D. Ashley - Firebar-D material

From: <ahmed.ouaou@exeloncorp.com>
To: <DJA1@nrc.gov>
Date: 10/04/2006 6:25:33 PM
Subject: Firebar-D material
CC: <fred.polaski@exeloncorp.com>, <donald.warfel@exeloncorp.com>, <john.hufnagel@exeloncorp.com>

Donnie:

Attached is part 2 of the GE report on Firebar-D.

<<GE Report on corrosion analysis- Part 2.pdf>>

>

Mail Envelope Properties (452434C5.9BA : 20 : 18874)

Subject:	Firebar-D material
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Recipients
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DJA1 (D. Ashley)

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TEXT.htm	1543	
GE Report on corrosion analysis- Part 2.pdf		4894671
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TABLE 1

DRYWELL STEEL

SPECIFICATION:	ASTM: A-212-61T Gr B
	FIREBOX FINE GRAIN - NORMALIZED
CHEMISTRY:	C - .23
(TYPICAL)	Mn - 1.06
	P - .010
	S - .023
	Si - .21
STRENGTH:	TENSILE - 75,000 PSI
(TYPICAL)	YIELD - 50,000 PSI
	ELONG - 35%

NOTE: MATERIAL WAS IMPACT TESTED

TABLE 2. GPUN Sand and Firebar-D Leachate Analysis

Analytical Parameters	Firebar-D* Leachate 1 Hr, 60° C (ug/g)	Moist Sand Leachate Bay 11 Drain 24 Hrs, Room Temp (ug/g)	Moist Sand Leachate Bay 11 Drain 1 Hr, 90° C (ug/g)	Moist Sand Leachate Plug #1 (19C) 1 Hr, 60° C (ug/g)	Dry Sand Leachate Plug #2 (15A) 1 Hr, 60° C (ug/g)
Na	777	25	25	37	47
K	784	25	20	37	23
Ca	176	30	25	47	< 23
Mg	1936	30	10	10	< 23
Al	< 0.3	< 0.5	1.5	39	2.3
Ni	< 0.3	< 0.5	0.5	< .33	< 2.3
Fe	< 0.3	5.0	1.0	82	8.4
Cr	< 0.3	< 0.5	< 0.5	< .33	< 2.3
Mn	< 0.3	0.5	< 0.5	3.7	< 2.3
Pb	0.6	1.5	< 0.5	< .33	< 2.3
NH_3 (N)	-	-	-	-	-
Cl	573	10.5	6.5	45	93
NO_3	132	2.5	1.5	< 17	6
SO_4	2850	< 25	32	28	79
PO_4	N.D.	N.D.	N.D.	N.D.	N.D.
F	14	N.D.	N.D.	N.D.	N.D.
TOC	1056	39	37	46.6	N.D.
Organic Acids	< 20	< 5	< 5	-	-
Total Sulfur	~ 50	-	-	-	-
B	-	-	-	-	-
Conductivity	588	-	-	-	-
pH	8.46	7.43	7.58	7.02	5.99

Table 3. Test Data Expressed Relative to the Water or Leachate - GE

		Insulation Leachate WS#6152-86	Bay #7 Scrapings Leachate WS#6153-86	Torus Sand Leachate WS#6154-86	Moist Sand Core Sample #3 Leachate WS#6260-86 17D	Moist Plug#4 Sand Core Sample Leachate WS#6261-86 19A	Dry Area 6 Sand Sample Leachate WS#6262-86 11A-H	Drywell Pipe Leak Water Sample WS#6221-86
Leached Material	(g)	13.647	6.6	260.5	247.6	151.2	339.5	--
Volume of Leachate	(mL)	36	293	549	645	539	97	--
Co-60	(mCi/L)	--	--	--	--	--	--	3.6E-06
Cs-137	(mCi/L)	6.2E-07	7.8E-07	--	1.6E-07	--	1.8E-06	--
Gross Beta	(mCi/L)	<8E-07	9.3E-07	<8E-07	<8E-07	<8E-07	2.4E-06	1.7E-06
Gross Alpha	(mCi/L)	<3E-07	<3E-07	<3E-07	<3E-07	<3E-07	<3E-07	<3E-07
Tritium	(mCi/L)	<4E-06	<4E-06	1.4E-04	<4E-06	6.0E-06	5.5E-06	2.8E-03
pH		8.5	8.9	7.9	7.8	7.1	6.5	8.6
Conductivity	(umhos/cm)	540.	2300.	88.	47.	45.	80.	680.
Alkalinity as $CaCO_3$	(mg/L)							
Bicarbonate		170.	110.	44.	23.	24.	9.	260.
Carbonate		8.	16.	<1	<1	<1	<1	21.
Hydroxide		<1	<1	<1	<1	<1	<1	<1
Total		180.	130.	44.	22.	24.	9.0	280.
Total Organic Carbon	(mg/L)	34.	22.	3.0	2.	3.8	12.	19.
Total Sulfur as SO_4	($mgSO_4$/L)	80.	880.	7.6	2.4	2.2	16.	56.
Chloride	(mg/L)	23.	240.	2.	0.8	0.5	9.0	20.
Fluoride	(mg/L)	0.5	0.6	0.1	0.1	0.2	0.4	0.2
Nitrogen, Nitrate	(mgN/L)	5.	0.1	0.4	<0.05	<0.05	0.06	6.3
Nitrogen, Nitrite	(mgN/L)	0.66	0.13	<0.04	<0.04	<0.04	<0.04	<0.04
Phosphate, Ortho	(mgP/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sulfate	($mgSO_4$/L)	96.	750.	7.4	1.4	1.0	14.	62.
Potassium	(mg/L)	46.	680.	12.	7.4	4.8	3.	98.
Sodium	(mg/L)	36.	220.	8.3	3.5	2.	1.	110.
Magnesium	(mg/L)	53.	3.	1.7	0.71	1.3	5.7	11.
Iron	(mg/L)	<0.02	<0.03	<0.02	0.14	<0.02	0.27	9.1
Calcium	(mg/L)	5.5	7.8	4.9	1.7	3.5	1.5	6.4
Boron	(mg/L)	0.89	0.93	0.46	0.074	<0.03	0.24	0.92
Strontium	(mg/L)	0.041	0.094	0.13	0.02	0.076	<0.014	0.28
Aluminum	(mg/L)	<0.02	<0.03	<0.02	<0.32	0.16	<0.02	<0.1
Lead	(mg/L)	0.042	0.15	<0.03	<0.03	<0.03	0.1	<0.3
Barium	(mg/L)	0.096	<0.005	0.0037	<0.003	<0.003	0.0042	<0.03
Arsenic	(mg/L)	0.035	0.05	<0.03	<0.03	<0.03	<0.03	<0.3

Table 4. Calculation of Charge Balances - GE
(Ion Concentrations in Milliequivalents per Liter)

	Insulation Leachate WS#6152-86	Bay #7 Scrapings Leachate WS#6153-86	Torus Sand Leachate WS#6154-86	Sand Core Sample #3 Leachate WS#6260-86 17D	Plug#4 Sand Core Sample Leachate WS#6281-86 19A	Area 6 Sand Sample Leachate WS#6282-86 11A-H	Drywell Pipe Leak Water Sample WS#6221-86
Bicarbonate	3.4	2.2	0.88	0.48	0.48	0.18	5.2
Carbonate	0.16	0.32					0.42
Chloride	0.65	6.8	0.056	0.023	0.014	0.25	0.56
Fluoride	0.026	0.032	0.0053	0.0053	0.011	0.021	0.011
Nitrate	0.36	0.007	0.029			0.0043	0.45
Nitrite	0.047	0.009					
Sulfate	2.0	16	0.15	0.029	0.021	0.29	1.3
Boron as borate	0.082	0.086	0.043	0.0068		0.022	0.085
Arsenic as arsenate	0.0014	0.0020					
Sum of Anions (me/L)	6.7	25	1.2	0.52	0.53	0.77	8.0
Potassium as K+	1.2	17	0.31	0.19	0.12	0.077	2.5
Sodium as Na+	1.6	9.6	0.36	0.15	0.087	0.043	4.8
Magnesium as Mg++	4.4	0.25	0.14	0.058	0.11	0.47	0.90
Iron as Fe++				0.005		0.0097	0.33
Calcium as Ca++	0.27	0.39	0.24	0.085	0.17	0.075	0.32
Strontium as Sr++	0.0009	0.0021	0.003	0.0005	0.0017		0.0064
Aluminum as Al+++					0.018		
Lead as Pb++	0.0004	0.0014				0.001	
Barium as Ba++	0.0014		0.0001			0.0001	
Sum of Cations (me/L)	7.5	27	1.1	0.49	0.51	0.68	8.9

Table 5. Test Data Expressed Relative to the Sample Weight-GE

		Insulation	Bay #7 Scrapings	Torus Sand	Sand Core Sample #3 17-D	Plug#4 Sand Core Sample 19A	Area 6 Sand Sample 11A-H
		WS#6152-86	WS#6153-86	WS#6154-86	WS#6260-86	WS#6261-86	WS#6262-86
Moisture Content		Dry	Dry	12.6%	1.1%	2.6%	Dry
LEACHABLE CHARACTERISTICS:							
Alkalinity as $CaCO_3$	(mg/g)						
Bicarbonate		4.5	4.9	0.093	0.06	0.086	0.026
Carbonate		0.21	0.71	<0.002	<0.003	<0.004	<0.003
Hydroxide		<0.03	<0.05	<0.002	<0.003	<0.004	<0.003
Total		4.7	5.6	0.093	0.057	0.086	0.026
Total Organic Carbon	(mg/g)	0.9	0.98	0.0063	0.0052	0.014	0.034
Total Sulfur as SO_4	($mgSO_4$/g)	2.1	39.	0.016	0.0063	0.0078	0.046
Chloride	(mg/g)	0.61	11.	0.0042	0.0021	0.0018	0.026
Fluoride	(mg/g)	0.013	0.027	0.00021	0.00026	0.00071	0.0011
Nitrogen, Nitrate	(mgN/g)	0.13	0.0044	0.00084	<0.0002	<0.0002	0.00017
Nitrogen, Nitrite	(mgN/g)	0.017	0.0058	<0.0001	<0.0001	<0.0002	<0.0001
Phosphate, Ortho	(mgP/g)	<0.003	<0.005	<0.002	<0.0003	<0.0004	<0.0003
Sulfate	($mgSO_4$/g)	2.5	33.	0.016	0.0036	0.0036	0.04
Potassium	(mg/g)	1.2	30.	0.025	0.019	0.017	0.0086
Sodium	(mg/g)	0.85	9.8	0.017	0.0091	0.0071	0.0029
Magnesium	(mg/g)	1.4	0.13	0.0036	0.0018	0.0046	0.016
Iron	(mg/g)	<0.0006	<0.002	<0.00004	0.00036	<0.00007	0.00077
Calcium	(mg/g)	0.14	0.35	0.01	0.0044	0.012	0.0043
Boron	(mg/g)	0.023	0.041	0.00097	0.00019	<0.00011	0.00069
Strontium	(mg/g)	0.0011	0.0042	0.00027	0.00005	0.00027	<0.00004
Aluminum	(mg/g)	<0.0006	<0.002	<0.00004	<0.0009	0.00057	<0.00006
Lead	(mg/g)	0.0011	0.0067	<0.00006	<0.00008	<0.00011	0.00029
Barium	(mg/g)	0.0025	<0.00022	0.00001	<0.00001	<0.00001	0.00001
Arsenic	(mg/g)	0.00092	0.0022	<0.00006	<0.00008	<0.00011	<0.0009

Table 6. DRYWELL BAY 11 DRAIN WATER (GPUN)

	BAY 11 DRAIN WATER 12/1/86 (ppm)	BAY 11 DRAIN WATER 12/6/86 (ppm)
Sodium	145	96
Potassium	142	85
Calcium	7.5	6.4
Magnesium	30	11
Aluminum	0.33	0.02
Nickel	< 0.01	< 0.02
Iron	< 0.01	0.74
Chromium	< 0.01	< 0.02
Manganese	< 0.01	0.02
Lead	0.06	< 0.02
NH_3 (N)	3.6	----
Chloride	32.5	25
Nitrate	8.7	6
Sulfate	153	60
Phosphate	5	ND
Fluoride	< 1	----
TOC	51	23.3
Organic Acid	< 0.1	----
Total Sulfur as $SO_4^{=}$	153	----
Conductivity (uS/cm)	1100	814
pH	8.90	8.70
* Alkalinity	----	260

* All Alkalinity Present As HCO_3^-

Table 7. OYSTER CREEK DEPOSIT SAMPLES (1) (GPUN)

144036 Deposit - Scrapings from Bay No. 7 between torus and drywell (Oyster Creek No. WS-6153-86)

144037 Deposit - Scrapings from in back of No. 11 expansion joint found in Bay No. 11 between torus and drywell (O. C. No. WS-6280-86)

144038 Deposit - Scrapings from under downcomer found in bay No. 11 between torus and drywell (Oyster Creek No. WS-6281-86)

	144036	144037	144038
Aluminum (Al_2O_3)	0.09%	0.23%	0.38%
Boron (B_2O_3)	0.35	0.35	0.32
Calcium (CaO)	0.21	2.07	1.39
Chromium (Cr_2O_3)	0.006	0.004	0.045
Copper (CuO)	0.013	0.038	0.088
Iron (Fe_2O_3)	78.51	69.93	65.35
Lead (PbO)	0.55	0.51	8.72
Magnesium (MgO)	0.27	2.12	4.78
Manganese (MnO)	0.33	0.25	0.48
Nickel (NiO)	0.013	0.025	0.044
Potassium (K_2O)	1.58	0.12	0.16
Sodium (Na_2O)	1.15	0.11	0.19
Total Yields	83.07%	75.76%	81.96%

* The remainder of the deposit was verified by EDAX to be silicon which is not soluble in hydrochloric acid. The chloride detected by EDAX is due to solvent.

(1) Samples taken between 12/1/86 and 12/6/86.

Table 8. EDAX Elemental Analysis of "Deposit" from Bay 7 - GE

Element	Detected Range (Wt.%)	Average (Wt.%)
Na	0.00 - 2.09	0.61
Si	0.00 - 0.66	0.15
S	0.00 - 11.65	4.15
Cl	0.40 - 6.74	2.11
K	0.76 - 21.24	8.00
Ca	0.00 - 1.30	0.20
Mn	0.00 - 0.93	0.25
Fe	41.37 - 96.82	73.49
Br	0.00 - 4.38	0.72
Pb	0.00 - 34.39	10.27

Table 9. UT Characterization of Damage by Bay Number

Bay No.	UT Characterization
1	Minor damage
3	Minor damage
5	Pitting/inclusion
7	Minor damage
9	Pitting/inclusions
11	Wastage
13	Wastage
15	Pitting/inclusions
17	Wastage
19	Wastage

Table 10. Core Sample Locations

Sample No.	Bay/ Location	Type	Elevation	Samples Obtained	Organization
1	19C	Wastage	11'-3 5/8"	Core, sand, bacteriological*	GPUN
2	15A	Pit/Incl	11'-5 1/4"	Core, sand, bacteriological	GPUN
3	17D	Wastage	11'-3 3/4"	Core, sand	GE
4	19A	Wastage	11'-3 3/8"	Core, sand bacteriological	GE
5	11A	Wastage	11'-3"	Core, sand	GPUN-Archive
6	11A-H	Minor damage	12'-2 3/4"	Core, sand bacteriological	GE
7	19A	Minor damage	12'-1"	Core, sand	GPUN-Archive

*Bacteriological analysis performed at York College

TABLE 11. ENERGY DISPERSION ANALYSES FROM THE SURFACE OF THE PLUG SAMPLES (GPUN)

SAMPLE	ELEMENTAL COMPOSITION * MAJOR	MINOR	TRACE
15A	Fe	Pb	Al,Si,Ca,Mn
19C	Fe	Cl	Al,Si,Mn

* MAJOR	>	10 wt. %
MINOR	>	1 wt. %
TRACE	<	1 wt. %

ELEMENTS BELOW ATOMIC NUMBER OF 11 ARE NOT DETECTABLE.

TABLE 12. ENERGY DISPERSION ANALYSIS OF THE SAND SAMPLE FROM THE 15A SAMPLE LOCATION (GPUN)

ELEMENTAL COMPOSITION *

MAJOR	Si
MINOR	Al, Fe
TRACE	Cl, K, Pb, Ti

* MAJOR	> 10 wt. %
MINOR	> 1 wt. %
TRACE	< 1 wt. %

TABLE 13. ENERGY DISPERSION ANALYSIS OF THE FLAKE DEPOSIT FROM THE 19C PLUG SAMPLE (GPUN)

ELEMENTAL COMPOSITION *

MAJOR	Fe
MINOR	--
TRACE	Si,Cl

pH DETERMINED BY LITMUS PAPER

4

* MAJOR	> 10 wt. %
MINOR	> 1 wt. %
TRACE	< 1 wt. %

Table 14. Oyster Creek Core Plug Corrosion Surfaces - GE

Element Conc. Range	Core Plug 17D	Core Plug 19A	Core Plug 11A-H
Al	---	---	0.00-0.04
Si	---	---	1.42-2.45
S	0.17-0.20	---	9.83-11.31
Cl	3.71-4.92	0.34-1.25	4.39-5.37
K	---	---	0.00-0.16
Ca	---	0.00-0.03	0.14-0.68
Mn	1.36-1.93	1.87-2.48	0.00-0.11
Fe	92.73-94.60	96.07-97.45	21.72-28.87
Pb	---	---	52.61-59.77
Br	0.00-0.35	0.00-0.16	1.17-1.37
Cu	---	---	---
Ti	0.04-0.07	0.03-0.07	---
Cr	0.08-0.09	0.06-0.10	---

Table 15. Oyster Creek Core Plug Cross-Section Analysis - GE

	Typical Concentration (Wt.%)		
Element	Plug 17D*	Plug 19A	Plug 11A-H
Al	---	---	---
Si	0.08	---	0.30
S	0.23	---	16.40
Cl	3.45	0.14	2.57
K	0.02	---	---
Ca	0.02	---	---
Mn	1.63	1.24	0.01
Fe	94.40	98.37	0.66
Pb	---	---	79.56
Br	0.08	---	0.16
Cu	---	---	0.27
Ti	0.04	0.07	0.05
Cr	0.09	0.18	0.02

*Average of (2) values

Table 16. Oyster Creek Plug Crust Samples (Wt.%) - GE

Elemental Conc. Range	Plug 17D	Plug 19A
Al	---	0.00-1.03
Si	0.00-0.63	3.81-30.34
S	---	0.07-1.72
Cl	0.02-0.38	0.33-1.93
K	0.00-0.09	0.00-0.65
Ca	0.00-0.11	0.00-0.66
Mn	1.54-10.92	0.00-1.50
Fe	88.32-98.26	64.69-93.36
Pb	---	---
Br	---	---
Cu	0.00-0.23	0.00-0.52
Ti	---	0.00-2.98

Table 17. Elements Present in Seawater[9]

Anions, ppm		Cations, ppm	
Cl	18980	Na	10561
SO_4	2652	Mg	1272
Br	65	Ca	400
F	1.4	K	380
I	0.05	Sr	13
Inorg. C	28	SiO_2	0.01-7.0
Org. C	1.2-3.0	B	4.6
$N(NO_3)$	0.001-0.7	H_3BO_3	26
$N(NO_2)$	0.001-0.05	Si	0.02-4.0
$N(NH_3)$	0.005-0.05	Al	0.6-1.9
Org. N	0.03-0.2	Rb	0.2
$P(PO_4)$	0.001-0.10	Li	0.1
Org. P	0-0.016	Ba	0.05
		As	0.003-0.024
		Fe	0.002-0.02
		Zn	0.005-0.014
		Cu	0.001-0.09

Table 18. Summary of Core Plug Thickness Measurements

Sample	Pre-Removal Average Thickness, in	Post-Removal Average Thickness, in	Comments
19C	0.815	0.825	Wastage, thick corrosion product
15A	(0.490 min) 1.17	1.17	Inclusions, superficial corrosion
17D	0.840	0.860	Wastage, thick corrosion product
19A	0.830	0.847	Wastage, thick corrosion product
11A	0.860	0.885	Wastage - Archive specimen
11A-H	1.17	1.19 center	Above wastage, no significant corrosion
19A	1.14	1.18 center	Above wastage, no significant corrosion

TABLE 19. CORROSION RATES OF CARBON STEEL UNDER STATIC-AIR SATURATED CONDITIONS[12-15]

WATER TYPE	TEMP °C(°F)	pH	EXPOSURE PERIOD, DAYS	CORROSION RATE, MPY	REF
DISTILLED + NaOH/HCL	40(104)	4.5-8	-	23.8	UHLIG/ WHITMAN
	22(72)	4.1-9.5	-	16.6	UHLIG/ WHITMAN
PARTIAL DEMIN (0.1/3.6μS/CM)	52(125)	-	62	2.1	BRUSH
		-	145	5.6	BRUSH
NA	40(104)	-	-	12	SPELLER
	60(140)	-	-	14	SPELLER
DISTILLED	25(77)	5.4-6.5	100	1.4	MERCER
	40(104)	5.4-7.0	100	2.9	MERCER
	60(140)	5.4-8.0	100	6.6	MERCER
TAP	40(104)	7.2-7.7	90	53.5	KHOMITCH
	50(122)	7.2-7.7	90	54.0	KHOMITCH
	60(140)	7.2-7.7	90	61.7	KHOMITCH
CONDENSATE	25(77)	-	35	8	BREDEN
FEEDWATER	45(113)	-	-	20	NOE
CONDENSATE	45(113)	7.5-11	365-1095	20	WAGNER
CONDENSATE	45(113	>6	-	15	OBRECHT
SEAWATER	25(77)	~7	-	3.5	HUDSON
SEAWATER	50(122)	~7	-	>50	NACE
SOIL MIX	15(59)	~7	1456	~18	UHLIG

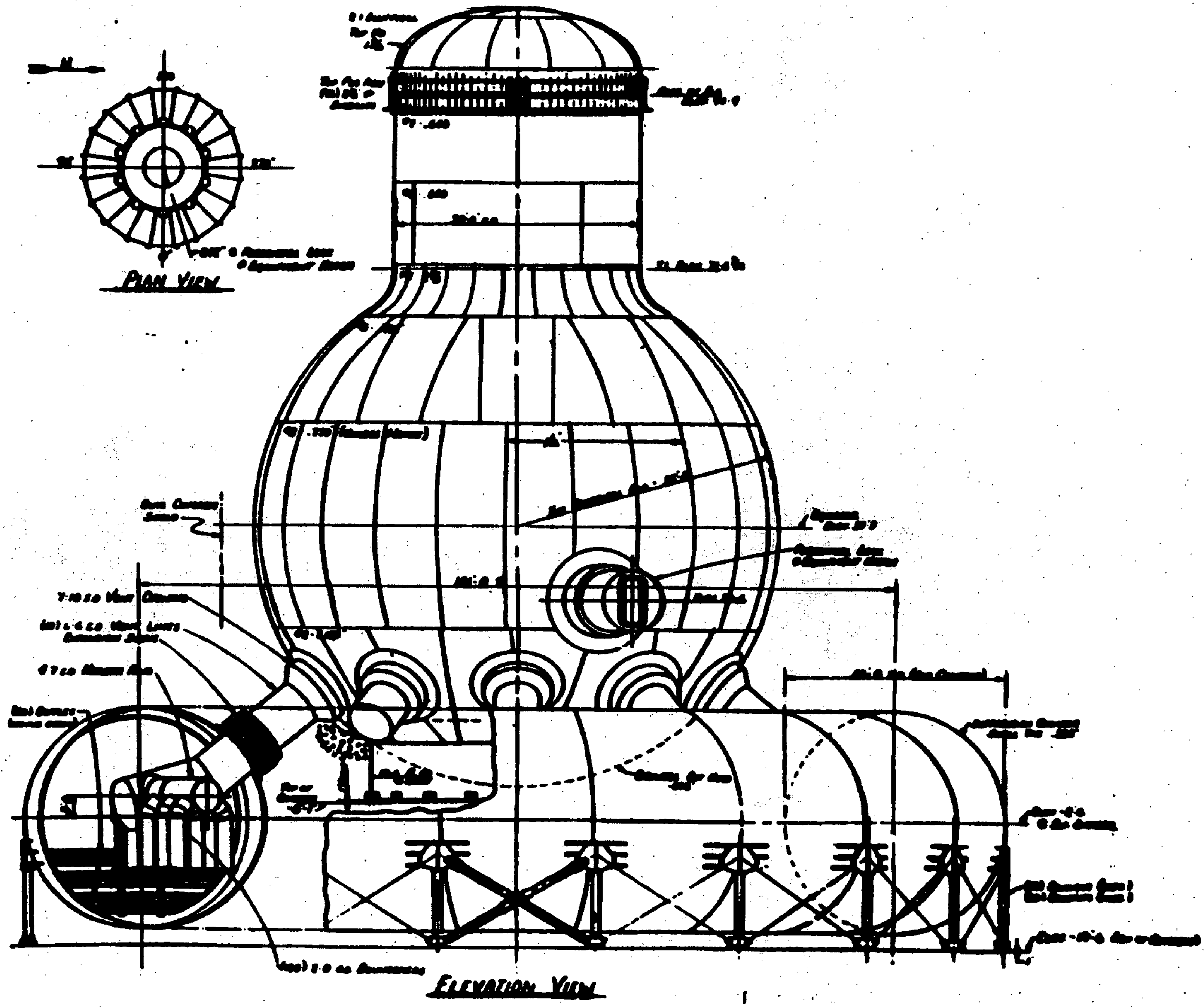


Figure 1. Oyster Creek Mark I Containment

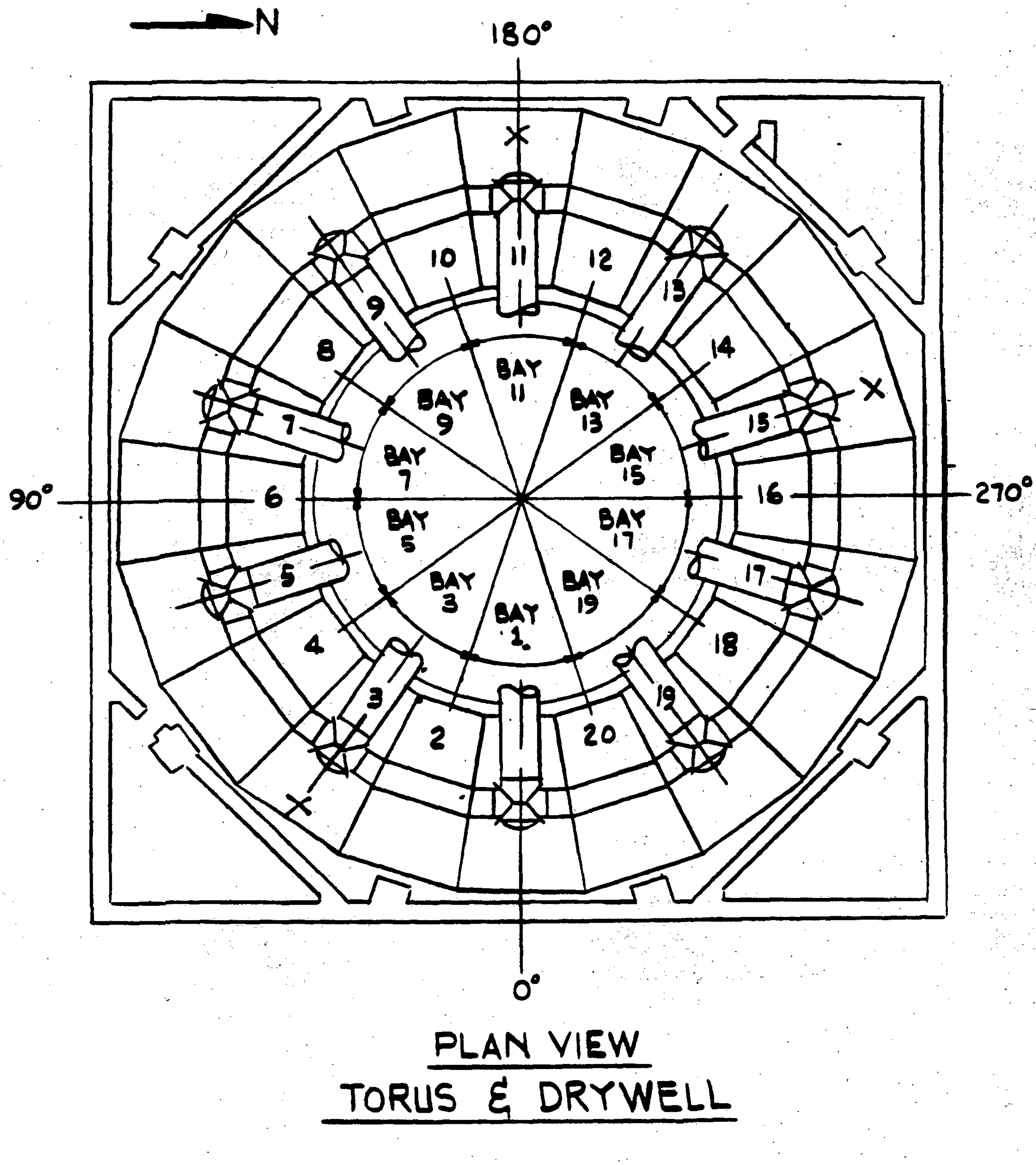


Figure 2. Location of Bays in Oyster Creek Torus and Drywell.
X=Sites of water on Torus floor.

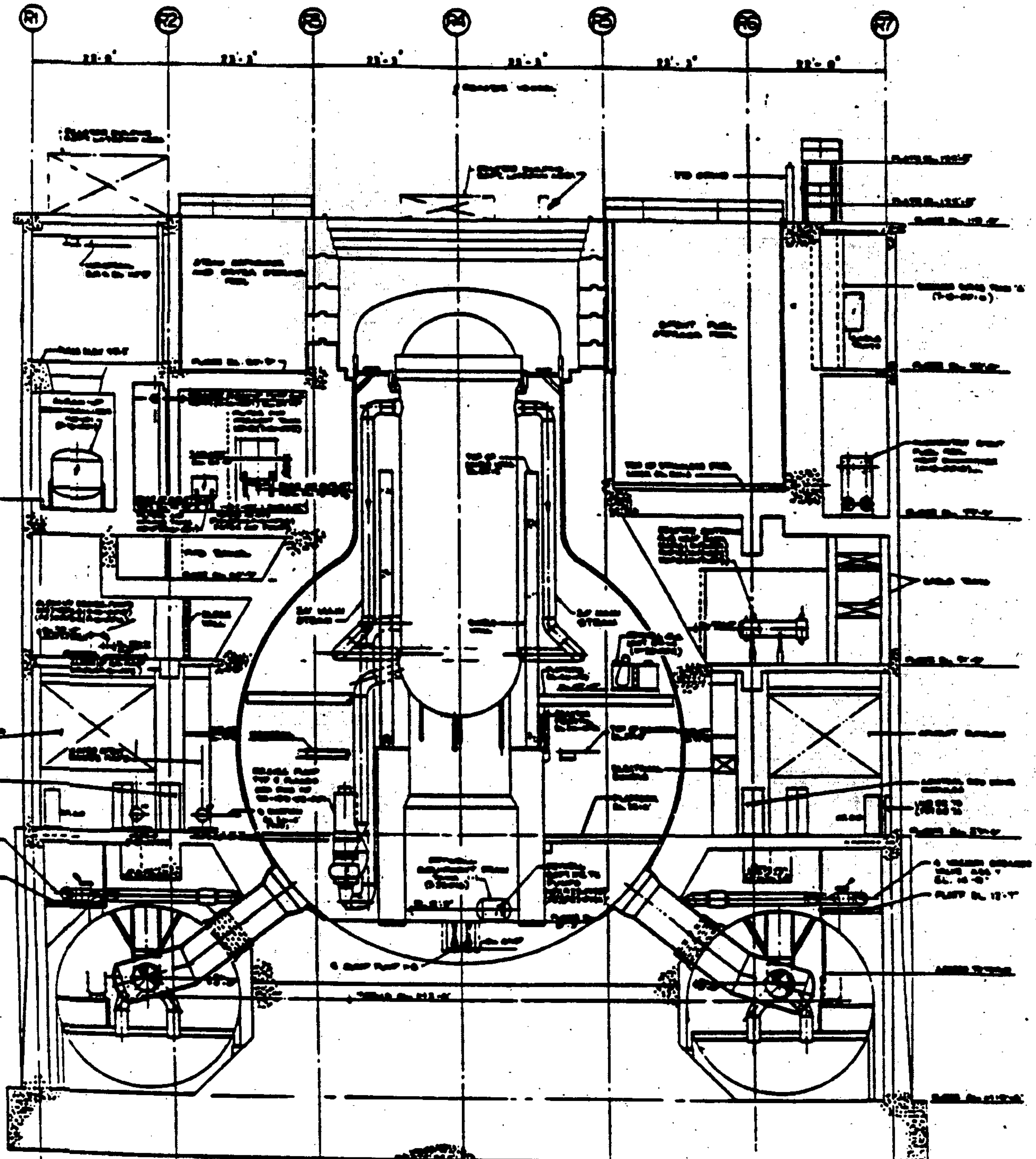


Figure 3. Primary Containment Geometry of Oyster Creek

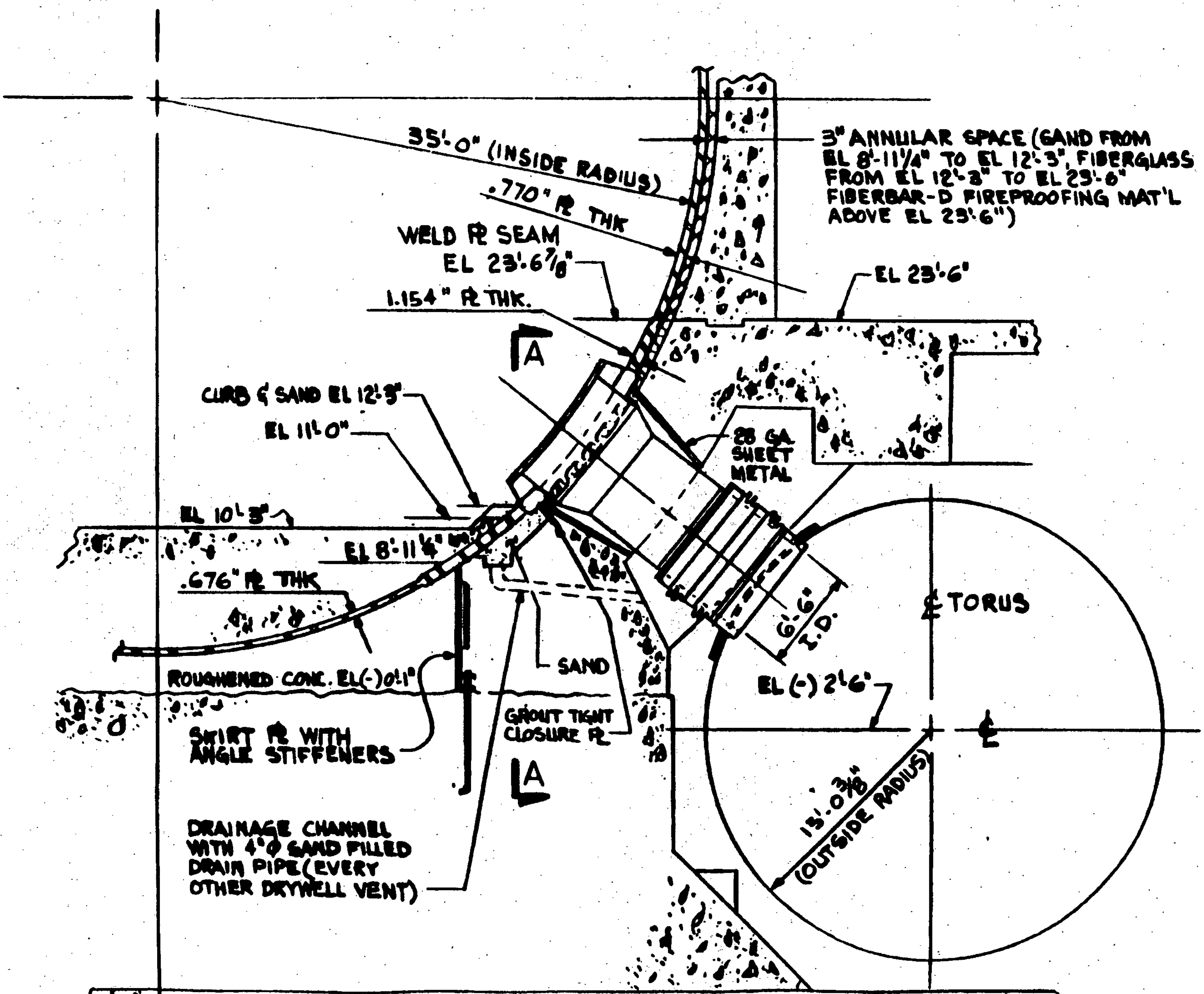


FIGURE 4. PARTIAL CROSS SECTION OF DRYWELL & TORUS

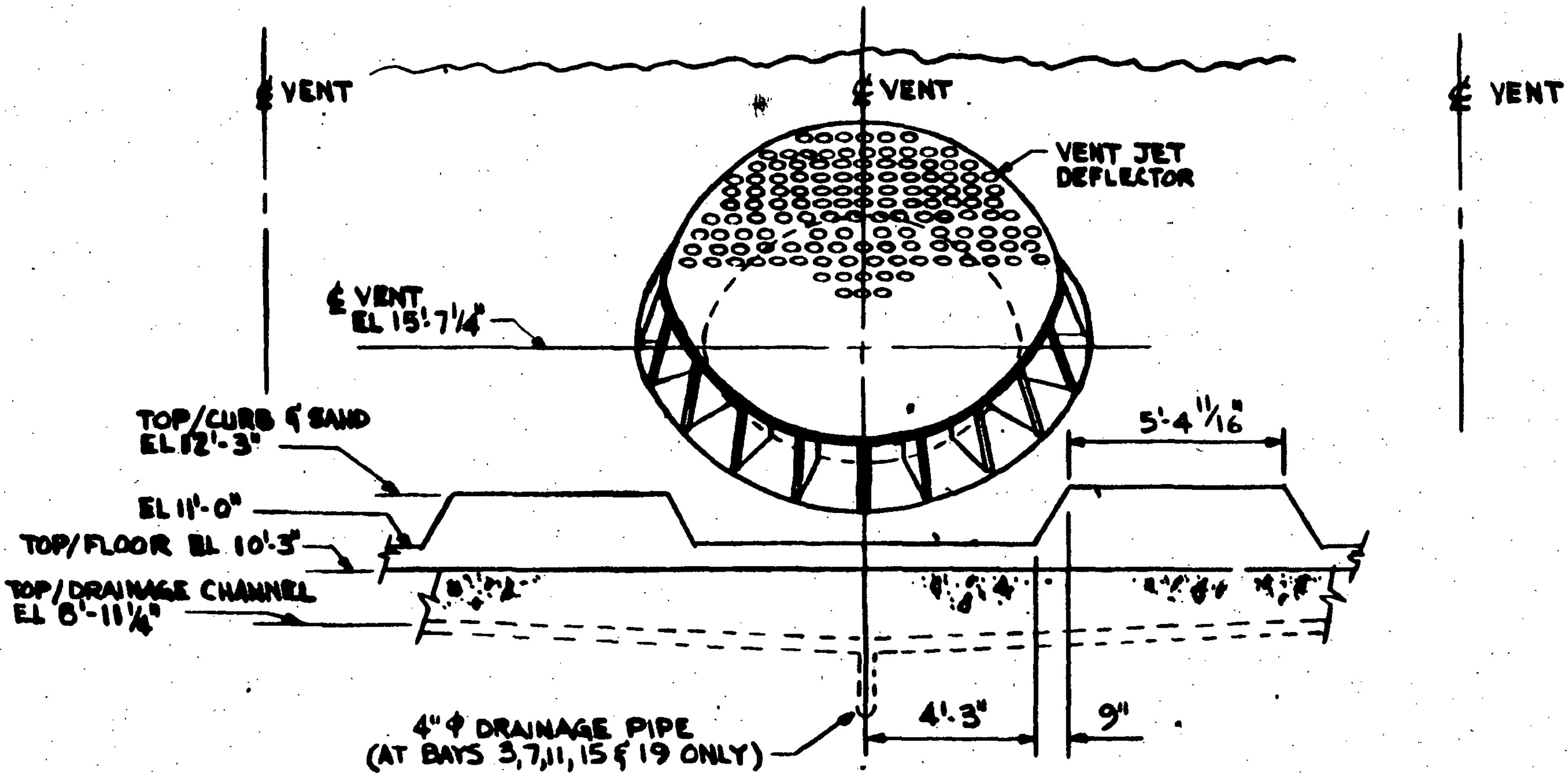


FIGURE 5. SECTION A-A AT VENT

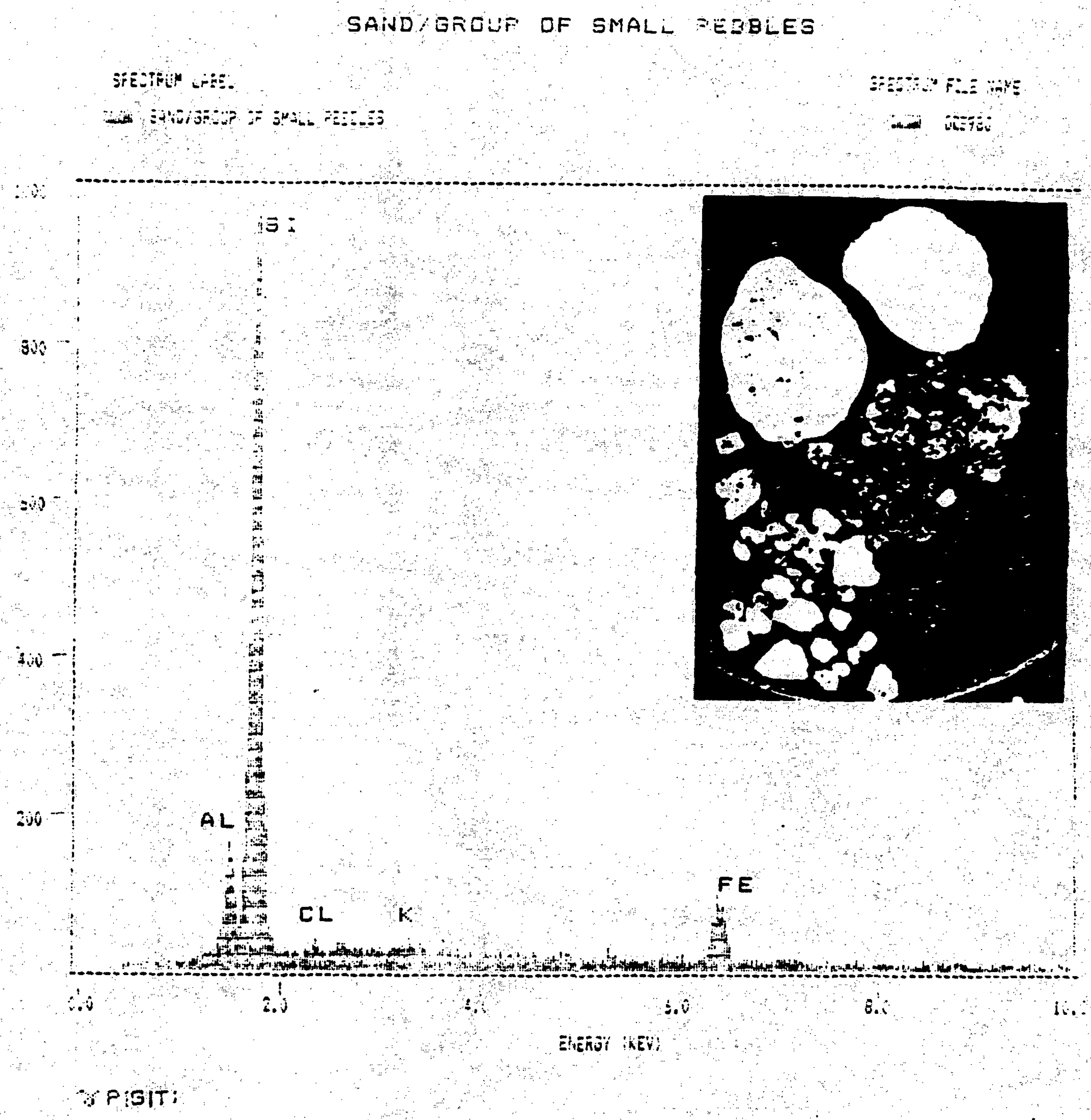


Figure 6. Photo shows distribution and type of sand particles. Spectra shows basic elemental composition. (GPUN)

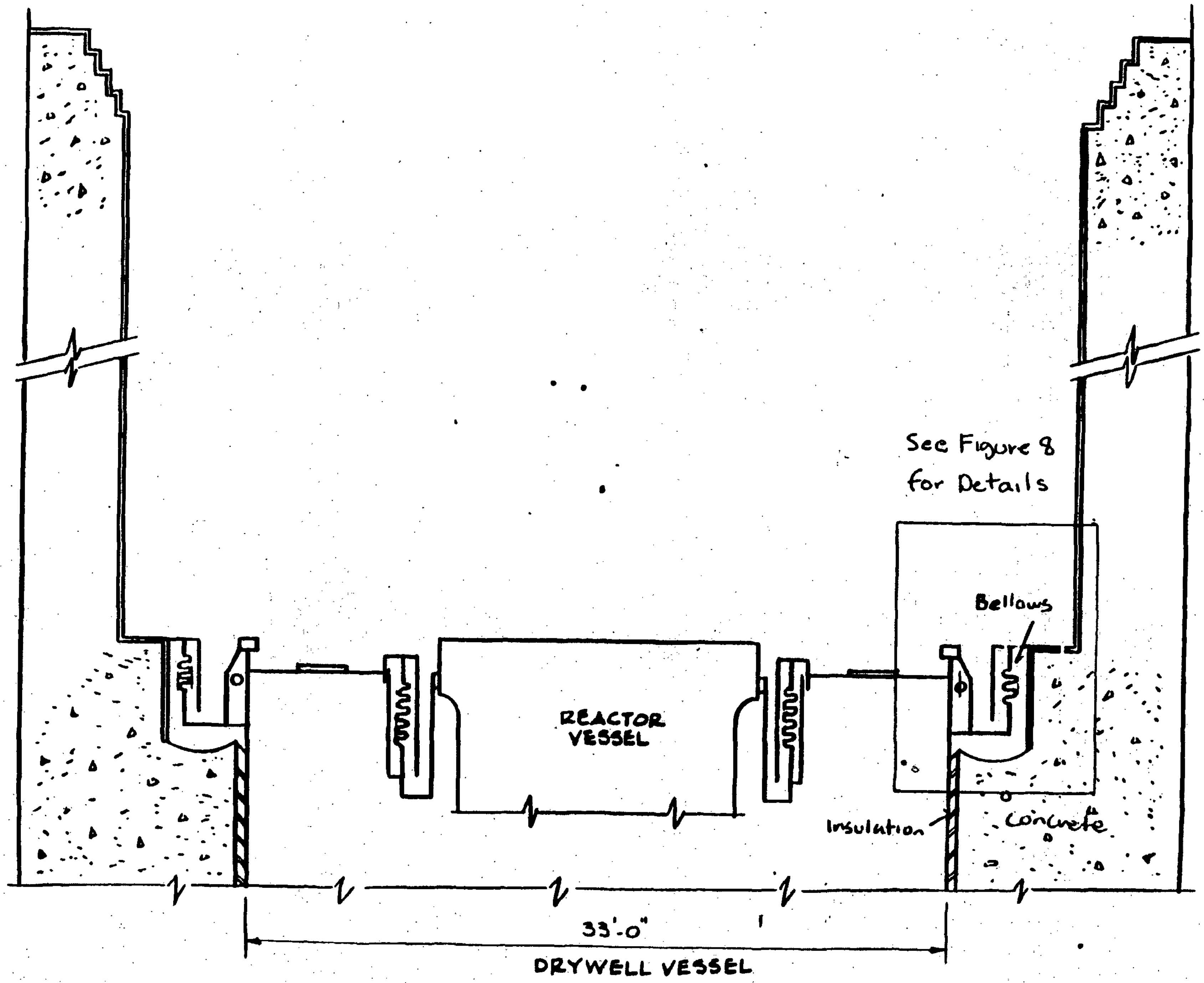


Figure 7. Top of Reactor Vessel. Note location of bellows, insulation and concrete.

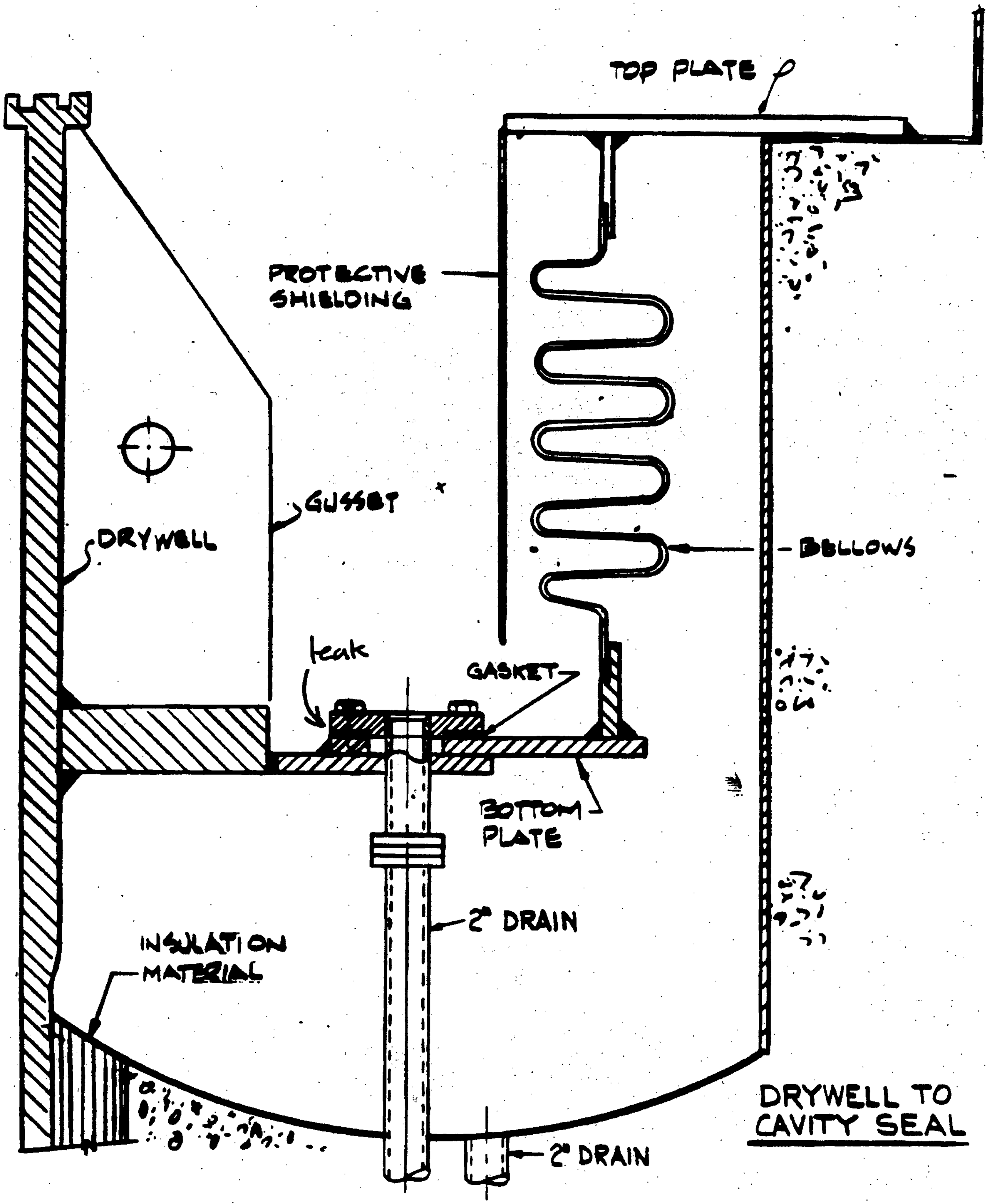


Figure 8. Close-up view of bellows and location of the two 2" drain lines.

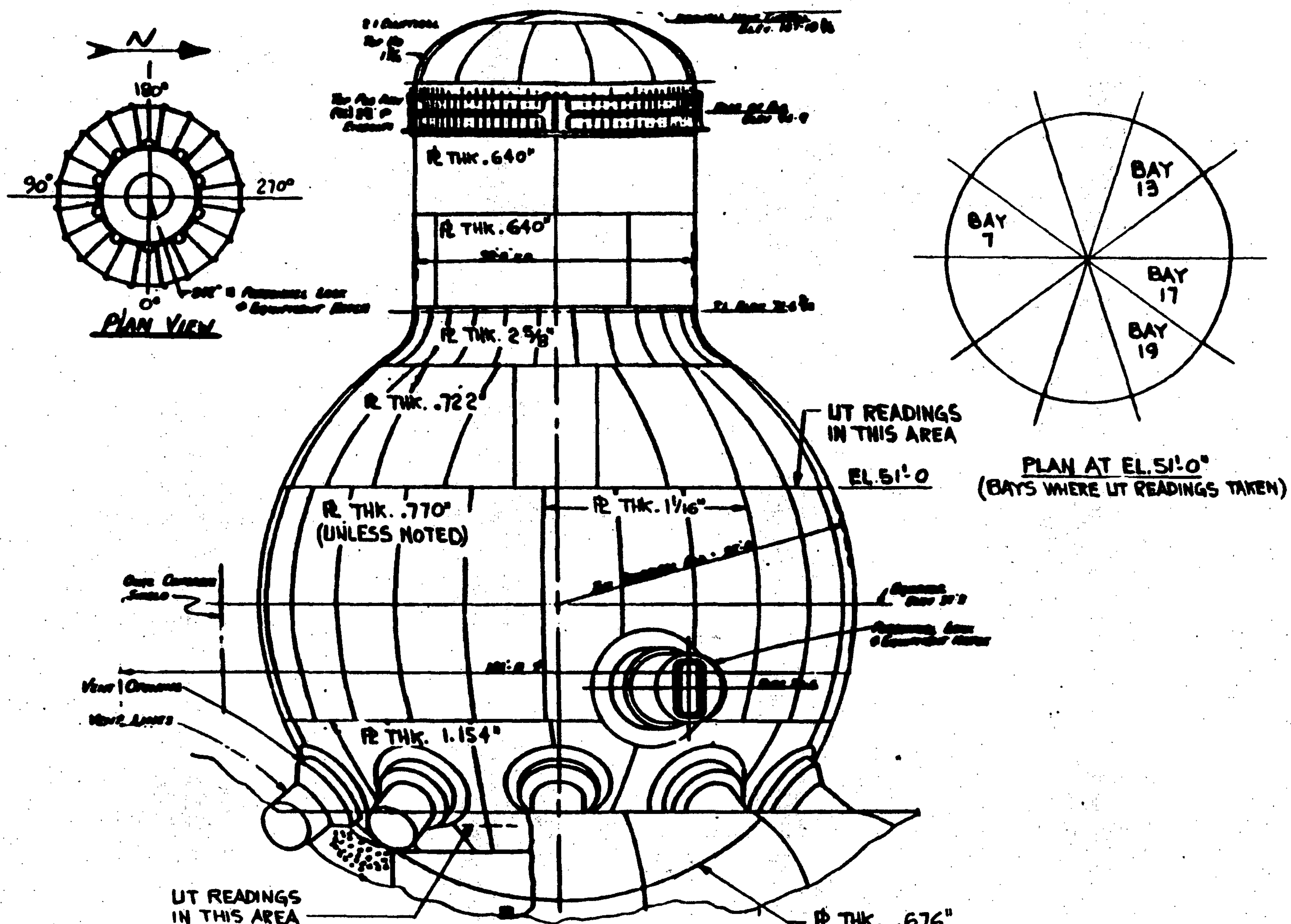
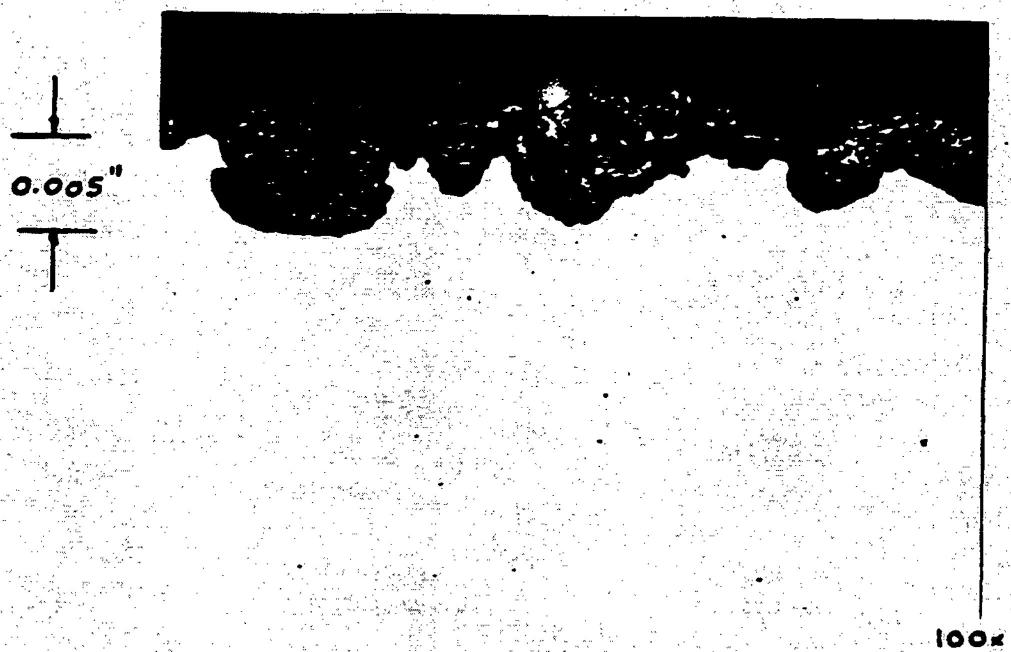
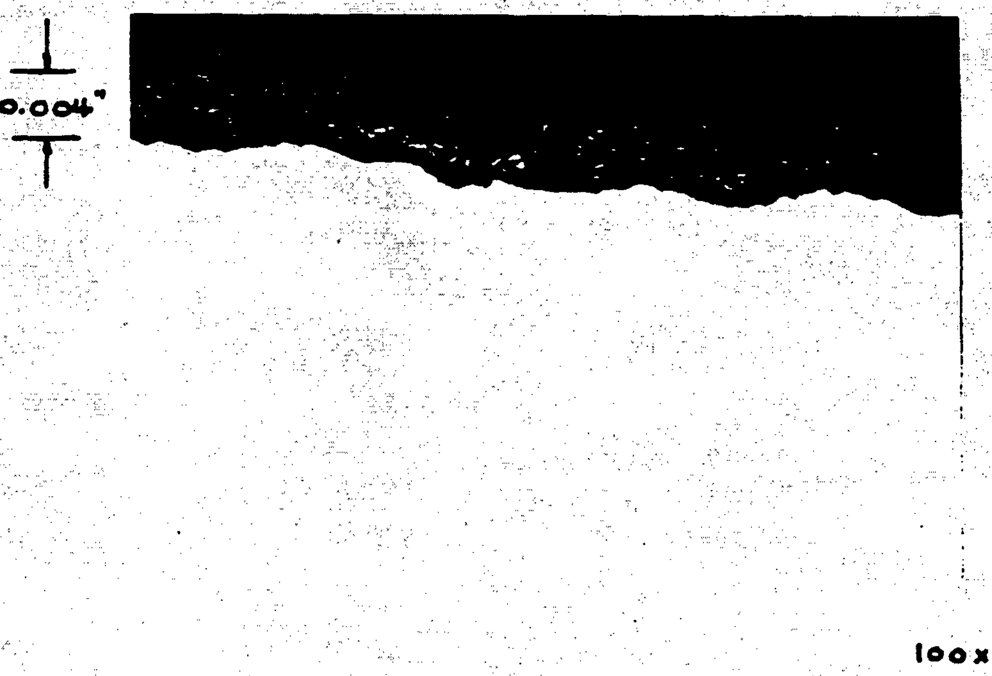


Figure 9. Location of UT measurements.

FIGURE 10. CROSS-SECTION VIEWS OF DRYWELL WALL CONDITIONS



PLUG 15A
(PITTING)

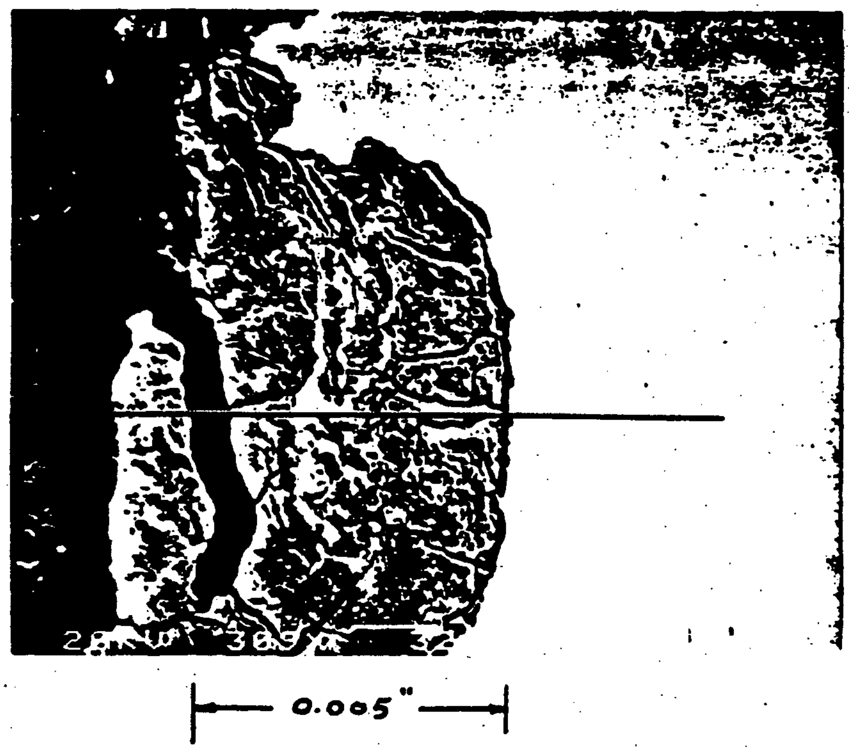


PLUG 19C
(UNIFORM CORROSION)

FIGURE 11.

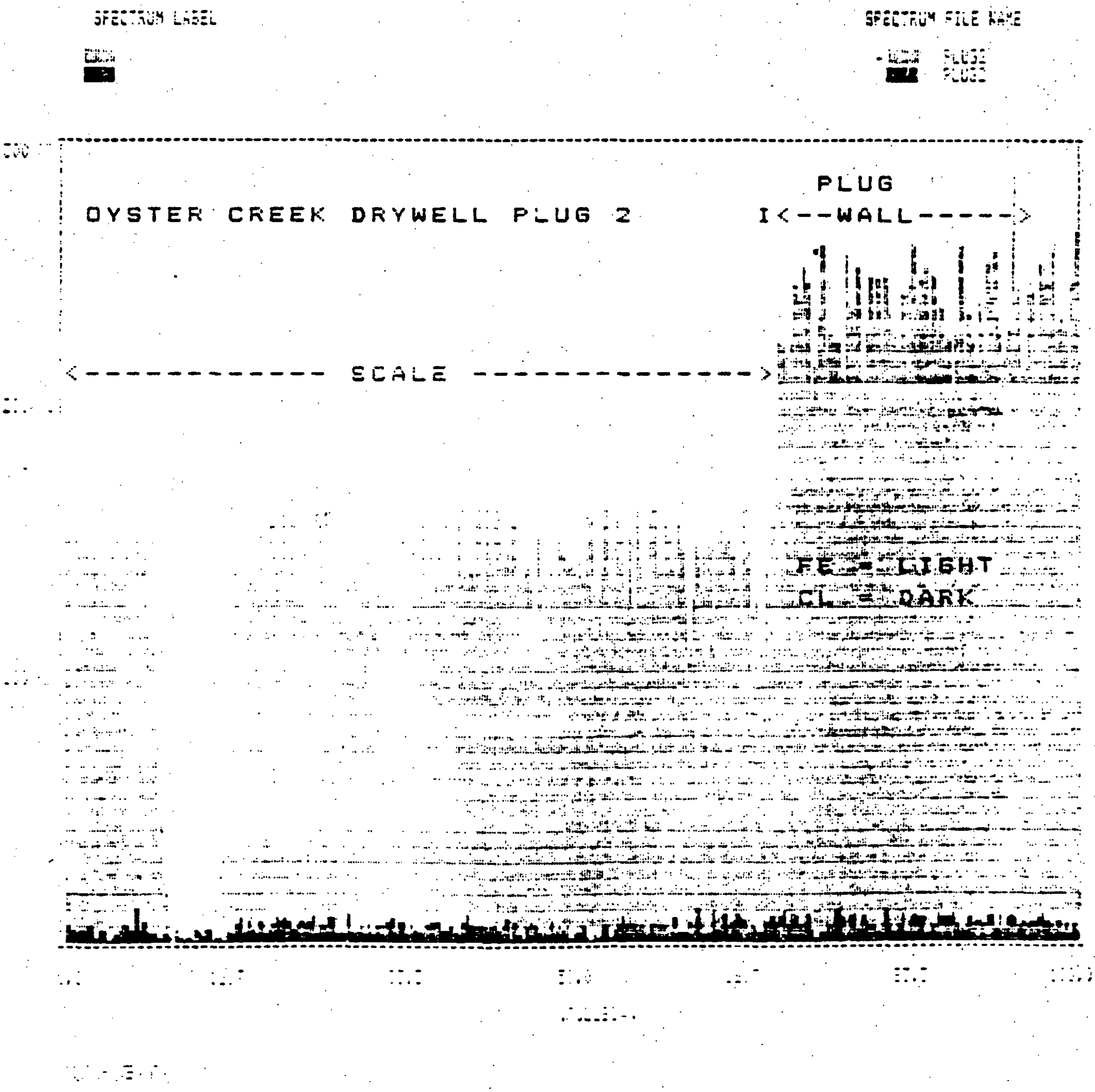
PLUG 15A
SCALE CHARACTERIZATION
MAGNIFICATION =309x

OXIDE SCALE DRYWELL WALL



LINE REPRESENTS ENERGY
DISPERSION LINE PROFILE
LOCATION.

FIGURE 12. OYSTER CREEK DRYWELL PLUG 2 (15A)



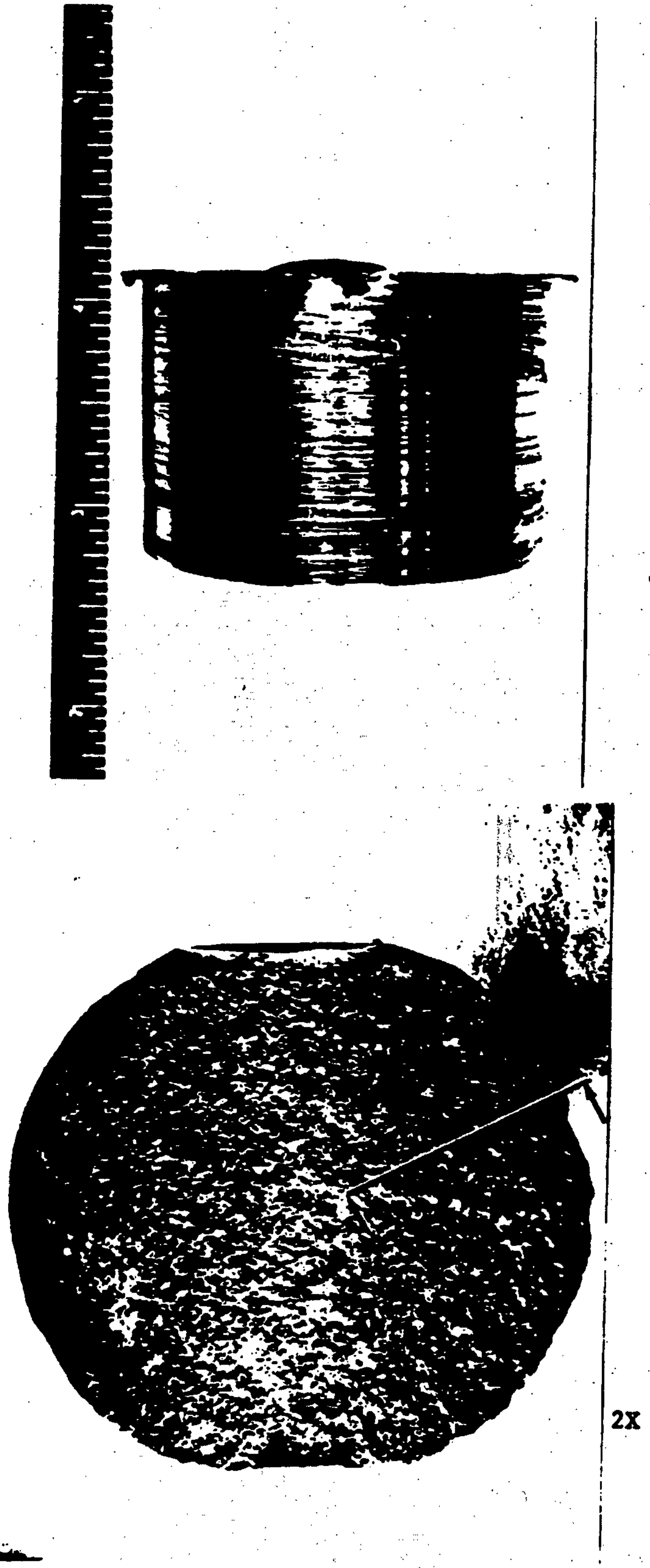


Figure 13. Plug 15A outside surface of drywell.
Uniform red brown corrosion product.

Figure 14. Plug 15A Aluminide stringer at mid-wall.
Plane parallel to rolling direction.

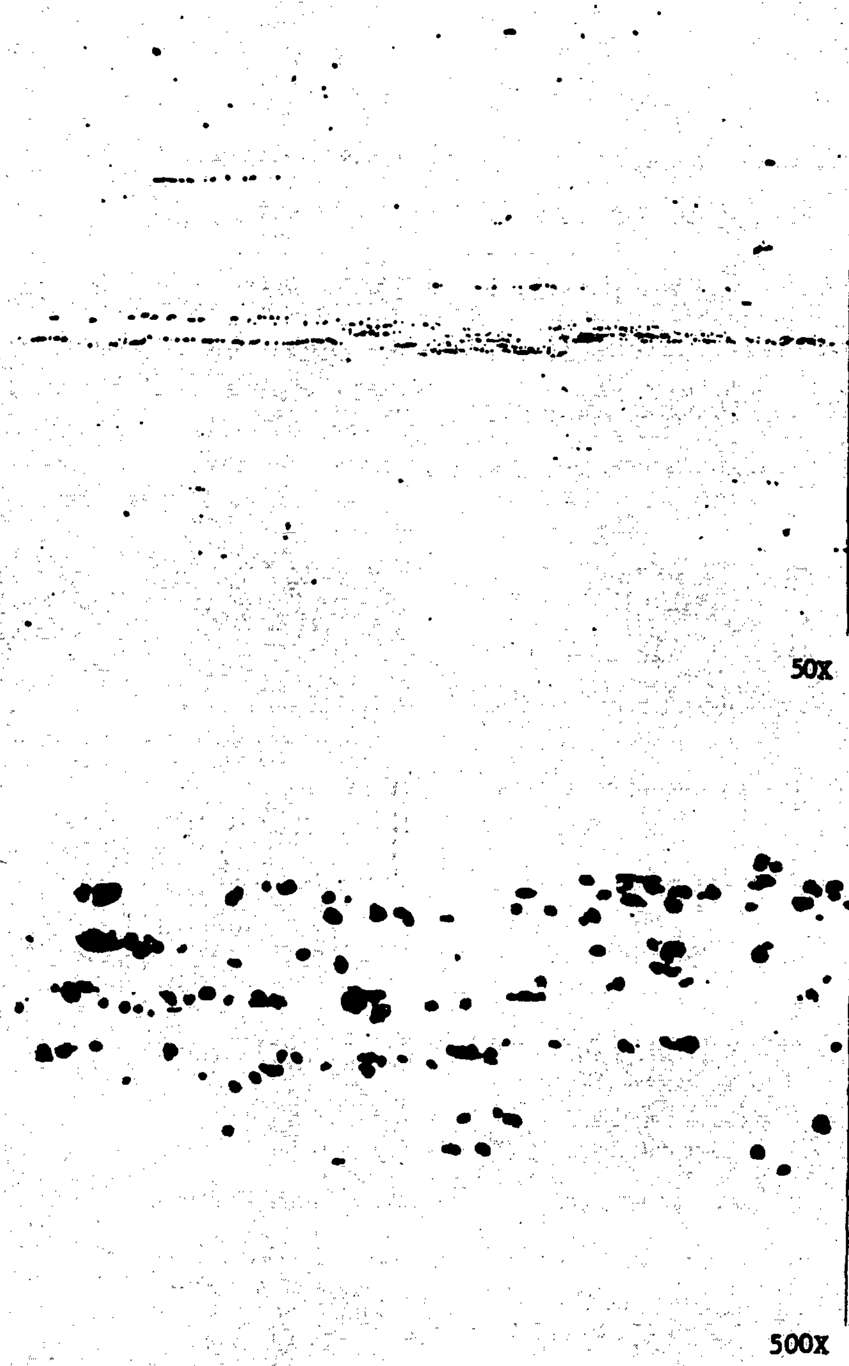
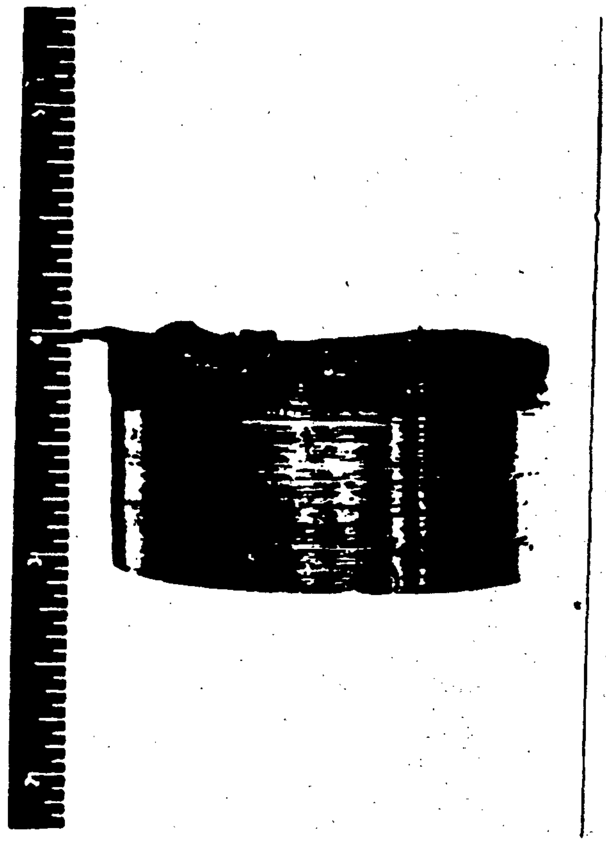


Figure 15. Plug 15A Aluminide Stringer at mid-wall.
Plane perpendicular to rolling direction.



Plug #1

Figure 16. Plug19C outer wall surface microplane is located

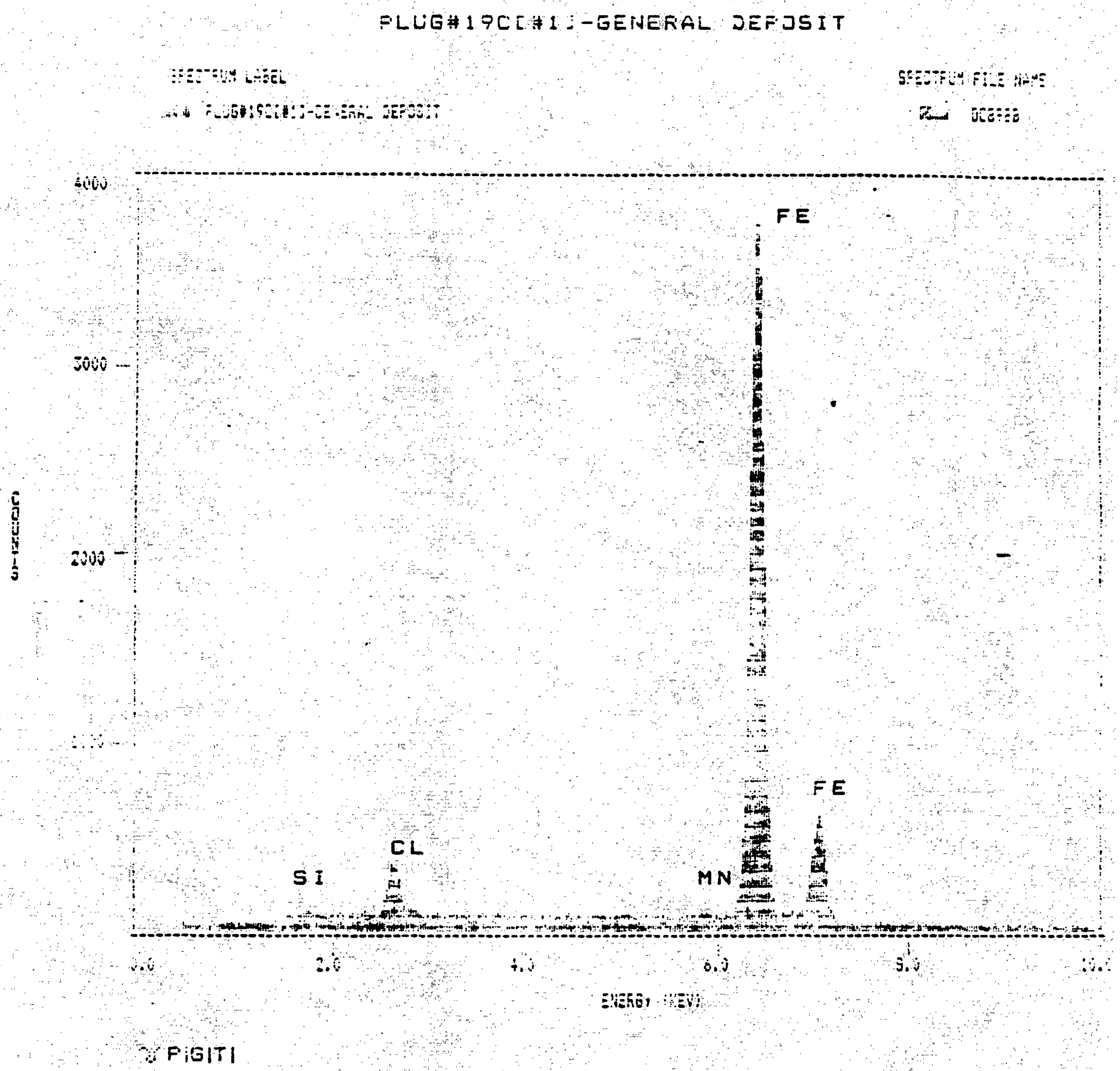
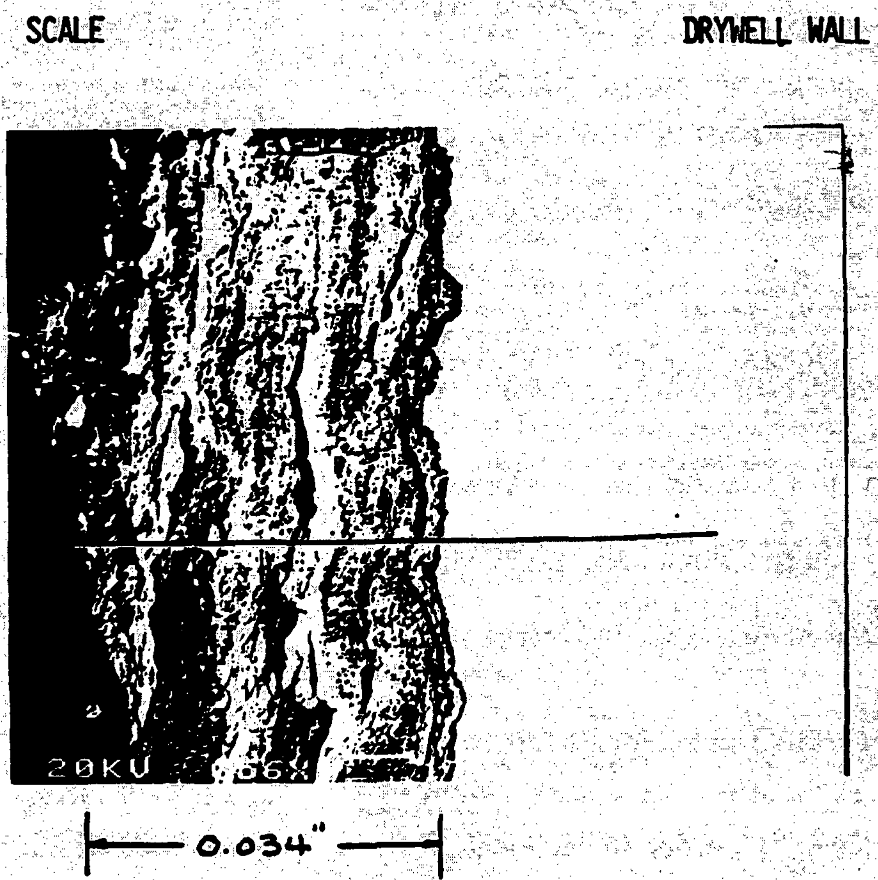


Figure 17. Typical elemental analysis of sample 19C corrosion product.

FIGURE 18. PLUG 19C
SCALE CHARACTERIZATION
MAGNIFICATION = 56X



LINE REPRESENTS ENERGY DISPERSION LINE PROFILE LOCATION.

Figure 19. OYSTER CREEK PLUG 1 (19C)

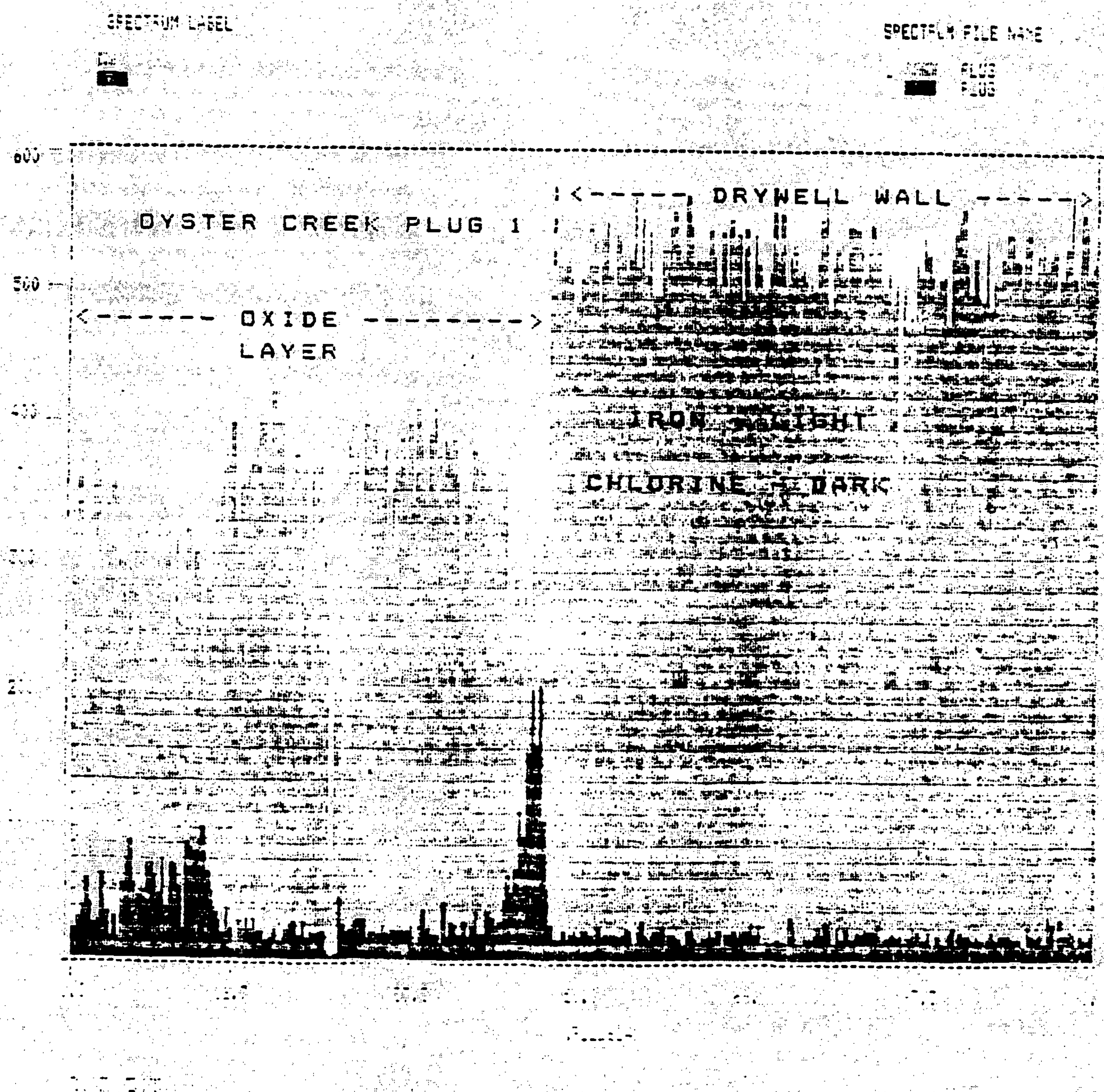


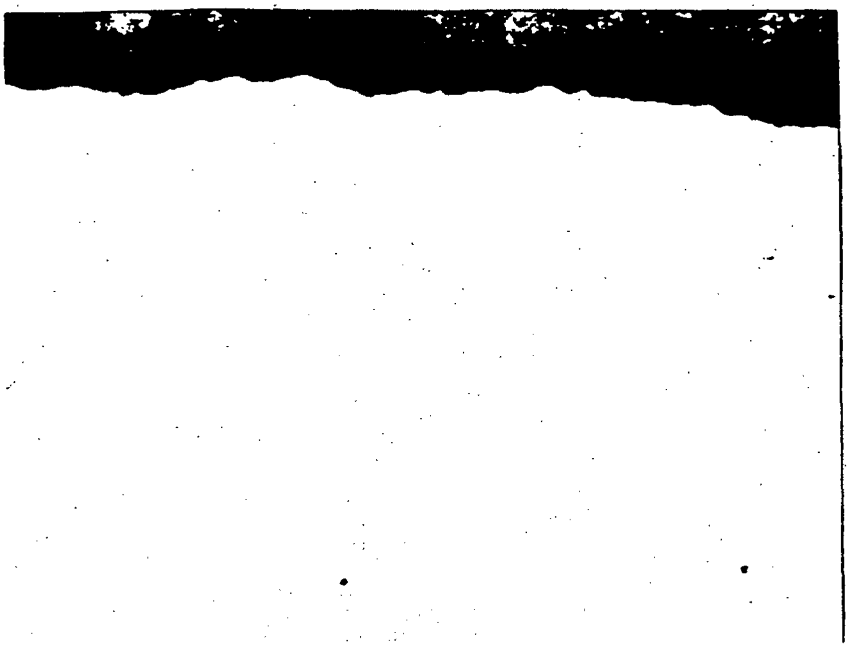
FIGURE 20. PLUG 19C
SCALE CHARACTERIZATION
MAGNIFICATION = 580X

SCALE | DRYWELL WALL

0.006"

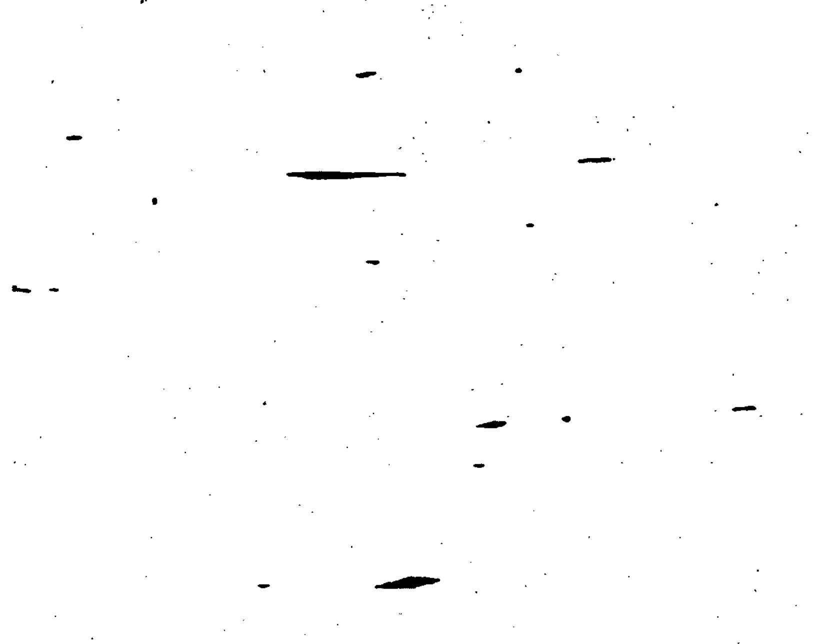
LINE REPRESENTS ENERGY DISPERSION LINE PROFILE LOCATION.

THE ARROW LOCATES A MANGANESE-SULFIDE INCLUSION WITHIN THE SCALE LAYER.



100X

O.D. surface; Plug #1



200X

Figure 21. MnS inclusions below surface.

SEM No. 1335

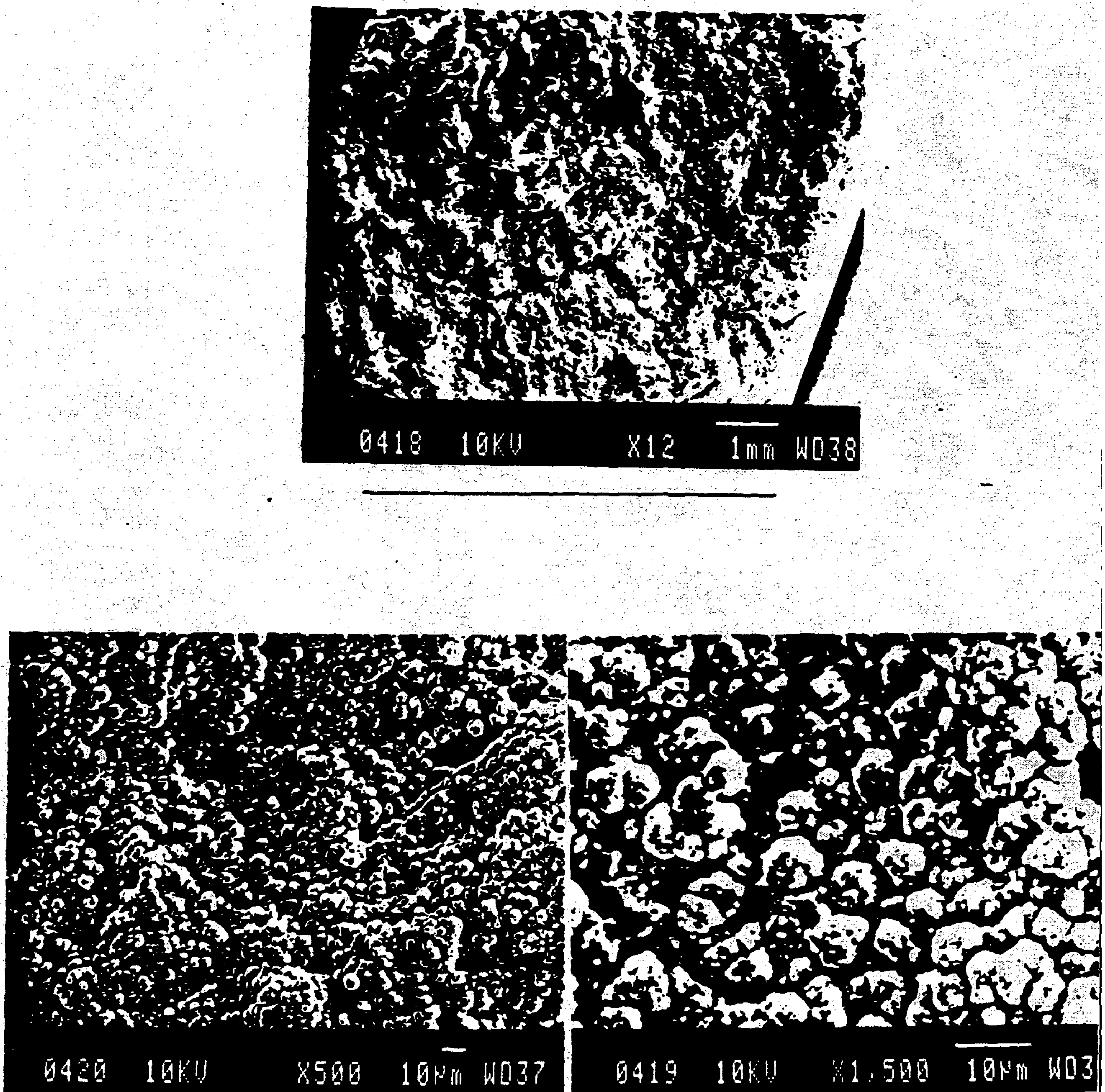
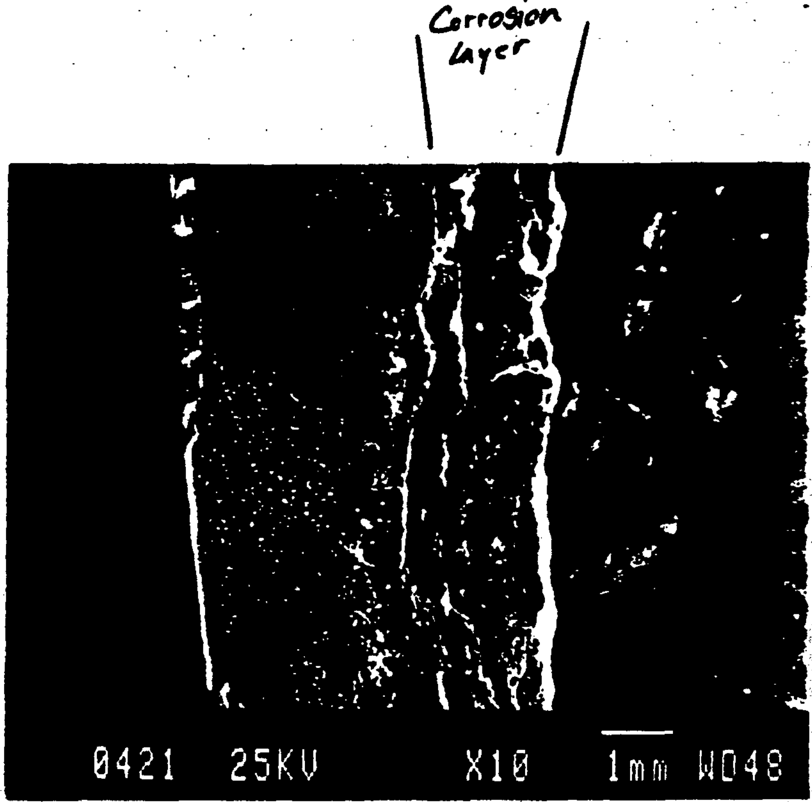


Fig. 22 Sample I.D. Core Plug Sample #3 (17D)
Corrosion Surface

Date

R.W. Warner

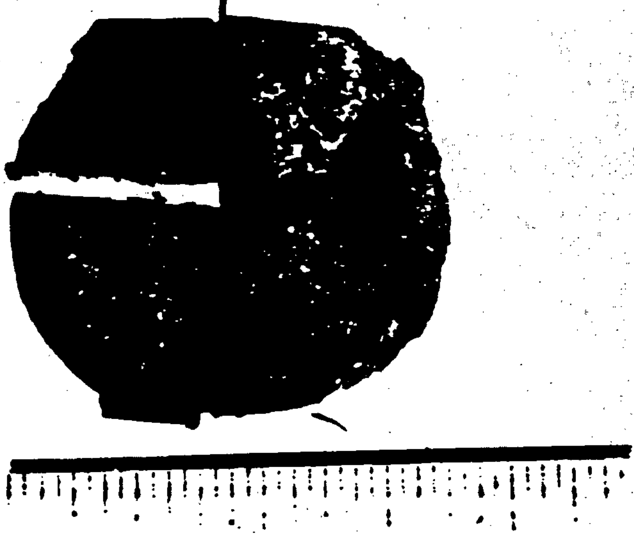
SEM No. 1335



typical cross-section

Fig. 23 Sample I.D. Oyster Creek Core Plug #3 (17D)

D. J. Warner



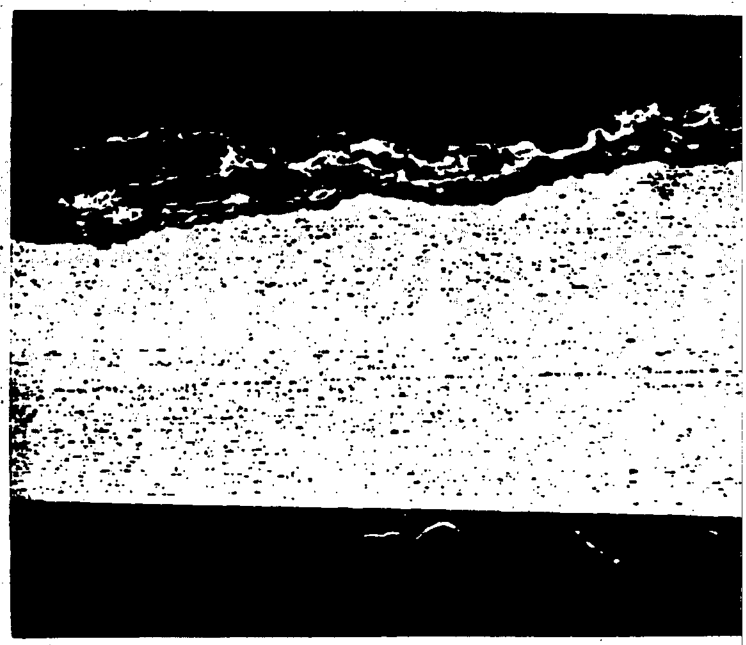


Fig. 24 BF☐ PL☐ ET☐ AP☐ Mag. ______ Fig. ______ BF☑ PL☐ ET☑ AP☐ Mag. 8X

MACRO

86C-61

Fig.______ BF☑ PL☐ ET☐ AP☑ Mag. 33X

CORRODED FACE

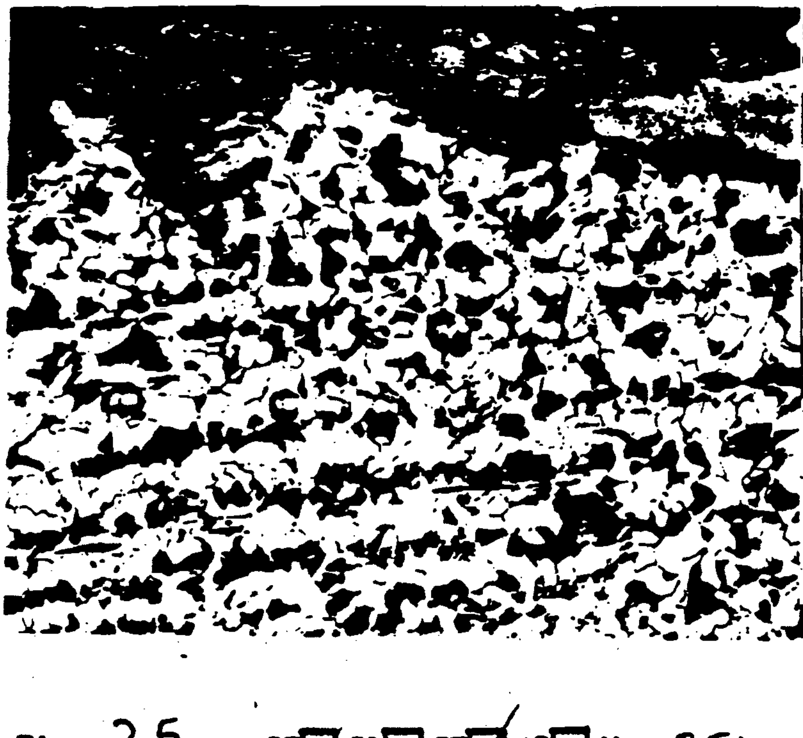


Fig. 25 BF☑ PL☐ ET☑ AP☐ Mag. 250

6C-61 CORRODED FACE

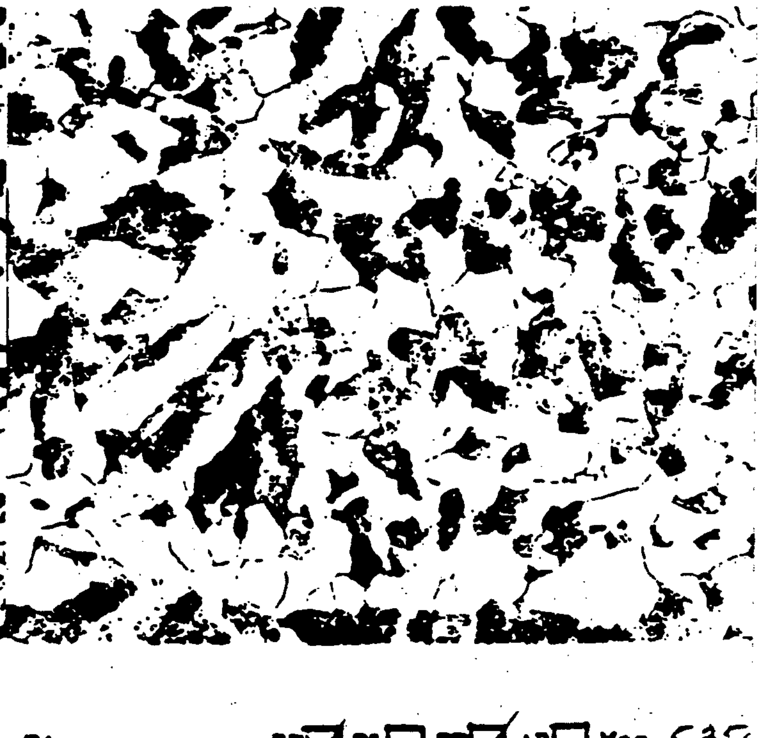
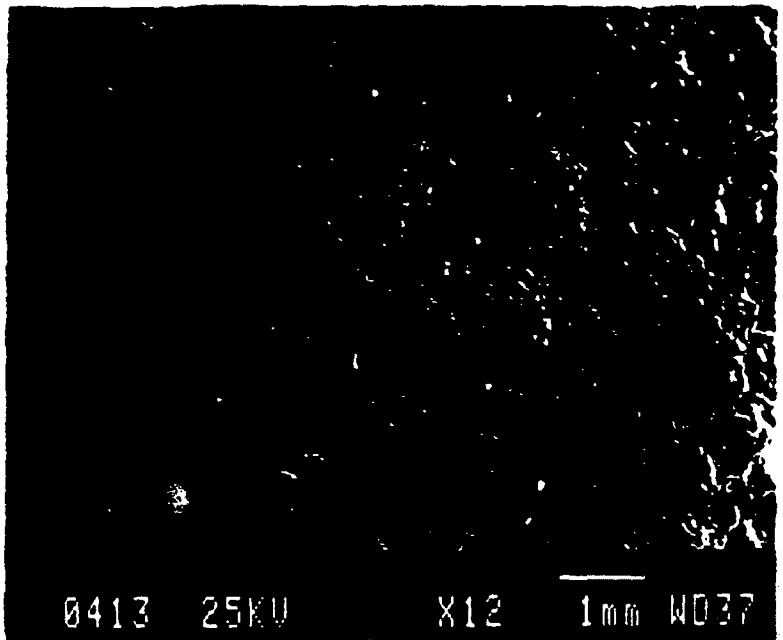


Fig.______ BF☑ PL☐ ET☑ AP☐ Mag. 525

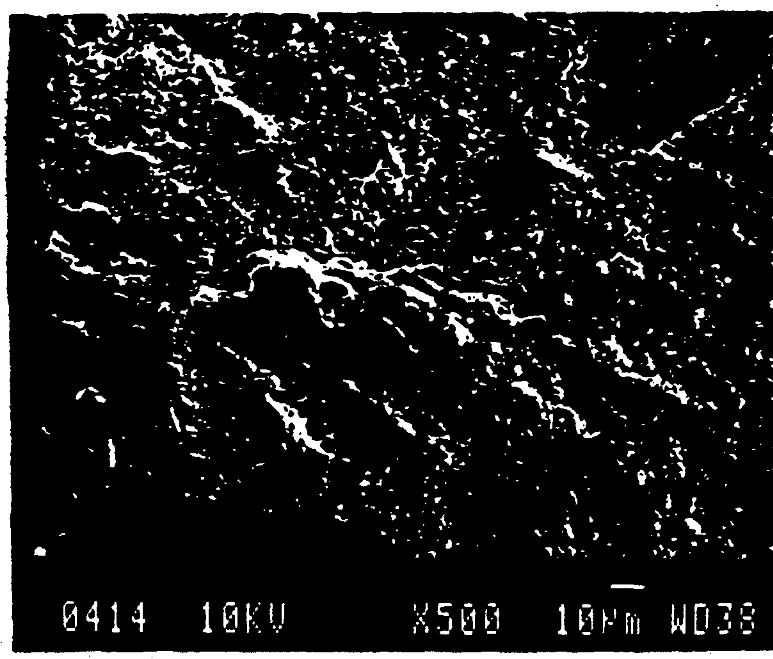
TYPICAL MICROSTRUCTURE

82(120)

SEM No. 1335



Typical region



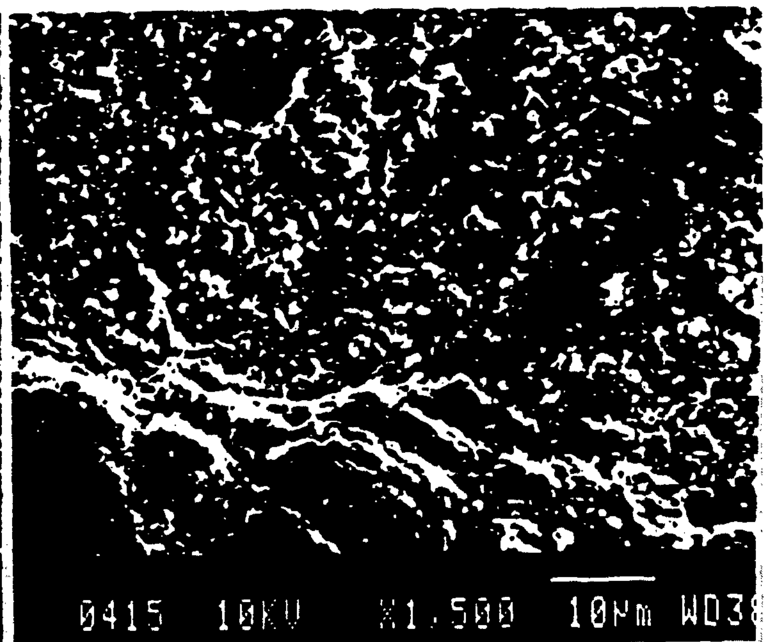
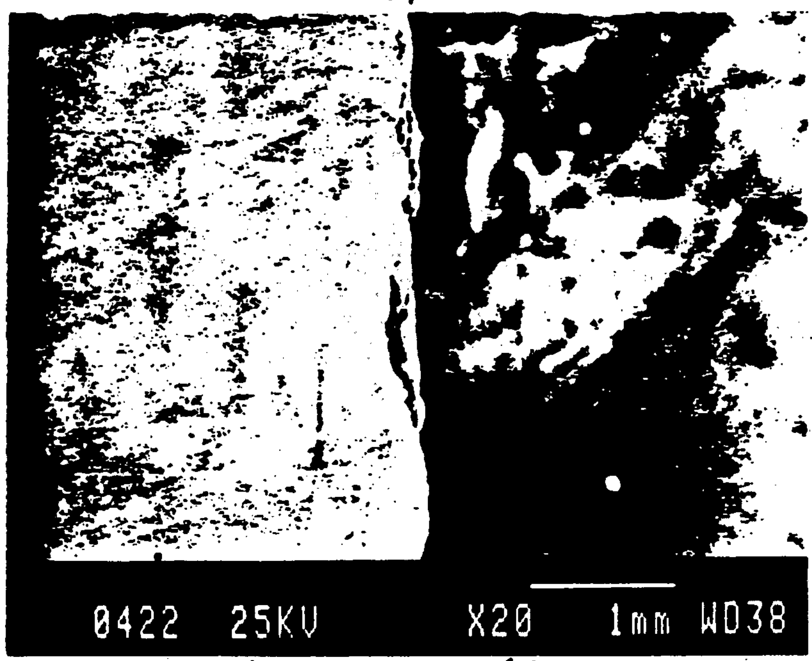


Fig. 26 Sample I.D. Core Plug Sample # 4 (19A)
Corrosion Surface

R.W. Warner

SEM No. 1335

Corrosion Layer



typical cross-section

Fig. 27 Sample I.D. Oyster Creek Core Plug #4 (19A)

R. W. Warner

86C-61

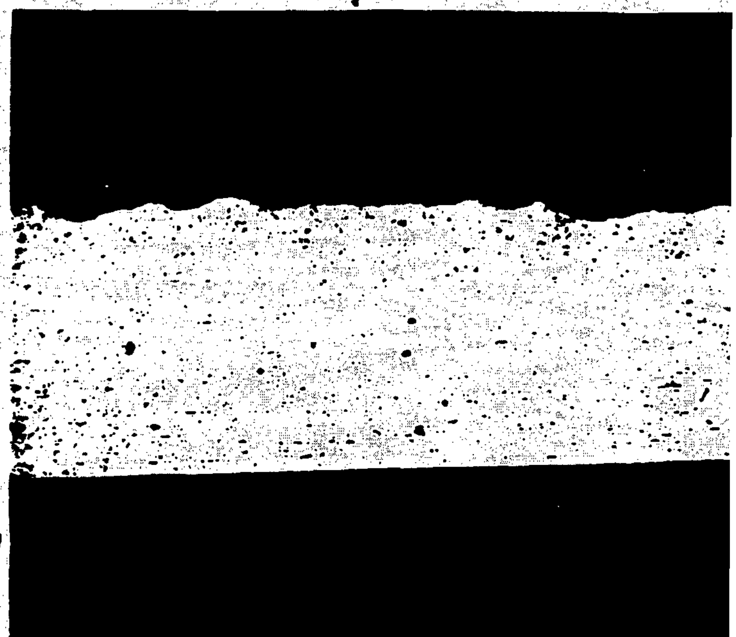


Fig. 28 BF☐ PL☐ ET☐ AP☐ Mag.______ Fig.______ BF☑ PL☐ ET☑ AP☐ Mag. 8X

MACRO

6C-62 OYSTER CREEK DRYWELL LINER- PLUG #4 (19A)

86C-61

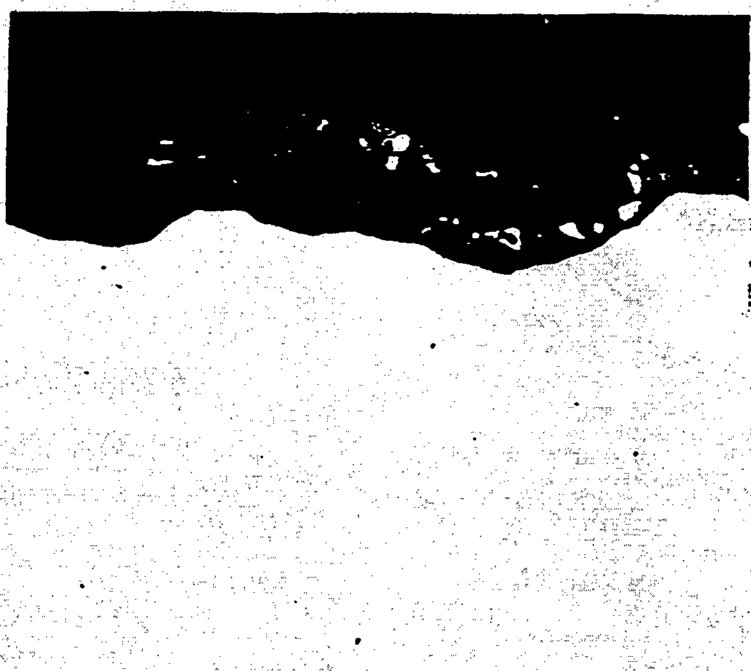
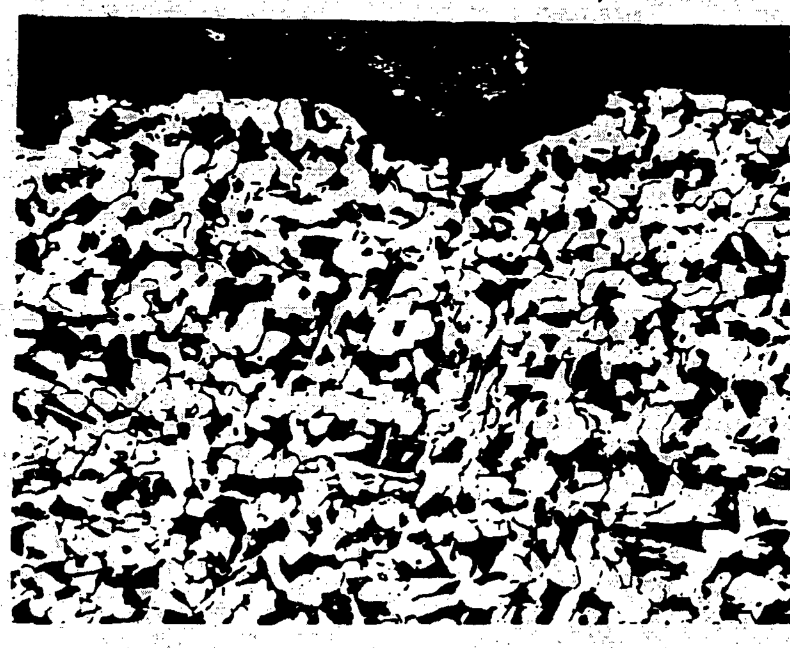


Fig. ______ BF ☑ PL ☐ ET ☐ AF ☑ Mag 33X   Fig. ______ BF ☑ PL ☐ ET ☐ AF ☑ Mag 125X

CORRODED FACE



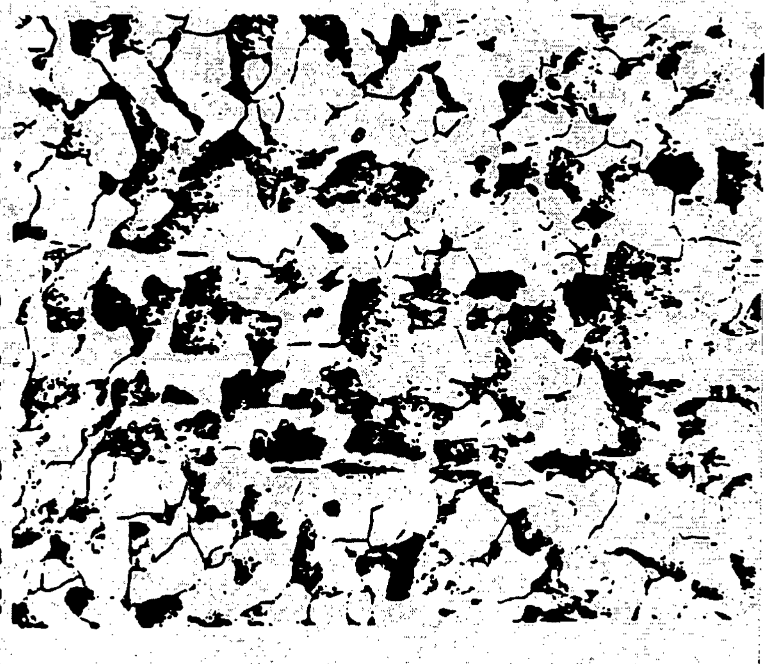
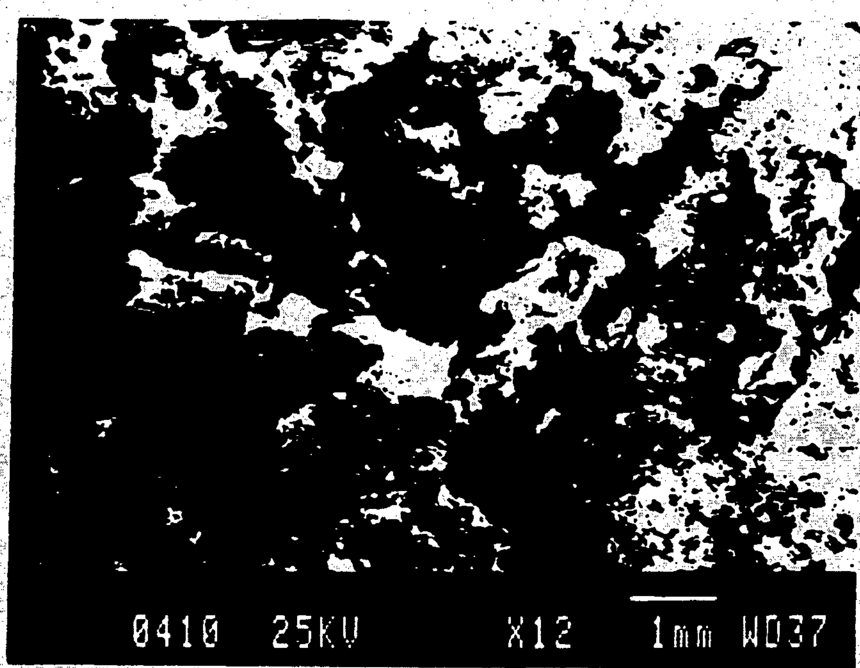


Fig. 29 BF ☑ PL ☐ ET ☑ AF ☐ Mag. 250X   Fig ______ BF ☑ PL ☐ ET ☑ AF ☐ Mag 525X

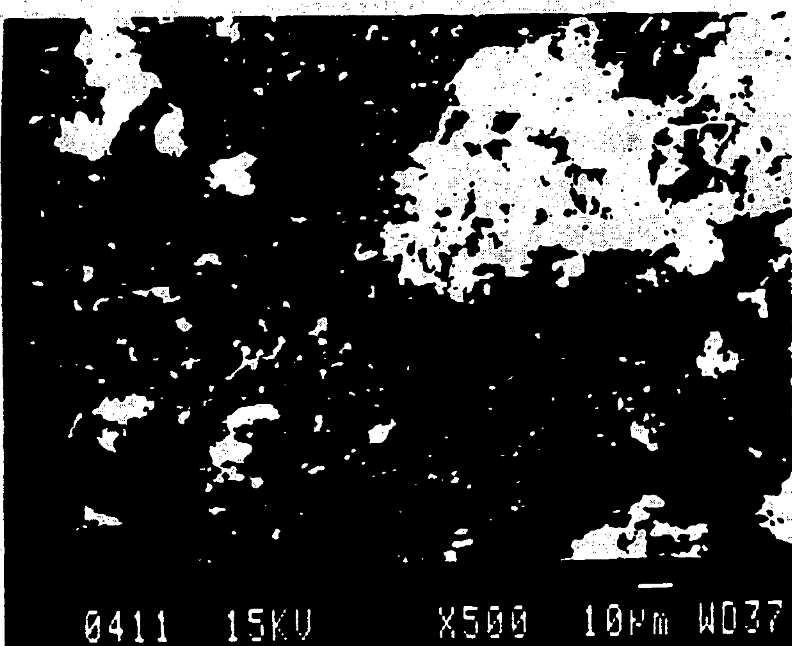
CORRODED FACE   TYPICAL MICROSTRUCTURE

[illegible] #4(19A)

SEM No. 1335



Typical region



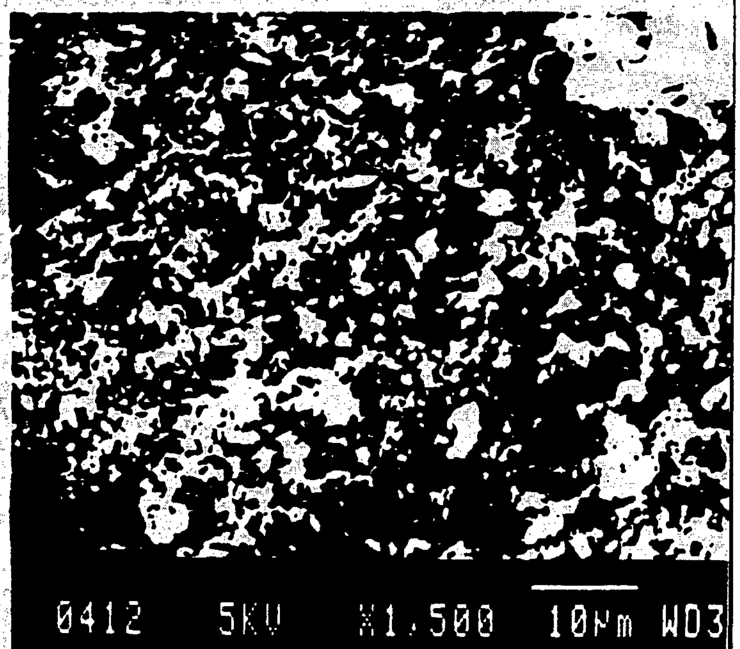
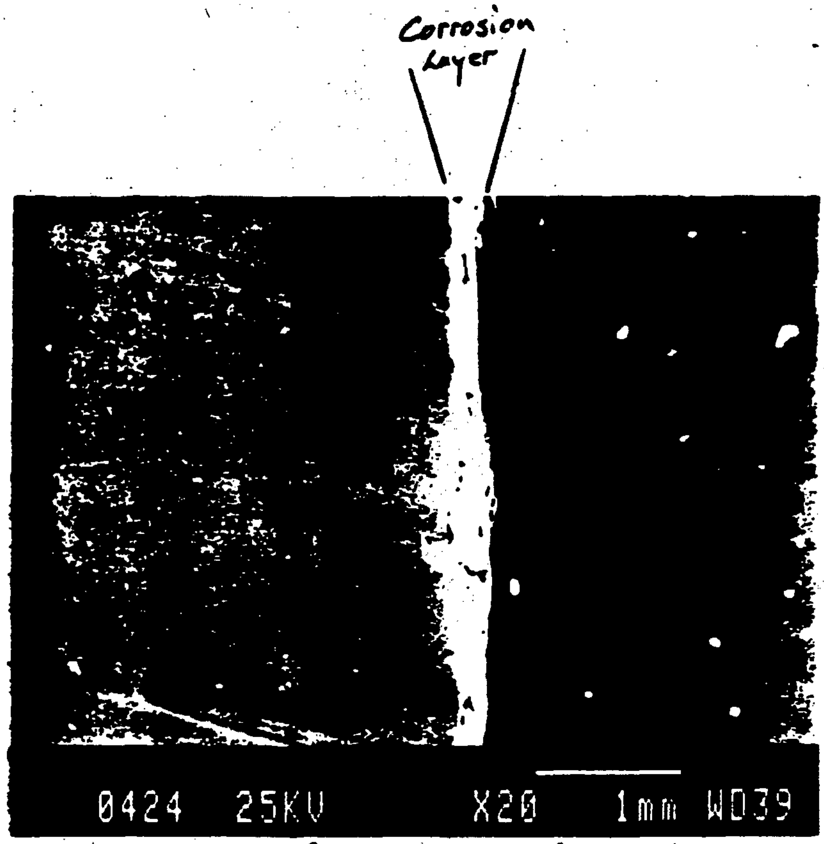


Fig. 30 Sample I.D. Core Sample #6 (11A-H)
Plug Corrosion Surface

R. W. Warner

SEM No. 1335

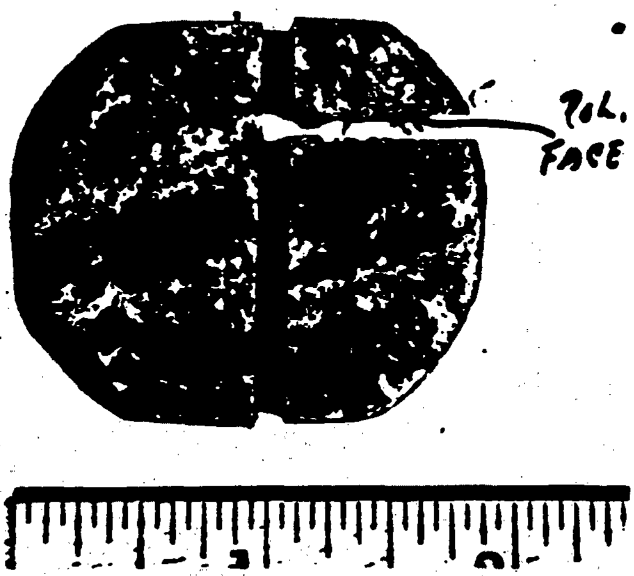


typical cross-section

Fig. 31 Sample I.D. Oyster Creek Core Plug #6 (11A-H)

R. W. Warner

86C-61



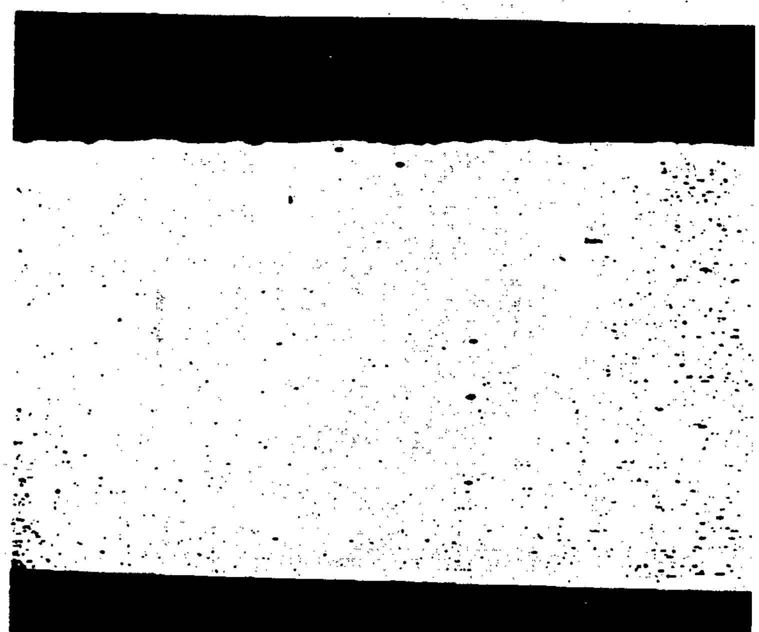


Fig. 32 BF☐ PL☐ ET☐ AP☐ Mag.______ Fig.______ BF☑ PL☐ ET☑ AP☐ Mag. 8X

MACRO

6C-59 OYSTER CREEK DRYWELL LINER - PLUG 6

86C-61

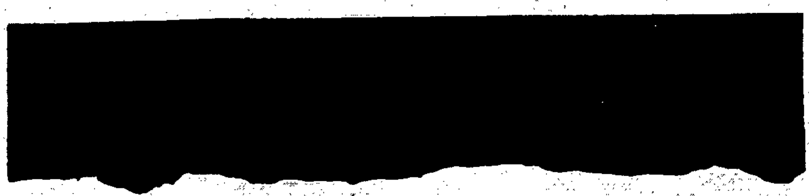


Fig. ________ BF ☑ PL ☐ ET ☐ AP ☑ Mag. 33X

CORRODED FACE

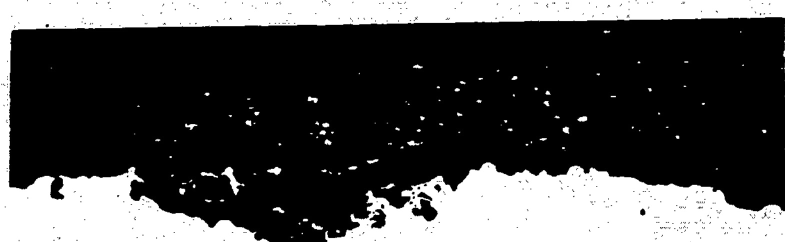


Fig. 33 BF ☑ PL ☐ ET ☐ AP ☑ Mag. 125X

6C-59 CORRODED FACE

Fig. ________ BF ☑ PL ☐ ET ☐ AP ☑ Mag. 125

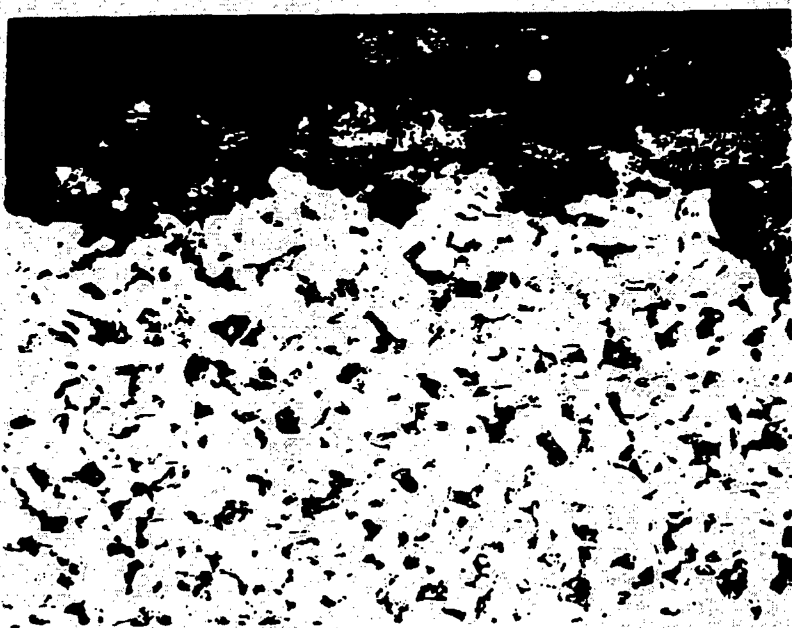


Fig. 34 BF☐ PL☐ ET☐ AP☐ Mag. 250X

CORRODED FACE

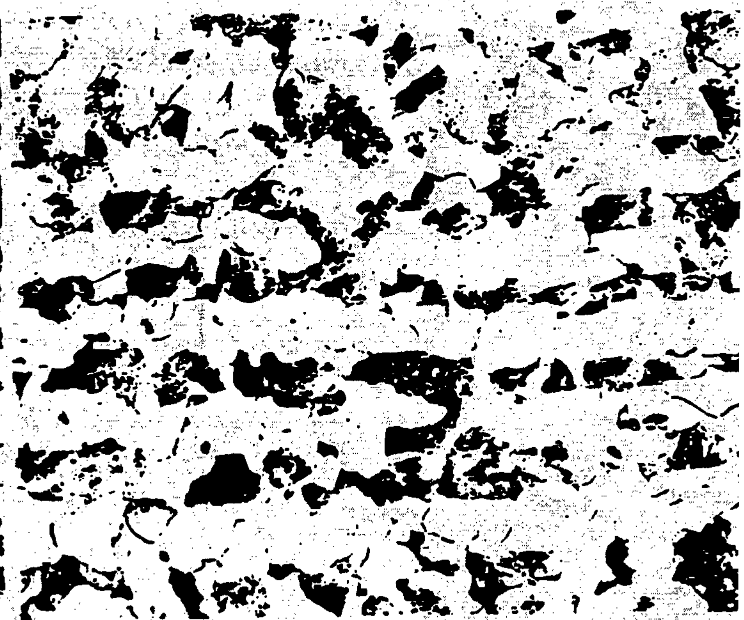


Fig. _____ BF☐ PL☐ ET☐ AP☐ Mag. 52

TYPICAL MICROSTRUCTURE

6C-59 OYSTER CREEK DRYWELL LINER - PLUG #6

FIGURE 35. CORROSION PRODUCTS OF IRON/STEEL WITHOUT CONTAMINANTS

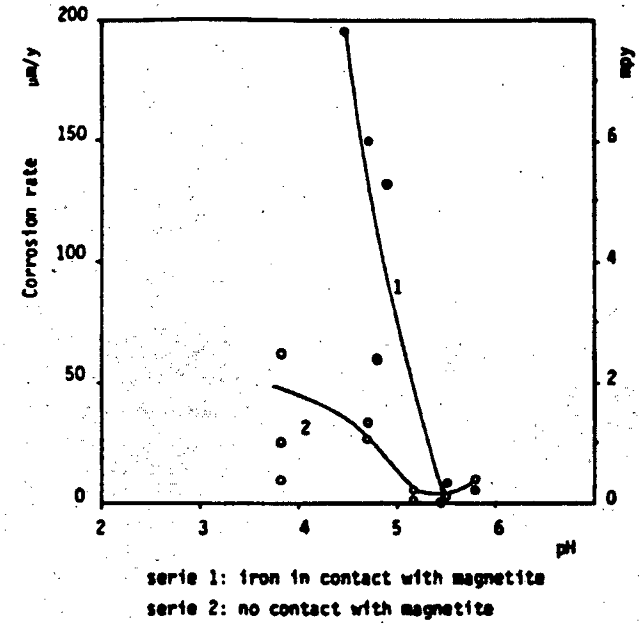
FE	$FeO \cdot nH_2O$ OR $Fe(OH)_2$	$Fe_3O_4 \cdot nH_2O$	Fe_2O_3 OR $Fe(OH)_3$

H_2 ... O_2

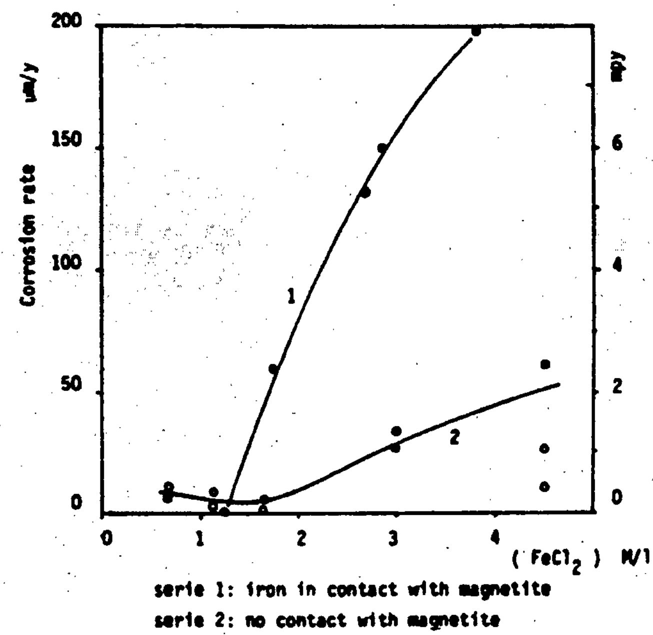
$$3Fe(OH)_2 \rightarrow Fe_3O_4 + 2H_2O + H_2$$

$$Fe(OH)_2 + 1/2\ H_2O + 1/4O_2 \rightarrow Fe(OH)_3$$

• HYDROUS FERROUS OXIDE	• HYDROUS FERROUS FERRITE	• HYDROUS FERRIC OXIDE
• FERROUS HYDROXIDE	• MAGNETITE	• FERRIC HYDROXIDE
• pH 9.5	• pH 7.0	• pH 7.0
• WHITE (PURE)	• BLACK	• ORANGE/BROWN RED (RUST)
• GREEN GREENISH/BLACK	• MAGNETIC	• NON MAGNETIC αFe_2O_3 HEMATITE
		• MAGNETIC γFe_2O_3



a. Corrosion rate of iron versus pH of solutions of $FeCl_2$, at 20°C (68°F)



b. Corrosion rate of iron versus (Fe^{++}) of solutions of $FeCl_2$ at 20°C (68°F)

Figure 36. Increase in instantaneous corrosion rate of iron in solutions of $FeCl_2$ with and without magnetite.[9]

Figure 37. Corrosion Rates Under Static/Air Saturated Conditions

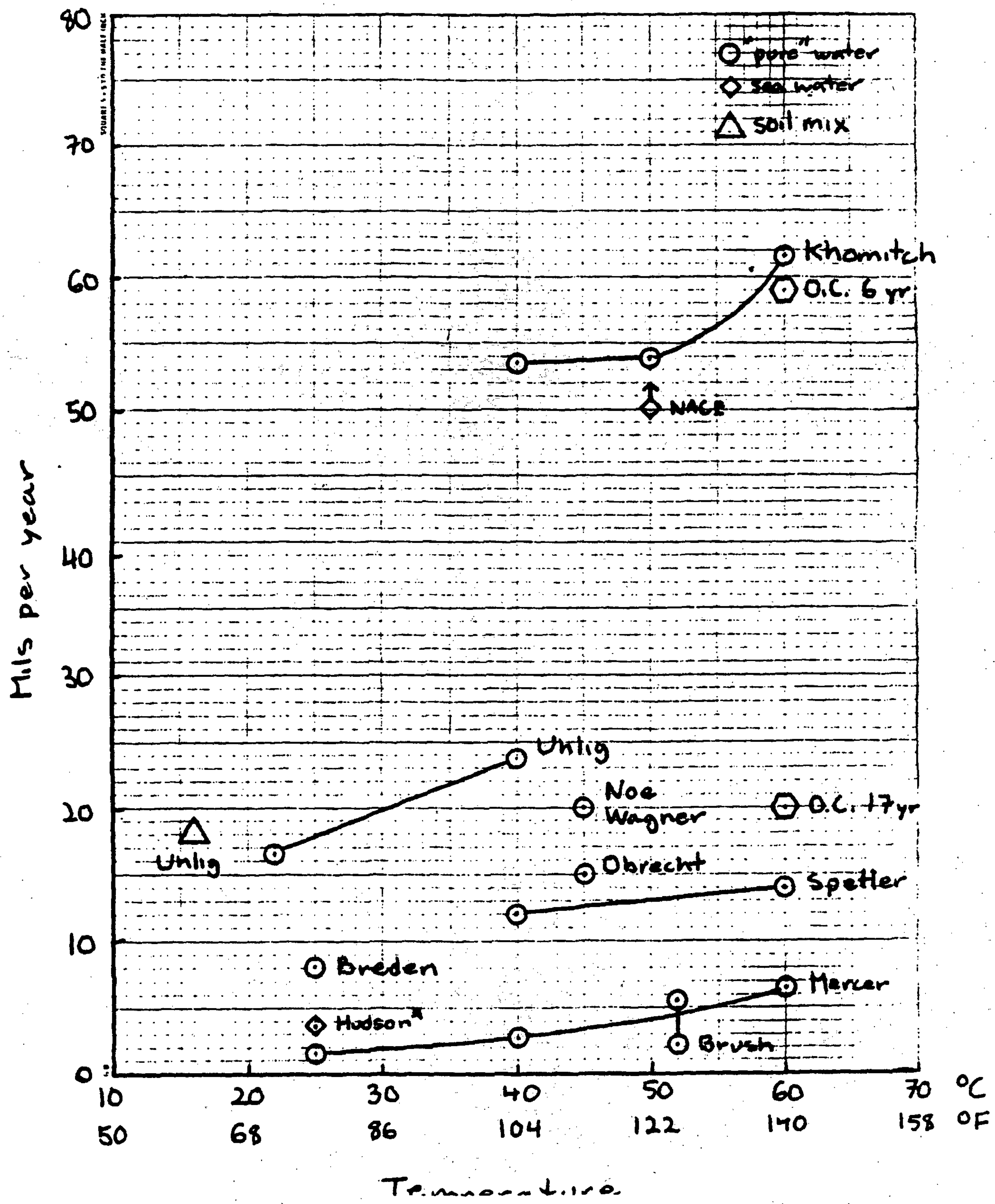


FIGURE 38. POSSIBLE CORROSION MECHANISM OF OYSTER CREEK DRYWELL