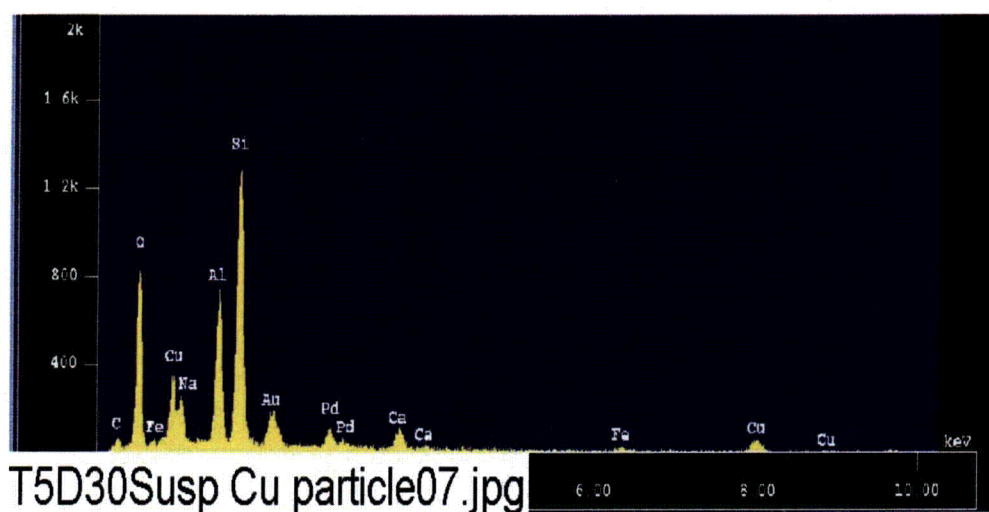
Image:	T5D30SubmCu019	100 ×	SEM image of fiberglass	Figure E2-5
	T5D30SubmCu020	1000 ×	SEM image higher magnification	Figure E2-6
EDS:	T5D30Subm Cu surface09		EDS of smooth particles in 020	Figure E2-7
	T5D30Subm Cu particle10		EDS of white particles in 020	Figure E2-8



**Figure E2-1.** SEM image magnified 100 times for a Test #5, Day-30 unsubmerged copper coupon sample. (T5D30SuspCu017.bmp)



**Figure E2-2.** Annotated SEM image magnified 1000 times for a Test #5, Day-30 unsubmerged copper coupon sample. (T5D30SuspCu018.bmp)



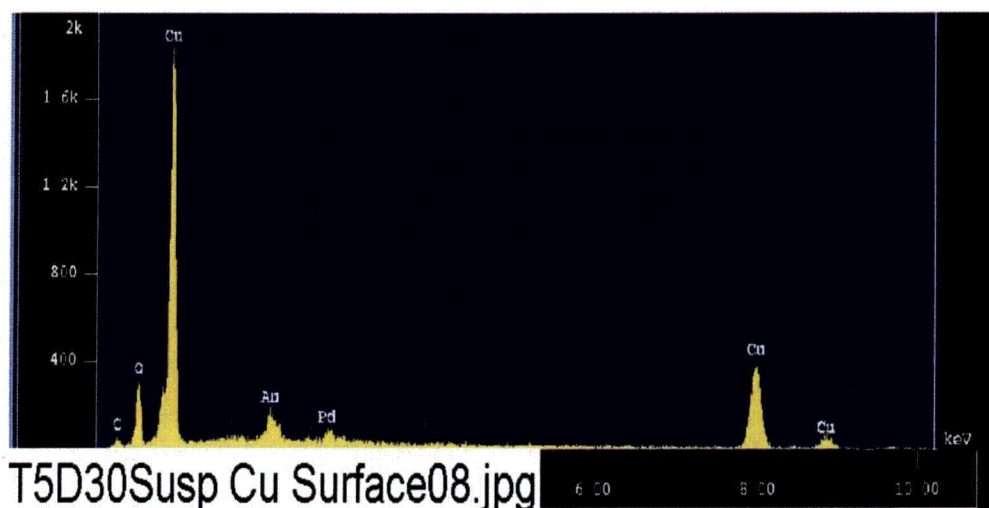
**Figure E2-3.** EDS counting spectrum for the light particle (EDS1) on the copper coupon surface shown in Figure E2-2. (T5D30Susp Cu particle07.jpg)



The results from the chemical composition analysis for T5D30Susp Cu particle07.jpg are given in Table E2-1.

**Table E2-1. Chemical Compositions for T5D30Susp Cu particle07.jpg, Figure E2-3**

Group	: NRC					
Sample	: T5D30 ID# : 13					
Comment	: Particles on suspended Cu					
Condition	: Full Scale : 20KeV(10eV/ch, 2Kch)					
	Live Time	: 60.000 sec	Aperture #	: 1		
	Acc. Volt	: 15.0 KV	Probe Current	: 1.005E-09 A		
	Stage Point	: X=16.143 Y=53.149 Z=11.848				
	Acq. Date	: Tue Aug 30 15:04:14 2005				
Element	Mode	ROI(KeV)	K-ratio(%)	+/-	Net/Background	
Na K	Normal	0.83- 1.28	2.3307	0.0092	1724 /	64
Al K	Normal	1.26- 1.78	5.5249	0.0015	6160 /	395
Si K	Normal	1.50- 2.07	9.9056	0.0011	12122 /	391
Ca K	Normal	3.40- 4.30	1.8982	0.0067	1119 /	16
Fe K	Normal	6.04- 7.40	0.8441	0.0021	224 /	9
Cu K	Normal	7.61- 9.28	5.2252	0.0023	760 /	7
O K	Normal	0.31- 0.74	28.9157	0.0133	27250 /	37
C K	Normal	0.11- 0.47	22.6341	0.0128	228 /	155
-----						
Chi_square = 4.3581						
Element	Mass%	Atomic%	ZAF	Z	A	F
Na	3.761	3.1269	1.2445	0.9775	1.2722	1.0008
Al	8.435	5.9747	1.1773	0.9854	1.1993	0.9962
Si	16.555	11.2653	1.2888	0.9775	1.3185	0.9999
Ca	2.419	1.1534	0.9827	0.9864	0.9968	0.9994
Fe	1.290	0.4413	1.1781	1.2064	0.9981	0.9783
Cu	8.607	2.5887	1.2701	1.2739	0.9971	1.0000
O	46.196	55.1835	1.2320	0.9852	1.2504	1.0000
C	12.737	20.2662	0.4339	0.9886	0.4390	1.0000
-----						
Total	100.000	100.0000				
Normalization factor = 1.2968						



**Figure E2-4.** EDS counting spectrum for the copper coupon surface (EDS2) shown in Figure E2-2. (T5D30Susp Cu Surface08.jpg)

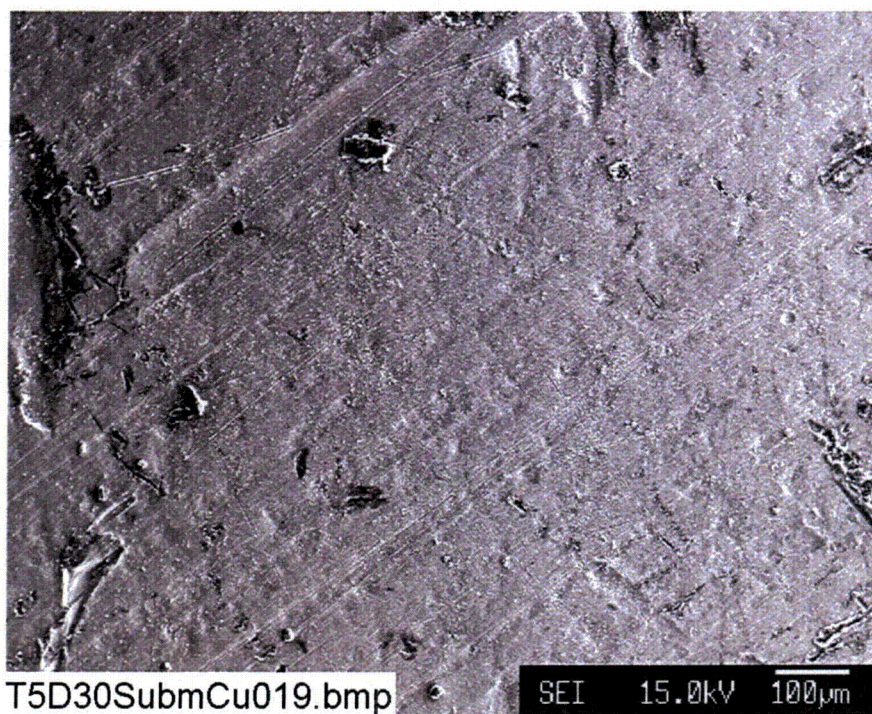


The results from the chemical composition analysis for T5D30Susp Cu Surface08.jpg are given in Table E2-2.

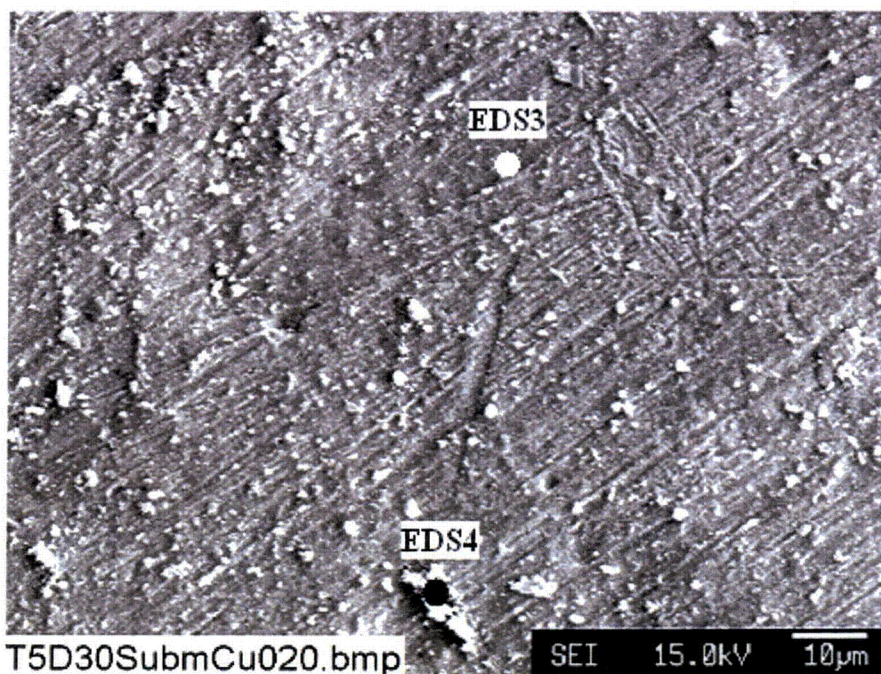
**Table E2-2. Chemical Compositions for T5D30Susp Cu Surface08.jpg, Figure E2-4**

Group	:	NRC					
Sample	:	T5D30	ID#	:	14		
Comment	:	Surface of suspended Cu					
Condition	:	Full Scale	:	20KeV(10eV/ch, 2Kch)			
	:	Live Time	:	60.000 sec	Aperture #	:	1
	:	Acc. Volt	:	15.0 KV	Probe Current	:	1.005E-09 A
	:	Stage Point	:	X=16.143 Y=53.149 Z=11.848			
	:	Acq. Date	:	Tue Aug 30 15:09:59 2005			
Element	Mode	ROI (KeV)		K-ratio(%)	+/-	Net/Background	
Cu K	Normal	7.61- 9.28		37.9341	0.0051	5518 /	9
O K	Normal	0.31- 0.74		9.8150	0.0087	9250 /	52
C K	Normal	0.11- 0.47		26.8105	0.0098	270 /	60
-----							
				Chi_square	=	2.8337	
Element	Mass%	Atomic%	ZAF	Z	A	F	
Cu	67.862	31.6586	1.1006	1.1031	0.9978	1.0000	
O	17.836	33.0455	1.1180	0.8760	1.2764	0.9999	
C	14.302	35.2958	0.3282	0.8796	0.3731	1.0000	
-----							
Total	100.000	100.0000					
Normalization factor			=	1.6254			

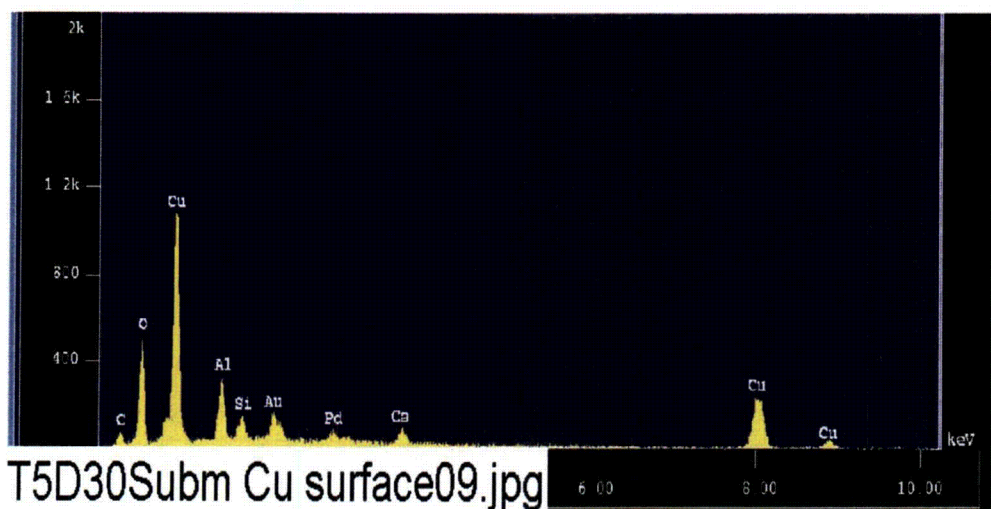




**Figure E2-5.** SEM image magnified 100 times for a Test #5, Day-30 submerged copper coupon sample. (T5D30SubmCu019.bmp)



**Figure E2-6.** SEM image magnified 1000 times for a Test #5, Day-30 submerged copper coupon sample. (T5D30SubmCu020.bmp)



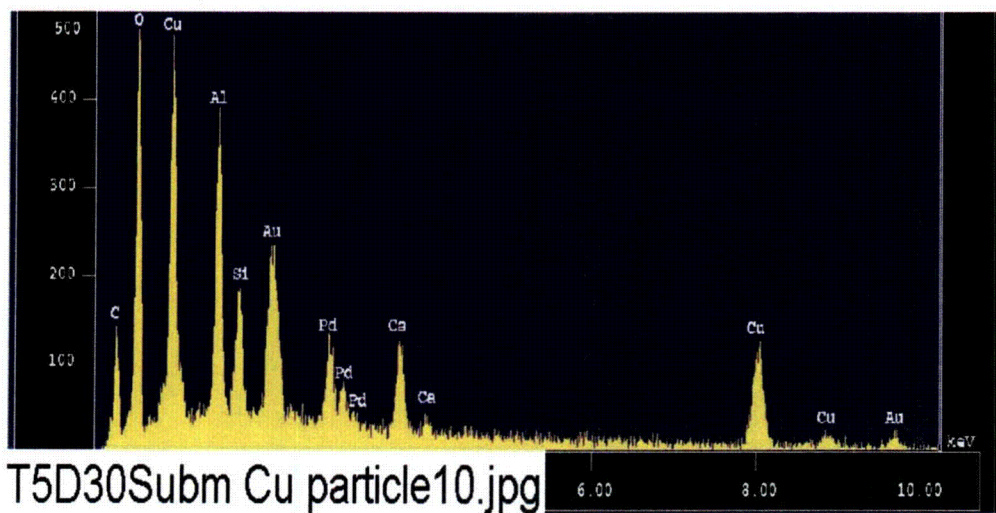
**Figure E2-7.** EDS counting spectrum for the grey copper coupon surface (EDS3) shown in Figure E2-6. (T5D30Subm Cu surface09.jpg)



The results from the chemical composition analysis for T5D30Subm Cu surface09.jpg are given in Table E2-3.

**Table E2-3. Chemical Compositions for T5D30Subm Cu surface09.jpg, Figure E2-7**

Group	: NRC					
Sample	: T5D30 ID# : 15					
Comment	: Surface of submerged Cu					
Condition	: Full Scale : 20KeV(10eV/ch, 2Kch)					
	Live Time	: 60.000 sec	Aperture #	: 1		
	Acc. Volt	: 15.0 KV	Probe Current	: 1.005E-09 A		
	Stage Point	: X=11.640 Y=63.166 Z=11.848				
	Acq. Date	: Tue Aug 30 15:20:19 2005				
-----						
Element	Mode	ROI (KeV)	K-ratio(%)	+/-	Net/Background	
Al K	Normal	1.26- 1.78	2.1463	0.0010	2393 /	79
Si K	Normal	1.50- 2.07	0.7437	0.0005	910 /	189
Ca K	Normal	3.40- 4.30	1.2241	0.0066	722 /	24
Cu K	Normal	7.61- 9.28	24.4152	0.0042	3551 /	9
O K	Normal	0.31- 0.74	15.7405	0.0101	14834 /	41
C K	Normal	0.11- 0.47	37.1593	0.0132	375 /	85
-----						
Chi_square = 3.4035						
Element	Mass%	Atomic%	ZAF	Z	A	F
Al	4.915	4.1748	1.5037	0.9203	1.6344	0.9997
Si	1.647	1.3440	1.4543	0.9126	1.5937	1.0000
Ca	1.717	0.9819	0.9211	0.9183	1.0049	0.9982
Cu	43.542	15.7063	1.1711	1.1747	0.9969	1.0000
O	29.739	42.6032	1.2406	0.9212	1.3468	1.0000
C	18.441	35.1897	0.3259	0.9247	0.3524	1.0000
-----						
Total	100.000	100.0000				
Normalization factor = 1.5228						



**Figure E2-8.** EDS counting spectrum for the light particles (EDS4) on the coupon surface shown in Figure E2-6. (T5D30Subm Cu particle10.jpg)



The results from the chemical composition analysis for T5D30Subm Cu particle10.jpg are given in Table E2-4.

**Table E2-4. Chemical Compositions for T5D30Subm Cu particle10.jpg, Figure E2-8**

Group	: NRC					
Sample	: T5D30 ID# : 16					
Comment	: Particles on submerged Cu					
Condition	: Full Scale : 20KeV(10eV/ch, 2Kch)					
	Live Time	: 60.000 sec	Aperture #	: 1		
	Acc. Volt	: 15.0 KV	Probe Current	: 1.005E-09 A		
	Stage Point	: X=11.640 Y=63.166 Z=11.848				
	Acq. Date	: Tue Aug 30 15:24:43 2005				

Element	Mode	ROI(KeV)	K-ratio(%)	+/-	Net/Background	
Al K	Normal	1.26- 1.78	2.6588	0.0011	2964 /	85
Si K	Normal	1.50- 2.07	1.0195	0.0005	1248 /	247
Ca K	Normal	3.40- 4.30	2.2751	0.0071	1341 /	27
Cu K	Normal	7.61- 9.28	11.1316	0.0031	1619 /	7
C K	Normal	0.11- 0.47	69.2823	0.0160	698 /	88
O K	Normal	0.31- 0.74	15.1166	0.0099	14246 /	38

Chi\_square = 4.8904

Element	Mass%	Atomic%	ZAF	Z	A	F
Al	5.525	3.7131	1.2874	0.9559	1.3474	0.9995
Si	2.175	1.4045	1.3219	0.9482	1.3942	0.9999
Ca	3.453	1.5625	0.9405	0.9570	0.9839	0.9988
Cu	22.087	6.3036	1.2293	1.2346	0.9957	1.0000
C	30.146	45.5152	0.2696	0.9588	0.2812	1.0000
O	36.614	41.5011	1.5007	0.9555	1.5705	1.0000

Total 100.000 100.0000

Normalization factor = 1.6140

# **Appendix E3**

## **SEM/EDS Data for Test #5, Day-30 Galvanized Steel Coupons**

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- Figure E3-1. SEM image magnified 100 times for a Test #5, Day-30 unsubmerged galvanized steel coupon sample. (T5D30SuspGalsteel013.bmp) .....E3-5
- Figure E3-2. Annotated SEM image magnified 1000 times for a Test #5, Day-30 unsubmerged galvanized steel coupon sample. (T5D30SuspGalsteel014.bmp) .....E3-5
- Figure E3-3. EDS counting spectrum for the needle-like crystal (EDS1) on the unsubmerged, galvanized steel coupon surface shown in Figure E3-2. (T5D30Susp GS needle 03.jpg) .....E3-6
- Figure E3-4. EDS counting spectrum for the cracked layer (EDS2) on the unsubmerged galvanized steel coupon surface shown in Figure E3-2. (T5D30 Susp GS layer 04.jpg) .....E3-7
- Figure E3-5. SEM image magnified 100 times for a Test #5, Day-30 submerged galvanized steel coupon sample. (T5D30SubmGalsteel015.bmp).....E3-9
- Figure E3-6. Annotated SEM image magnified 1000 times for a Test #5, Day-30 submerged galvanized steel coupon sample. (T5D30SubmGalsteel016.bmp) .....E3-9
- Figure E3-7. EDS counting spectrum for the light deposits (EDS3) on the submerged galvanized steel coupon surface shown in Figure E3-6. (T5D30Subm GS Particle05.jpg) .....E3-10
- Figure E3-8. EDS counting spectrum for the grey coupon surface (EDS4) of the submerged galvanized steel shown in Figure E3-6. (T5D30Subm GS Surface06.jpg) .....E3-12

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Table E3-2. Chemical Compositions for T5D30 Susp GS layer 04.jpg, Figure E3-4.....	E3-8
Table E3-3. Chemical Compositions for T5D30Subm GS Particle05.jpg, Figure E3-7.....	E3-11
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This appendix shows the SEM/EDS results for the metal galvanized steel coupons under two categories: (1) unsubmerged and (2) submerged. Unsubmerged coupons were contacted with the solution only during the initial 4-hour spray phase. In addition, the surface of the unsubmerged coupons may be affected during the test by the moist air in the tank gas space. Submerged refers to the coupons submerged in the solution during the test.

The coupon samples were collected on August 25, 2005 (the date Test #5 was shut down), and examined by SEM/EDS on August 30 and September 6, 2005. The galvanized steel coupon samples were dried in air before being coated with Au/Pd for SEM examination. SEM results present the surface condition of the galvanized steel coupons. In addition, EDS results provide a semi-quantitative elemental analysis of the coupon surface and the corrosion products.

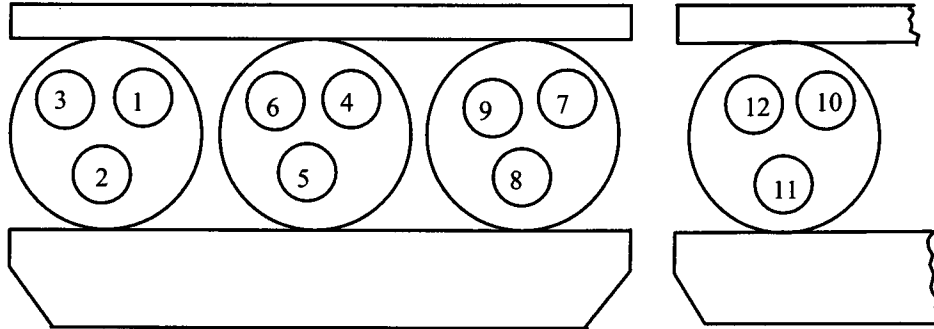


## Transcribed Laboratory Log

Laboratory session from September 6, 2005.

SEM Test #5, Day-30 Galvanized Steel Coupons

Conditions: e=15.0kV, WD=11mm



1--Yellow Deposits on Submerged Rack	2--Sediment (T5D30)	3--Al-Unsubmerged
4--Al-Submerged	5--Gal-Steel Unsubmerged	6--Gal-Steel Submerged
7--Cu Unsubmerged	8--Cu-Submerged	9--Steel-Unsubmerged
10--Steel-Submerged	11--Drain Collar Interior	12--Drain Collar Outside Ext.

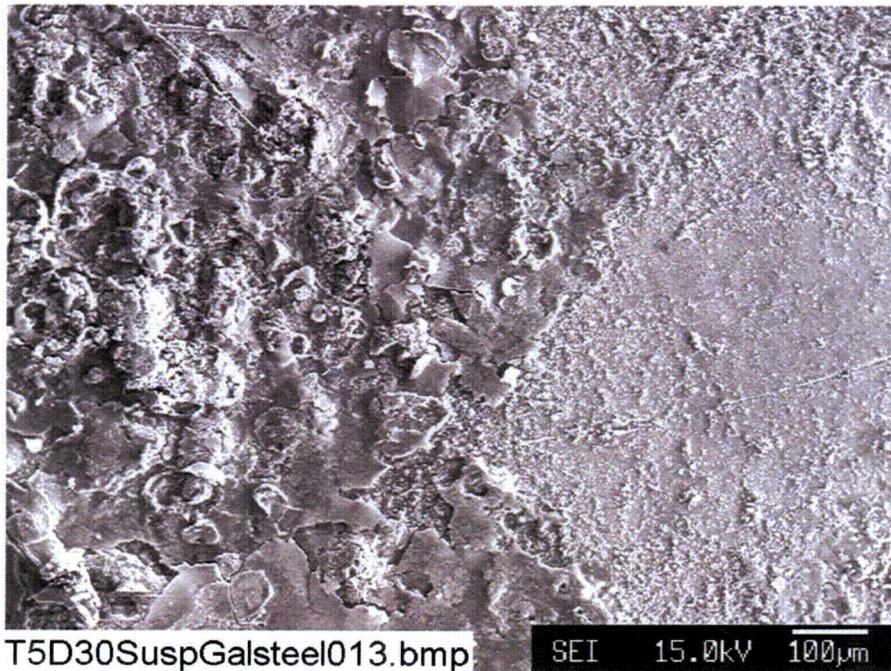
### Unsubmerged Galvanized Steel Coupon

Image:	T5D30SuspGalsteel013	100 ×	SEM image	Figure E3-1
	T5D30SuspGalsteel014	1000 ×	SEM Annotated image	Figure E3-2
EDS:	T5D30Susp GS needle03		On needle like crystal shown in image 014	Figure E3-3
	T5D30 Susp GS layer04		On cracked skin layer shown in image 014	Figure E3-4

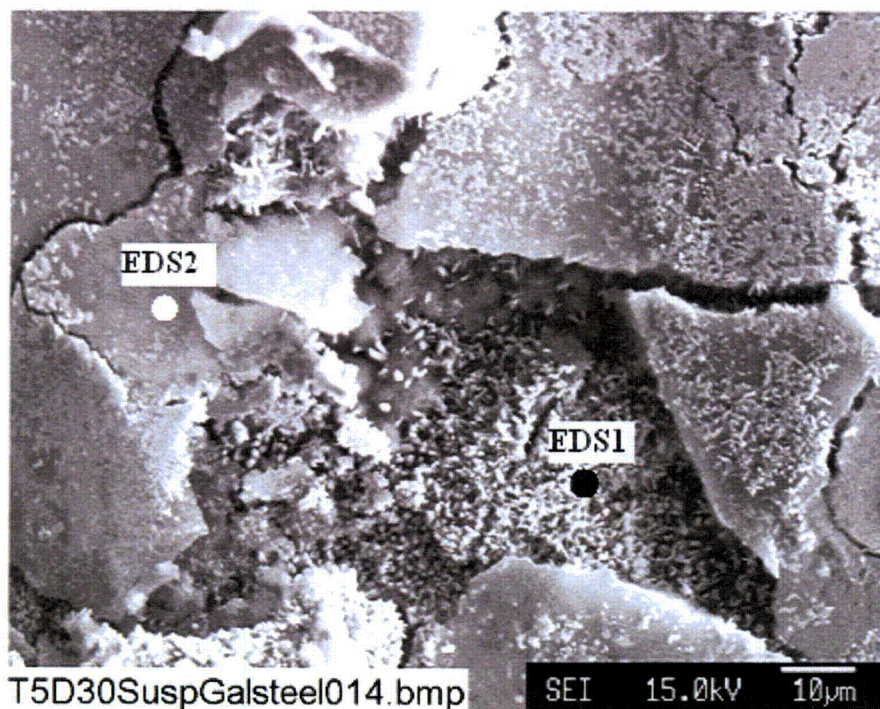
### **Submerged Galvanized Steel Coupon**

Image:	T5D30SubmGalsteel015	100 ×	SEM image of fiberglass	Figure E3-5
	T5D30SubmGalsteel016	1000 ×	SEM image higher magnification	Figure E3-6
EDS:	T5D30Subm GS Particle05		On particles shown in image 016	Figure E3-7
	T5D30Subm GS Particle05		On particles shown in image 016	Figure E3-8



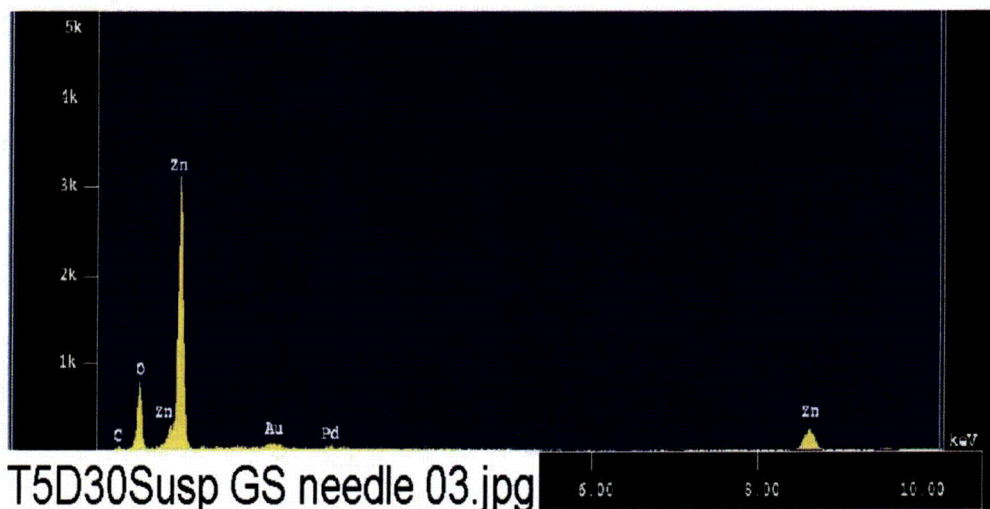


**Figure E3-1.** SEM image magnified 100 times for a Test #5, Day-30 unsubmerged galvanized steel coupon sample. (T5D30SuspGalsteel013.bmp)



**Figure E3-2.** Annotated SEM image magnified 1000 times for a Test #5, Day-30 unsubmerged galvanized steel coupon sample. (T5D30SuspGalsteel014.bmp)



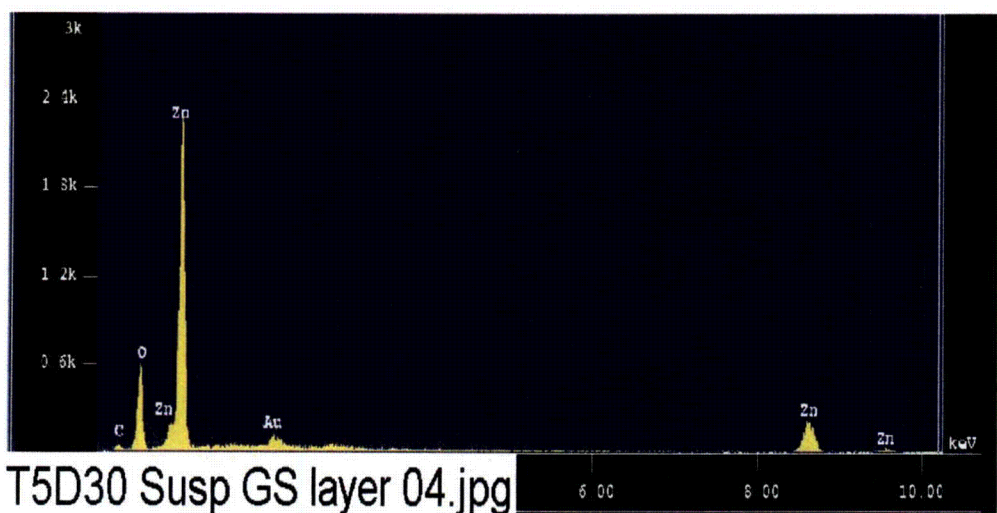


**Figure E3-3.** EDS counting spectrum for the needle-like crystal (EDS1) on the unsubmerged, galvanized steel coupon surface shown in Figure E3-2. (T5D30Susp GS needle 03.jpg)

The results from the chemical composition analysis for T5D30Susp GS needle 03.jpg are given in Table E3-1.

**Table E3-1. Chemical Compositions for T5D30Susp GS needle 03.jpg, Figure E3-3**

Group	:	NRC					
Sample	:	T5D30 ID# : 9					
Comment	:	Needle crystal on suspended Gal-steel					
Condition	:	Full Scale : 20KeV(10eV/ch, 2Kch)					
	:	Live Time : 60.000 sec	Aperture #	:	1		
	:	Acc. Volt : 15.0 KV	Probe Current	:	1.005E-09 A		
	:	Stage Point : X=44.601 Y=63.875 Z=11.848					
	:	Acq. Date : Tue Aug 30 14:27:56 2005					
Element	Mode	ROI(KeV)	K-ratio(%)	+/-	Net/Background		
Zn K	Normal	8.19-10.06	30.9955	0.0087	3521 /	5	
O K	Normal	0.31- 0.74	24.2024	0.0125	22808 /	40	
C K	Normal	0.11- 0.47	29.4584	0.0106	297 /	123	
-----							
Chi_square =				7.1611			
Element	Mass%	Atomic%	ZAF	Z	A	F	
Zn	48.925	17.6401	1.1674	1.1710	0.9969	1.0000	
O	36.525	53.8072	1.1161	0.9160	1.2184	1.0000	
C	14.550	28.5527	0.3653	0.9195	0.3973	1.0000	
-----							
Total	100.000	100.0000					
Normalization factor =	1.3522						



**Figure E3-4.** EDS counting spectrum for the cracked layer (EDS2) on the unsubmerged galvanized steel coupon surface shown in Figure E3-2. (T5D30 Susp GS layer 04.jpg)

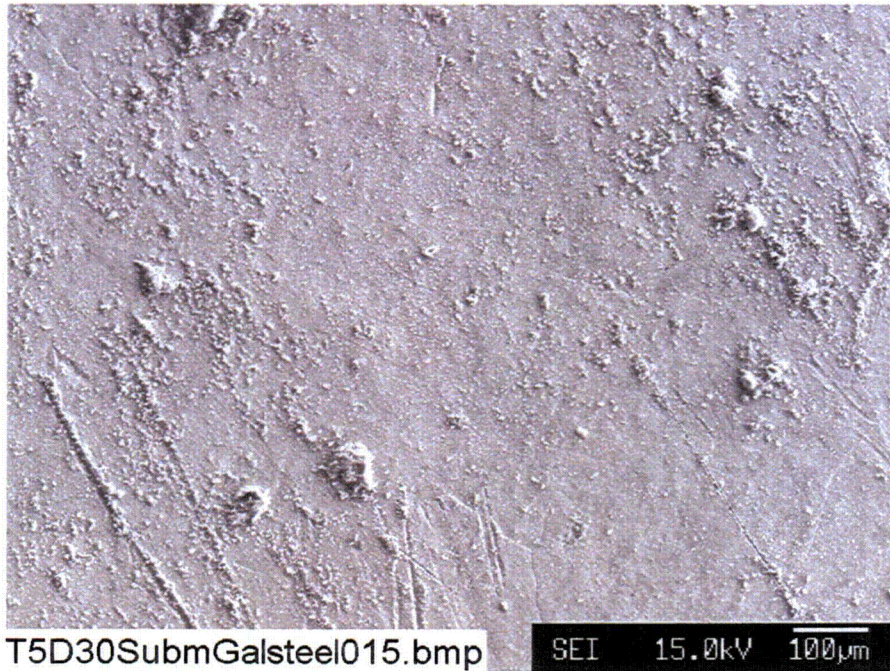


The results from the chemical composition analysis for T5D30 Susp GS layer 04.jpg are given in Table E3-2.

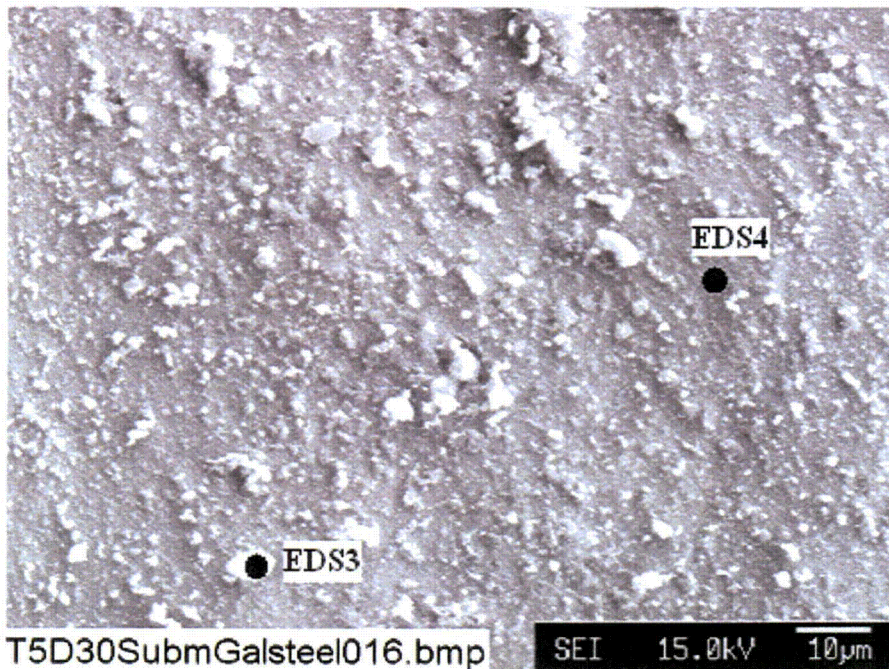
**Table E3-2. Chemical Compositions for T5D30 Susp GS layer 04.jpg, Figure E3-4**

Group	:	NRC				
Sample	:	T5D30 ID# : 10				
Comment	:	Cracked layer on suspended Gal-steel				
Condition	:	Full Scale : 20KeV(10eV/ch, 2Kch)				
	:	Live Time : 60.000 sec	Aperture #	:	1	
	:	Acc. Volt : 15.0 KV	Probe Current	:	1.006E-09 A	
	:	Stage Point : X=44.601 Y=63.875 Z=11.848				
	:	Acq. Date : Tue Aug 30 14:32:43 2005				
-----						
Element	Mode	ROI(KeV)	K-ratio(%)	+/-	Net/Background	
Zn K	Normal	8.19-10.06	27.9430	0.0081	3177 /	6
C K	Normal	0.11- 0.47	29.1554	0.0102	294 /	100
O K	Normal	0.31- 0.74	19.0550	0.0110	17975 /	35
-----						
Chi_square =			4.1819			
-----						
Element	Mass%	Atomic%	ZAF	Z	A	F
Zn	49.823	17.9813	1.1635	1.1671	0.9970	1.0000
C	16.397	32.2068	0.3670	0.9167	0.4003	1.0000
O	33.780	49.8119	1.1568	0.9133	1.2667	1.0000
-----						
Total	100.000	100.0000				
Normalization factor =			1.5324			

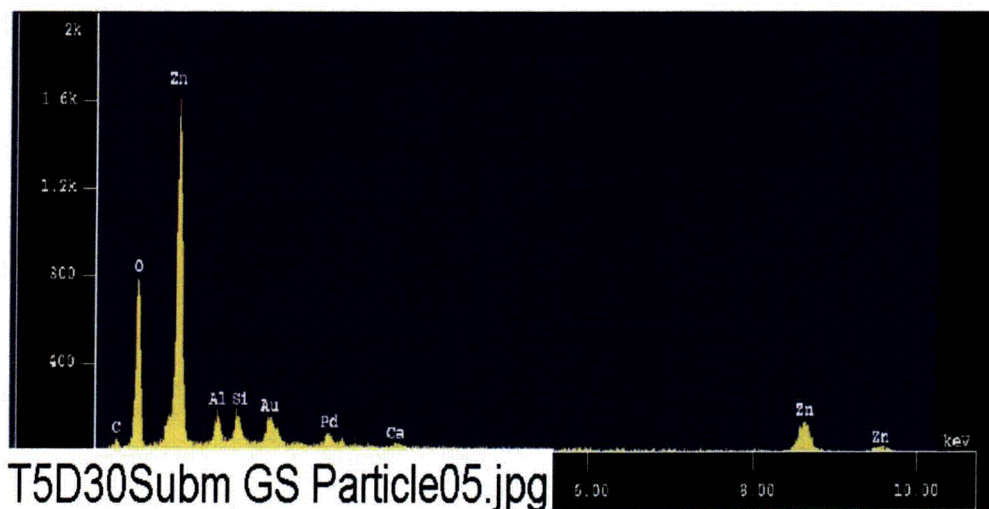




**Figure E3-5.** SEM image magnified 100 times for a Test #5, Day-30 submerged galvanized steel coupon sample. (T5D30SubmGalsteel015.bmp)



**Figure E3-6.** Annotated SEM image magnified 1000 times for a Test #5, Day-30 submerged galvanized steel coupon sample. (T5D30SubmGalsteel016.bmp)



**Figure E3-7.** EDS counting spectrum for the light deposits (EDS3) on the submerged galvanized steel coupon surface shown in Figure E3-6. (T5D30Subm GS Particle05.jpg)



The results from the chemical composition analysis for T5D30Subm GS Particle05.jpg are given in Table E3-3.

**Table E3-3. Chemical Compositions for T5D30Subm GS Particle05.jpg, Figure E3-7**

Group	: NRC					
Sample	: T5D30 ID# : 11					
Comment	: Particles on submerged Gal_steel surface					
Condition	: Full Scale : 20KeV(10eV/ch,2Kch)					
	Live Time	: 60.000 sec	Aperture #	: 1		
	Acc. Volt	: 15.0 KV	Probe Current	: 1.005E-09 A		
	Stage Point	: X=56.678 Y=62.490 Z=11.848				
	Acq. Date	: Tue Aug 30 14:47:04 2005				

Element	Mode	ROI (KeV)	K-ratio(%)	+/-	Net/Background	
Al K	Normal	1.26- 1.78	0.9951	0.0008	1109 /	70
Si K	Normal	1.50- 2.07	0.9148	0.0005	1119 /	125
Ca K	Normal	3.40- 4.30	0.4234	0.0049	250 /	25
Zn K	Normal	8.19-10.06	17.3542	0.0070	1971 /	7
C K	Normal	0.11- 0.47	19.5680	0.0121	197 /	121
O K	Normal	0.31- 0.74	25.0700	0.0122	23626 /	28

-----

Chi_square = 5.5084						
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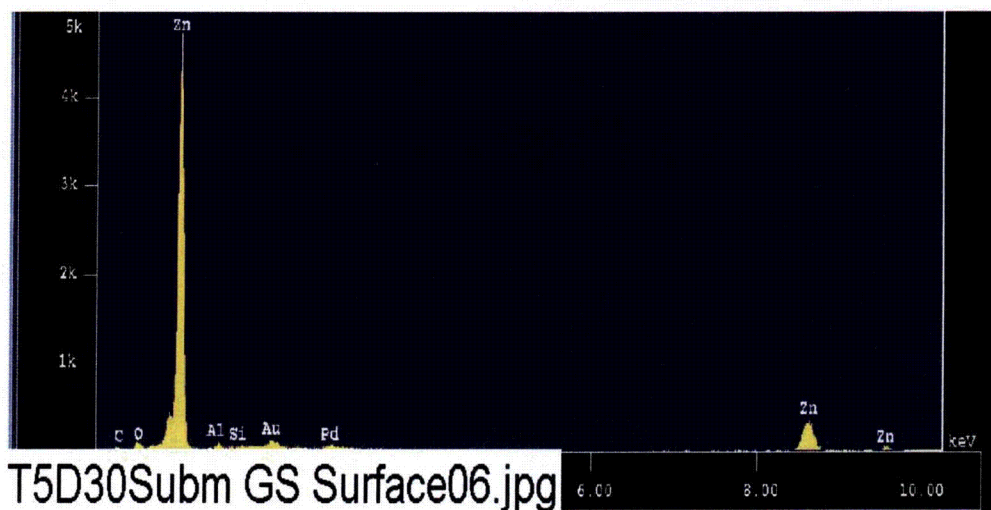
  

Element	Mass%	Atomic%	ZAF	Z	A	F
Al	2.628	2.0964	1.5366	0.9406	1.6342	0.9996
Si	2.296	1.7594	1.4602	0.9328	1.5654	1.0000
Ca	0.685	0.3677	0.9409	0.9394	1.0025	0.9991
Zn	36.016	11.8565	1.2072	1.2114	0.9965	1.0000
C	12.092	21.6651	0.3595	0.9447	0.3805	1.0000
O	46.283	62.2547	1.0739	0.9412	1.1410	1.0000

-----

Total	100.000	100.0000				
Normalization factor	= 1.7191					



**Figure E3-8.** EDS counting spectrum for the grey coupon surface (EDS4) of the submerged galvanized steel shown in Figure E3-6. (T5D30Subm GS Surface06.jpg)



The results from the chemical composition analysis for T5D30Subm GS Surface06.jpg are given in Table E3-4.

**Table E3-4. Chemical Compositions for T5D30Subm GS Surface06.jpg, Figure E3-8**

```

Group       : NRC
Sample      : T5D30 ID# : 12
Comment     : Surface of submerged Gal_steel
Condition   : Full Scale : 20KeV(10eV/ch,2Kch)
              Live Time  : 60.000 sec Aperture # : 1
              Acc. Volt  : 15.0 KV Probe Current : 1.006E-09 A
              Stage Point: X=56.678 Y=62.490 Z=11.848
              Acq. Date  : Tue Aug 30 14:52:18 2005

```

---

Element	Mode	ROI(KeV)	K-ratio(%)	+/-	Net/Background	
Al K	Normal	1.26- 1.78	0.4278	0.0007	477 /	58
Si K	Normal	1.50- 2.07	0.1268	0.0004	155 /	91
Zn K	Normal	8.19-10.06	45.4077	0.0105	5163 /	10
O K	Normal	0.31- 0.74	2.7433	0.0065	2588 /	58
C K	Normal	0.11- 0.47	21.6706	0.0104	219 /	36

---

Chi\_square = 1.5563

---

Element	Mass%	Atomic%	ZAF	Z	A	F
Al	1.263	1.6261	1.8551	0.8522	2.1770	1.0000
Si	0.331	0.4087	1.6372	0.8446	1.9384	1.0000
Zn	77.389	41.1116	1.0705	1.0718	0.9988	1.0000
O	5.427	11.7800	1.2426	0.8547	1.4540	0.9999
C	15.590	45.0735	0.4519	0.8583	0.5265	1.0000

---

Total 100.000 100.0000  
Normalization factor = 1.5921



## Appendix E4

### SEM/EDS Data for Test #5, Day-30 Steel Coupons

#### List of Figures

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- Figure E4-3. Annotated SEM image magnified 1000 times for a Test #5, Day-30 unsubmerged steel coupon sample. (T5D30SuspSteel023.bmp).....E4-6
- Figure E4-4. EDS counting spectrum for the dark coupon surface (EDS1) of the unsubmerged steel shown in Figure E4-3. (T5D30Susp Steel Surface11.jpg) .....E4-6
- Figure E4-5. EDS counting spectrum for the light particle (EDS2) on the unsubmerged steel coupon surface shown in Figure E4-3. (T5D30Susp Steel Particle12.jpg).....E4-8
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- Figure E4-8. EDS counting spectrum for the light particle (EDS1) on the submerged steel coupon surface shown in Figure E4-7. (T5D30Subm Steel light particle13.JPG) .....E4-10
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Table E4-4. Chemical Compositions for T5D30Subm Steel dark particle14.JPG, Figure E4-9.....	E4-13
Table E4-5. Chemical Compositions for T5D30Subm Steel Surface15.jpg, Figure E4-10 .....	E4-14



This appendix shows the SEM/EDS results for the metal steel coupons under two categories: (1) unsubmerged and (2) submerged. Unsubmerged coupons were contacted with the solution only during the initial 4-hour spray phase. In addition, the surface of the unsubmerged coupons may be affected during the test by the moist air in the tank gas space. Submerged refers to the coupons submerged in the solution during the test.

The coupon samples were collected on August 25, 2005 (the date Test #5 was shut down), and examined by SEM/EDS on August 30 and September 6, 2005. The steel coupon samples were dried in air before being coated with Au/Pd for SEM examination. SEM results present the surface condition of the steel coupons. In addition, EDS results provide a semi-quantitative elemental analysis of the coupon surface and the corrosion products.

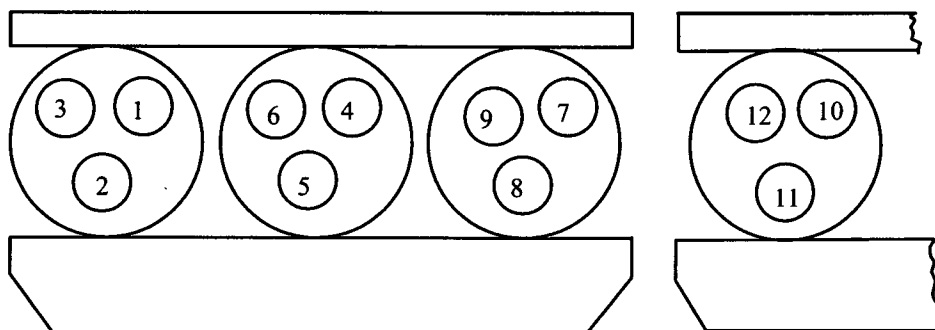


## Transcribed Laboratory Log

Laboratory session from September 6, 2005.

SEM Test #5, Day-30 Steel Coupons

Conditions: e=15.0kV, WD=11mm



- |                                      |                           |                               |
|--------------------------------------|---------------------------|-------------------------------|
| 1--Yellow Deposits on Submerged Rack | 2--Sediment (T5D30)       | 3--Al-Unsubmerged             |
| 4--Al-Submerged                      | 5--Gal-Steel Unsubmerged  | 6--Gal-Steel Submerged        |
| 7--Cu Unsubmerged                    | 8--Cu-Submerged           | 9--Steel-Unsubmerged          |
| 10--Steel-Submerged                  | 11--Drain Collar Interior | 12--Drain Collar Outside Ext. |

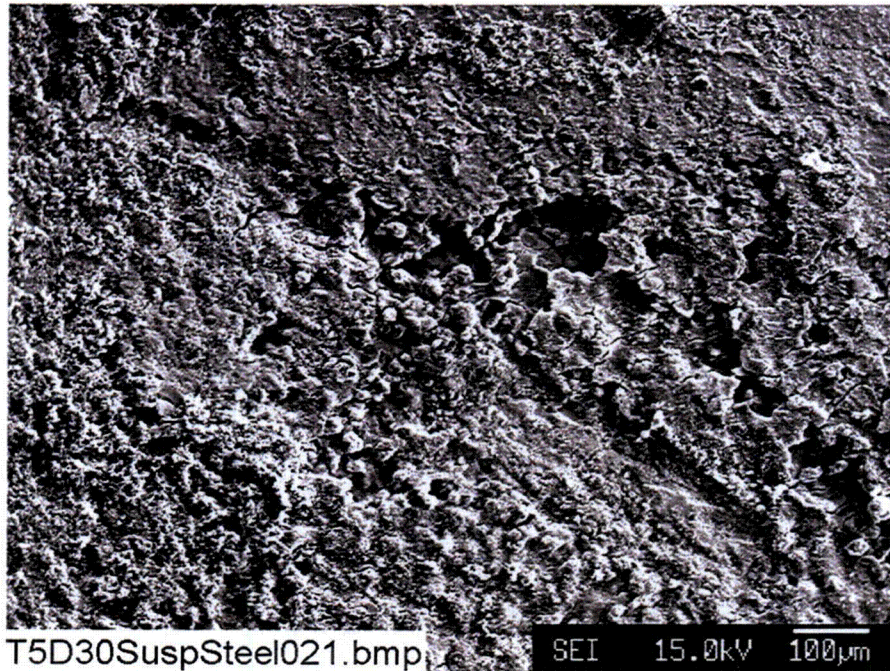
### Unsubmerged Steel Coupon

Image:	T5D30SuspSteel021	100 ×	SEM image	Figure E4-1
	T5D30SuspSteel022	1000 ×	SEM image higher magnification	Figure E4-2
EDS:	T5D30SuspSteel023	1000 ×	SEM annotated image	Figure E4-3
	T5D30Susp Steel Surface11		On smooth surface shown in image 023	Figure E4-4
	T5D30Susp Steel Particle12		On white particles shown in image 023	Figure E4-5

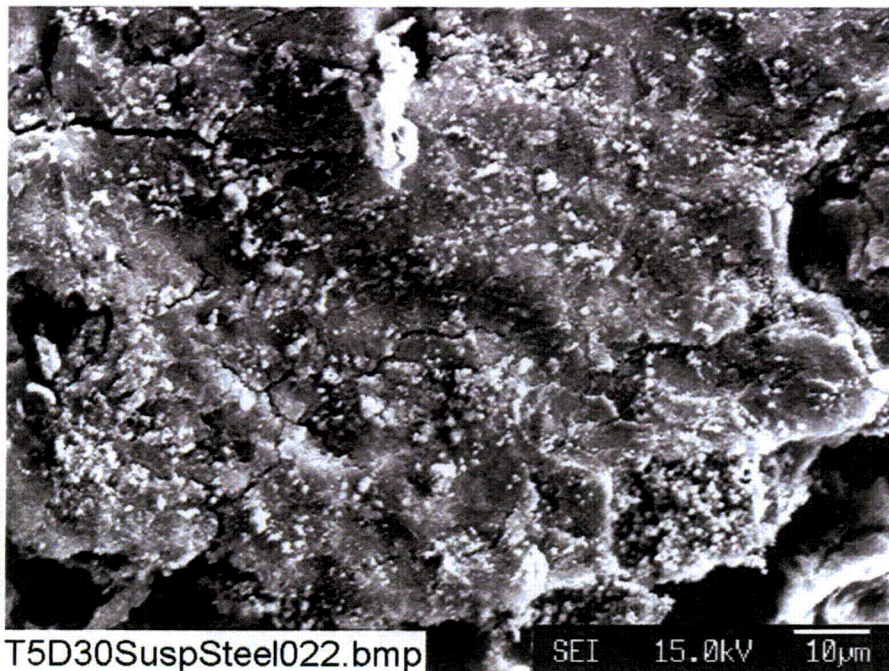
### Submerged Steel Coupon

Image:	T5D30SubmSteel024	100 ×	SEM image of fiberglass	Figure E4-6
	T5D30SubmSteel025	1000 ×	SEM Annotated image	Figure E4-7
EDS:	T5D30Subm Steel light particle13		EDS of light particles in 025	Figure E4-8
	T5D30Subm Steel dark particle14		EDS of dark particle in 025	Figure E4-9
	T5D30Subm Steel Surface15		EDS of surface in 025	Figure E4-10



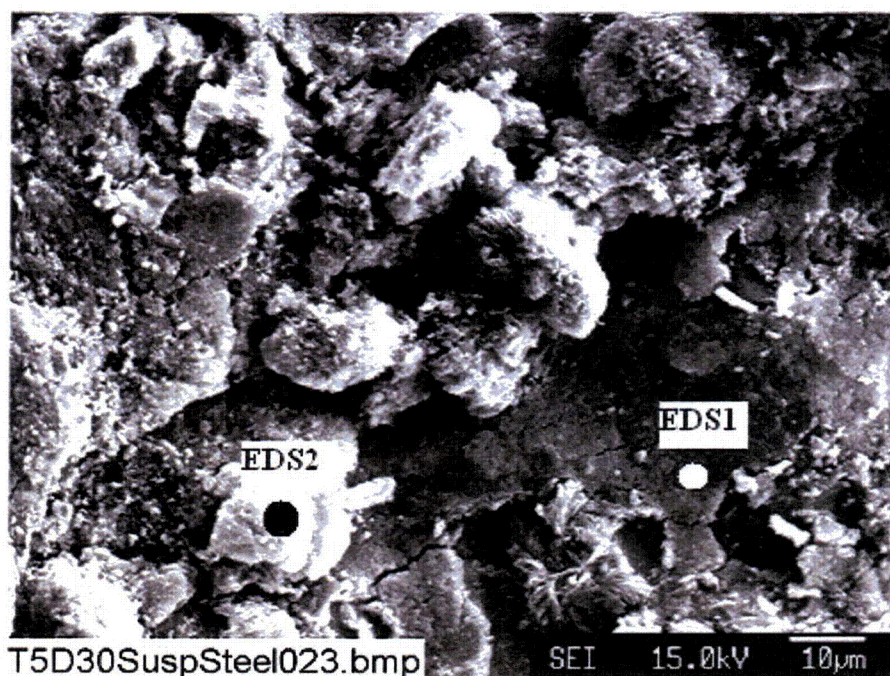


**Figure E4-1.** SEM image magnified 100 times for a Test #5, Day-30 unsubmerged steel coupon sample. (T5D30SuspSteel021.bmp)

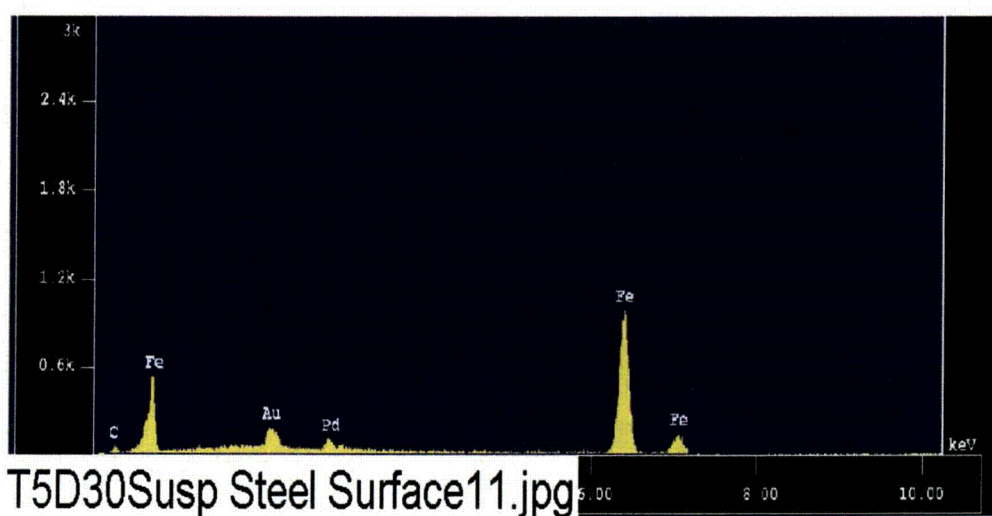


**Figure E4-2.** SEM image magnified 1000 times for a Test #5, Day-30 unsubmerged steel coupon sample. (T5D30SuspSteel022.bmp)





**Figure E4-3.** Annotated SEM image magnified 1000 times for a Test #5, Day-30 unsubmerged steel coupon sample. (T5D30SuspSteel023.bmp)



**Figure E4-4.** EDS counting spectrum for the dark coupon surface (EDS1) of the unsubmerged steel shown in Figure E4-3. (T5D30Susp Steel Surface11.jpg)

The results from the chemical composition analysis for T5D30Susp Steel Surface11.jpg are given in Table E4-1.

**Table E4-1. Chemical Compositions for T5D30Susp Steel Surface11.jpg, Figure E4-4**

Group	:	NRC				
Sample	:	T5D30 ID# : 17				
Comment	:	Surface of Suspended Steel				
Condition	:	Full Scale : 20KeV(10eV/ch, 2Kch)				
		Live Time : 60.000 sec	Aperture #	:	1	
		Acc. Volt : 15.0 KV	Probe Current	:	1.004E-09 A	
		Stage Point : X=21.743 Y=66.867 Z=11.848				
		Acq. Date : Tue Aug 30 15:38:16 2005				
Element	Mode	ROI (KeV)	K-ratio(%)	+/-	Net/Background	
Fe K	Normal	6.04- 7.40	57.1720	0.0094	15164 /	18
C K	Normal	0.11- 0.47	25.4488	0.0098	256 /	25
-----						
			Chi_square	=	3.9338	
Element	Mass%	Atomic%	ZAF	Z	A	F
Fe	89.763	65.3492	1.0215	1.0227	0.9989	1.0000
C	10.237	34.6509	0.2617	0.8592	0.3046	1.0000
-----						
Total	100.000	100.0000				
			Normalization factor	=	1.5370	



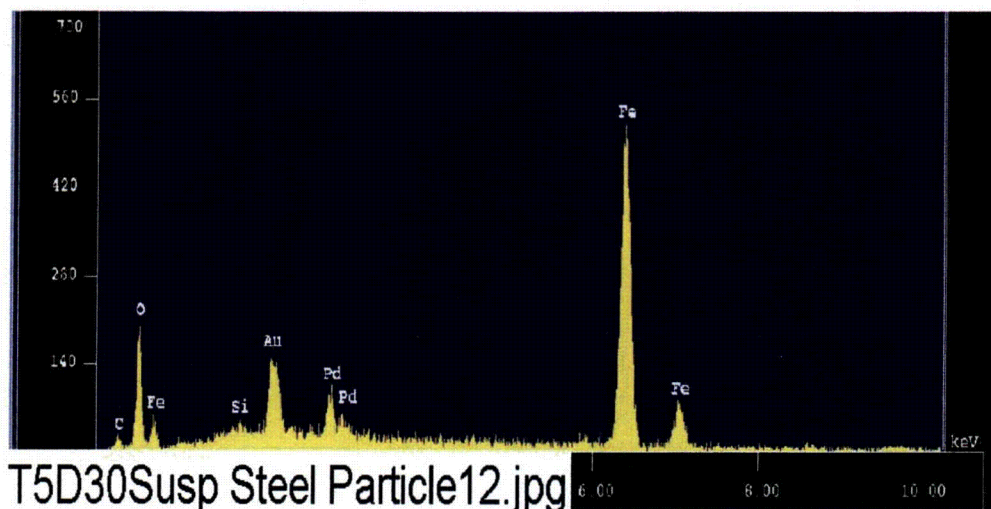


Figure E4-5. EDS counting spectrum for the light particle (EDS2) on the unsubmerged steel coupon surface shown in Figure E4-3. (T5D30Susp Steel Particle12.jpg)

The results from the chemical composition analysis for T5D30Susp Steel Particle12.jpg are given in Table E4-2.

Table E4-2. Chemical Compositions for T5D30Susp Steel Particle12.jpg, Figure E4-5

Group	: NRC					
Sample	: T5D30 ID# : 18					
Comment	: Particles on Suspended Steel					
Condition	: Full Scale : 20KeV(10eV/ch,2Kch)					
	Live Time	: 60.000 sec	Aperture #	: 1		
	Acc. Volt	: 15.0 KV	Probe Current	: 1.005E-09 A		
	Stage Point	: X=21.743 Y=66.867 Z=11.848				
	Acq. Date	: Tue Aug 30 15:43:38 2005				
Element	Mode	ROI(KeV)	K-ratio(%)	+/-	Net/Background	
Si K	Normal	1.50- 2.07	0.1045	0.0003	128 /	47
Fe K	Normal	6.04- 7.40	29.4350	0.0070	7815 /	13
C K	Normal	0.11- 0.47	15.9559	0.0066	161 /	35
O K	Normal	0.31- 0.74	6.1537	0.0065	5799 /	21
-----						
Chi_square = 2.8510						
Element	Mass%	Atomic%	ZAF	Z	A	F
Si	0.348	0.4060	1.3604	0.8714	1.5612	0.9999
Fe	76.176	44.6485	1.0562	1.0587	0.9976	1.0000
C	10.179	27.7411	0.2604	0.8849	0.2942	1.0000
O	13.297	27.2045	0.8818	0.8813	1.0011	0.9995
-----						
Total	100.000	100.0000				
Normalization factor = 2.4503						



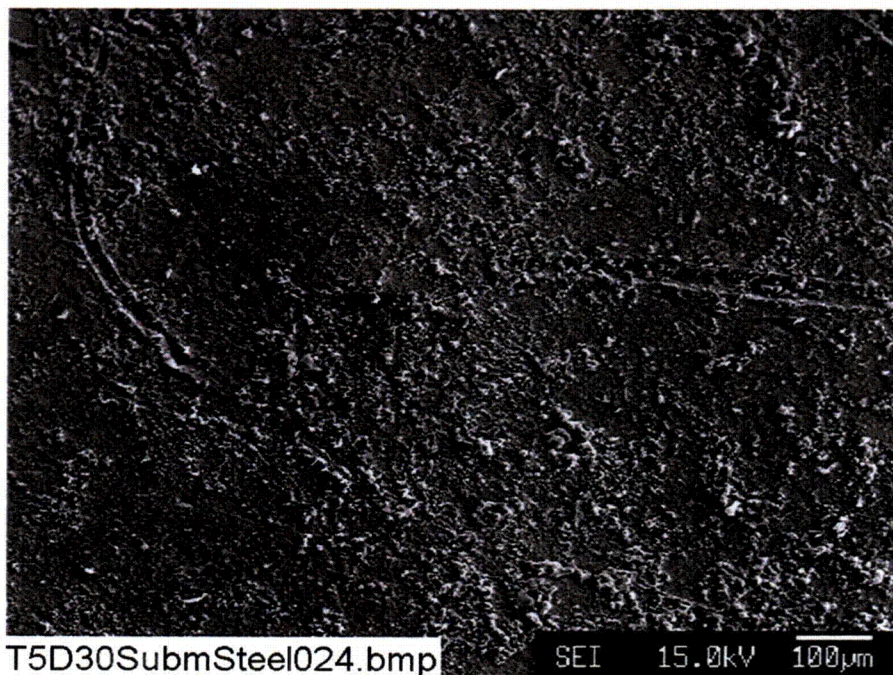


Figure E4-6. SEM image magnified 100 times for a Test #5, Day-30 submerged steel coupon sample. (T5D30SubmSteel024.bmp)

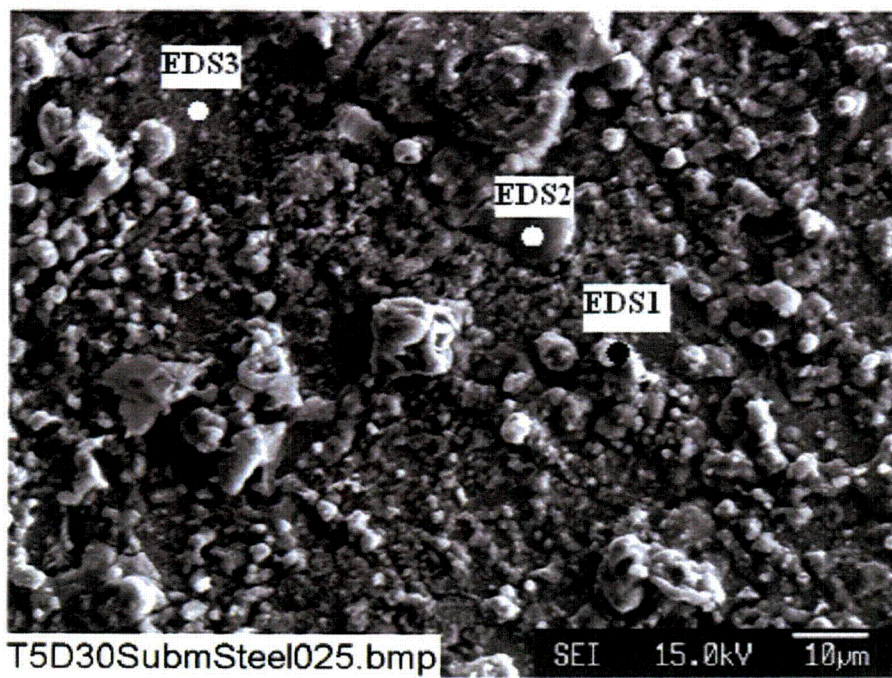
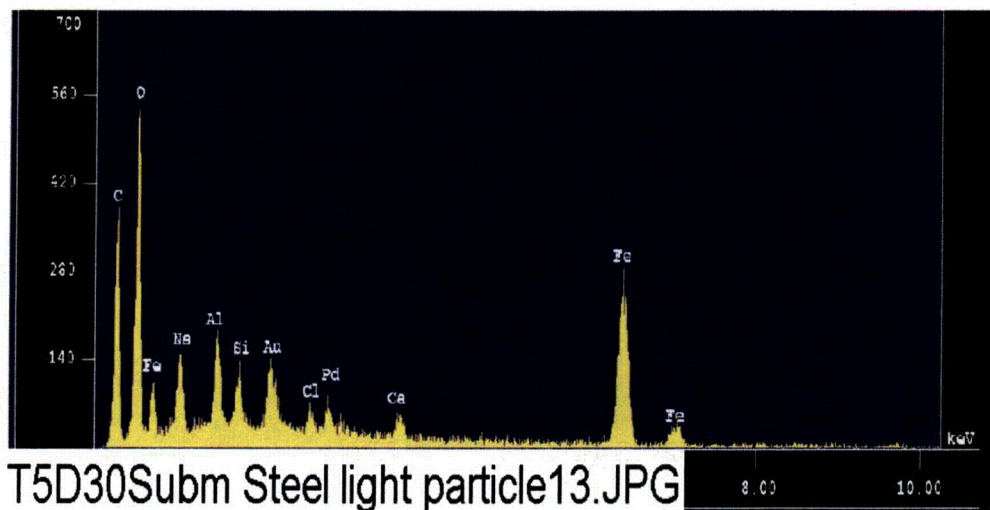


Figure E4-7. Annotated SEM image magnified 1000 times for a Test #5, Day-30 submerged steel coupon sample. (T5D30SubmSteel025.bmp)





**Figure E4-8.** EDS counting spectrum for the light particle (EDS1) on the submerged steel coupon surface shown in Figure E4-7. (T5D30Subm Steel light particle13.JPG)

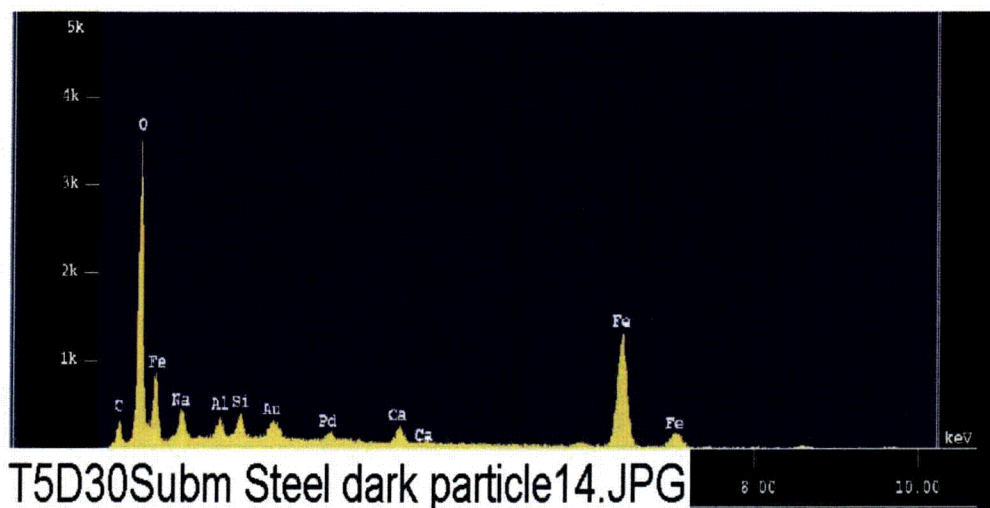


The results from the chemical composition analysis for T5D30Subm Steel light particle13.JPG are given in Table E4-3.

**Table E4-3. Chemical Compositions for T5D30Subm Steel light particle13.JPG, Figure E4-8**

Group	:	NRC					
Sample	:	T5D30 ID# : 19					
Comment	:	Light particle on submerged Steel					
Condition	:	Full Scale : 20KeV(10eV/ch,2Kch)					
		Live Time : 60.000 sec	Aperture #	:	1		
		Acc. Volt : 15.0 KV	Probe Current	:	1.003E-09 A		
		Stage Point : X=76.455 Y=54.980 Z=11.000					
		Acq. Date : Tue Aug 30 16:26:04 2005					
-----							
Element	Mode	ROI (KeV)	K-ratio(%)	+/-	Net/Background		
C K	Normal	0.11- 0.47	255.6311	0.0237	2571 /	99	
O K	Normal	0.35- 0.72	14.1923	0.0039	3803 /	62	
Na K	Normal	0.83- 1.28	1.2501	0.0063	923 /	34	
Al K	Normal	1.26- 1.78	1.1529	0.0008	1283 /	66	
Si K	Normal	1.50- 2.07	0.6334	0.0009	704 /	119	
Cl K	Normal	2.32- 3.09	0.5137	0.0007	485 /	36	
Ca K	Normal	3.40- 4.30	0.8103	0.0053	477 /	27	
Fe K	Normal	6.04- 7.40	15.7888	0.0051	4184 /	6	
-----							
Chi_square =				3.2813			
-----							
Element	Mass%	Atomic%	ZAF	Z	A	F	
C	49.124	65.0147	0.1870	0.9620	0.1944	1.0000	
O	26.855	26.6826	1.8416	0.9574	1.9235	0.9999	
Na	1.678	1.1603	1.3065	0.9520	1.3704	1.0015	
Al	1.365	0.8042	1.1523	0.9602	1.2004	0.9998	
Si	0.695	0.3932	1.0673	0.9487	1.1251	0.9999	
Cl	0.522	0.2339	0.9882	1.0049	0.9842	0.9991	
Ca	0.770	0.3053	0.9247	0.9632	0.9661	0.9937	
Fe	18.991	5.4057	1.1706	1.1807	0.9915	1.0000	
-----							
Total	100.000	100.0000					
Normalization factor =		1.0275					





**Figure E4-9.** EDS counting spectrum for the dark particle (EDS2) on the submerged steel coupon surface shown in Figure E4-7. (T5D30Subm Steel dark particle14.JPG)

The results from the chemical composition analysis for T5D30Subm Steel dark particle14.JPG are given in Table E4-4.

**Table E4-4. Chemical Compositions for T5D30Subm Steel dark particle14.JPG, Figure E4-9**

```

Group       : NRC
Sample      : T5D30 ID# : 20
Comment     : Dark particle on submerged Steel
Condition   : Full Scale : 20KeV(10eV/ch,2Kch)
              Live Time  : 191.130 sec      Aperture #      : 1
              Acc. Volt  : 15.0 KV          Probe Current   : 1.003E-09 A
              Stage Point: X=76.455 Y=54.980 Z=11.000
              Acq. Date  : Tue Aug 30 17:08:10 2005

```

---

Element	Mode	ROI(KeV)	K-ratio(%)	+/-	Net/Background	
Na K	Normal	0.83- 1.28	0.9443	0.0114	2221 /	116
Al K	Normal	1.26- 1.78	0.5316	0.0013	1884 /	212
Si K	Normal	1.50- 2.07	0.5549	0.0008	2159 /	284
Ca K	Normal	3.40- 4.30	1.2563	0.0109	2354 /	73
Fe K	Normal	6.04- 7.40	24.3440	0.0113	20548 /	36
O K	Normal	0.31- 0.74	33.9978	0.0267	101858 /	292
C K	Normal	0.11- 0.47	58.5353	0.0260	1876 /	551

---

Chi\_square = 20.3524

Element	Mass%	Atomic%	ZAF	Z	A	F
Na	1.969	1.7446	1.6775	0.9412	1.7796	1.0015
Al	0.872	0.6582	1.3195	0.9486	1.3913	0.9998
Si	0.890	0.6453	1.2897	0.9408	1.3709	0.9999
Ca	1.439	0.7313	0.9214	0.9484	0.9798	0.9916
Fe	34.836	12.7034	1.1509	1.1573	0.9945	1.0000
O	43.074	54.8293	1.0190	0.9488	1.0741	0.9999
C	16.919	28.6879	0.2325	0.9522	0.2442	0.9999

---

Total 100.000 100.0000  
Normalization factor = 1.2433



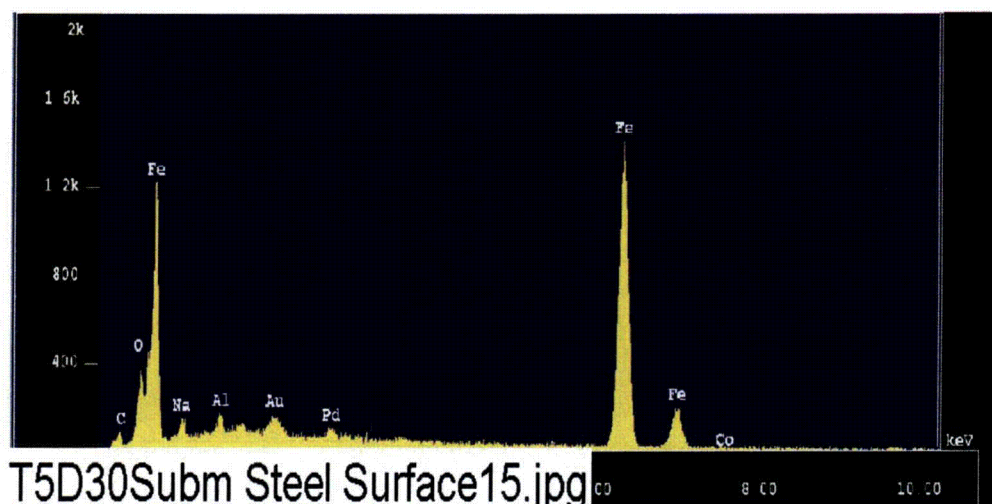


Figure E4-10. EDS counting spectrum for the submerged steel coupon surface (EDS3) shown in Figure E4-7. (T5D30Subm Steel Surface15.jpg)

The results from the chemical composition analysis for T5D30Subm Steel Surface15.jpg are given in Table E4-5.

Table E4-5. Chemical Compositions for T5D30Subm Steel Surface15.jpg, Figure E4-10

Group	: NRC					
Sample	: T5D30 ID# : 21					
Comment	: Surface of submerged Steel					
Condition	: Full Scale : 20KeV(10eV/ch, 2Kch)					
	Live Time	: 83.100 sec	Aperture #	:	1	
	Acc. Volt	: 15.0 KV	Probe Current	:	1.003E-09 A	
	Stage Point	: X=76.455 Y=54.980 Z=11.000				
	Acq. Date	: Tue Aug 30 17:15:50 2005				
<hr/>						
Element	Mode	ROI(KeV)	K-ratio(%)	+/-	Net/Background	
Na K	Normal	0.83- 1.28	0.6403	0.0069	655 /	72
Fe K	Normal	6.04- 7.40	58.7678	0.0113	21567 /	30
Co K	Normal	6.53- 8.02	0.1879	0.0017	64 /	66
O K	Normal	0.31- 0.74	5.4760	0.0120	7133 /	270
C K	Normal	0.11- 0.47	28.0267	0.0128	390 /	86
Al K	Normal	1.26- 1.78	0.5087	0.0009	784 /	108
<hr/>						
Chi_square = 8.3983						
<hr/>						
Element	Mass%	Atomic%	ZAF	Z	A	F
Na	1.768	2.7579	2.0987	0.8635	2.4268	1.0016
Fe	80.660	51.7984	1.0432	1.0450	0.9983	1.0000
Co	0.264	0.1607	1.0680	1.0710	0.9972	1.0000
O	6.395	14.3354	0.8877	0.8717	1.0189	0.9994
C	9.925	29.6345	0.2692	0.8754	0.3075	1.0000
Al	0.988	1.3132	1.4761	0.8693	1.6981	1.0000
<hr/>						
Total	100.000	100.0000				
Normalization factor = 1.3156						



## **Appendix F**

### **SEM/EDS Data for Test #5, Day-30 Sediment**

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- Figure F-3. Annotated SEM image magnified 300 times for the Test #5, Day-30 sediment at the bottom of the tank. (T5D30Sediment005.bmp) ..... F-6
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Particulate sediments at the bottom of the tank directly relate to the corrosion products and debris generated during ICET tests. This appendix presents the probe SEM/EDS and XRD/XRF results for the sediment samples collected from the bottom of the tank on the date Test #5 was shut down (August 25, 2005). The purpose of these analyses is to provide the information of the morphology and the composition of the sediments.

The sediment samples were dried in air before being coated with Au/Pd for probe SEM examination. EDS results provide a semi-quantitative elemental composition of the sediment. The SEM/EDS results of the Test #5, Day-30 sediment samples were obtained on September 6, 2005. XRD and XRF analysis was performed on October 3 and August 30, 2005, respectively. Based on XRD results, the sediment sample contained crystalline substance of quartz, which likely comes from fiberglass debris. XRF results show the chemical composition of the sediment.

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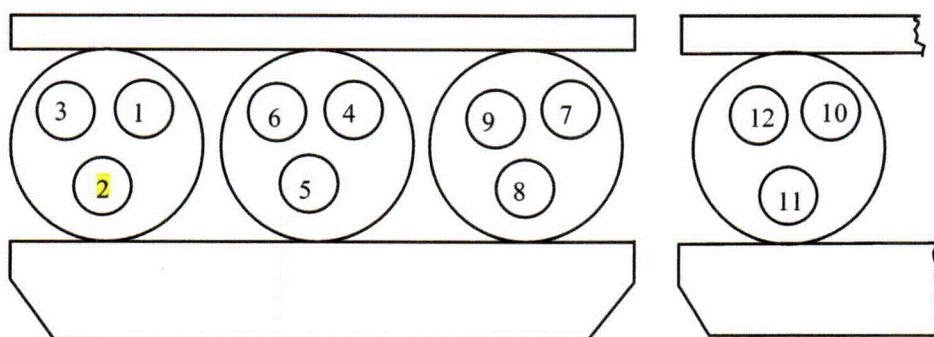


## Transcribed Laboratory Log

Laboratory session from September 6, 2005.

SEM Test #5 Day-30 Sediment

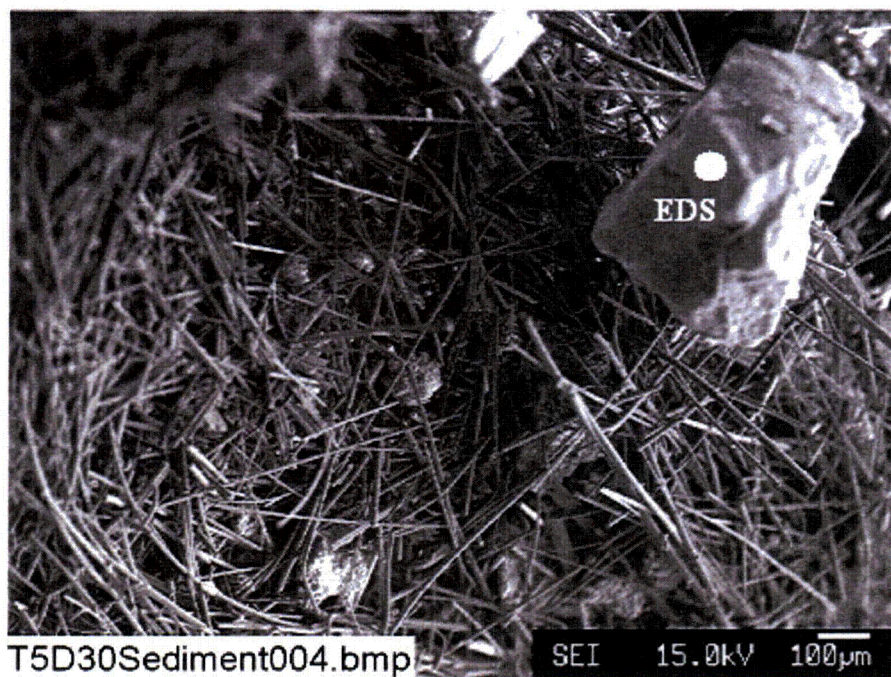
Conditions: e=15.0kV, WD=11mm



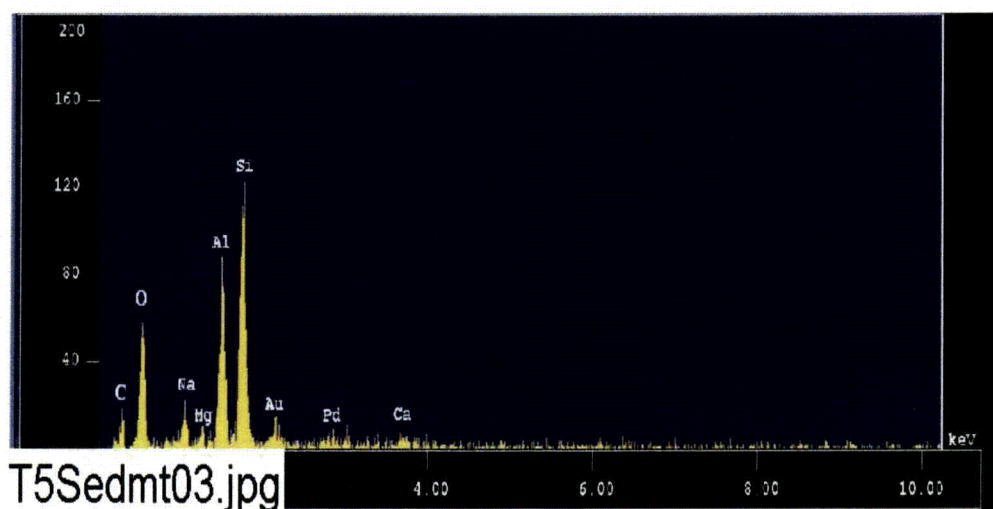
1--Yellow Deposits on Submerged Rack	2--Sediment (T5D30)	3--Al-Suspended
4--Al-Submerged	5--Gal-Steel Suspended	6--Gal-Steel Submerged
7--Cu Suspended	8--Cu-Submerged	9--Steel-Suspended
10--Steel-Submerged	11--Drain Collar Interior	12--Drain Collar Outside Ext.

### Sediment Sample

Image:	T5D30Sediment004	70 ×	Annotated SEM image	Figure F-1
EDS:	T5Sedmt03		EDS on big particle shown in 004	Figure F-2
Image:	T5D30Sediment005	300 ×	Annotated SEM image	Figure F-3
EDS:	T5Sedmt04		EDS on particles shown in 005	Figure F-4
Image:	T5D30Sediment006	600 ×	SEM at higher magnification	Figure F-5



**Figure F-1.** Annotated SEM image magnified 70 times for the Test #5, Day-30 sediment at the bottom of the tank. (T5D30Sediment004.bmp)



**Figure F-2.** EDS counting spectrum for the big particulate deposit shown in Figure F-1. (T5Sedmt03.jpg)



The results from the chemical composition analysis for T5Sedmt03.jpg are given in Table F-1.

**Table F-1. Chemical Compositions for T5Sedmt03.jpg, Figure F-2**

Group	: NRC					
Sample	: T5D30 ID# : 31					
Comment	: Big particle in sediment					
Condition	: Full Scale : 20KeV(10eV/ch, 2Kch)					
	Live Time	: 174.760 sec	Aperture #	: 5		
	Acc. Volt	: 15.0 KV	Probe Current	: 1.996E-08 A		
	Stage Point	: X=45.414 Y=58.152 Z=11.027				
	Acq. Date	: Tue Sep 6 11:10:45 2005				

Element	Mode	ROI(KeV)	K-ratio(%)	+/-	Net/Background	
Na K	Normal	0.83- 1.28	3.5839	0.0020	121 /	4
Mg K	Normal	1.00- 1.53	1.2764	0.0001	37 /	21
Al K	Normal	1.26- 1.78	12.2138	0.0005	622 /	33
Si K	Normal	1.50- 2.07	18.2484	0.0003	1021 /	39
Ca K	Normal	3.40- 4.30	2.8124	0.0018	76 /	2
O K	Normal	0.31- 0.74	38.3211	0.0034	1650 /	2
C K	Normal	0.11- 0.47	242.5716	0.0044	112 /	10

Chi\_square = 1.9507

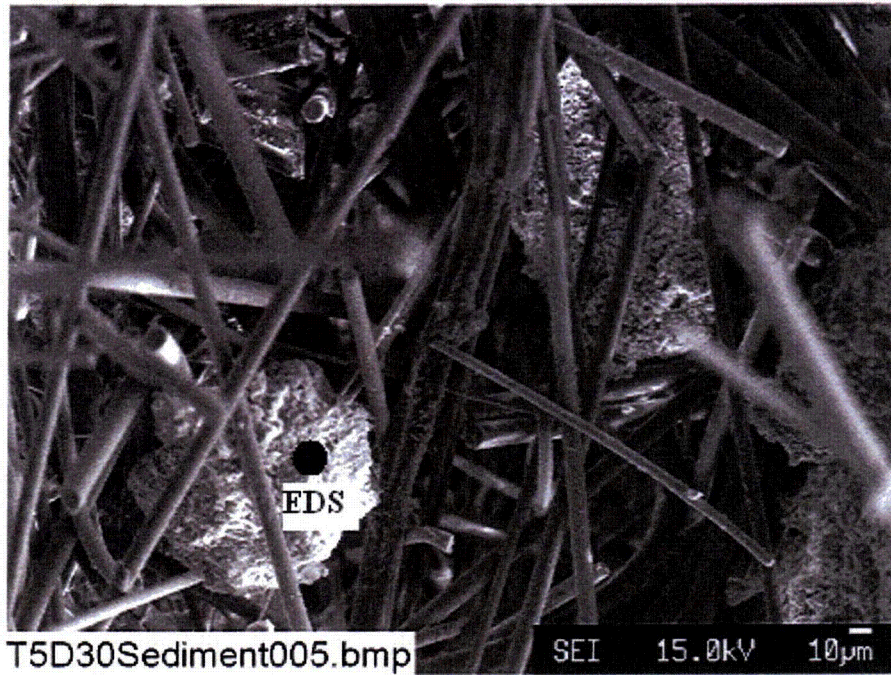
Element	Mass%	Atomic%	ZAF	Z	A	F
Na	1.925	1.2891	0.9857	0.9838	1.0014	1.0006
Mg	0.918	0.5814	1.3200	0.9736	1.3595	0.9973
Al	6.842	3.9044	1.0282	0.9924	1.0399	0.9963
Si	11.585	6.3513	1.1653	0.9848	1.1833	1.0000
Ca	1.488	0.5718	0.9714	0.9964	0.9748	1.0001
O	36.681	35.3029	1.7570	0.9908	1.7731	1.0000
C	40.561	51.9992	0.3069	0.9939	0.3088	1.0000

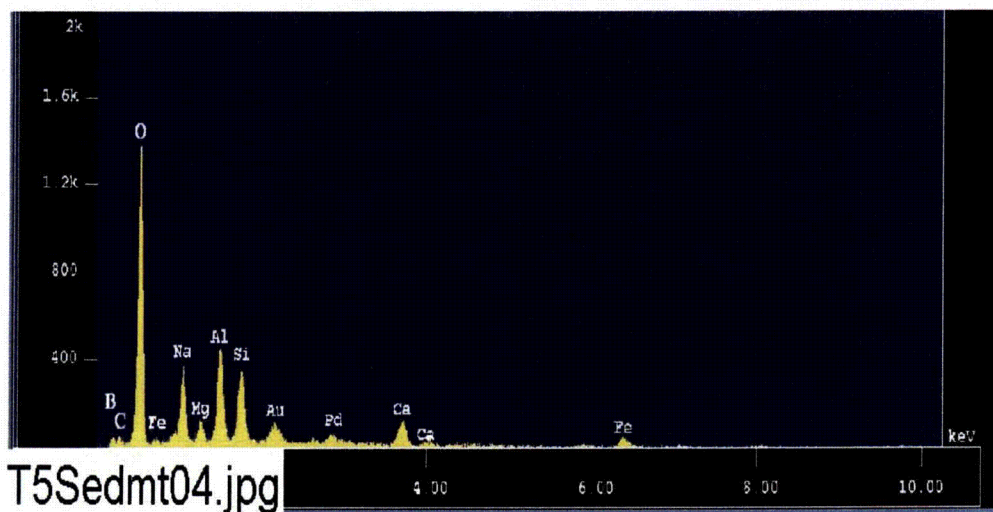
Total 100.000 100.0000

Normalization factor = 0.5448





**Figure F-3.** Annotated SEM image magnified 300 times for the Test #5, Day-30 sediment at the bottom of the tank. (T5D30Sediment005.bmp)



**Figure F-4.** EDS counting spectrum for the particulate deposit shown in Figure F-3. (T5Sedmt04.jpg)

The results from the chemical composition analysis for T5Sedmt04.jpg are given in Table F-2.

**Table F-2. Chemical Compositions for T5Sedmt04.jpg, Figure F-4**

```

Group       : NRC
Sample      : T5D30 ID# : 32
Comment     : Small particle in sediment
Condition   : Full Scale : 20KeV(10eV/ch,2Kch)
              Live Time  : 84.130 sec      Aperture #      : 5
              Acc. Volt   : 15.0 KV         Probe Current   : 1.996E-08 A
              Stage Point : X=45.414 Y=58.152 Z=11.027
              Acq. Date   : Tue Sep 6 11:20:28 2005

```

Element	Mode	ROI(KeV)	K-ratio(%)	+/-	Net/Background	
Na K	Normal	0.83- 1.28	153.4448	0.0087	2497 /	60
Mg K	Normal	1.00- 1.53	61.4743	0.0005	850 /	209
Al K	Normal	1.26- 1.78	151.9680	0.0012	3728 /	172
Si K	Normal	1.50- 2.07	114.4332	0.0006	3081 /	250
Ca K	Normal	3.40- 4.30	110.9579	0.0070	1439 /	18
Fe K	Normal	6.04- 7.40	94.8041	0.0025	554 /	8
O K	Normal	0.31- 0.74	1963.2505	0.0155	40703 /	31
C K	Normal	0.11- 0.47	742.3510	0.0103	165 /	210
B K	Normal	0.00- 0.40	8313.1895	0.2895	28 /	22

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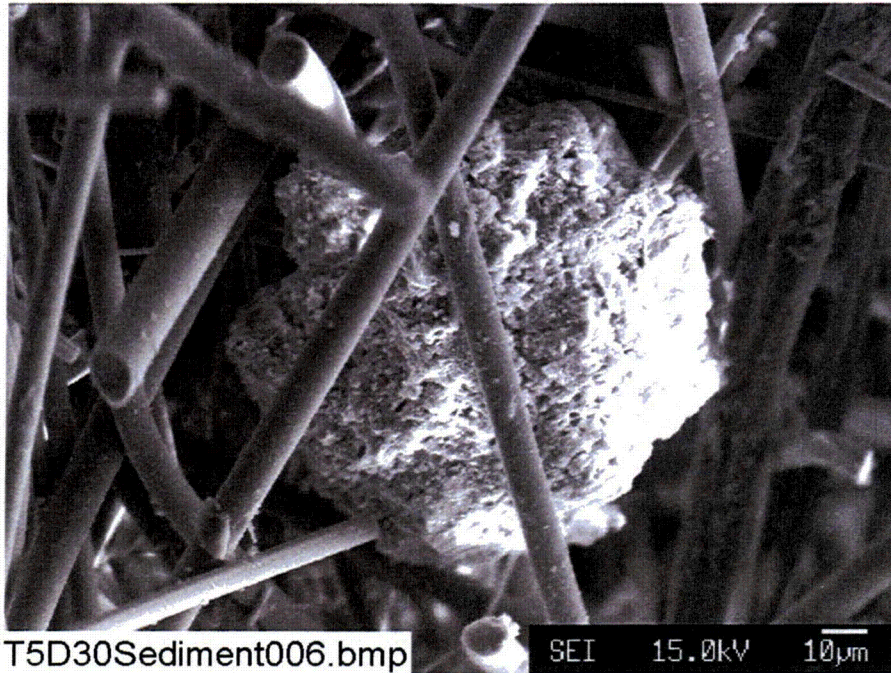
Chi\_square = 10.8445

Element	Mass%	Atomic%	ZAF	Z	A	F
Na	0.536	0.2721	0.7359	0.8962	0.8200	1.0014
Mg	0.302	0.1447	1.0326	0.8873	1.1642	0.9997
Al	0.607	0.2624	0.8408	0.9049	0.9295	0.9997
Si	0.503	0.2090	0.9259	0.8984	1.0307	1.0000
Ca	0.453	0.1317	0.8587	0.9126	0.9413	0.9997
Fe	0.500	0.1045	1.1112	1.1262	0.9867	1.0000
O	15.144	11.0404	1.6238	0.9016	1.8010	1.0001
C	5.435	5.2784	1.5413	0.9038	1.7053	1.0000
B	76.520	82.5568	1.9377	1.0331	1.8757	1.0000

---

Total 100.000 100.0000  
Normalization factor = 0.0047





**Figure F-5.** SEM image magnified 600 times for the Test #5, Day-30 sediment at the bottom of the tank. (T5D30Sediment006.bmp)



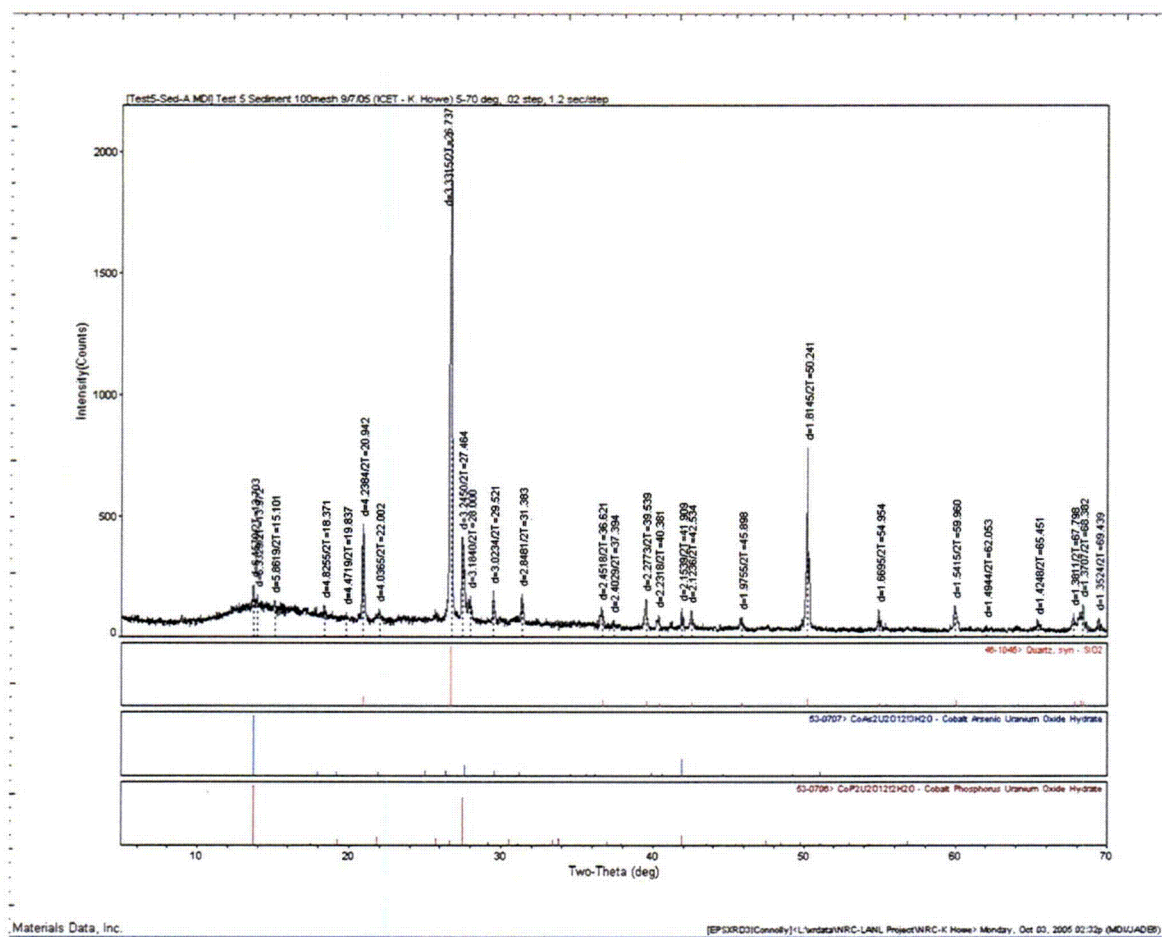


Figure F-6. The XRD result of Test #5, Day-30 sediment.

Table F-3. Dry Mass Composition of the Test #5, Day-30 Sediment Sample by XRF Analysis

Sample ID	SiO <sub>2</sub>	TiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	FeO	MnO	MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	H <sub>2</sub> O (-)	H <sub>2</sub> O(+) CO <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>	Total	H2O(+)CO2 /DF (10) & Cover. To %
ICET Test #5	63.76	0.18	6.00	1.34	0.00	0.07	1.78	5.49	9.28	1.09	0.69	3.27	0.07	93.02	1.0033



## Appendix G

### TEM Data for Test #5 Solution Samples

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- Figure G-10. TEM energy-dispersive x-ray spectrum for a Test #5, Day-30 unfiltered sample. The copper peak likely comes from the copper sample holder for TEM analysis. (T5D30~UF~EDS.jpg)..... G-7
- Figure G-11. TEM magnified 10,000 times for one Test #5, Day-30 unfiltered sample location. (T5D30~UF~10k.jpg) ..... G-8





This appendix presents TEM images and EDS results for Test #5, Day-4, Day-15, and Day-30 unfiltered solution samples. The unfiltered solution samples were directly extracted from the tank. A tiny drop of the testing solutions was transferred to a copper mesh followed by drying in air for TEM analysis. The TEM and EDS results were obtained on September 1, 2005.





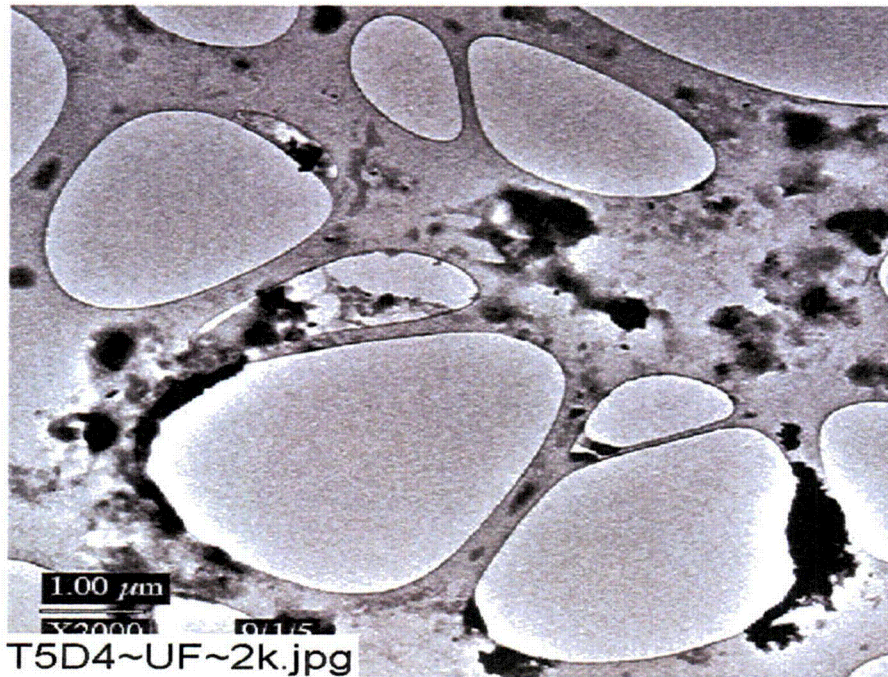


Figure G-1. TEM magnified 2000 times for one Test #5, Day-4 unfiltered sample location. (T5D4~UF~2k.jpg)

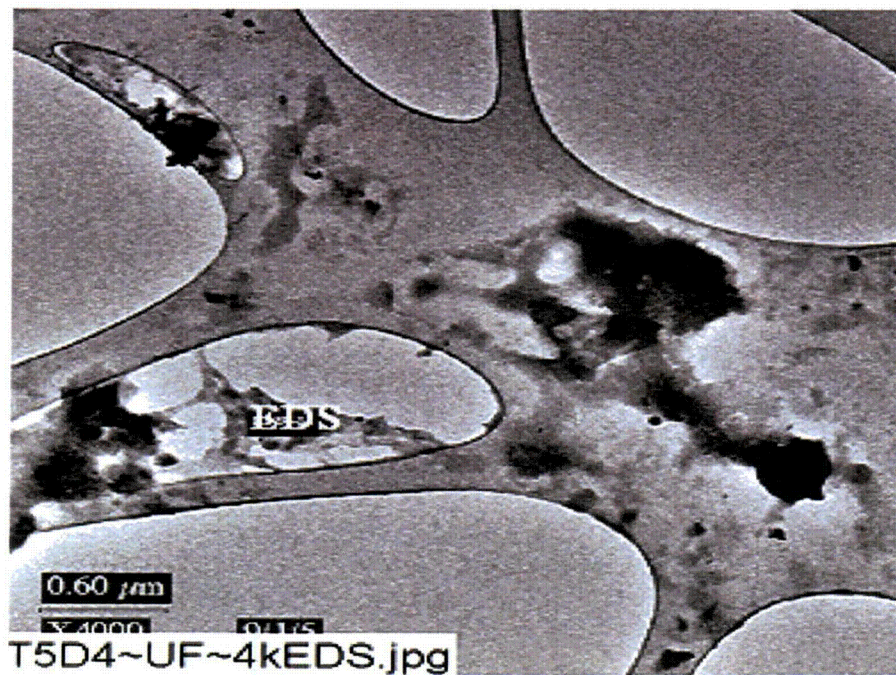
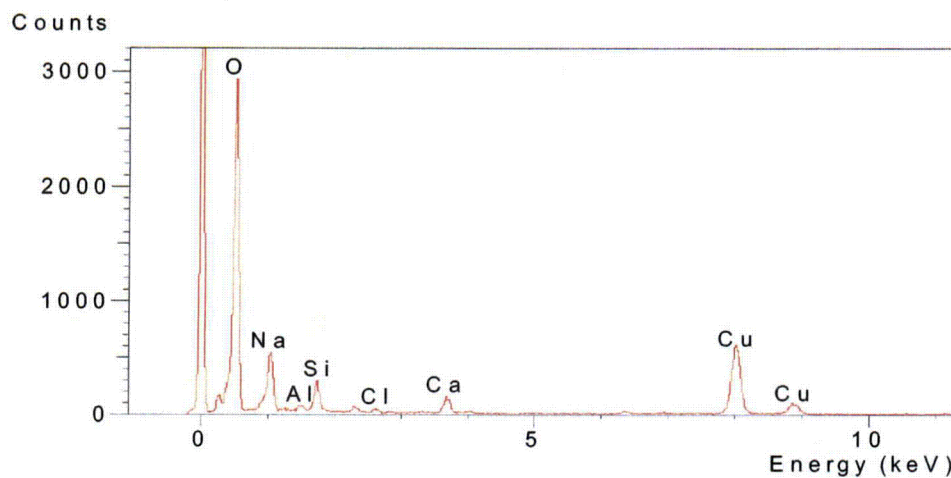
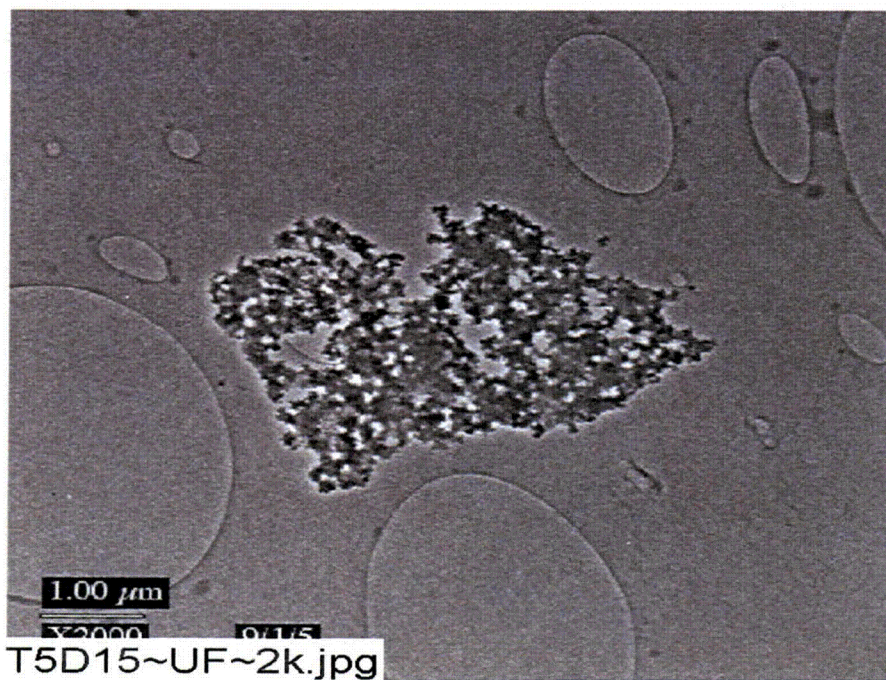


Figure G-2. Annotated TEM magnified 4000 times for one Test #5, Day-4 unfiltered sample location. (T5D4~UF~4kEDS.jpg)

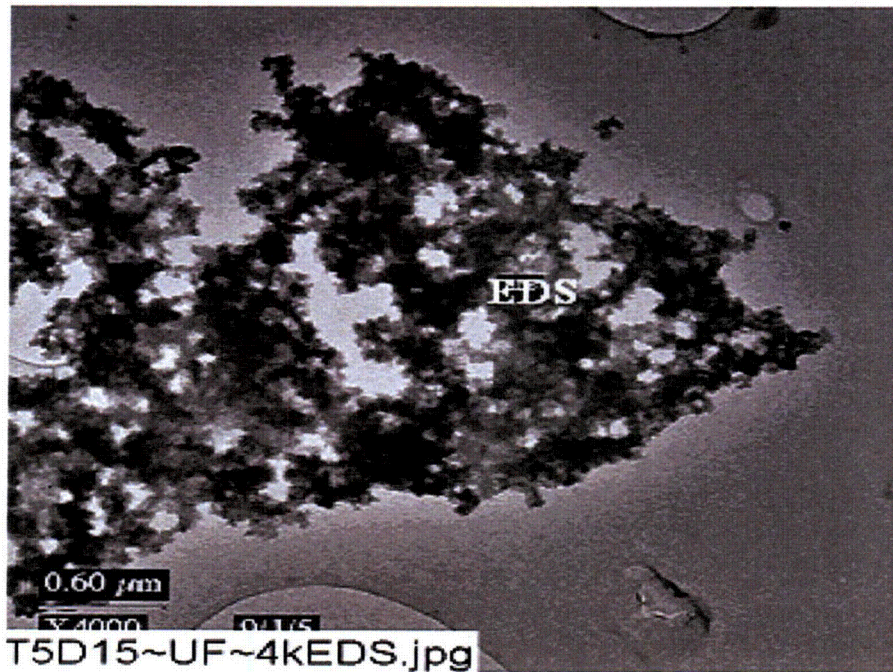




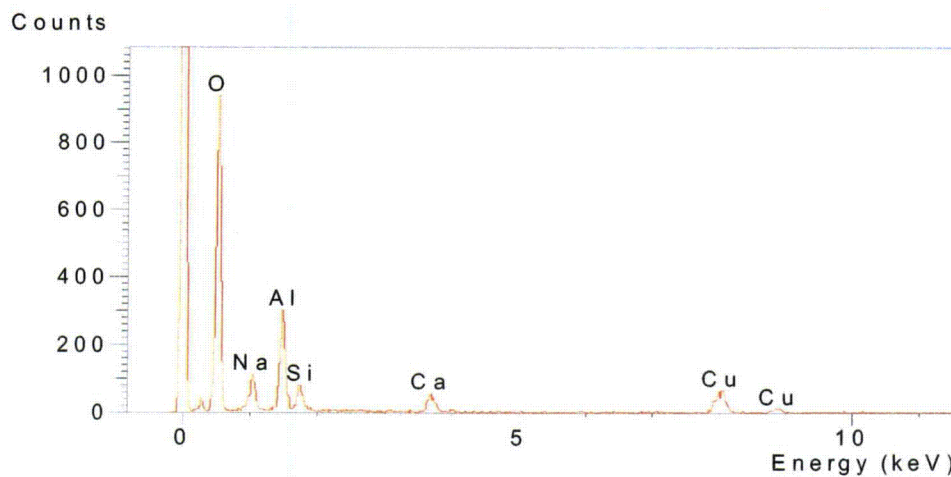
**Figure G-3.** TEM energy-dispersive x-ray spectrum for a Test #5, Day-4 unfiltered sample. The copper peak likely comes from the copper sample holder for TEM analysis. (T5D4~UF~EDS.jpg)



**Figure G-4.** TEM magnified 2000 times for one Test #5, Day-15 unfiltered sample location. (T5D15~UF~2k.jpg)



**Figure G-5.** Annotated TEM magnified 4000 times for one Test #5, Day-15 unfiltered sample location. (T5D15~UF~4kEDS.jpg)



**Figure G-6.** TEM energy-dispersive x-ray spectrum for a Test #5, Day-15 unfiltered sample. The copper peak likely comes from the copper sample holder for TEM analysis. (T5D15~UF~EDS.jpg)



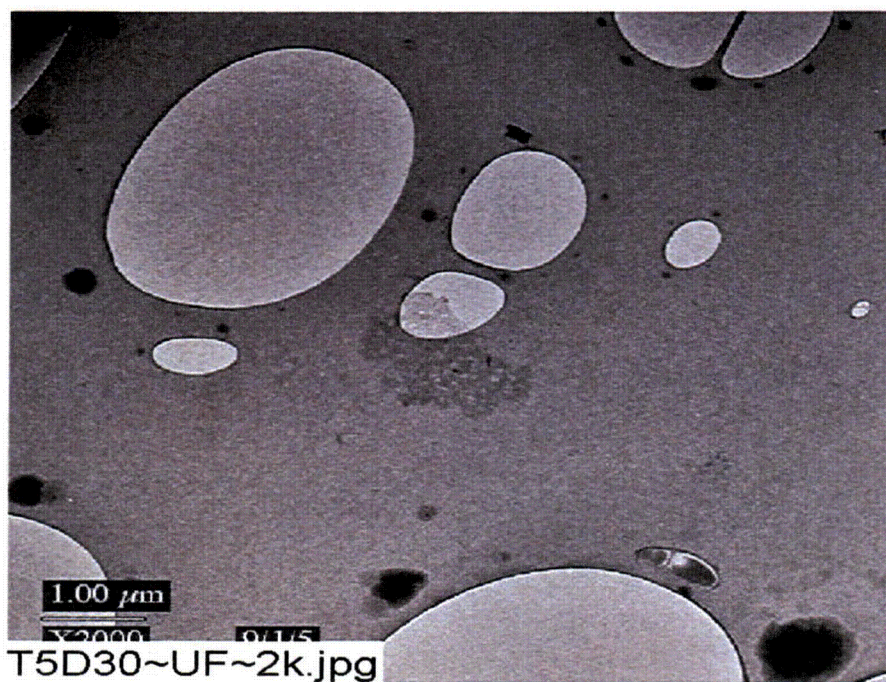


Figure G-7. TEM magnified 2000 times for one Test #5, Day-30 unfiltered sample location. (T5D30~UF~2k.jpg)

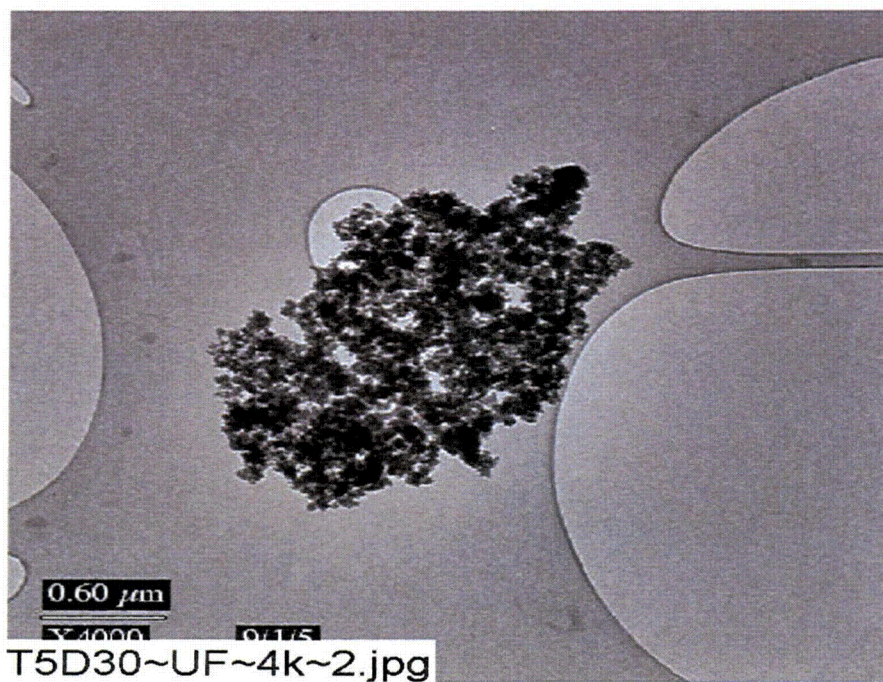
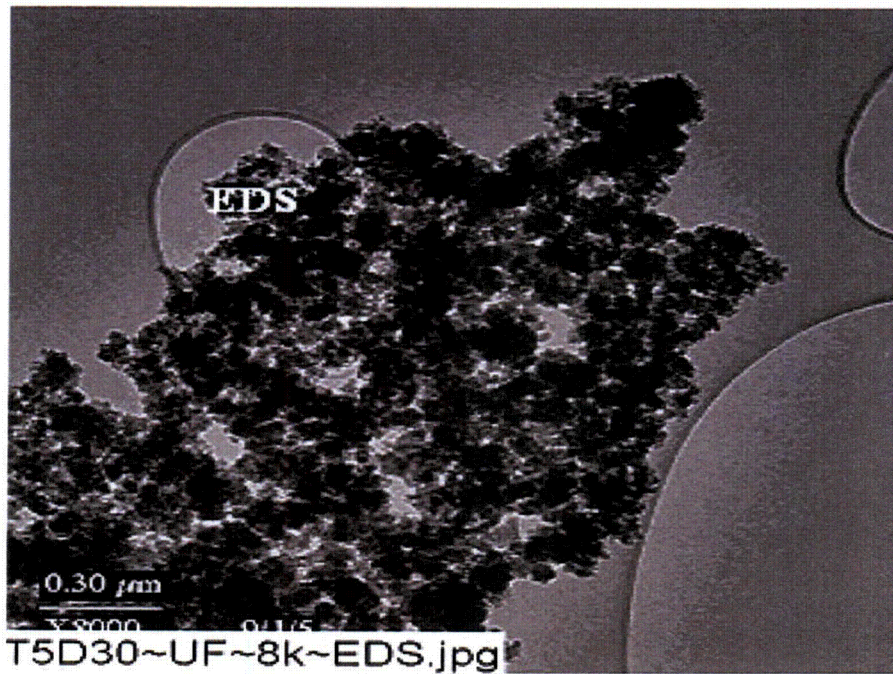
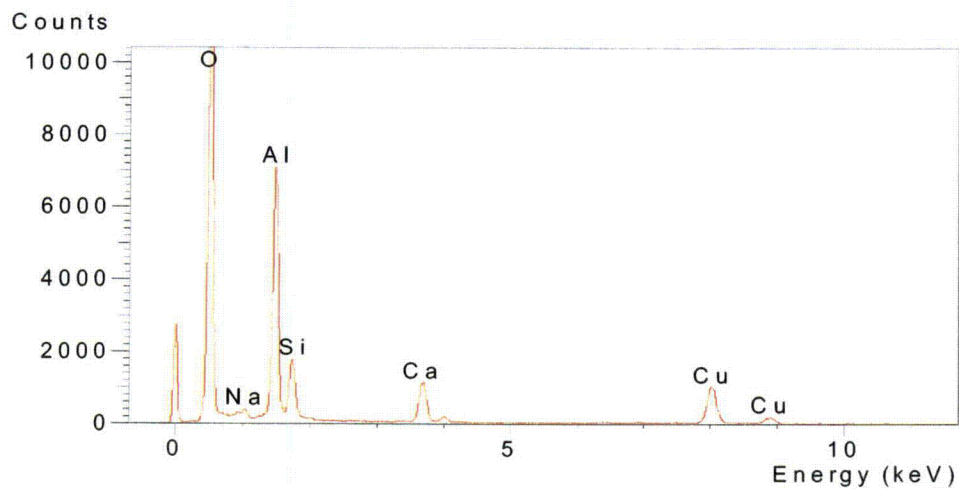


Figure G-8. TEM magnified 4000 times for one Test #5, Day-30 unfiltered sample location. (T5D30~UF~4k~2.jpg)





**Figure G-9.** Annotated TEM magnified 8000 times for one Test #5, Day-30 unfiltered sample location. (T5D30~UF~8k~EDS.jpg)



**Figure G-10.** TEM energy-dispersive x-ray spectrum for a Test #5, Day-30 unfiltered sample. The copper peak likely comes from the copper sample holder for TEM analysis. (T5D30~UF~EDS.jpg)

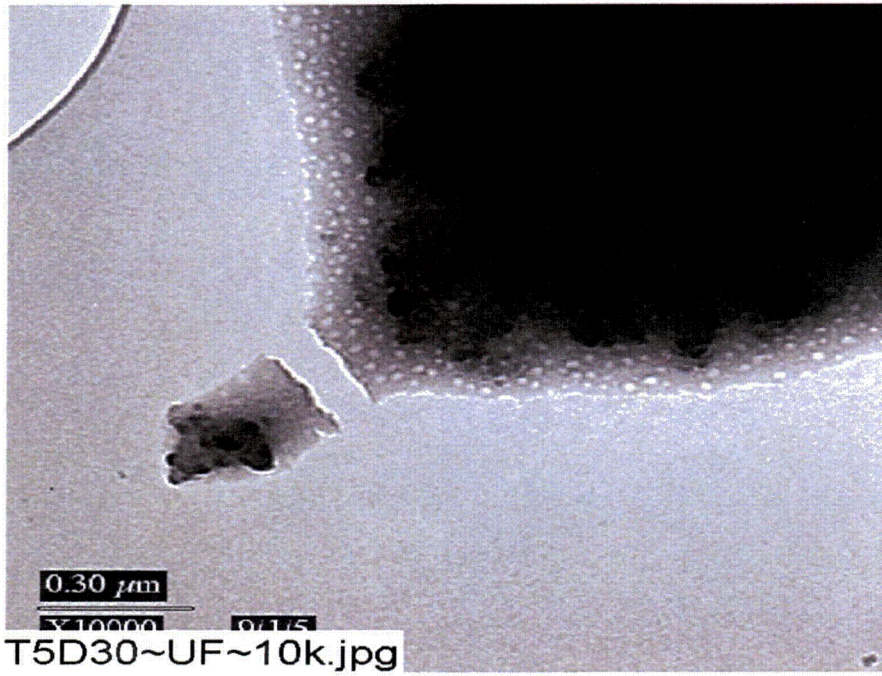


Figure G-11. TEM magnified 10,000 times for one Test #5, Day-30 unfiltered sample location.  
(T5D30~UF~10k.jpg)

## **Appendix H**

### **UV Absorbance Spectrum—Day-30 Solution Samples**

#### **List of Figures**

Figure H-1. UV absorbance spectrum for Test #5, Day-30 solution samples. .... H-3

#### **List of Tables**

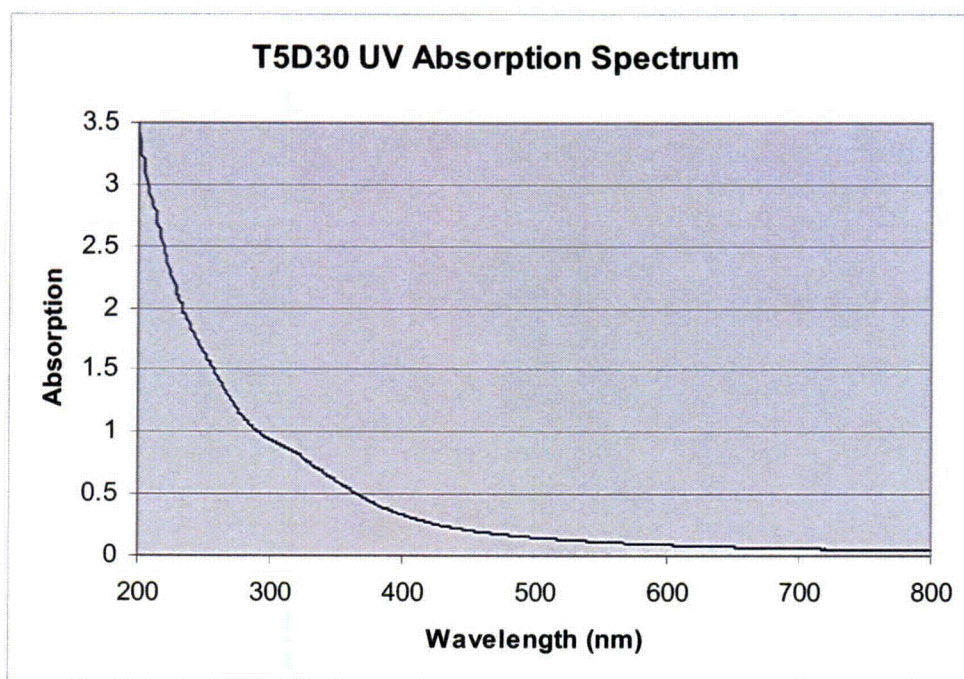
Table H-1. Test #5, Day-30 Solution Sample Laboratory Settings..... H-4





This appendix presents the UV absorbance results of the Test #5, Day-30 solution sample. The purpose of this analysis was to find any distinguished absorbance peaks to identify the organics present in the solution. The solution sample was collected through a 0.7- $\mu$ m fiberglass filter at 60°C to remove particulate impurities, followed by being scanned over the wavelength ranging from 200 to 800 nm by a UV-visible spectrophotometer at room temperature. The spectrum of RO water was used as background subtraction. From the result, no distinguished absorbance peaks were found. The results were obtained on August 28, 2005.





**Figure H-1. UV absorbance spectrum for Test #5, Day-30 solution samples.**



**Table H-1. Test #5, Day-30 Solution Sample Laboratory Settings**

<b>Test #5, Day 30</b>	
Collection Time:	8/25/2005 5:26:10 PM
Operator Name:	
Scan Software Version:	3.00(182)
Parameter List :	
Instrument:	Cary 50
Instrument Version:	3.00
Start (nm):	800.0
Stop (nm):	200.0
X Mode:	Nanometers
Y Mode:	Abs
UV-Vis Scan Rate (nm/min):	600.00
UV-Vis Data Interval (nm):	1.00
UV-Vis Ave. Time (s):	0.1000
Beam Mode:	Dual Beam
Baseline Correction:	On
Baseline Type:	Baseline Correction
Baseline File Name:	
Baseline Std Ref File Name:	
Cycle Mode:	Off
Comments:	
Method Log:	
Method Name:	Default
Date/Time Stamp:	8/25/2005 5:13:49 PM
Method Modifications:	
Cell Changer 6 × 6 Changed:	8/25/2005 5:13:53 PM / OLD:1 / NEW:0
UVVIS SAT Changed:	8/25/2005 5:14:14 PM / OLD:0.0125 / NEW:0.1000
NIR SAT Changed:	8/25/2005 5:14:14 PM / OLD:0.0125 / NEW:0.1000
Common SAT Changed:	8/25/2005 5:14:14 PM / OLD:0.0125 / NEW:0.1000
Baseline Correction Changed:	8/25/2005 5:14:14 PM / OLD:0 / NEW:1

<b>Temp Controller Changed:</b>	<b>8/25/2005 5:14:14 PM / OLD:0 / NEW:2</b>
<b>Sipper Type Changed:</b>	<b>8/25/2005 5:14:14 PM / OLD:INTERNAL RSA / NEW:EXTERNAL SIPPER</b>
<b>End Method Modifications</b>	
<b>&lt;Current Wavelength&gt;</b>	<b>200</b>





## **Appendix I**

### **ICET Test #5: Pre-Test, Test, and Post-Test Project Instructions**



The ICET test series is conducted under the guidance of project instructions (PIs), which identify the steps to follow for certain activities. These PIs are revised or rewritten as needed for each test. For Test #5, new PIs were written to address pre-test and test operations. The PI that addresses post-test operations was unchanged from Tests #3 and #4. These three PIs are included in this appendix to describe more completely the test apparatus and chemical solution preparations, the test startup and daily sampling, and the steps followed after test shutdown.

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## **1.0 INTRODUCTION**

### **1.1 PURPOSE**

The purpose of this instruction is to ensure that all data acquisition, test samples, testing supplies, chemicals, and related materials are ready and accounted for prior to testing. In addition, this instruction provides instructions on preparing the chemical test apparatus for testing.

### **1.2 SCOPE**

The pre-test operations preparation will ensure that successful initiation of the testing activity is achieved.

### **1.3 REFERENCES**

- Test Plan: Characterization of Chemical and Corrosion Effects Potentially Occurring Inside a PWR Containment Following a LOCA, Revision 13, July 20, 2005
- Chemical Additive Analysis Revisions – ICET-CALC-007, November 11, 2004; Test #5 Addendum, July 12, 2005
- Laboratory Safety Guidelines
- ASTM A 380 – 99, Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems
- Material Safety Data Sheets (MSDS) for all chemicals involved

## **2.0 PREREQUISITES**

The data acquisition setup and inspection; instrument calibration; and the coupon receipt, preparation, inspection, and storage tasks must be completed in full prior to the completion of this activity. Fiberglass and calcium silicate (cal-sil) samples must be weighed and their planned locations in the tank identified. That data must be recorded.

### **2.1 Training Requirements**

The following personnel training is required for this task:

- 1) LabVIEW and computer data acquisition training
- 2) Chemical handling training, specifically for ethyl alcohol, ammonium hydroxide, and lithium hydroxide.
- 3) Safe lift execution training

## **2.2 Equipment Requirements**

The following equipment is required to perform this activity: computer with installed LabVIEW software, data acquisition system, and fully assembled and calibrated ICET test apparatus.

Safety equipment must be available: goggles, gloves, lab coats, eye wash station.

## **3.0 DOCUMENTATION REQUIRED**

MSDSs must be available for all chemicals used.

A lab notebook must be maintained throughout the pre-test operations instruction. Contained within the lab notebook will be the date, times, description of activities, and quantities of chemicals added, number of cleanings, and physical observations of the tank cleaning and preparation procedures.

## **4.0 HAZARDS**

The hazards associated with this activity include potential injuries associated with chemical handling.

## **5.0 INSTRUCTIONS**

1. Ensure that all testing materials and supplies are ready and on-site. See checklist at the end of this document. Verify that eye wash station is operational. Note: The following solutions are not used in this instruction, but are to be prepared in advance of entering ICET-PI-018, "Test Operations, Test #5 (fiberglass and sodium tetraborate at pH 8)." After preparation, clearly label the containers with the solutions and place in an area restricted for ICET Project test use.
2. Prepare 21.2 g of concrete dust and 63.7 g of latent debris.
3. Prepare LiOH solution: dissolve 0.284 g of lithium hydroxide (LiOH) in about 100 mL water in a 250-mL sample container.
4. Prepare HCl solution for spray nozzle feed.
  - a. Add 90.8 mL of 12.24 N HCl to 2 gallons of RO water in a 10-L container.
  - b. Properly label and store the container.
5. Prepare laboratory control sample (LCS). See ICET-PI-005, "Chemical Sampling and Analysis," for details on the laboratory control sample.
6. Start the data acquisition system. Verify that the data acquisition system is monitoring flow rate, pump speed, temperature, and pH.
7. Clean the tank and piping.

- 
- a. Cleaning should commence as soon after a test is completed as possible, to prevent material from hardening in the tank or piping and to maximize the time available for cleaning.
  - b. Cleaning chemicals may consist of weak acids (e.g., acetic acid, citric acid, or dilute mineral acids), weak bases (e.g., ammonium hydroxide), weak organic solvents (e.g., ethanol), or detergents/surfactants (e.g., trisodium phosphate, sodium dodecyl sulfate), as necessary. Cleaning solutions can be heated if necessary. Note that the discharge limit to the sanitary sewer is a maximum temperature of 140 °F and pH between 5.0 and 11.5. Cleaning solutions that are not within this range should be neutralized before discharge.
  - c. During cleaning, the pump should be run and water directed through both recirculation lines (through the spray nozzles and lower headers)
  - d. The sample line should be removed from the piping, physically cleaned, and carefully inspected. If the sample line cannot be adequately cleaned, it should be replaced.
  - e. After each cleaning step, the tank and piping should be thoroughly rinsed with tap water or demineralized water.
  - f. After each cleaning step, a segment of pipe should be removed, and the interior of the pipe visually inspected.
  - g. Cleanliness criteria: When the tank visually appears to be satisfactorily cleaned, the tank and piping should be thoroughly rinsed with demineralized water. The interior surfaces of the tank and piping shall be free of any deposits that can be removed by vigorous scrubbing. Demineralized water drained from the tank should have turbidity less than 0.3 NTU and conductivity less than 50 uS/cm.
8. Tank is now ready for testing. Proceed immediately to Instruction No. ICET-PI-018, "Test Operations, Test #5 (fiberglass and sodium tetraborate at pH 8).

## 6.0 ATTACHMENTS

No forms are attached to this document.

## 7.0 Materials Checklist

- \_\_\_\_\_ lithium hydroxide, 0.284 g
- \_\_\_\_\_ 90.8 mL of 12.24 N HCl
- \_\_\_\_\_ tap water supply
- \_\_\_\_\_ demineralized water production system
- \_\_\_\_\_ chemical handling safety equipment (lab coat, goggles, rubber gloves)

- 
- \_\_\_\_\_ analytical balance
  - \_\_\_\_\_ top loading balance
  - \_\_\_\_\_ chemical spatula
  - \_\_\_\_\_ chemical scoop
  - \_\_\_\_\_ weigh boats
  - \_\_\_\_\_ 10-L plastic container
  - \_\_\_\_\_ 250 mL graduated cylinder
  - \_\_\_\_\_ 250-mL HDPE or PP bottle
  - \_\_\_\_\_ 2.5 gallons ethanol
  - \_\_\_\_\_ 2.5 gallons ammonium hydroxide
  - \_\_\_\_\_ turbidimeter and associated equipment
  - \_\_\_\_\_ conductivity meter and associated equipment



## **1.0 INTRODUCTION**

### **1.1 PURPOSE**

The intent of the instruction is to outline the steps that are to be followed during testing.

### **1.2 SCOPE**

This activity forms the core of the entire Chemical Effects Testing project. All activities involved in this project affect and are affected by this activity.

### **1.3 REFERENCES**

- Test Plan: Characterization of Chemical and Corrosion Effects Potentially Occurring Inside a PWR Containment Following a LOCA, Revision 13, July 20, 2005
- ASTM Standard G 4-01
- ASTM Standard D 3370-95a
- ASTM Standard G 31-72
- Material Safety Data Sheets (MSDS) for all chemicals involved
- LabVIEW operation manual
- Laboratory Safety Guidelines
- Chemical Additive Analysis Revisions – ICET-CALC-007, November 11, 2004; Test #5 Addendum, July 12, 2005

## **2.0 PREREQUISITES**

All sample coupons must be placed in their corresponding racks. Also, the pre-operation test preparation activity must be completed in full.

### **2.1 Training Requirements**

The following personnel training is required for this task:

- 1) LabVIEW and computer data acquisition training.
- 2) Chemical handling training for all chemicals involved.

### **2.2 Equipment Requirements**

The following equipment is required to perform this activity: computer with installed LabVIEW software, data acquisition system, and fully assembled and calibrated ICET test apparatus.

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Safety equipment must be available: goggles, gloves, lab coats, hard hats, steel-toed shoes, eye wash station, hydrogen detector and hydrogen removal system.

### 3.0 DOCUMENTATION REQUIRED

A lab notebook must be maintained throughout the testing procedure. In addition, a binder will be maintained that includes pertinent test instructions and the completed daily log sheets (see Attachment A). The daily log sheet contains the date, times, physical description, and quantity of fiberglass and water samples obtained each day. In addition, the daily log sheet contains information from the data acquisition system (DAS), the water samples taken, and other test information.

The electronic data that are acquired are backed up daily and stored in a separate location each testing day. Refer to ICET-PI-001, Data Acquisition Setup and Inspection.

### 4.0 HAZARDS

The hazards associated with this activity include tipping of the chemical tank assembly, ingestion and/or respiration of any chemicals involved, and scalding and/or burning hazards involved in daily tank venting, and possible hydrogen gas generation from corrosion reactions. Appropriate measures to control hydrogen gas must be in place before operations commence.

Lifting hazards associated with the tank lid and coupon racks are also associated with this activity.

### 5.0 INSTRUCTIONS

1. Because of the time required for heating the tank contents and dissolving chemicals, this sequence should be started at least 48 hours before the scheduled time  $t = 0$ . Pre-test operations preparation should be complete before proceeding with this sequence.
2. Ensure that all testing materials and supplies are ready and on-site (see checklist at end of this instruction).
3. Add 248 gallons of RO water to the tank by pumping water from the RO skid through the totalizing flow meter. Record flow to the nearest 0.5 gallon.
4. Verify valves are positioned as follows:

Valve	Description	Position
V-1	tank drain	closed
V-2	pump isolation	open
V-3	instrument loop supply	open
V-4	instrument loop discharge	open
V-5	instrument loop bypass	closed

---

V-6	in-line filter isolation	open
V-7	recirculation line supply	open
V-8	tank spray nozzle supply	closed
V-9	sample line	closed
V-10	recirculation line injection	closed

---

5. Start pump and adjust to flow rate of approximately 25 gpm.
6. Start computer, start LabVIEW, verify that flow rate, pump speed, temperature, and pH are being recorded properly.
7. Turn on heater and allow water in tank to heat to  $60\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ . (This may take up to 20 hours.)
8. Add the pre-mixed LiOH solution.
9. Add 6.48 kg of boric acid ( $\text{H}_3\text{BO}_3$ ), weighing in approximately 2 kg increments, recording the weight of each increment to the nearest 10 g.
10. Add 10.0 kg of Borax (sodium tetraborate) weighing in approximately 2 kg increments, recording the weight of each increment to the nearest 10 g.
11. Allow the water to circulate until the solution is visibly clear, indicating that the boric acid and Borax is completely dissolved. If it is observed that the chemicals are not remaining in solution, consider running the pump at a higher speed during pre-test operations.
12. Allow water in tank to heat to  $65\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ .
13. Take grab water sample for analysis for the parameters identified in steps a – h below. Also record physical appearance of the sample (clarity, presence of gelatinous material, etc). All Day 1 and subsequent samples will be analyzed by Assaigai Analytical Laboratory. In addition, periodic test samples and laboratory control samples (LCSs) will also be analyzed by the UNM laboratory.
  - a. pH
  - b. temperature
  - c. turbidity
  - d. viscosity
  - e. total suspended solids (TSS)
  - f. dissolved oxygen (DO)
  - g. chloride
  - h. metals (Al, B, Ca, Cu, Fe, Pb, Li, Mg, Ni, K, Si, Na, and Zn), total and dissolved
14. Add 21.2 g of concrete dust and 63.7 g of latent debris samples (prepared earlier), wait 10 minutes, take 100 mL water sample for particulate size distribution, density, and TSS.
15. Stop pump.
16. Place coupon racks and fiberglass holders into tank.
17. Verify locations of coupon racks and fiberglass holders.
18. Verify the tank temperature is  $60\text{--}62\text{ }^{\circ}\text{C}$ .
19. Start pump and adjust pump speed to 25 gpm.
20. Open valve V-8 (tank spray nozzle supply) to direct water to nozzles and adjust valves V-7 (recirculation line supply) and V-8 (tank spray nozzle supply) until nozzle

- 
- flowmeter is reading 3.5 gpm. Verify total flow is still 25 gpm and adjust variable frequency drive (VFD) if necessary.
21. Record date and time at which nozzle flow started. This is time  $t = 0$  for the test.
  22. During the first few hours of the test, if the test solution is cloudy, consider frequent measurements of turbidity, pH, and TSS.
  23. At  $t = 2$  hours, start chemical metering pump and inject pre-measured HCl solution into the tank. The objective here is to add the 2-gallon HCL solution in 2 hours.
  24. At  $t = 4$  hours, shut off chemical metering pump and isolate this line.
  25. Take a measurement of hydrogen concentration. At 2-hour increments, repeat the hydrogen concentration measurement. If the concentration reaches 10% of the flammability limit, purge the tank atmosphere. This needs to be repeated until the hydrogen concentration has been determined to be below 10% of the flammability limit, and then the frequency of hydrogen concentration measurements is to be re-evaluated.
  26. At  $t = 4$  hours, stop the spray flow by closing valve V-8.
  27. After closing valve V-8 (at  $t = 4$  hours), take water grab sample for analysis for the parameters listed below. Record the time of sample collection.
    - a. pH
    - b. temperature
    - c. turbidity
    - d. viscosity
    - e. chloride
    - f. total suspended solids (TSS)
    - g. dissolved oxygen (DO)
    - h. metals (Al, B, Ca, Cu, Fe, Pb, Li, Mg, Ni, K, Si, Na, and Zn), total and dissolved.
  28. At  $t = 24$  hours, and daily thereafter, take water grab sample for analysis for the parameters listed below. (The LANL PI will propose a different sampling frequency to the project sponsors if test data support it.) Record the time of sample collection.
    - a. pH
    - b. turbidity
    - c. viscosity
    - d. temperature
    - e. total suspended solids (TSS)
    - f. metals (Al, B, Ca, Cu, Fe, Pb, Li, Mg, Ni, K, Si, Na, and Zn), total and dissolved. An exception is that B, Li, K, Pb, and chloride analyses will be performed only at  $t =$  days 15 and 30. Also, dissolved oxygen will be measured at day 30.
  29. During each daily water sample collection, look inside tank (through windows) and record observations. If the tank water level indicates that the water volume is 245 gallons or less, add RO water to bring the volume up to 250 gallons and record the amount added.
  30. At  $t = 24$  hours, weekly thereafter, and at the end of the test, collect 100 mL water sample for particulate size distribution and density analysis, to be performed at AALI. The particulate size ranges to be used will be as close as possible to those called out in the test plan: (in microns), 1-10, 11-25, 26-50, 51-75, 76-100, and  $> 100$  microns.



- 
31. At  $t = 24$  hours, weekly thereafter, and at the end of the test, collect water samples for strain rate viscosity measurements (see PI-010 for sample details.)
  32. After 2 to 5 days of testing, it is anticipated that the solution will be stable and no suspended particles will be visible. If that is the case, insert the three types of fiberglass samples described in Attachment B. Note that one of the samples (long, narrow stainless steel holder) is to be placed in front of the water distribution headers, and the others are to be placed behind the headers. (The date and time of the addition of these samples will be recorded in the lab notebook.)
  33. At  $3 \text{ days} \leq t \leq 5 \text{ days}$ ,  $14 \text{ days} \leq t \leq 16 \text{ days}$  and at the end of the test, collect a sacrificial fiberglass sample to be inspected and examined with SEM.
  34. At 24 hours, at  $14 \text{ days} \leq t \leq 16 \text{ days}$  and at the end of the test, run 1L of water through a nucleopore filter. The filter will be taken for SEM analysis as specified in ICET-PI-007. (Note that depending on the solution, some filter material will not work well for this operation. If possible, use a nucleopore filter for SEM analysis, and then collect a second sample on nitrocellulose filter for later digestion and ICP analysis.)
  35. Shut down pump
  36. Indicate end of test on the data acquisition system and shut down the data acquisition software.
  37. Proceed directly to PI-008 Post-Test Operations.

## **6.0 ATTACHMENTS**

Attachment A. Daily Log Sheet

Attachment B. Test #5 Fiberglass Sample Addition after Test Start

## **7.0 MATERIAL CHECKLIST**

- \_\_\_\_\_ boric acid, 6.48 kg
- \_\_\_\_\_ Borax, 10.0 kg
- \_\_\_\_\_ pre-mixed LiOH solution
- \_\_\_\_\_ concrete dust, 21.2 g
- \_\_\_\_\_ latent debris, 63.7 g
- \_\_\_\_\_ Nucleopore filter
- \_\_\_\_\_ chemical handling safety equipment (lab coat, goggles, rubber gloves)
- \_\_\_\_\_ top-loading balance
- \_\_\_\_\_ weigh pan for 2 kg aliquots of boric acid
- \_\_\_\_\_ stainless steel filter paper holder
- \_\_\_\_\_ 500 mL graduated cylinder (for TSS)
- \_\_\_\_\_ totalizing flow meter
- \_\_\_\_\_ sample containers (see Chemical Sampling Instruction)
- \_\_\_\_\_ analytical equipment (see Chemical Sampling Instruction)
- \_\_\_\_\_ pre-assembled coupon racks
- \_\_\_\_\_ pre-assembled fiberglass baskets, total of 11 lb of fiberglass
- \_\_\_\_\_ coupon handling safety equipment (hard hat, leather gloves, boots)
- \_\_\_\_\_ computer disks for backup of Labview data
- \_\_\_\_\_ Masterflex peristaltic pump and tubing
- \_\_\_\_\_ demineralized water production system

**Attachment A. Daily Log Sheet**

**Daily Log Sheet**

**Integrated Chemical Effects Test (Test # 5)**

Date: \_\_\_\_\_ Time of sample collection: \_\_\_\_\_

Sample taking and data reduction by \_\_\_\_\_ and \_\_\_\_\_

**Sample bottle identification:**

Assaigai (total): \_\_\_\_\_

Assaigai (filtered): \_\_\_\_\_

UNM (total): \_\_\_\_\_

UNM (filtered): \_\_\_\_\_

**Control system readings:**

Temperature: \_\_\_\_\_ Flow: \_\_\_\_\_ pH: \_\_\_\_\_

**Analyses:**

Volume filtered for TSS: \_\_\_\_\_ pH: \_\_\_\_\_

Temperature: \_\_\_\_\_ Dissolved oxygen: \_\_\_\_\_

Turbidity (at 60 °C): \_\_\_\_\_ (at 23 °C; and 10 min.) \_\_\_\_\_

Viscosity, unfiltered (60 °C): \_\_\_\_\_ (at 23 °C) \_\_\_\_\_

Viscosity, filtered (60 °C): \_\_\_\_\_ (at 23 °C) \_\_\_\_\_

Water Level: \_\_\_\_\_ Water Added: \_\_\_\_\_

Hydrogen: \_\_\_\_\_ Other: \_\_\_\_\_

Fiberglass or other samples taken: \_\_\_\_\_

TSS filter #: \_\_\_\_\_ TSS (mg/L): \_\_\_\_\_

**Comments:**

Observations written in lab notebook by \_\_\_\_\_

☐ Continued on back

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**Attachment B. Test #5 Fiberglass Sample Addition after Test Start**

Recent experience gained in ICET Test #3 with adding large quantities of Calcium Silicate (Cal-Sil) debris to the tank suggests that contamination of fiber samples with suspended particulate may complicate the post-test identification and analysis of chemical products that may be contained within the samples. Similar behavior without Cal-Sil in Tests #1 and #2 was also observed. Past experience also suggests that the circulating tank solution will clarify after 1 to 2 days, providing an opportunity to introduce fiber samples for immersion in the chemical environment without substantially shortening the exposure time and while avoiding the complications of particulate contamination. (Several other fiber samples are immersed at the initiation of the test so that they are directly exposed to large quantities of the particulates).

This attachment to ICET-PI-018 Rev 0 addresses the addition of three types of containers for fiberglass samples that are to be inserted in the test solution between Days 2 and 5 after substantial water clarity has been achieved and as needed to match operations schedules. These containers include: (A) a long (5-6 in.), thin (1/4 to 1/2 in.), narrow (1-2 in.) stainless steel mesh envelope that will be placed in front of a discharge hole on one of the water distribution headers (a "high-flow" area of the tank); (B) a nylon mesh envelope of approximately 4 to 6 inches square containing 5 to 10 g of fiberglass, and (C) 3 to 5, two-inch diameter pucks of fiberglass that are prepared in rings of CPVC and encased in typical envelopes of stainless steel mesh. Each container will hold less than 10 g of fiberglass and their fiberglass contents are considered negligible with respect to the total test amount of fiberglass. The nylon mesh envelope and pucks will be placed in "low-flow" areas of the tank behind the water distribution headers. Technical descriptions and justifications for each item follow.

**Test Item (A): thin sample in high flow**

This sample may provide evidence of whether chemical deposits are enhanced or inhibited by the direct impingement of water flow. The large aspect ratio of this envelope (length/width) is designed to avoid large perturbations in the inlet flow patterns that would occur by placing a large flat object near the distribution headers. Post-test examination of this sample will be made using typical ESEM and SEM/EDS survey techniques.

**Test Item (B): nylon mesh envelope**

ICET Test #1 results indicated a possible preference for chemical deposits to form near the interface between fiberglass and the stainless steel mesh that was used to form the sample envelopes. The introduction of a nonmetallic casing material may permit a comparison of this effect under exposure to a similar chemical environment. Nylon mesh was selected as a suitably inert material for constructing an envelope for this fiber. Based on qualitative assessments and recommendations of material performance made by



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chemical supply vendors (see for instance, chemical resistance information given at [www.eldonjames.com/html](http://www.eldonjames.com/html)), nylon is expected to exhibit “Excellent” resistance to NaOH solutions of up to 50% concentration and “Good” resistance to industrial concentrations of boric acid. This container material has not been submitted for independent bench-scale leaching tests in the ICET solution. The small quantity of foreign material is not expected to perturb interpretation of results from ICET Test #5 regardless of its performance characteristics. Post test examination of this sample will be made using typical ESEM and SEM/EDS survey techniques.

#### Test Item (C): Fiber pucks

The MOU established between NRC and EPRI for conduct of the ICET series specifically excludes modification of the apparatus for the purpose of obtaining in-line flow head loss data. However, the presence of chemical deposits observed on and within fiberglass samples obtained from ICET Test #1 to Test #2 raises questions regarding the potential of these products to impede water flow and about their behavior under flowing conditions, for example, whether they will be adherent or wash out of the fiber matrix. Unanswered questions also remain regarding the possible formation of deposits in the presence of flow, but without a direct mechanism of studying formation under flow, it may be useful to examine whether the deposits can form in fiberglass that represents a prototypical debris bed. Two of the attributes that may distinguish fiberglass on a debris bed from fiberglass in a debris flock are (a) degree of mechanical separation between fibers, and (b) degree of compaction in the bed.

12 fiberglass pucks will be prepared as shown in Figure 1 for jacketing in a stainless steel envelope. Four of the pucks will be immersed in the Test #5 test solution at the start of the test. The remaining eight pucks will be immersed in the test solution after the water clarity has improved. Approximately 5-10 grams of dry fiberglass are required to fill the ½-inch thick, 2-in. diameter sample ring. The sample ring is cut from a 2-inch diameter CPVC pipe to provide a standard dimension for any flow testing that may be desired after the conclusion of Test #5 and to avoid the introduction of unapproved foreign materials in the test tank. Before introducing the fiberglass to the mold, it will first be agitated in a kitchen blender for at least 2 minutes in two batches, each batch containing approximately half the debris and approximately 2 quarts of water. The purpose of agitation is to separate fibers from the raw flocks of manufactured insulation. The batches will be sequential poured into the mold placed across a mesh screen. Gentle manual tamping may be required to ensure uniformity of the bed.



**Figure 1. Example fiber pucks prepared for immersion in ICET test solution.**

The introduction of fiberglass pucks will provide the following technical opportunities for post-test examination:

- 1) Any observed chemical deposits will be relatively free from contamination of suspended particulates.
- 2) ESEM and SEM/EDS examines can be made for the presence of deposits inside of a relatively compact debris bed.
- 3) If exams 1 and 2 are positive, the pucks will provide a concentrated quantity of the deposit for possible extraction, isolation and identification.
- 4) The pre-measured dry mass of the fiber may permit a determination of dry mass for any deposited chemical products. This may provide a first step towards quantifying rates and quantities of formation.
- 5) The convenient form of the debris in the mold will facilitate any head loss testing that is deemed interesting or necessary as a post-test analysis activity. Samples of this type could be placed either within a continuously circulating closed loop or within a static head drain column for measurement of flow loss. The primary objective of any such examinations would be the direct comparison of fresh, identically prepared samples with cultured samples that have been exposed to the test environment. Expected variability between the samples suggests that several replicates should be prepared for comparison. Any work of this type will be conducted under a separate approved procedure.

**Note:** The purpose of this attachment is to describe the samples to be added to Test #5 after test initiation. Any post-test evaluations of these samples other than ESEM and SEM/EDS will be done under separate procedure/project instructions. In

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**addition, any post-test head loss testing will require appropriate documentation and sponsor approvals.**

## **1.0 INTRODUCTION**

### **1.1 PURPOSE**

The intent of this instruction is to ensure that the experimental samples are removed from the test apparatus, the test apparatus is rinsed and inspected, and the test apparatus is made ready for subsequent pre-test operations.

### **1.2 SCOPE**

This activity marks the end of one chemical effects test run. Experimental sample removals and inspections, test apparatus rinsing, and preparations for cleaning and subsequent tests are addressed here.

### **1.3 REFERENCES**

- Test Plan: Characterization of Chemical and Corrosion Effects Potentially Occurring Inside a PWR Containment Following a LOCA, Revision 12.c, March 30, 2005
- ASTM Standard G 4-01
- ASTM Standard G 31-72
- ICET-PI-002, Coupon Receipt, Preparation, Inspection, and Storage, November 19, 2004
- ICET-PI-014, Rev. 0, Test Operations, Test #3 (cal-sil and fiberglass, with TSP, April 5, 2005
- ICET-PI-005, Rev. 1, Chemical Sampling and Analysis, February 3, 2005
- Laboratory safety guidelines
- ICET Project Safety Plan

## **2.0 PREREQUISITES**

All test operation PI criteria must be completed prior to conducting this task.

### **2.1 Training Requirements**

- Laboratory Safety Guidelines
- ICET Project Safety Plan

### **2.2 Equipment Requirements**

A city tap water supply outlet is required for this activity and chemical handling and lifting safety equipment. A reverse osmosis unit is required for the final flush.



### **3.0 DOCUMENTATION REQUIRED**

Documentation related to test parameters, chemical water analyses, coupon and fiberglass examinations, and daily test operations are outlined elsewhere. In this instruction, the steps required to remove samples from the test apparatus and to make it ready for the next test are outlined. In addition, observations as to the test apparatus' condition are obtained and recorded here.

### **4.0 HAZARDS**

The hazards associated with this activity include ingestion/respiration and/or dermal and eye contact with residual chemicals. Lifting hazards associated with the tank lid and coupon racks are also associated with this activity.

### **5.0 INSTRUCTIONS**

- 1) On the last day of testing, collect water samples and perform analyses as outlined in ICET-PI-014 and ICET-PI-005.
- 2) Remove 10L of water from the test apparatus and store at test temperature, for future analyses
- 3) Shut off the recirculation pump.
- 4) Remove the small fiberglass samples for SEM examination.
- 5) Leave one heater on and continue to monitor tank water temperature.
- 6) Isolate and drain the test apparatus piping.
- 7) Remove the tank lid.
- 8) Before removing coupon racks or insulation samples, examine and take photographs and notes of the inside of the tank, the coupons and racks, and the insulation samples.
- 9) Remove the six non-submerged coupon racks to a staging area for drying and post-test examinations (refer to ICET-PI-002).
- 10) Take additional photographs of the inside of the tank.
- 11) Drain the tank slowly, down to the level that uncovers the submerged rack, but keeping the water level above the heater.
- 12) Remove the submerged coupon rack to the staging area.
- 13) Repeat step # 10.
- 14) Turn off the heater.
- 15) Completely drain the tank, taking precautions so that the sediment on the bottom of the tank is not disturbed any more than necessary.
- 16) Store water that was drained from the test apparatus until it is cleared for disposal or shipment. (This step was just moved from later in the PI – the old step #26.)
- 17) When the tank is drained, repeat step # 10. Note especially the locations and orientations of the remaining samples.
- 18) Remove the remaining insulation samples to the staging area to dry.

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- 19) Ensure that all samples removed from the tank are clearly marked as to their location and orientation within the tank.
  - 20) After all samples have been removed, repeat step # 10.
  - 21) Inspect the interior of the tank, noting any observations.
  - 22) Note the presence of any sediment. Carefully remove as much sediment as possible, noting any unique aspects of it, such as location. Place the sediment in plastic containers with lids, marking the location of the sediment in the tank.
  - 23) Remove the tank drain screen and remove the insulation sample for future analysis.
  - 24) Remove the flow meter from the loop and take pictures of the flow meter interior.
  - 25) Remove any deposits within the flow meter and place the deposits in plastic containers with lids. This is to keep the samples hydrated.
  - 26) Remove a section of pipe, take pictures of the pipe interior, and remove and store any deposits there.
  - 27) Replace the flow meter and piping section.
  - 28) Rinse the tank with tap water and drain the water.
  - 29) Fill the system with 250 gallons of tap water and circulate water through the spray nozzles and recirculation headers for at least 60 minutes. Repeat with de-mineralized water.
  - 30) If any signs of deterioration are observed on the inside of the test apparatus tank, remove selected insulation on the tank. Inspect the stainless steel tank for any abnormalities.

## **6.0 ATTACHMENTS**

No forms are attached to this document.

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<b>11. ABSTRACT (200 words or less)</b>  A 30-day test was conducted in the Integrated Chemical Effects Test (ICET) project test apparatus. The test simulated the chemical environment present inside a pressurized water reactor containment water pool after a loss-of-coolant accident. The initial chemical environment contained 6.48 kg of boric acid, 10.0 kg of sodium tetraborate, and 0.284 g of lithium hydroxide. 90.8 mL of hydrochloric acid was added during the last two hours of the four-hour spray phase. The test was conducted at a constant temperature of 60°C (140°F). The materials tested within this environment included representative amounts of submerged and unsubmerged aluminum, copper, concrete, zinc, carbon steel, and insulation samples (100% fiberglass). Representative amounts of concrete dust and latent debris were also added to the test solution. The test solution pH varied from 8.2 to 8.4 for the duration of the test. The test solution turbidity decreased to approximately 2 NTU after 7 days and then to approximately 1 NTU the following day. At 23°C, the turbidity increased to 5 NTU from Day 19 to the end of the test. Wispy precipitates were visible in room temperature solution when the sample bottles were turned upside down, and they took 2-3 days to settle again. The submerged metallic coupons all developed thin particulate deposits. Post-test examinations showed that the submerged aluminum coupons lost approximately 3% of their weight, but there were very little weight changes on the other coupons. The unsubmerged coupons exhibited some streaking, but little or no weight changes. The bottom of the tank contained very little post-test sediment. The test solution at 60°C remained Newtonian for the entire test. When cooled to 25°C, the solution exhibited shear thinning, and the viscosity generally increased at all shear rates as the test progressed. Aluminum concentration rose to over 50 mg/L by Day 11 and fluctuated between 33 and 55 mg/L for the duration of the test.					
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