CATHODIC PROTECTION EVALUATION

Appendices to Final Report

ODOT CONTRACT PSK28885

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ODOT Contract PSK28885

by

John S. Tinnea
Ryan J. Tinnea
Tinnea & Associates, LLC
2018 E. Union Street
Seattle, WA 98122-2836

for

Oregon Department of Transportation
Bridge Preservation Unit
4040 Fairview Industrial Drive SE, MS 4
Salem OR 97302-1142

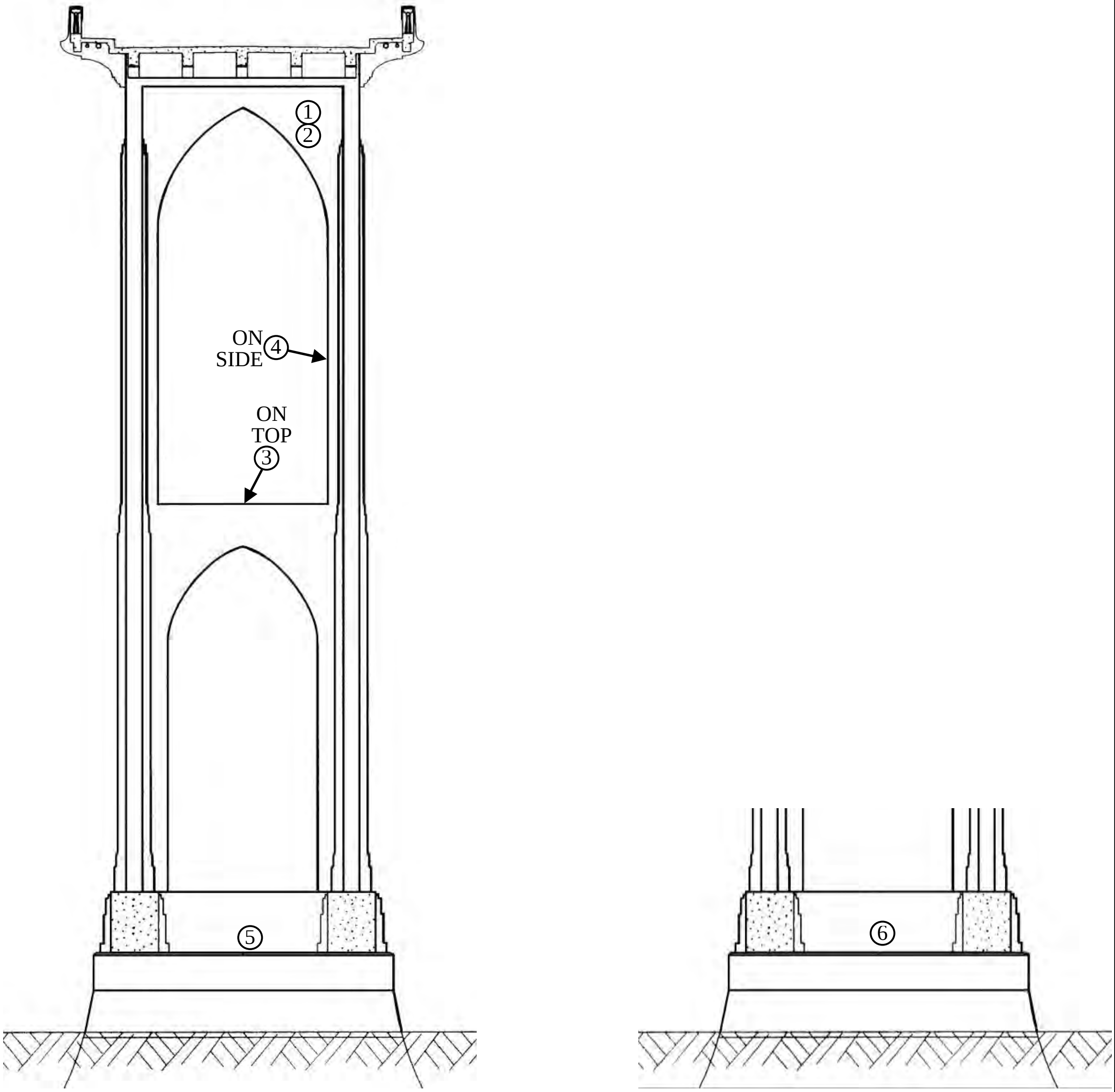
October 2014

CATHODIC PROTECTION EVALUATION - APPENDICES

APPENDIX A

COOS BAY
GECOR TESTING LOCATIONS

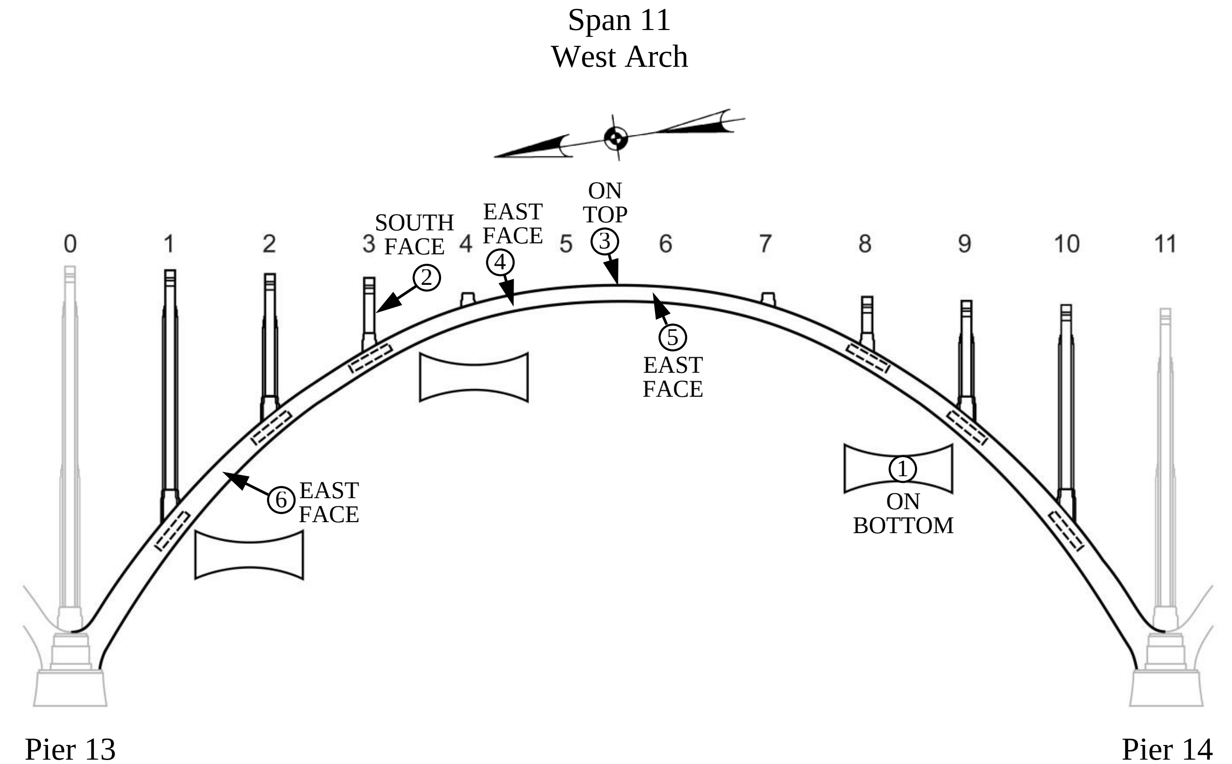
Pier 13



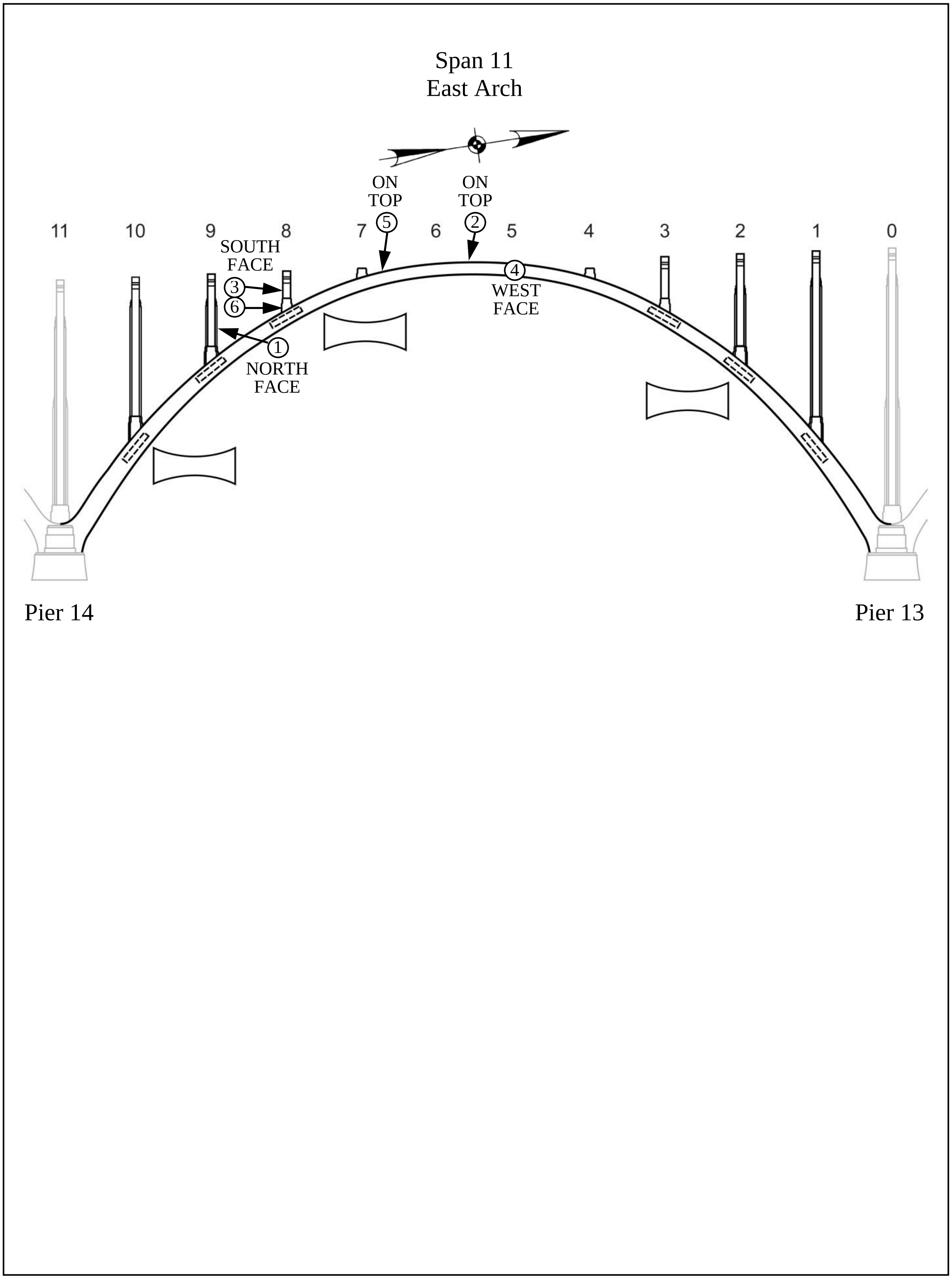
South Face

North Face

Zone 11: Coos Bay GECOR Test Locations

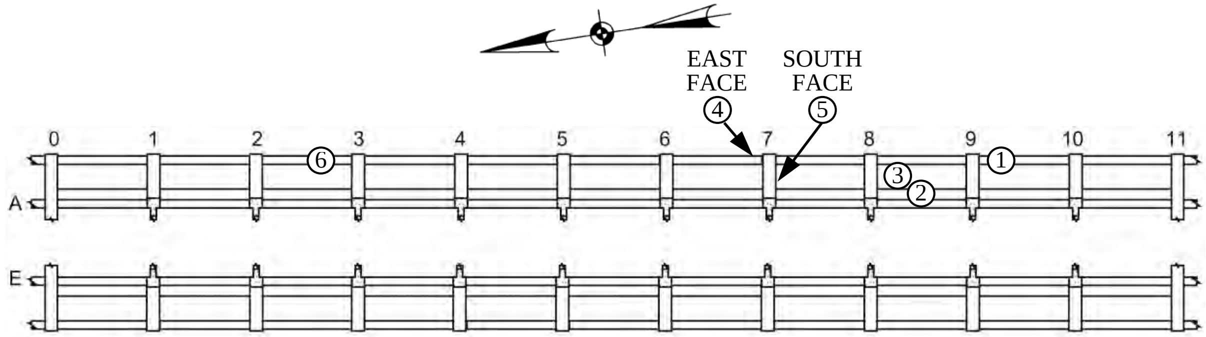


Zone 12: Coos Bay GECOR Test Locations



Zone 13: Coos Bay GECOR Test Locations

Span 11
Sidewalks

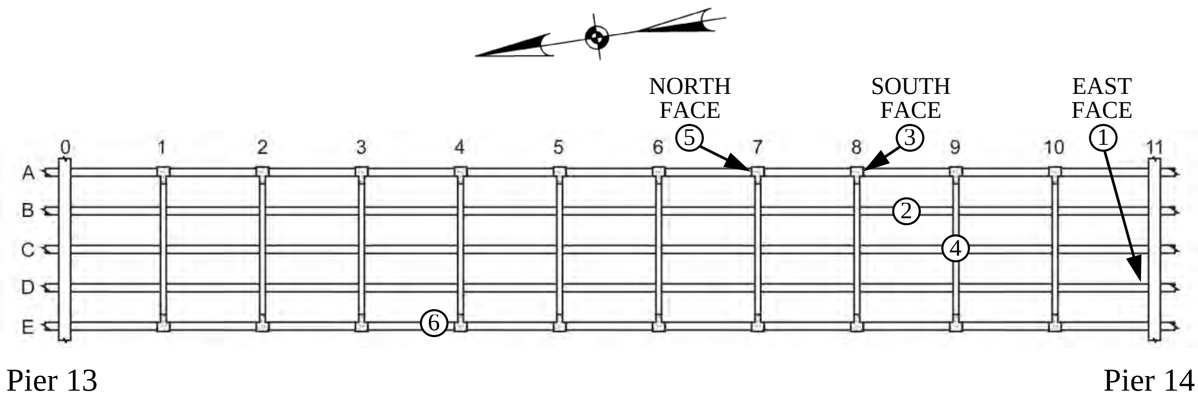


Pier 13

Pier 14

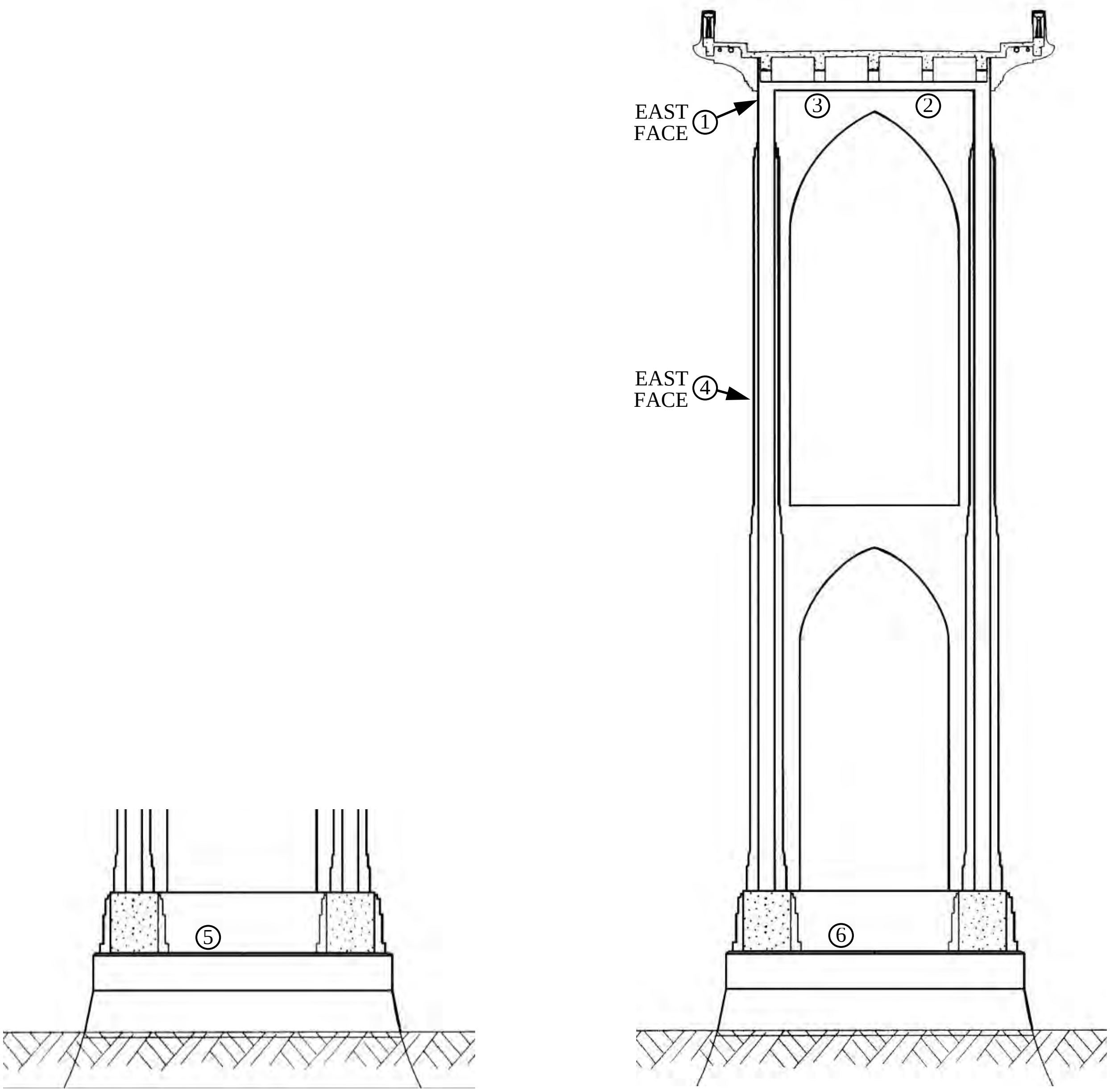
Zone 14: Coos Bay GECOR Test Locations

Span 11
Deck



Zone 15: Coos Bay GECOR Test Locations

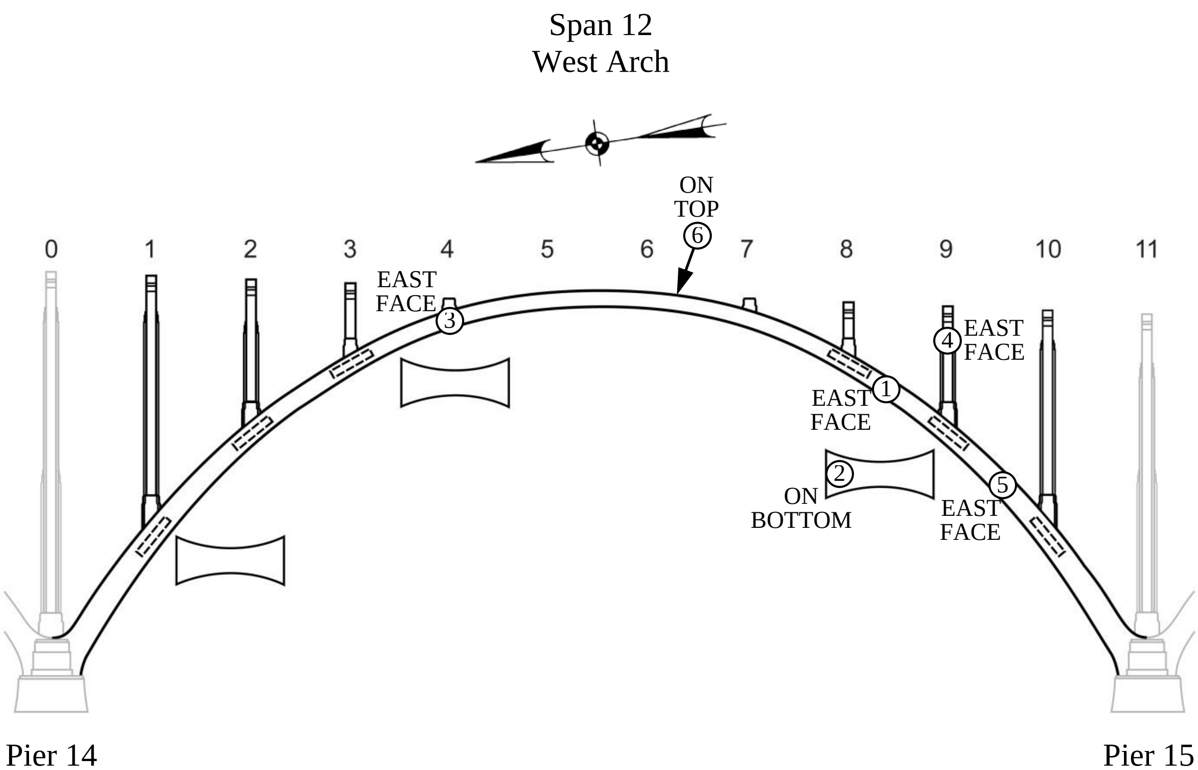
Pier 14



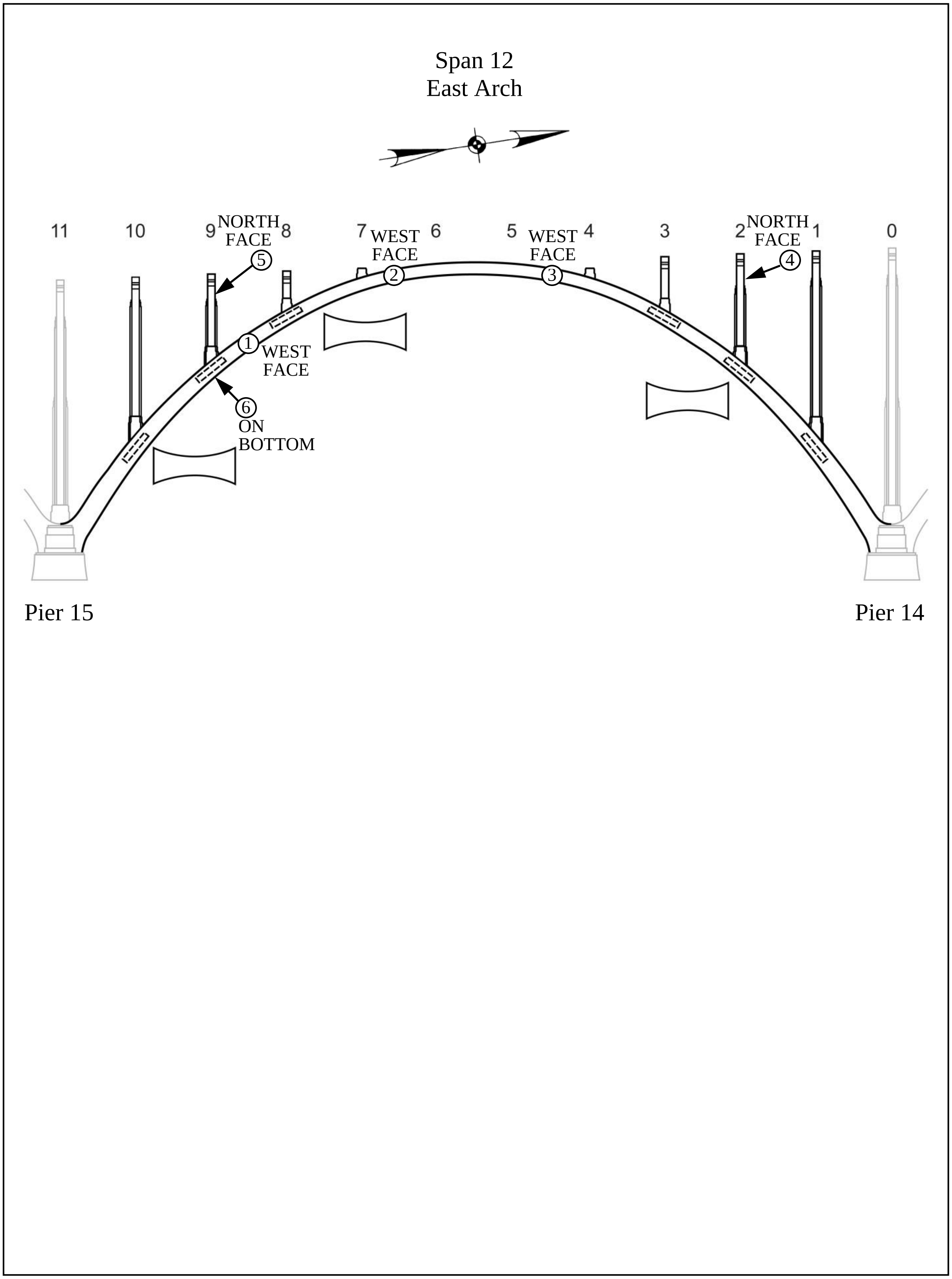
South Face

North Face

Zone 16: Coos Bay GECOR Test Locations

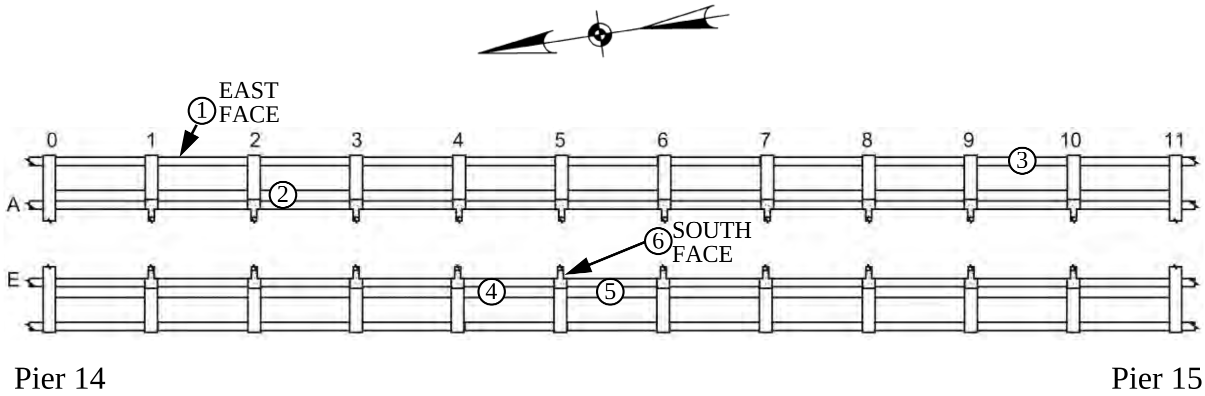


Zone 17: Coos Bay GECOR Test Locations

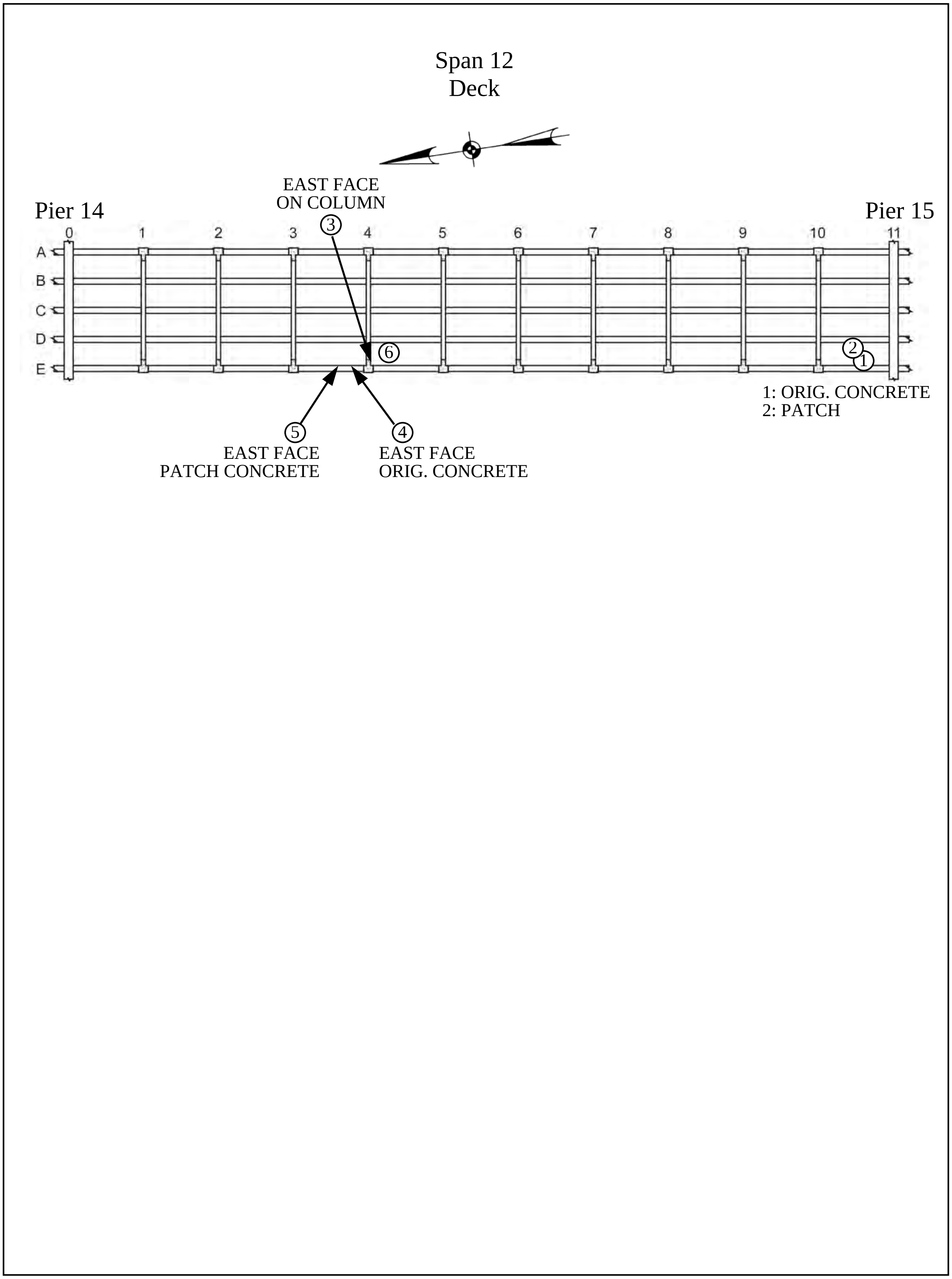


Zone 18: Coos Bay GECOR Test Locations

Span 12
Sidewalks

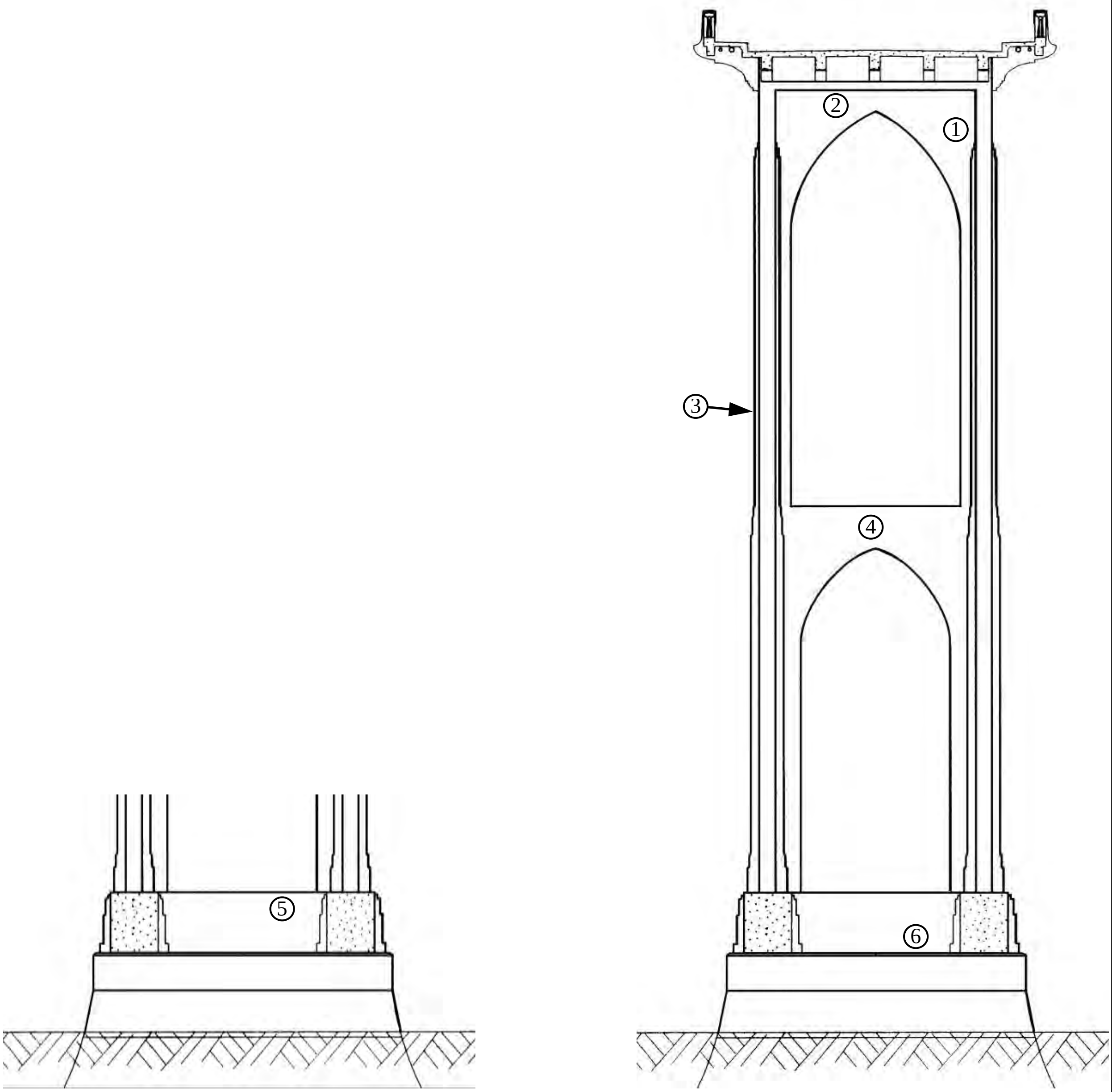


Zone 19: Coos Bay GECOR Test Locations



Zone 20: Coos Bay GECOR Test Locations

Pier 15

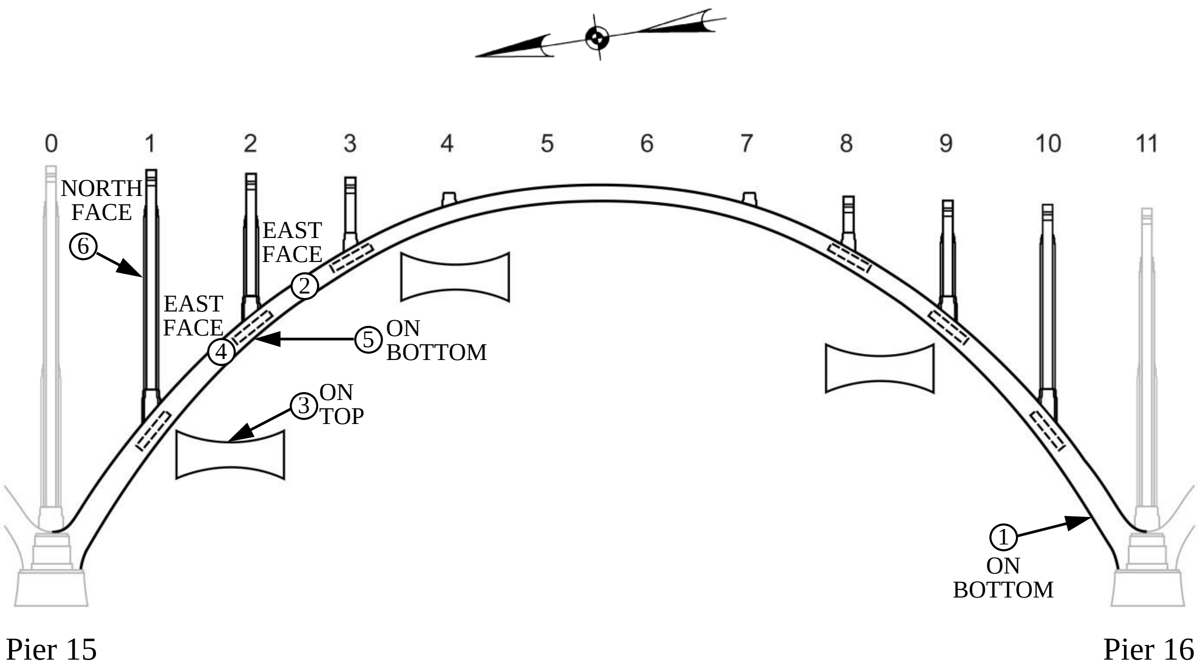


South Face

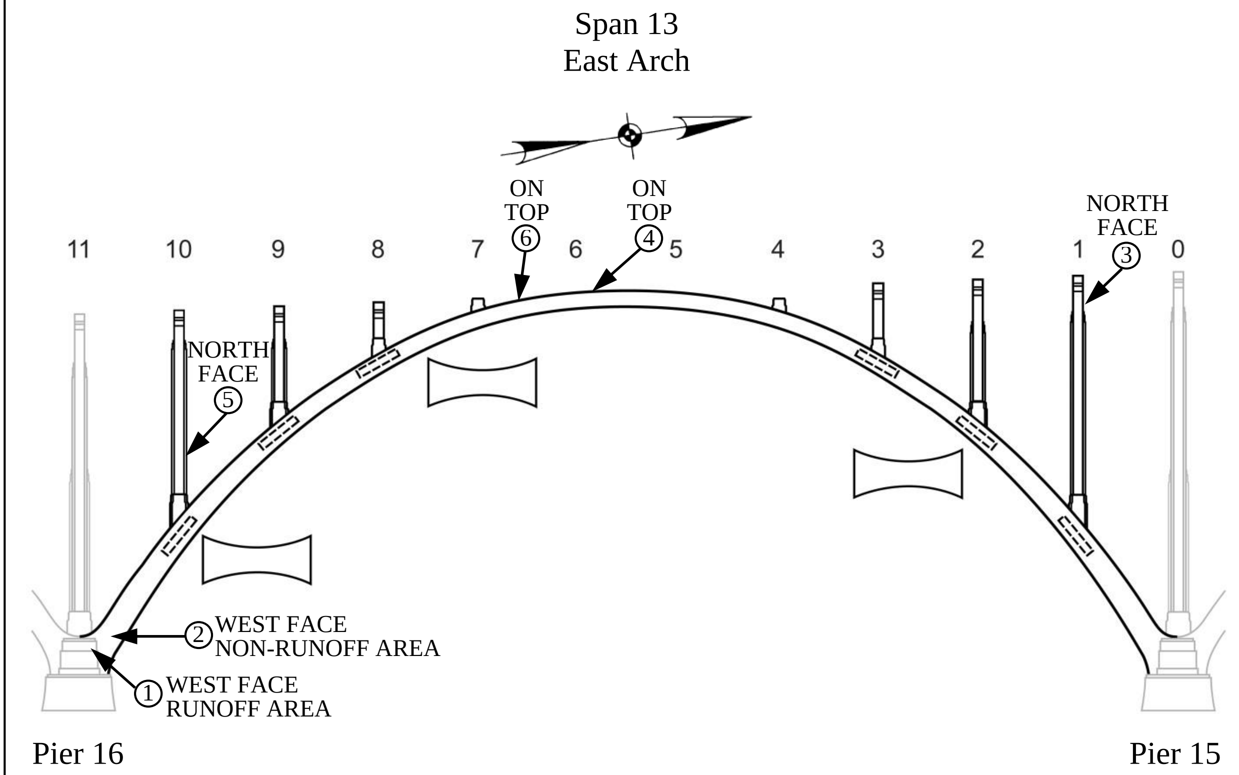
North Face

Zone 21: Coos Bay GECOR Test Locations

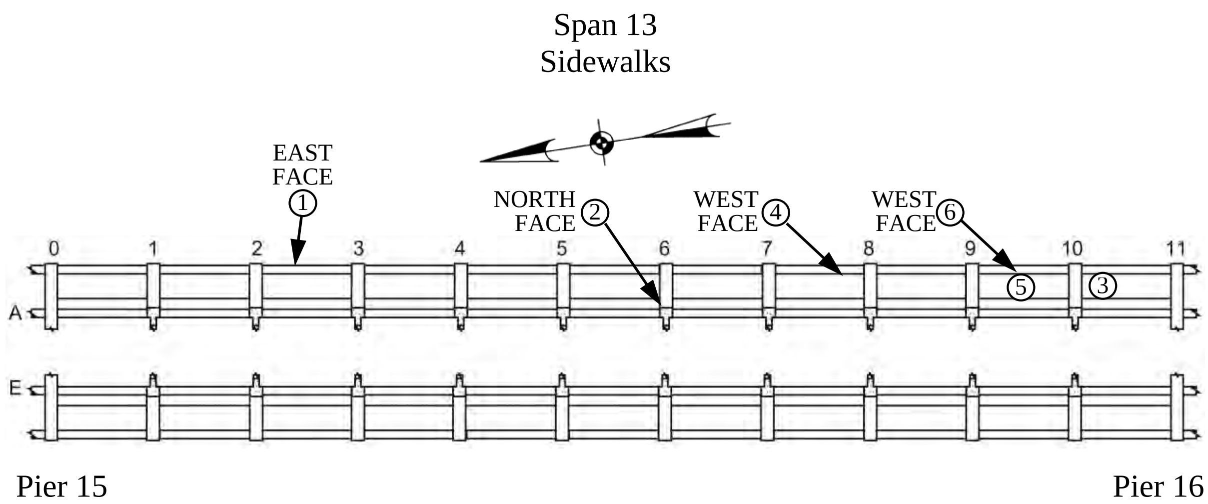
Span 13
West Arch



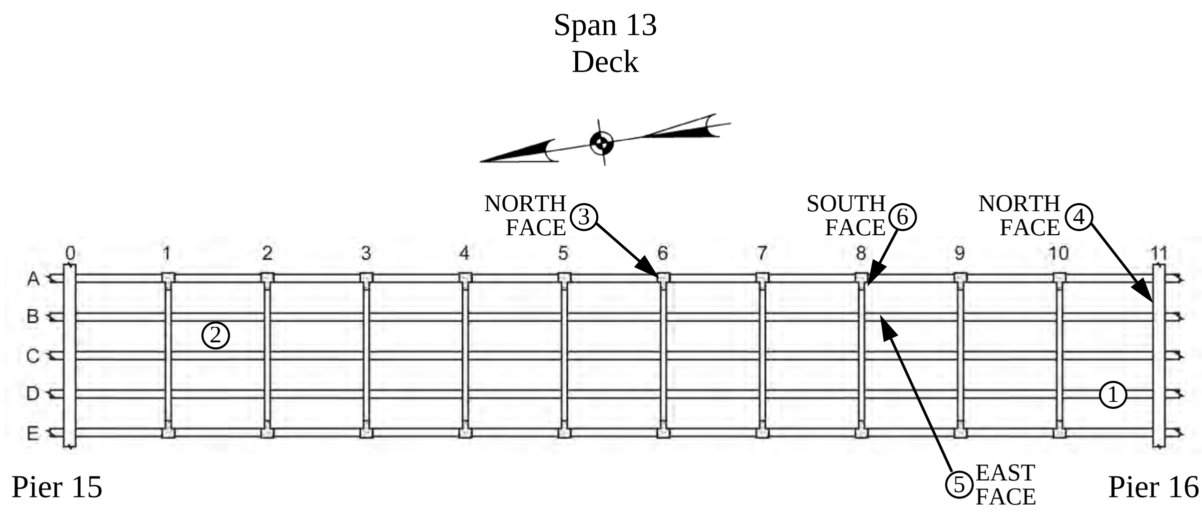
Zone 22: Coos Bay GECOR Test Locations



Zone 23: Coos Bay GECOR Test Locations

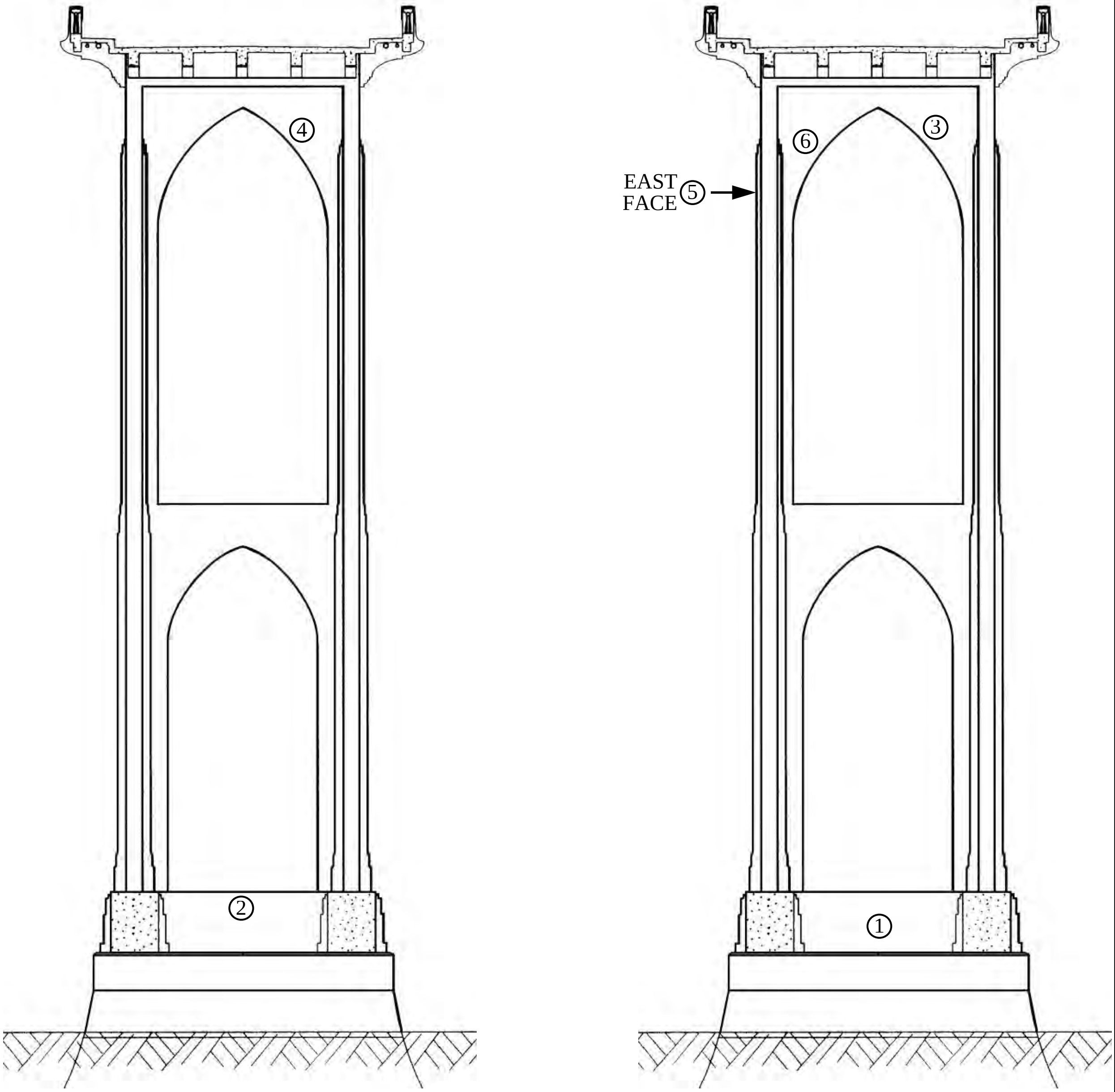


Zone 24: Coos Bay GECOR Test Locations



Zone 25: Coos Bay GECOR Test Locations

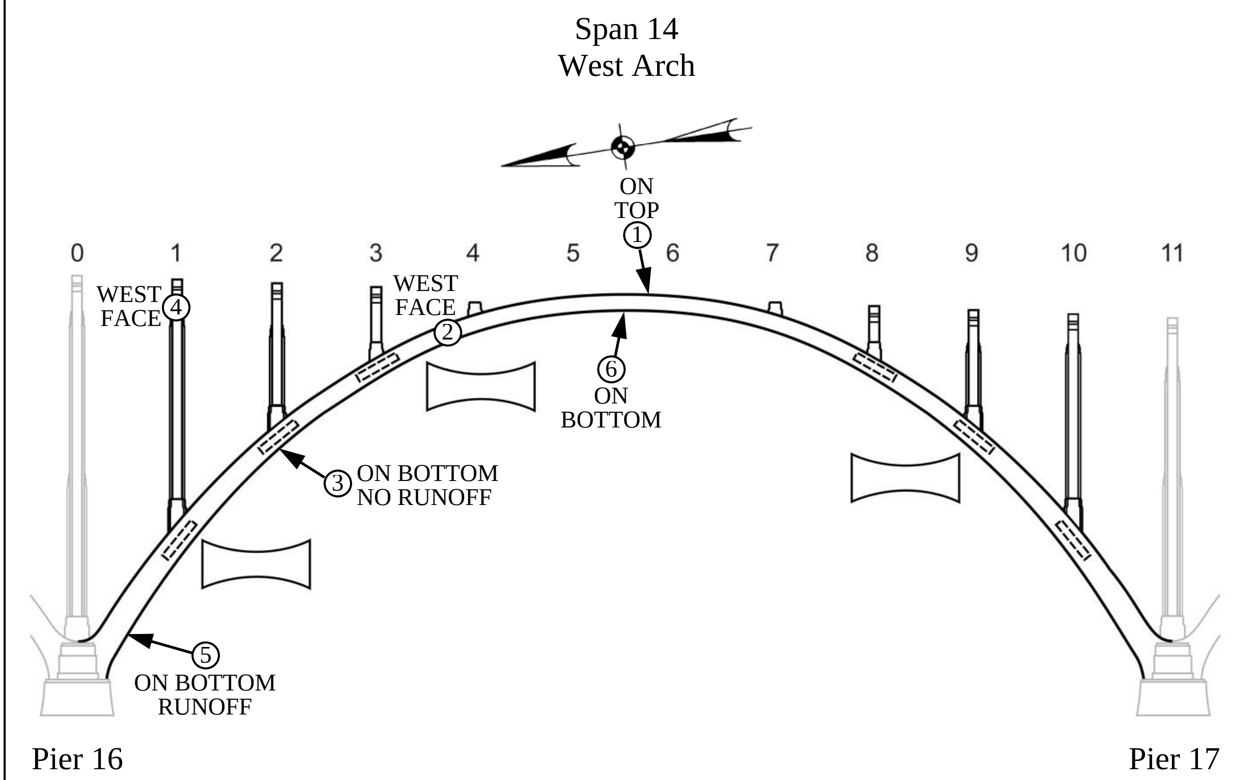
Pier 16



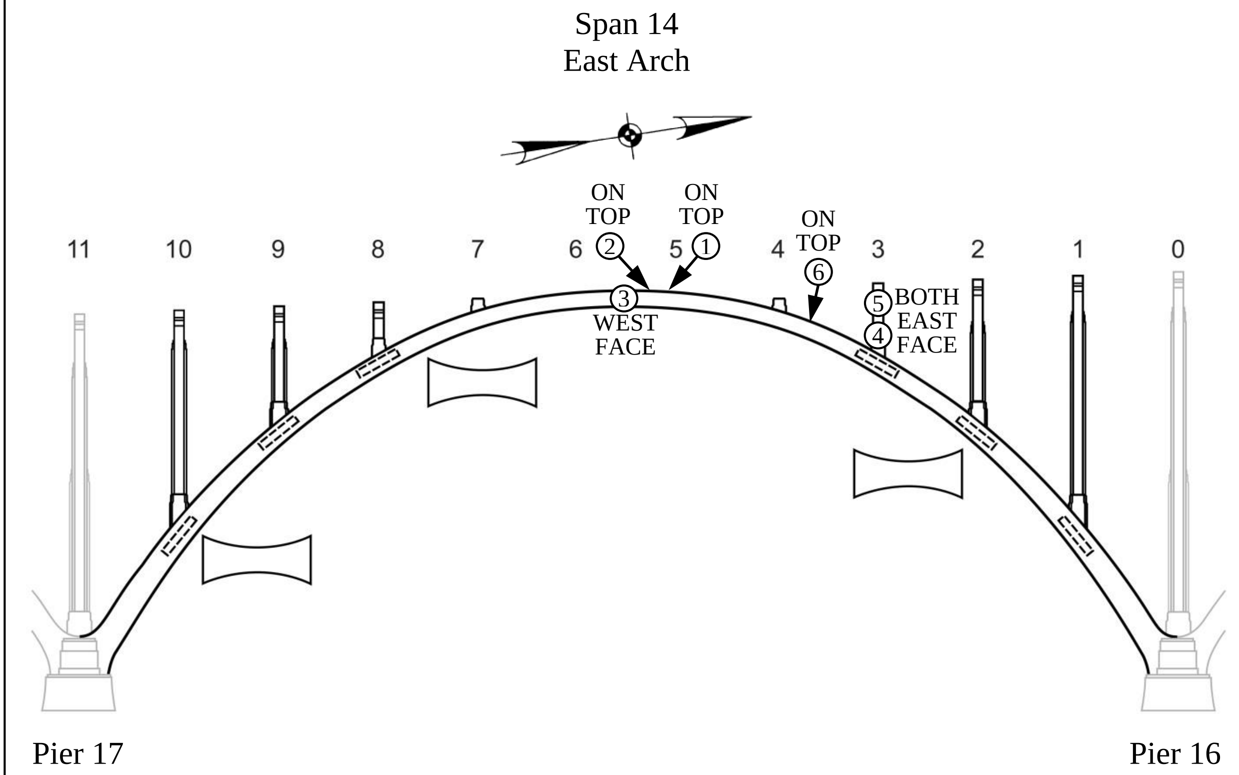
South Face

North Face

Zone 26: Coos Bay GECOR Test Locations

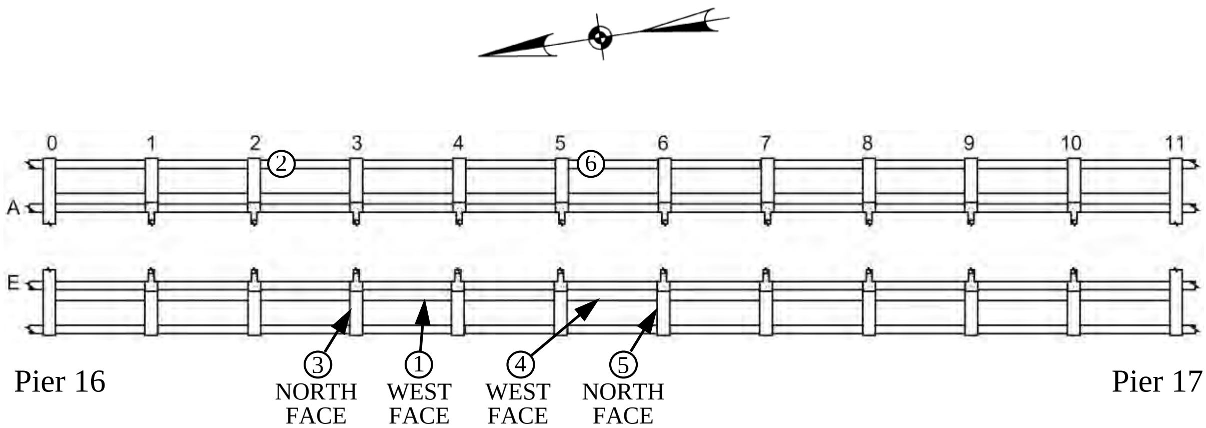


Zone 27: Coos Bay GECOR Test Locations

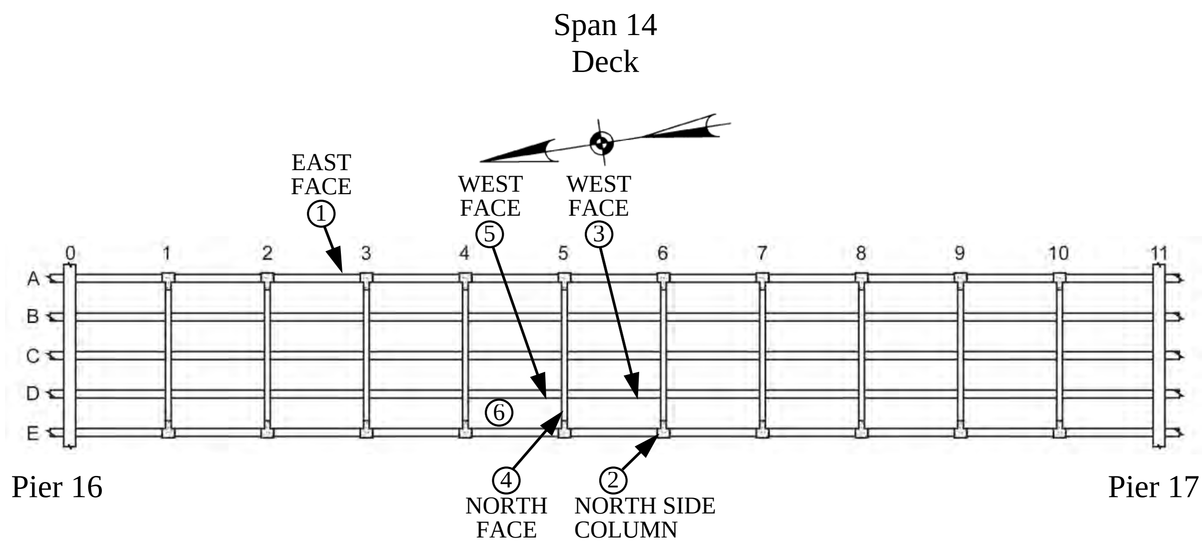


Zone 28: Coos Bay GECOR Test Locations

Span 14
Sidewalks

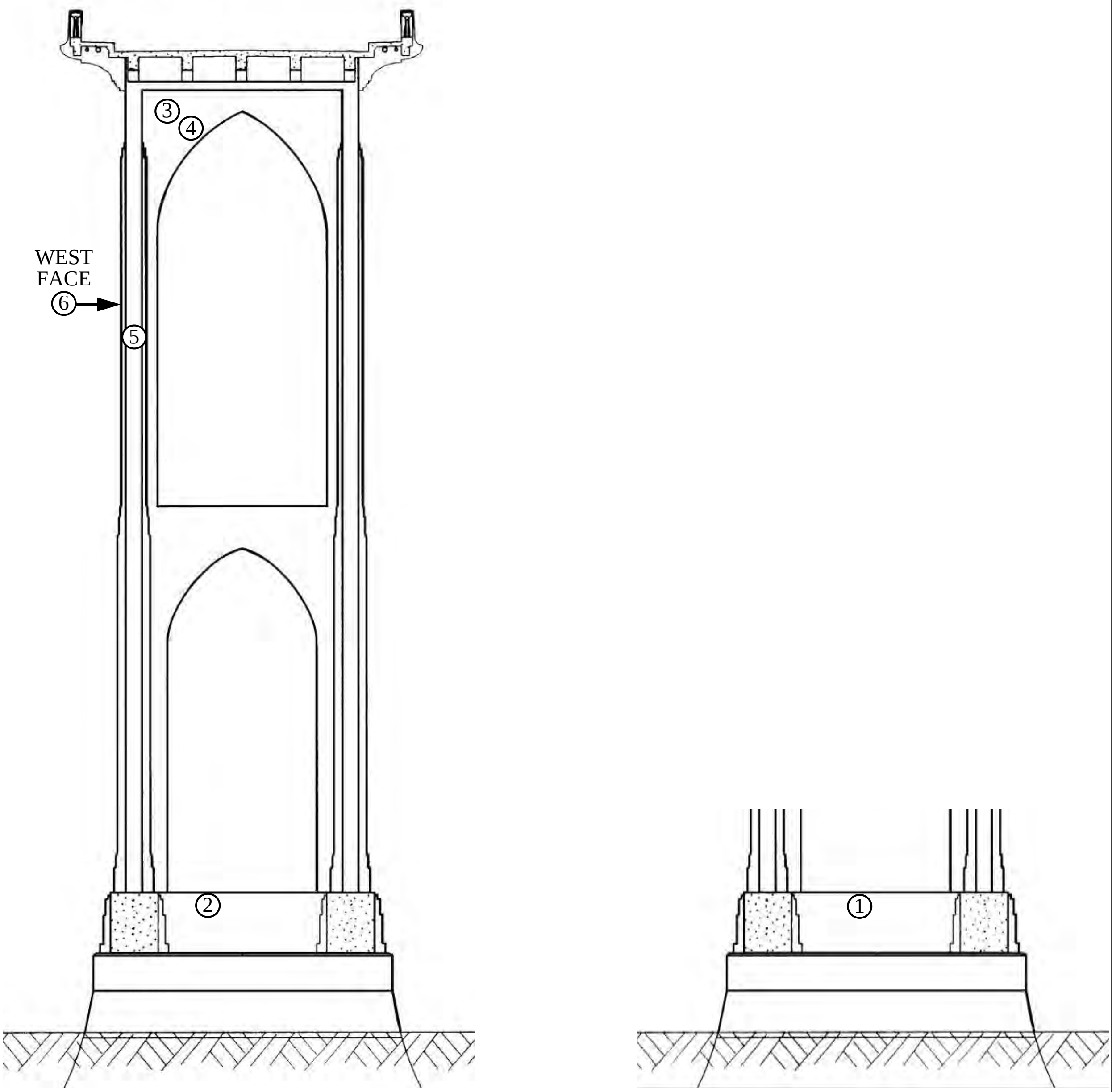


Zone 29: Coos Bay GECOR Test Locations



Zone 30: Coos Bay GECOR Test Locations

Pier 17



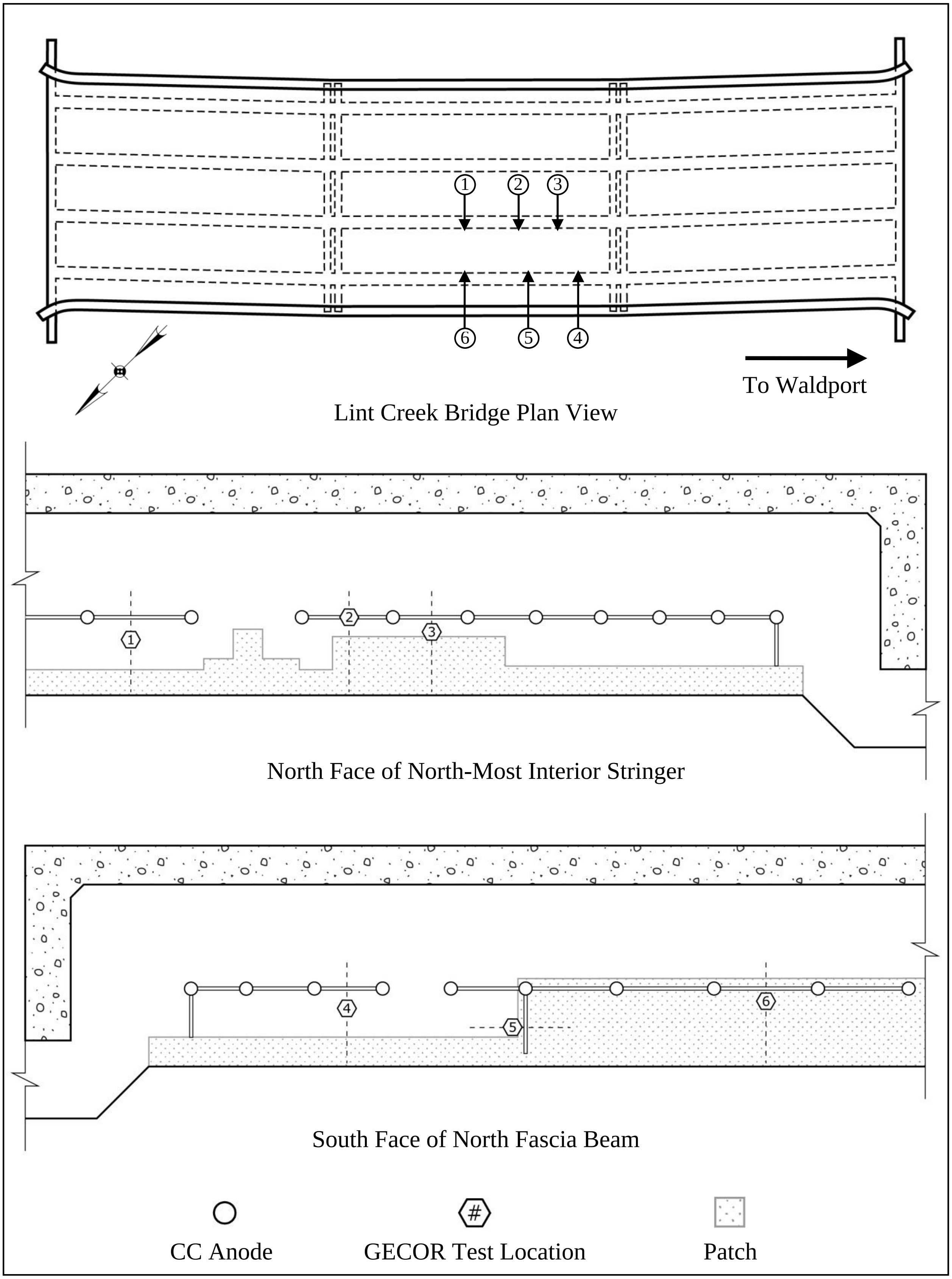
South Face

North Face

Zone 31: Coos Bay GECOR Test Locations

APPENDIX B

LINT CREEK
GECOR TESTING LOCATIONS

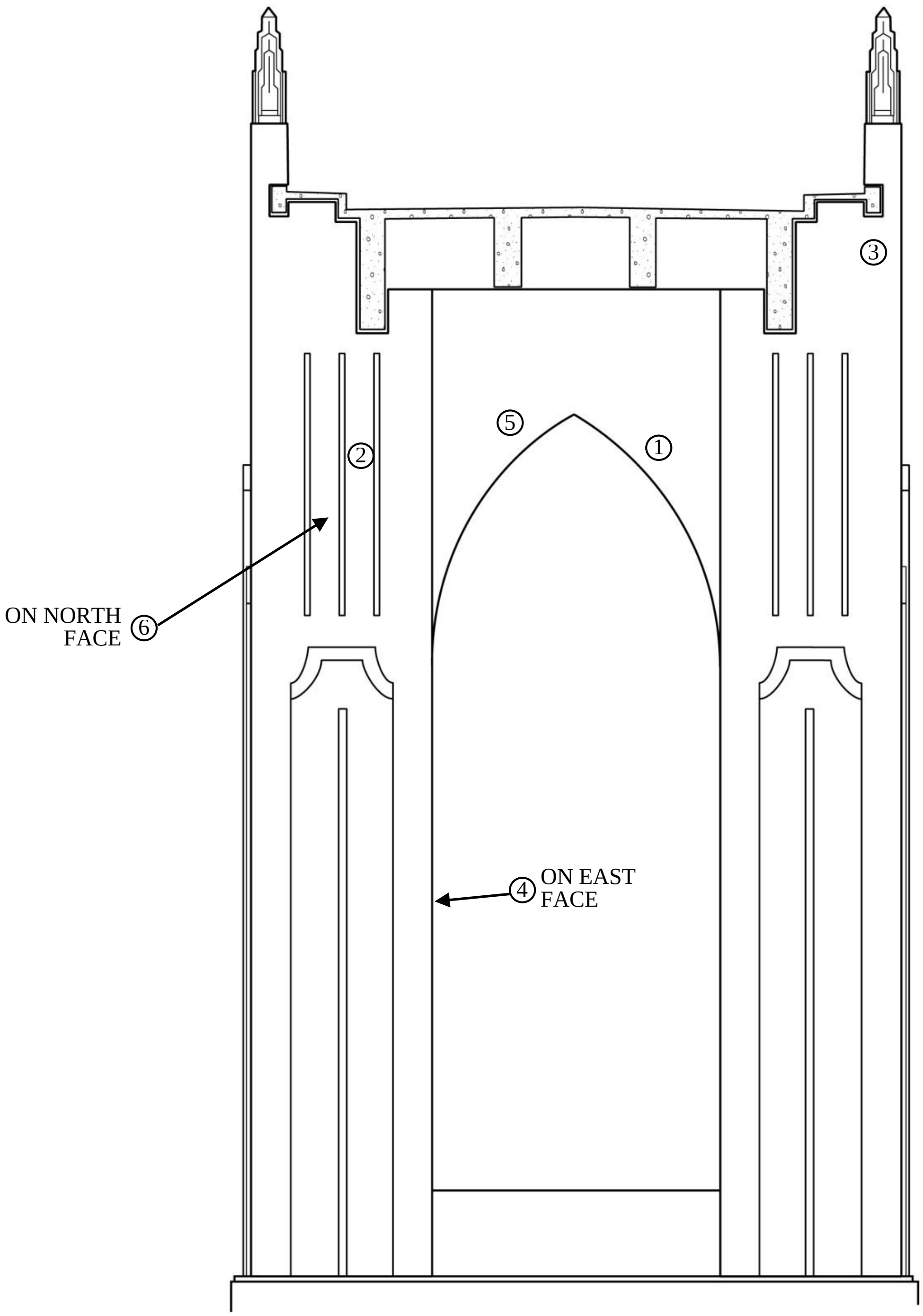


Lint Creek: Lint Creek GECOR Test Locations

APPENDIX C

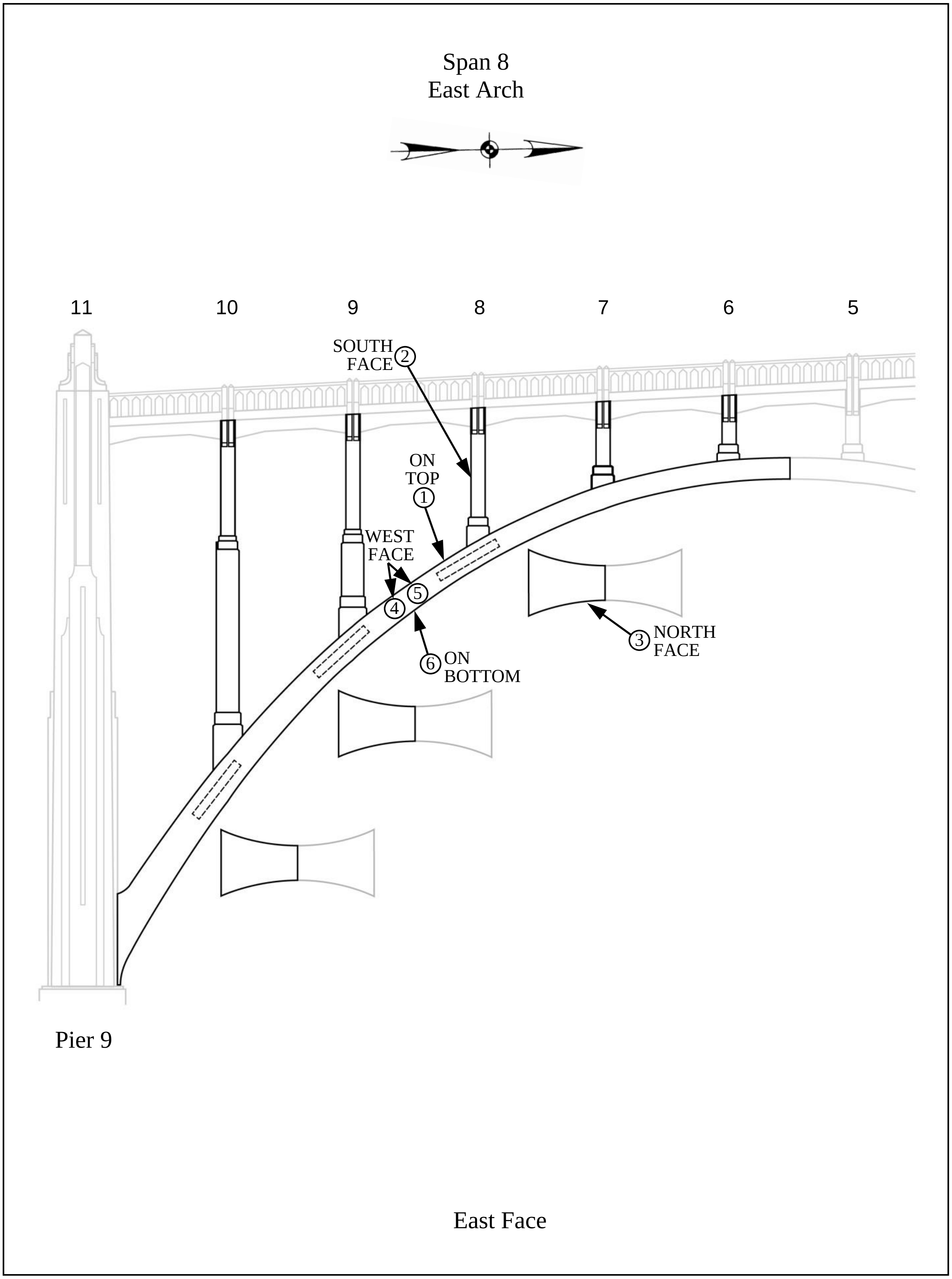
YAQUINA BAY
GECOR TESTING LOCATIONS

Pier 9



South Face

Zone 16: Yaquina Bay GECOR Test Locations



Zone 18: Yaquina Bay GECOR Test Locations

APPENDIX D

COOS BAY
GECOR TESTING RESULTS

Span	Zone	Gecor Test Site	Sensor A LPR Testing Potential mV/CSE	Resistivity KΩ	Corrosion Rate µA/cm²	Rating	Sensor B (average of readings) Potential mV/CSE	Resistivity KΩ	Risk Rating	No. Readings	Difference Potential	Difference Resistivity	Depth of Cover (in)	Rebar Orientation[1]	Date	Comments
Pier 13	11	1	-217	30	< 0.1	negligible	-216	29	green	4	1	0	4.50	H center	05/18/11	SF at top on crack / construction joint
		2	-211	28	< 0.1	negligible	-190	31	green	4	22	3	2.40	V-OC-R	05/18/11	~ 6" below # 1
		3	-608	23	0.42	low	-605	23	red	4	4	0	>5.00	--	05/18/11	on top of mid-level brace
		4	-436	14	0.41	low	-429	14	orange	4	8	0	2.45	H OC-B	05/18/11	WF E column, mid between brace and start of upper arch
		5	-290	9	1.32	high	-284	9	green	4	6	0	>5.00	--	05/19/11	SF pedistal near reference
		6	-287	14	1.19	high	-283	14	green	4	4	0	>5.00	--	05/19/11	NF pedistal near reference
Span 11	12	1	-70	30	0.51	moderate	-32	29	green	4	38	1	1.95	V OC-R	05/16/11	bottom of center strut on S end of arch near reference
west arch		2	-183	15	0.50	moderate	-188	14	green	4	5	0	1.75	H-OC-B	05/16/11	SF column 3, near zone break
		3	-232	18	0.16	low	--	--	--	--	--	--	>5.00	--	05/16/11	top arch mid span near PA
		4	-133	22	0.11	low	-129	23	green	4	5	1	>5.00	--	05/16/11	EF arch near bond
		5	-144	34	0.14	low	-150	28	green	4	6	6	>5.00	--	05/16/11	EF arch near PA
		6	-133	19	0.17	low	-136	18	green	4	3	1	>5.00	--	05/16/11	EF arch, vic reference
Span 11	13	1	-106	31	0.33	low	-86	32	green	4	20	0	>5.00	--	05/16/14	NF column 9, near reference
east arch		2	-252	27	0.21	low	-241	28	green	4	11	1	>5.00	--	05/16/14	top arch mid span near PA
		3	-190	16	0.23	low	-208	16	green	4	18	0	1.30	H-OC-D	05/16/14	SF column 8 near zone break
													2.80	V center		
		4	-123	28	0.22	low	-147	27	green	4	24	0	>5.00	--	05/16/11	WF arch near reference vic column 5
		5	-101	*	0.15	low	-106	*	green	4	6		>5.00	--	05/16/11	top arch vic NB near column 7
		6	-155	24	0.56	moderate	-159	24	green	4	4	0	>5.00	--	05/16/11	SF column 8 on pedistal near arch
Span 11	14	1	-254	35	< 0.1	negligible	-133	37	green	4	121	2	1.65	V-OC-R	05/18/11	bottom of outer beam near reference
													2.00	H-OC-A		
													2.00	H-OC-B		
sidewalk		2	-129	49	0.37	low	-115	49	green	4	14	0	1.50	V-OC-L	05/18/11	bottom inner beam near deck PA over crack
		3	-16	45	0.13	low	-11	44	green	4	6	1	>5.00	--	05/18/11	sidewalk soffit near PA & TS2
		4	34	45	0.20	low	-38	43**	green	4	72	2	2.50	V center	05/18/11	EF outer beam
		5	-74	75	< 0.1	negligible	-102	120**	green	4	28	46	2.80	H center	05/18/11	SF haunch
		6	-161	16	0.28	low	-142	15	green	4	19	0	1.20	V-OC-R	05/18/11	bottom outer beam near reference
Span 12	17	1	-93	26	0.11	low	-81	26	green	7	13	0	>5.00	--	05/11/11	EF arch between PA & top strut, between columns 8 & 9
west arch		2	112	106	< 0.1	negligible	-68	98	green	6	180	8	>5.00	--	05/11/11	bottom of middle strut @ column 9 near zone break
		3	-115	46	0.11	low	-120	45	green	4	5	1	>5.00	--	05/11/11	EF arch at column 4 near reference
		4	-10	108	< 0.1	negligible	-2	109	green	6	8	1	>5.00	--	05/11/11	EF column 9, near reference & zone break
		5	-107	42	0.40	low	-102	41	green	7	5	1	>5.00	--	05/11/11	EF arch between column 9 & 10, near NB
		6	-29	96	0.11	low	-13	76	green	6	16	20	>5.00	--	05/11/11	arch top near column 6
Span 12	19	1	-236	33	< 0.1	negligible	-229	33	green	9	8	0	2.50	V center	05/09/11	EF outer beam near reference
sidewalk		2	-134	18	0.43	low	-127	18	green	6	8	0	1.25	H-OC-B	05/09/11	bottom inner beam in patch
		3	-268	25	< 0.1	negligible	-194	27	green	4	74	2	0.70	H center	05/06/11	bottom outer beam near reference
		4	-59	72	0.15	low	-55	76	green	5	4	4	1.00	H-OC-B	05/11/11	bottom inner beam
													1.50	V-OC-L		
		5	-35	88	0.17	low	-35	84	green	5	0	4	1.25	H-OC-B	05/11/11	bottom inner beam
		6	-112	57	0.10	low	-136	53	green	5	25	4	1.50	V center	05/10/11	SF haunch
12	20	1	-34	--	< 0.1	negligible	-3	107	green	4	31	--	0.90	H-OC-A	05/05/11	deck soffit orig
													0.80	H-OC-B		
deck		2	-67	--	< 0.1	negligible	-143	39	green	4	76	--	3.50	H-OC-B	05/05/11	deck soffit patch
		3	-11	115	0.41	low	-36	107	green	4	25	8	1.65	V center	05/11/11	deck column 4 near zone break
		4	-95	126	0.1	low	-86	114	green	5	9	12	2.05	V-OC-L	05/11/11	EF (inner) fascia orig near reference
													2.25	H center		
		5	-126	73	< 0.1	negligible	-126	71	green	5	0	2	1.85	V center	05/11/11	EF (inner) fascia patch
													2.00	H center		
		6	-7	42	< 0.1	negligible	-2	39	green	6	5	3	2.25	V center	05/10/11	deck soffit patch near reference
		Average	-129	45	0.32		-127	46			23	4	3.08			
		Std Dev	104	32	0.30		90	33			36	8	1.64			
		Max	112	126	1.32		-2	120			180	46	5.00			
		Min	-608	9	0.10		-605	9			0	0	0.70			

--	no readings obtained	H horz (east- west)	L	left	EF	East Face	NB	Negative Bond
*	negative resistivity, readings not included in statistics	V vert (north-south)	R	right	NF	North Fac	PA	Primary Anode
**	one reading with extremely high resistivity that was not included in average	OC off center	A	above	SF	South Fac	TOW	Time of Wetness
'	one reading with extremely negative potential that was not included in average		B	below	W	West Face		

Coos Bay GECOR Pre-CP Test Results: Constant Current 1

Span	Zone	Gecor Test Site	Sensor A LPR Testing Potential mV/CSE	Resistivity KΩ	Corrosion Rate μA/cm²	Rating	Sensor B (average of readings) Potential mV/CSE	Resistivity KΩ	Risk Rating	No. Readings	Difference Potential	Difference Resistivity	Depth of Cover (in)	Rebar Orientation[1]	Date	Comments
Pier 15	21	1	-254	48	0.13	low	-254′	47	green	4	0	1	2.25	V center	05/05/11	NF at top near PA
		2	-328	54	< 0.1	negligible	-328	54	green	4	0	1	2.25	V center	05/05/11	NF at top between PA & NB
		3	-299	76	< 0.1	negligible	-313	74	green	4	13	2	2.15	H-OC-A	05/05/11	EF E column mid way
		4	-267	111	< 0.1	negligible	-342	124	green	4	75	13	>5.00	--	05/05/11	NF above peak of lower arch
		5	-218	--	0.37	low	--	--	--	--	--	--	>5.00	--	05/03/11	SF pedistal near reference
		6	-204	--	1.65	high	--	--	--	--	--	--	>5.00	--	05/03/11	NF pedistal near reference
13	23	1	-312	--	0.13	low	--	--	--	--	--	--	>5.00	--	05/03/11	WF arch area of run-off
east arch		2	-222	--	< 0.1	negligible	--	--	--	--	--	--	>5.00	--	05/03/11	WF arch adjacent area no run-off
		3	-251	28	< 0.1	negligible	-252	29	green	4	1	1	1.45	H-OC-A	05/12/11	NF column 1 top reference near zone break, near reference
													2.15	V-OC-L		
		4	-121	22	0.11	low	-123	22	green	4	2	0	>5.00	--	05/12/11	arch top mid span near PA
		5	-263	36	0.43	low	-260	38	green	2	3	1	2.20	H center	05/18/11	NF column 10 near base & reference
		6	-211	13	0.30	low	-205	13	green	4	5	0	1.50	H-OC-A	05/18/11	arch top near neg
													2.00	V-OC-R		
13	25	1	16	131	< 0.1	negligible	11	137	green	4	5	6	3.25	not clear	05/06/11	stringer beam soffit vicinity of deck reference
deck		2	-319	57	< 0.1	negligible	-299	58	green	4	21	1	1.25	H center	05/12/11	deck soffit near reference
													1.65	V-OC-L		
		3	-98	41	0.10	low	-101	42	green	4	3	1	>5.00	--	05/12/11	NF columnumn
		4	-	-	-	-	-	-	-	-	-	-	>5.00	--	--	NF spandrel beam near earthquake restraint
		5	-193	48	0.10	low	-182	49	green	4	11	1	>5.00	--	05/18/11	EF stringer close to NB
		6	-178	34	0.19	low	-167	33	green	4	11	1	1.80	V center	05/18/11	SF of spandrel beam haunch close to zone border
Pier 16	26	1	-241	--	0.18	low	--	--	--	--	--	--	>5.00	--	05/03/11	NF pedistal
		2	-79	--	0.21	low	--	--	--	--	--	--	>5.00	--	05/03/11	SF pedistal
		3	-27	--	< 0.1	negligible	-19	77	green	4	8	--	>5.00	--	05/06/11	NF top near PA
		4	-45	--	0.48	low	-73	113	green	4	28	--	1.95	V center	05/06/11	SF top near reference
		5	-153	--	0.16	low	--	--	--	--	--	--	>5.00	--	05/06/11	EF column towards the top
		6	-302	--	0.32	low	--	--	--	--	--	--	>5.00	--	05/09/11	NF between PA & bond in area of high TOW
14	27	1	21	14	< 0.1	negligible	--	--	--	--	--	--	--	--	05/05/11	top arch near reference
west arch		2	-134	34	0.19	low	-88	53	green	2	46	19	--	--	05/05/11	WF arch N of reference under column
		3	-218	61	< 0.1	negligible	-199	62	green	4	20	1	--	--	05/05/11	halfway up, underside of arch - dry
		4	-291	121	0.25	low	-279	120	green	4	13	1	--	--	05/05/11	WF top column 1
		5	-222	61	< 0.1	negligible	--	--	--	--	--	--	--	--	05/05/11	underside of arch near pier - wet
		6	53	46	< 0.1	negligible	83	83	green	4	30	37	--	--	05/05/11	bot arch near top/middle
14	28	1	-231	--	0.10	low	-268	73	green	4	38	--	--	--	05/04/11	arch top, just E of reference on column 5
east arch		2	-305	--	1.21	high	--	--	--	--	--	--	--	--	05/04/11	arch top, just S of reference on column
		3	-190	--	0.10	low	--	--	--	--	--	--	--	--	05/04/11	WF arch top near PA
		4	-368	--	0.70	moderate	-343	22	green	4	25	--	--	--	05/04/11	EF column 3 orig concrete
		5	-304	--	0.30	low	-354	32	red	4	50	--	>5.00	--	05/04/11	EF column 3 patch
		6	-128	--	< 0.1	negligible	--	--	--	--	--	--	--	--	05/04/11	arch top
14	29	1	33	--	< 0.1	negligible	--	--	--	--	--	--	--	--	05/06/11	WF inner beam near drain pipe - no water exposure
sidewalks		2	-266	--	0.11	low	-235	110	green	4	30	--	--	--	05/05/11	outer beam near reference
		3	-412	73	0.12	low	-284	139	green	4	128	66	--	--	05/05/11	NF haunch
		4	-436	96	< 0.1	negligible	-385	98	red	4	51	2	--	--	05/05/11	sidewalk soffit near PA
		5	-393	42	0.15	low	-322	41	green	2	72	1	--	--	05/05/11	NF haunch
		6	--	--	--	--	--	--	--	--	--	--	--	--	--	outer beam near reference
		Average	-209	57	0		-215	67			26	8	3.60			
		Std Dev	123	33	0		123	38			30	16	1.57			
		Max	53	131	1.21		83	139			128	66	5.00			
		Min	-436	13	0.10		-385	13			1	0	1.25			

--	no readings obtained	H	horz (east- west)	L	left	EF	East Face	NB	Negative Bond
*	negative resistivity, readings not included in statistics	V	vert (north-south)	R	right	NF	North Fac	PA	Primary Anode
**	one reading with extremely high resistivity that was not included in average	OC	off center	A	above	SF	South Fac	TOW	Time of Wetness
′	one reading with extremely negative potential that was not included in average			B	below	W	West Face		
	moisture extended to zinc anode								

Coos Bay GECOR Pre-CP Test Results: Constant Current 2

Span	Zone	Gecor Test Site	Type	Nom. Out	Test Well	Run Off	Conc Cover	Other Location Information	Pre-CP	Potential (mV, CSE) 04/07/12	06/29/12	09/20/12	AVG ON		Rectifier Output 04/07/12	06/29/12	09/20/12	Protected (Not / Moderate / Well) 04/07/12	06/29/12	09/20/12
Pier 13	11	1	Pier	0.200 mA/SF			4.5"	S face top on const. joint	69	-214	-7	-185	-135	Volts	1.20	1.90	1.18	N	N	N
		2					2.4"	just below #1	-211	-319	-24	-164	-169	Amps	0.95	0.95	0.95	N	N	N
		3					>5"	top of lower arch	-608	-273	-155	-109	-179	Ohms	1.27	2.00	1.24	N	W	N
		4					3.0"	inside face of E col	-426	-439	-283	-115	-279					N	N	W
		5			X		>5"	S face of base	-290	-248	-166	-244	-219					W	N	N
		6			X		>5"	N face of base	-287	-225	-182	-231	-213					W	N	N
Span 11	12	1	West Arch	0.050 mA/SF	X		2.0"	underside of strut	-70	-223	-229	-308	-253	Volts	0.65	3.00	2.83	N	M	N
		2					1.8"	S. face of col	-183	-284	-335	-308	-309	Amps	0.47	0.47	0.47	W	W	N
		3					4.2"	top mid span	-232	-187	-110	-190	-162	Ohms	1.39	6.38	6.02	W	N	N
		4					>5"	E face near primary	-133	-189	-151	-166	-168					N	N	N
		5					>5"	E face near bond	-144	-237	-194	-251	-227					W	N	N
		6			X		>5"	E face	-133	-7	-109	-212	-109					M	N	N
Span 11	13	1	East Arch	0.150 mA/SF	X		>5"	N face of col	-106	-477	-302	-157	-312	Volts	1.95	1.90	1.38	N	W	W
		2					>5"	top mid span	-252	-274	-115	-89	-159	Amps	1.39	1.40	1.40	N	N	N
		3					2.1"	S face of col near break	-190	-410	-361	-187	-319	Ohms	1.40	1.36	0.99	W	W	W
		4			X		>5"	W face	-123	-275	-121	-86	-161					N	N	N
		5					>5"	top	-101	-226	-35	8	-84					W	N	N
		6					>5"	S face col near arch	-155	-441	-556	43	-318					W	W	W
Span 11	14	1	Sidewalks	0.100 mA/SF	X		1.7"	E beam bottom	-254	-13	-230	-117	-120	Volts	1.01	1.60	0.96	N	N	N
		2					1.5"	E deck gutter	-16	-42	-112	-103	-86	Amps	0.46	0.46	0.46	N	W	N
		3					mesh	E soffit	-129	-131	-252	-173	-185	Ohms	2.19	3.48	2.09	N	M	W
		4					2.5"	E face E beam	34	-371	-240	-196	-269					M	W	N
		5					2.8"	S face haunch	-74	-187	-150	-137	-158					W	N	N
		6			X		2.5"	E beam bottom	-161	-266	-166	-188	-206					M	N	N
Span 12	17	1	West Arch	0.075 mA/SF			>5"	E face @ primary	-93	-174	-118	1335	348	Volts	1.26	3.40	3.25	N	N	N
		2					>5"	N face strut near E arch	112	-178	-184	-267	-210	Amps	0.62	0.62	0.62	M	N	N
		3			X		>5"	E face at column	-115	-237	-149	-258	-215	Ohms	2.03	5.48	5.24	N	W	N
		4			X		>5"	E face col near top	-10	-349	-259	-253	-287					N	W	N
		5					>5"	E face at bond	-107	-129	-166	-193	-163					M	W	N
		6					>5"	top at bond	-29	-132	-2	-144	-93					N	N	N
Span 12	19	1	Sidewalks	0.175 mA/SF	X		2.5"	E face E beam	-236	-284	-207	-147	-213	Volts	1.00	1.20	0.90	N	W	W
		2					1.3"	E deck gutter	-134	-204	-159	-129	-164	Amps	0.76	0.75	0.75	N	W	N
		3			X		0.7"	E beam bottom	-268	-260	-169	-180	-203	Ohms	1.31	1.60	1.20	N	W	N
		4					1.3"	W deck gutter	-59	-209	-153	-171	-178					N	N	W
		5					1.7"	W deck gutter	-126	-193	-110	-162	-155					N	W	W
		6					1.5"	S face W haunch	-112	-280	-159	-155	-198					N	M	W
12	20	1	Deck	0.075 mA/SF			0.9"	deck org concrete	-34	-345	-314	-362	-340	Volts	1.07	1.30	1.00	N	N	N
		2					3.5"	deck patch near 1	-67	-287	-261	-214	-254	Amps	0.78	0.78	0.75	N	N	N
		3					1.7"	E face col near break	-11	-83	-121	-121	-108	ohms	1.37	1.67	1.33	N	W	W
		4			X		2.1"	E face fascia orig conc.	-95	-213	-249	-240	-234					W	W	N
		5					1.9"	E face fascia patch	-126	-302	-171	-180	-218					W	N	N
		6			X		2.3"	deck in patch	-45	-79	-87	-111	-92					N	N	N
								Average*	-125	-236	-181	-138	-185				Non protected	26	23	32
								Std Dev*	104	±108	±102	±245	±108				Moderately protected	5	3	0
								Max	112	-7	-2	1335	348				Well protected	11	16	10
		zinc in reading						**Min**	-608	-477	-556	-362	-340					42	42	42
								Positive for CP	--	3	4	3	--							

* Calculated without zinc reading

Coos Bay GECOR Test Results: Constant Current 1

Span	Zone	Gecor Test Site	Type	Nom. Out	Test Well	Run Off	Conc Cover	Other Location Information	Pre-CP	Potential (mV, CSE) 04/07/12	06/29/12	09/20/12	AVG ON		Rectifier Output 04/07/12	06/29/12	09/20/12	Protected (Not / Moderate / Well) 04/07/12	06/29/12	09/20/12
Pier 15	21	1	Pier	0.125 mA/SF			2.3"	N face top W near bond	-351	-490	-254	-393	-379	Volts	1.82	3.80	4.31	N	N	N
		2					2.3"	N face top E @ primary	-423	-579	-276	-335	-397	Amps	0.48	0.47	0.47	M	N	W
		3					2.2"	E face E col mid	-299	-524	-272	-183	-326	Ohms	3.78	8.09	9.17	N	M	N
		4					>5"	N face mid strut	-267	-390	-331	-235	-319					M	N	N
		5			X		4.5"	S face of base	-201	-738	-322	-552	-537					W	W	N
		6			X		>5"	N face of base	-204	-563	-276	-237	-359					N	N	N
13	23	1	East Arch	0.125 mA/SF		X	1.6"	W face @ base	-279	-127	-142	-147	-139	Volts	0.68	3.20	3.22	N	N	N
		2					1.5"	W face @ base	-222	-115	-119	-122	-119	Amps	0.92	0.93	0.93	N	N	N
		3			X		1.5"	N face col near break	-251	-472	-372	-315	-386	ohms	0.74	3.44	3.46	N	W	N
		4					>5"	top of arch	-121	-140	-141	-222	-168					N	M	N
		5			X		>5"	N face col near arch	-263	-214	-144	-168	-176					W	N	W
		6					2.0"	top of arch	-211	-129	601	-223	83					W	W	N
13	25	1	Deck	0.150 mA/SF			3.8"	stringer bottom	17	-281	-178	-227	-229	Volts	2.00	2.70	2.12	N	N	N
		2					1.3"	deck	-405	-362	-250	-251	-287	Amps	1.45	1.45	1.45	N	M	W
		3					>5"	NF column	-98	-176	-121	-112	-136	ohms	1.38	1.86	1.46	M	W	N
		4				X	>5"	N face beam @ retraint	--	-69	-154	-331	-185					N	N	N
		5					2.2"	S face stringer @ bond	-193	-138	-137	-114	-130					W	W	N
		6					1.8"	S face beam	-198	-174	141	-128	-54					M	M	N
Pier 16	26	1	Pier	0.100 mA/SF			>5"	N face base	-241	-377	-334	-371	-361	Volts	1.06	3.60	3.87	N	N	N
		2			X		>5"	S face base	-79	-405	-310	-301	-338	Amps	0.31	0.34	0.34	W	W	W
		3					>5"	N face top W @ primary	-23	-459	-332	-414	-401	ohms	3.43	10.59	11.38	N	N	N
		4			X		2.0"	S face E top	-45	-376	-361	-410	-382					W	W	N
		5					3.2"	E col top	-153	-443	-200	-266	-303					M	N	N
		6				X	>5"	N face top E @ bond	-302	-126	-413	-323	-287					W	W	N
14	27	1	West Arch	0.050 mA/SF	X		>5"	top of arch	21	-176	-435	-375	-329	Volts	1.48	1.90	1.61	N	N	N
		2			X	X	>5"	W face	-134	-199	-143	-36	-126	Amps	0.35	0.34	0.34	N	N	N
		3					3.8"	arch bottom	-218	-556	-724	-168	-483	ohms	4.23	5.59	4.74	N	N	W
		4					1.7"	W face col @ top	-291	-535	-223	-108	-289					N	N	N
		5				X	>5"	arch bottom	53	-514	-109	-310	-311					W	N	N
		6					3.1"	arch bottom	-231	-141	-82	-41	-88					M	N	N
14	28	1	East Arch	0.175 mA/SF	X		>5"	top of arch	-231	-159	-24	-282	-155	Volts	1.87	2.30	2.11	N	N	N
		2			X		2.7"	top of arch E of col	-305	-72	-91	-355	-173	Amps	1.21	1.19	1.19	N	N	N
		3					>5"	W face @ primary	-190	-191	-87	-139	-139	ohms	1.55	1.93	1.77	N	N	N
		4					1.8"	E face col	-368	-337	-131	-131	-199					N	W	N
		5					1.7"	E face col	-304	-399	-115	-117	-210					N	W	N
		6					>5"	top of arch	-41	-44	104	-330	-90					N	W	N
14	29	1	Sidewalks	0.200 mA/SF			1.6"	W face W deck gutter	-343	-564	-254	-264	-361	Volts	1.45	1.30	1.42	N	N	N
		2			X		2.7"	E beam bottom	-266	-266	-191	-173	-210	Amps	0.73	0.73	0.73	N	N	N
		3					1.4"	N face W haunch	-411	-519	-502	-734	-585	ohms	1.99	1.78	1.95	N	N	N
		4					mesh	W soffit	-436	-685	-675	-924	-762					N	N	N
		5					1.7"	N face W haunch	-393	-705	-610	-235	-517					N	N	N
		6			X		2.2"	E beam bottom	-202	-265	-142	-145	-184					W	W	N
								Average	-222	-338	-217	-268	-274	Non protected				27	26	37
								Std Dev	±126	±195	±220	±170	±160	Moderately protected				6	4	0
								Max	53	-44	601	-36	83	Well protected				9	12	5
								Min	-436	-738	-724	-924	-762					42	42	42
								Positive for CP		1	4	2								

Coos Bay GECOR Test Results: Constant Current 2

			Sensor A LPR Testing				Sensor B (average of readings)									
		Gecor	Potential	Resistivity	Corrosion Rate		Potential	Resistivity	Risk	No.	Difference		Depth of	Rebar		
Span	Zone	Test Site	mV/CSE	KΩ	µA/cm²	Rating	mV/CSE	KΩ	Rating	Readings	Potential	Resistivity	Cover (in)	Orientation¹	Date	Comments
11	15	1	-134	68	0.15	low	-124	72	green	5	10	4	>5.00	--	05/09/11	stringer beam pier haunch near reference
deck		2	-274	36	0.32	low	-302	37	green	4	29	0	2.75	V-OC-R	05/16/11	bottom of stringer beam
		3	-281	45	0.22	low	-284	45	green	4	3	0	1.15	H-OC-A	05/16/11	stringer beam near reference
		4	96	254	< 0.1	negligible	89	263	green	4	7	8	>5.00	--	05/16/11	on deck column just above zone break has second run with zinc
		5	-369	26	0.46	low	-336	26	green	4	34	0	>5.00	--	05/16/11	at apex of spandrel beam arch
		6	-113	25	0.32	low	-136	24	green	4	23	1	2.10	V-OC-R	05/16/11	top of column/haunch at outer beam of exp joint
Pier 14	16	1	-220	71	< 0.1	negligible	-155	81	green	5	65	10	3.00	H center	05/09/11	EF column at top
		2	-74	27	< 0.1	negligible	-71	27	green	4	3	0	>5.00	--	05/09/11	web beam at top near PA
		3	57	69	0.23	low	34	71	green	5	23	2	>5.00	--	05/09/11	web beam at top near NB
		4	12	30	0.22	low	-20	28	green	6	32	2	>5.00	--	05/09/11	EF column mid point
		5	-116	13	0.30	low	-125	13	green	4	8	0	>5.00	--	05/18/11	SF pier pedestal
		6	-114	29	0.48	low	-115	15	green	4	1	14	>5.00	--	05/18/11	NF pier pedestal near reference
12	18	1	-121	27	0.26	low	-121	27	green	4	0	0	>5.00	--	05/11/11	WF arch near PA
east arch		2	88	101	< 0.1	negligible	81	104	green	5	7	3	>5.00	--	05/11/11	WF arch near NB
		3	40	92	< 0.1	negligible	25	99	green	7	15	7	>5.00	--	05/11/11	WF arch near NB
		4	-65	34	0.24	low	-96	34	green	10	31	1	2.00	H-OC-A	05/09/11	NF column @ top near reference & zone boundary
		5	-5	103	0.17	low	-10	110	green	6	5	7	1.25	H-OC-A	05/11/11	NF column @ top near reference & zone boundary
		6	-67	102	0.26	low	-84	88	green	6	17	14	>5.00	--	05/11/11	arch bottom at strut near const joint
13	22	1	-58	--	< 0.1	negligible	-13	35	green	4	45	--	>5.00	--	05/03/11	arch bottom near pier near reference
west arch		2	-49	28	0.20	low	-58	22	green	4	9	6	>5.00	--	05/12/11	EF arch near PA
		3	-231	16	0.28	low	-240	16	green	6	10	0	1.85	V-OC-R	05/12/11	top of south edge of lower strut
													2.15	H center		
		4	-90	25	0.22	low	-104	25	green	4	14	0	>5.00	--	05/12/11	EF arch ~1/2 of cicle in mud-stain area from drain run-off near NB
		5	-97	26	0.11	low	-109	26	green	6	12	0	>5.00	--	05/12/11	bot of arch in area with mud stain
		6	-161	23	0.54	moderate	-169	24	green	4	8	1	2.00	H-OC-A	05/12/11	NF mid of column 1 near reference
13	24	1	-237	23	0.19	low	-326	16	green	2	89	7	1.00	V center	05/12/11	EF beam bar half in patch half out near test well on beam bottom
sidewalk		2	-131	58	0.22	low	-123	65	green	4	8	7	1.55	V-OC-R	05/12/11	NF haunch near column
		3	-237	23	0.36	low	--	--	--	--			1.00	mesh	05/12/11	soffit near PA
		4	-116	33	0.25	low	-114	34	green	4	2	2	>5.00	--	05/13/11	WF beam near reference
		5	--	--	--	--	--	--	--	--	--	--	1.00	mesh	--	soffit near PA
		6	-265	32	0.17	low	-257	32	green	4	9	0	1.25	H center	05/13/11	beam bottom
14	30	1	-29	--	< 0.1	negligible	-38	143	green	4	10	--	--	--	05/04/11	EF fascia
deck		2	-122	--	0.12	low	--	--	--	--	--	--	--	--	05/05/11	NF columnnum
		3	-115	52	0.11	low	-115	54	green	3	1	2	--	--	05/05/11	WF stringer beam
		4	-132	55	0.49	low	-168	55	green	4	36	0	--	--	05/05/11	NF spandrel beam
		5	-111	56	0.11	low	-135	58	green	4	24	2	--	--	05/05/11	WF stringer beam near PA
		6	-255	52	< 0.1	negligible	-213	53	green	4	42	1	--	--	05/05/11	soffit near reference
Pier 17	31	1	-91	27	< 0.1	negligible	--	--	--	--	--	--	--	--	05/04/11	NF pedestal above TS
		2	-44	16	< 0.2	negligible	--	--	--	--	--	--	--	--	05/04/11	SF pedestal above TS
		3	-106	34	0.26	low	-112	34	green	4	6	0	>5.00	--	05/18/11	SF top near NB
		4	-31	98	< 0.2	negligible	-43	93	green	4	12	5	>5.00	--	05/18/11	SF top near PA
		5	-135	50	0.29	low	-137	51	green	4	2	1	>5.00	--	05/18/11	SF column mid
		6	-157	68	0.35	low	-151	67	green	4	5	0	>5.00	--	05/18/11	WF column mid
		Average	-109	51	0.27		-114	56			18	3	3.76			
		Std Dev	100	43	0.12		101	47			19	4	1.65			
		Max	96	254	0.54		89	263			89	14	5.00			
		Min	-369	13	0.11		-336	13			0	0	1.00			

-- no readings obtained

H	horz (east- west)	L	left	EF	East Face	NB	Negative Bond
V	vert (north-south)	R	right	NF	North Fac	PA	Primary Anode
OC	off center	A	above	SF	South Fac	TOW	Time of Wetness
		B	below	W	West Face		

Coos Bay GECOR Pre-CP Test Results: Constant Voltage

Span	Zone	Gecor Test Site	Type	Nom. Out	Test Well	Run Off	Conc Cover	Other Location Information	Potential (mV, CSE) Pre-CP	04/07/12	06/29/12	09/20/12	AVG ON		Rectifier Output 02/09/12	04/07/12	06/29/12	09/20/12	Protected 04/07/12	06/29/12	09/20/12
																			Not	Moderate	Well
11	15	1	Deck	0.125 mA/SF	X		2.0"	stringer face	-134	-256	-234	-236	-242	Amps	1.38	0.76	0.70	0.60	N	M	W
		2					2.8"	stringer bot.	-273	-227	-206	-200	-211	Volts	1.10	1.10	1.10	1.10	N	N	W
		3			X		1.2"	stringer bot.	-281	-310	-260	-170	-246	ohms	0.80	1.45	1.57	1.83	M	M	N
		4					2.0"	col @ bot. break	78	-182	-169	-152	-168						N	W	N
		5					>5"	beam bot.	-369	-109	-85	-49	-81						N	W	N
		6					2.1"	col @ top break	-113	-349	-279	-278	-302						N	N	N
Pier 14	16	1	Pier	0.175 mA/SF			>5"	E face top	-220	-376	-345	-214	-311	Amps	0.73	0.29	0.18	0.01	N	W	W
		2			X		2.0"	NE face top	-74	-261	-218	-193	-224	Volts	1.00	1.00	1.00	1.00	N	M	N
		3			X		>5"	NW face top	57	-175	-160	-147	-161	ohms	1.37	3.45	5.56	100.00	N	W	N
		4					3.0"	E face mid elev	-259	-454	-376	-77	-303						N	W	M
		5					>5"	S face bottom	-116	-154	-39	-122	-105						N	N	N
		6					>5"	N face bottom	-114	-129	-102	-122	-118						N	N	N
12	18	1	East Arch	0.100 mA/SF			>5"	W face @ primary	-121	-285	-73	-56	-138	Amps	0.83	0.28	0.20	0.09	N	W	N
		2					>5"	W face @ bond	88	-211	-33	-67	-104	Volts	0.60	0.60	0.60	0.60	N	W	N
		3					>5"	W face @ bond	40	-206	-58	-111	-125	ohms	0.72	2.14	3.00	6.67	N	M	W
		4			X		2.0"	N face col 9 top	-65	-321	-292	-236	-283						N	W	M
		5			X		1.3"	N face col 2 top	-5	-258	-212	-145	-205						N	N	N
		6					>5"	bot. @ const. jnt.	-67	-129	-97	-68	-98						N	W	N
13	22	1	West Arch	0.200 mA/SF	X		>5"	bot. near Pier 16	-58	-176	-200	-203	-193	Amps	1.48	0.48	0.10	0.07	N	N	N
		2				X	>5"	E face @ primary	-49	-345	-32	-14	-130	Volts	1.10	1.10	1.10	1.10	N	W	N
		3					1.9"	top of strut	-231	-425	-64	-70	-187	ohms	0.74	2.29	11.00	15.71	N	W	N
		4				X	>5"	E face @ bond	-90	-307	-21	-21	-116						N	W	N
		5				X	>5"	arch bottom	-95	-301	-13	-31	-115						N	W	N
		6			X		3.0"	NF col 1 mid	-161	-390	-199	-257	-282						N	M	N
13	24	1	Sidewalks	0.150 mA/SF	X		1.9"	E beam bot, patch	-310	-277	-238	-261	-259	Amps	0.59	0.00	0.00	0.00	N	W	N
		2					1.9"	N face haunch	-131	-223	-162	-137	-174	Volts	0.80	0.80	0.80	0.80	N	W	N
		3					mesh	soffit @ primary	-154	-284	-220	-274	-259	ohms	1.36	200.00	200.00	200.00	N	W	N
		4			X		>5"	E face E beam	-116	-594	-250	-277	-373						M	W	N
		5					mesh	soffit	--	-266	-263	-298	-276						W	W	N
		6					mesh	soffit @ primary	-265	-300	-151	-303	-251						N	W	N
14	30	1	Deck	0.050 mA/SF			3.2"	outer face of facia	-29	-67	-18	-29	-38	Amps	0.45	0.11	0.00	0.01	N	N	N
		2					2.4"	N face col @ facia	-122	-619	-170	-98	-296	Volts	0.60	0.60	0.60	0.60	N	N	N
		3					2.7"	stringer face @ primary	-125	-262	-100	-68	-143	ohms	1.33	5.45	150.00	60.00	N	N	N
		4					4.5"	N face of beam	-132	-277	-123	-119	-173						N	N	N
		5					3.4"	stringer face	-111	-345	-189	-73	-202						N	N	N
		6			X		2.1"	deck	-255	-861	-179	-151	-397						M	N	N
Pier 17	31	1	Pier	0.075 mA/SF	X		>5"	N face base	-91	-188	-202	-112	-167	Amps	0.35	0.09	0.00	0.04	N	N	N
		2					>5"	S face base	-44	-211	-221	-95	-176	Volts	0.40	0.40	0.40	0.80	W	W	N
		3					>5"	S face top W @ bond	-106	-210	-87	-72	-123	ohms	1.14	4.44	100.00	20.00	N	N	N
		4					>5"	S face top W @ primary	-31	-198	-132	-66	-132						N	N	N
		5					>5"	S face mid elev	-135	-267	-106	-112	-162						W	N	N
		6					>5"	W face mid elev	-156	-361	-115	-127	-201						N	N	N
								Average*	-121	-267	-159	-141	-196					Non protected	36	17	36
								Std Dev*	±103	±101	±91	±84	±81					Moderately protected	3	5	2
								Max	88	-67	-13	-14	-38					Well protected	3	20	4
zinc in reading								**Min**	-369	-861	-376	-303	-397						42	42	42
* Calculated without zinc reading								**Positive for CP**		0	6	5									

Coos Bay GECOR Test Results: Constant Voltage

APPENDIX E

LINT CREEK
GECOR TESTING RESULTS

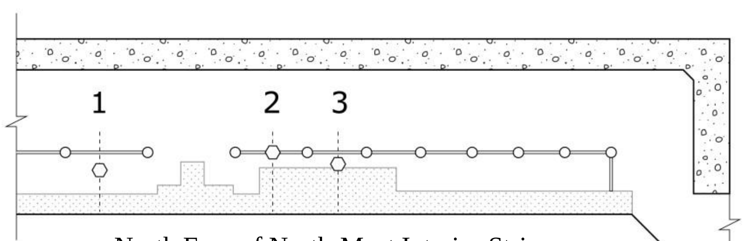
Initial Visit - 5/17/11: rainy, mid 50s °F		
Location	**Potential[1]**	**Level of Protection**
1	-349 mV	moderately protected
2	-454 mV	moderately protected
3	-414 mV	not protected
4	-432 mV	moderately protected
5	-400 mV	not protected
6	-398 mV	well protected

Location	Anode Potential[1]	Distance from Anode Centerline[2]
1	-831 mV	3 inches below, midway
2	-790 mV	on centerline, midway
3	-758 mV	2 inches below, midway
4	-819 mV	3 inches below, midway
5	-610 mV	6 inches below, 2 inches
6	-587 mV	2 inches below, midway

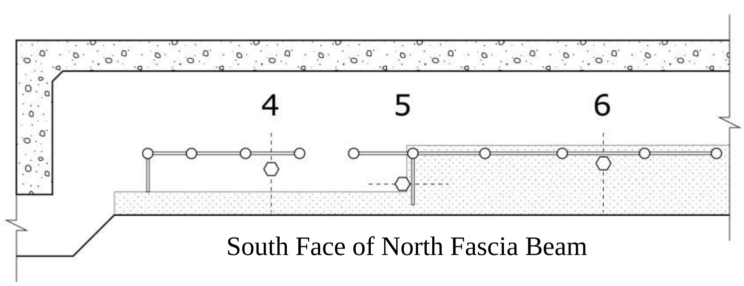
2nd Visit - 6/28/11: partly cloudy, upper 50s °F		
Location	**Potential[1]**	**Level of Protection**
1	-356 mV	moderately protected
2	-427 mV	well protected
3	-461 mV	well protected
4	-431 mV	well protected
5	-395 mV	well protected
6	-408 mV	moderately protected

3rd Visit - 09/22/12: clear, upper 50s, low 60s °F		
Location	**Potential[1]**	**Level of Protection**
1	-321 mV	well protected
2	-330 mV	well protected
3	-303 mV	well protected
4	-380 mV	well protected
5	-302 mV	well protected
6	-331 mV	moderately protected

1. Rebar potential at test location, Cu-$CuSO_4$ reference equivalent
2. Location of test reading. First figure distance below horizontal centerline of anodes. Second figure notes either "midway" between two anodes or the distance left or right of closest anode.



North Face of North-Most Interior Stringer



South Face of North Fascia Beam

APPENDIX F

YAQUINA BAY
GECOR TESTING RESULTS

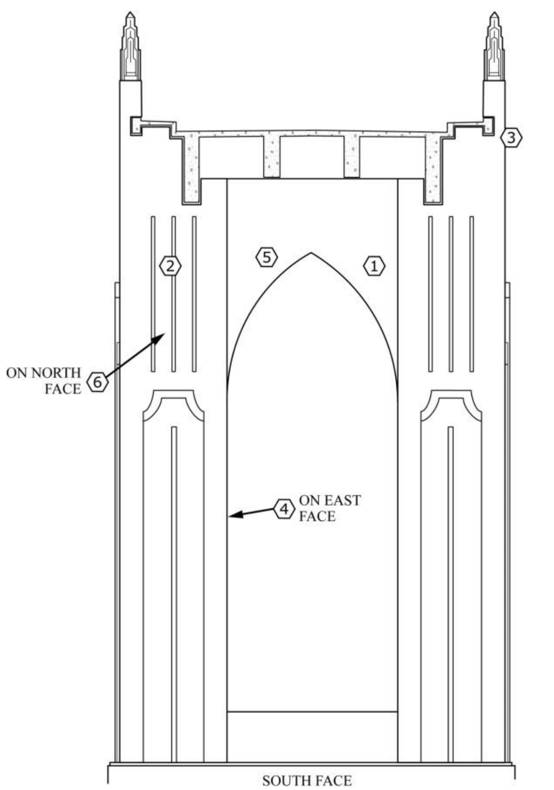
Zone 16 - 6/29/11: partly cloudy, upper 50s, low 60s °F

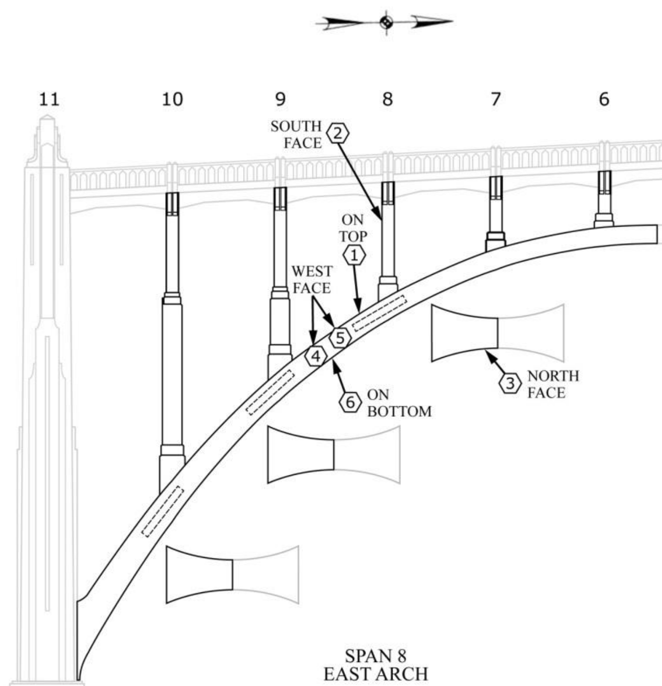
Location	Rebar Potential[1]	Concrete Resistivity[2]	Rebar Cover	Corrosion Risk
1	-237 mV	116 KΩ-cm	>5"	low risk
2	-179 mV	261 KΩ-cm	2.4"	low risk
3	-67 mV	89 KΩ-cm	2.2"	low risk
4	-258 mV	85 KΩ-cm	>5"	low risk
5	-248 mV	33 KΩ-cm	>5"	low risk
6	-180 mV	54 KΩ-cm	2.1"	low risk

Zone 18 - 6/29/11: partly cloudy, upper 50s, low 60s °F

Location	Rebar Potential[1]	Concrete Resistivity[2]	Rebar Cover	Corrosion Risk
1	-79 mV	29 KΩ-cm	>5"	low risk
2	29 mV	57 KΩ-cm	2.7"	low risk
3	-39 mV	24 KΩ-cm	>5"	low risk
4	9 mV	83 KΩ-cm	>5"	low risk
5	-48 mV	35 KΩ-cm	>5"	low risk
6	-122 mV	40 KΩ-cm	4.2"	low risk

1. Rebar potential at test location, Cu-$CuSO_4$ reference
2. Average of four resistivity measurements





APPENDIX G

GECOR INSTRUCTION MANUAL

The GECOR8 Corrosion Rate Meter
Instruction Manual

Second edition
January 2002

CONTENTS

Annexes

Figures

Tables

1 INTRODUCTION

The corrosion of reinforcement in concrete structures is one of the most important deterioration mechanisms that affect their service life. However, in spite of the economic impact, quantification of the corrosion rate remains a matter of highly detailed research. Present corrosion rate meters fill this gap between research and practice.

GECOR8[1] was developed from the experience obtained during the 10 years of application of the former version (GECOR6). It measures the Corrosion Rate of steel in concrete by applying the Polarization Resistance technique for on-site measuring. In addition, other corrosion parameters of rebars including Corrosion Potential and Resistivity are measured.

The device can also be used to estimate Corrosion Rate in submerged or very wet structures and to check the efficiency of cathodic protection without switching-off the current.

Four different techniques have been implemented in GECOR8:

- Mapping. (Potential and resistivity)
- Measurements in aerial structures (non submerged structures). (Modulated Confinement Technique)
- Measurements in submerged or very wet structures. (Attenuation of Potential Technique)
- Measurement in structures with cathodic protection. (Passivity Verification Technique)

MAPPING

Measurement of Corrosion Potential and Resistivity has been developed to get a fast appraisal of the corrosion state of the structure. The cross comparison of both parameters is used to have a qualitative understanding of the structure.

The half-cell technique is well known and is used to identify areas of corrosion risk (ASTM C876). It is important to stress that this technique only gives a probability of corrosion.

Resistivity (ρ) is a complementary measurement to establish the risk of corrosion as it is related to the humidity content of the concrete. The technique implemented in GECOR8 (disc method) makes use of the formula (1)(2):

$$\rho = 2 \cdot R \cdot D$$

Where: R is the resistance by the “Ir drop” from a pulse between the counter electrode of the sensor and the rebar network.

D is the diameter of the counter electrode

[1] GECOR8 has been developed by GEOCISA with the collaboration of Eduardo Torroja Institute (CSIC).

The technique is applied through a very small sensor that allows access anywhere in the structure.

The combination of the two parameters gives qualitative information about state of the structure on each point identifying areas with risk of corrosion (high, medium, low). Introducing these values into the co-ordinates of the measurement grid, a map for each corrosion parameter or with the risk level of corrosion can be obtained.

MEASUREMENTS IN AERIAL STRUCTURES (non submerged structures)

As in GECOR6, The Polarization Resistance (Rp) is obtained through the change in potential, divided by the applied current. GECOR8 obtains the Corrosion Rate (Icorr) from the Rp by means of the "Stern and Geary" relationship:

$$Icorr = B/Rp$$

Where B is a constant (in GECOR8 the value 26 mV has been assigned).

GECOR8 includes an advanced **Modulated Confinement Technique (MCT)** to measure Corrosion Rate of steel in concrete by the Polarization Resistance technique. This is a non-destructive technique that works by applying a small current to the reinforcing bar and measuring the change in the half-cell potential. The confinement is now quicker and more stable than with GECOR6 as the control of the guard ring has been improved. That is why the confinement is now “modulated”.

GECOR8 is able to accurately confine the area of measurement in that area delimited by the width below the sensor. This means that corrosion rate measurement is referred to a defined area, and gives the true corrosion current, Icorr at the place of measurement. (3)(4)(5)(6)(7)

MEASUREMENTS IN SUBMERGED OR VERY WET STRUCTURES

GECOR8 incorporates a new method for submerged or very wet structures. On this group, concrete structures with less than 28 days of age or structures with de-icing salts have to be considered too. Due to the low Resistivity of these structures the MCT is not evenly efficient. These measurements will be made by means of the **Attenuation of Potential Technique (APT)**.

The method uses a potentiostatic pulse for the measurement of Polarisation Resistance, which is referred to the area of steel reached by the current. The technique uses a special sensor with four reference electrodes for the measurement of potential attenuation with the distance. By this way, it is possible to calculate the area really polarized. (8)

MEASUREMENT IN STRUCTURES WITH CATHODIC PROTECTION

The checking of the efficiency of cathodic protection without switching-off the current is made through the **Passivity Verification Technique (PVT)**. The technique is based on the analysis of the impedance obtained from an alternate current applied with modulated confinement (sensor A). GECOR8 gives indication on the efficiency of the CP in percentage.

The equipment also includes the well-known **Instant Off Technique (IOT)** to check the efficiency of cathodic protection by switching-off the current.

COMPONENTS

GECOR8 has four major components, the corrosion rate meter and three different types of sensors:

- **SENSOR A**: for measurement in aerial structures and for measurement in structures with cathodic protection.
- **SENSOR B**: for mapping of Corrosion Potential and Resistivity.
- **SENSOR C**: for measurement in submerged or very wet structures.

<table>
<tr><th>Sensor</th><th>Application</th><th>Technique</th><th>Measurements</th></tr>
<tr><td rowspan="3">A</td><td>Measurement in aerial structures</td><td>Modulated Confinement Technique (MCT)</td><td>Corrosion Rate
Corrosion Potential
Concrete Electrical Resistance</td></tr>
<tr><td rowspan="2">Measurement in structures with cathodic protection</td><td>Passivity Verification Technique (PVT)</td><td>Corrosion Potential
Efficiency of Protection</td></tr>
<tr><td>Instant Off Technique (IOT)</td><td>Initial Potential
Instant off Potential
Final Potential</td></tr>
<tr><td>B</td><td>Mapping</td><td>Mapping</td><td>Corrosion Potential
Resistivity
Risk level</td></tr>
<tr><td>C</td><td>Measurements in submerged or very wet structures</td><td>Attenuation of Potential Technique (APT)</td><td>Corrosion Rate
Corrosion Potential
Concrete Electrical Resistance
Resistivity</td></tr>
</table>

Table 1.- Summary of measurement methods

For sensor A and B there are two different available versions, depending on the reference electrodes incorporated on them. For sensor C there is only available the $Cu/CuSO_4$ version.

- **Copper / Copper Sulphate ($Cu/CuSO_4$)**: electrodes with $CuSO_4$ solution reservoirs.

- **Silver / Silver Chloride (Ag/AgCl)**: electrodes with a gel electrolyte (non-liquid). They are detachable and can be replaced from the sensor.

OPERATION

Measurements are taken by making an electrical connection to the reinforced steel and placing the sensor on the surface. The sensor includes a sponge pad, which has to be wetted to ensure a good electrical connection to the surface.

DATA PROCESSING

The complete system is portable and easy to use due to its user-friendly operator interface. The microprocessor control system selects the correct parameters, carries out the measurement and store data in a PCMCIA card.

Data transmission to a host computer can be made via PCMCIA card or through a standard RS232 serial port with the RX8 software for downloading provided with the equipment.

GECOR8 has an optional pre-post processing software (BASEGECOR) for making easier the planning of the measurement campaigns allowing preparation of predefined tasks and for the processing of the results obtained with the equipment. (9)

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2 TECHNICAL SPECIFICATION

2.1 CORROSION RATE METER

(See Figure 1)

- **Current output and millivoltmeters:**
  - 2 constant current sources with a resolution of 12 bits, 0±1 mA
  - 1 potentiostat of ± 3000 mV
  - 4 potential measurement entries with the following characteristics:
    - Entry impedance of 10000 MΩ
    - Sample and hold simultaneous
    - Scale 300, 600, 1200, 2500 mV
    - Resolution 16 bits
- **Processor:**
  - C.P.U Intel 486 SXSK
  - 4 Mbytes DRAM
  - 256 Kbytes flash BIOS
  - 2 Mbytes flash disk
  - Interface RS-232
  - Interface PCMCIA
- **Keyboard:** 20 keys
- **Display:** Liquid crystal screen with 320x240 points and 16 grey level colours
- **Power:**
  - Battery pack 13.7 V and 5Ah. Nickel-metal hydride (see Figure 6)
  - Weight: 1.8 Kg
- **Dimensions:** 21 x 31.5 x 22 cm
- **Weight:** 4.5 Kg (without the battery)
- **Downloading specification:**
  - Rate: 9600 bauds, Parity: none, word length: 8 bits, 1 stop bit

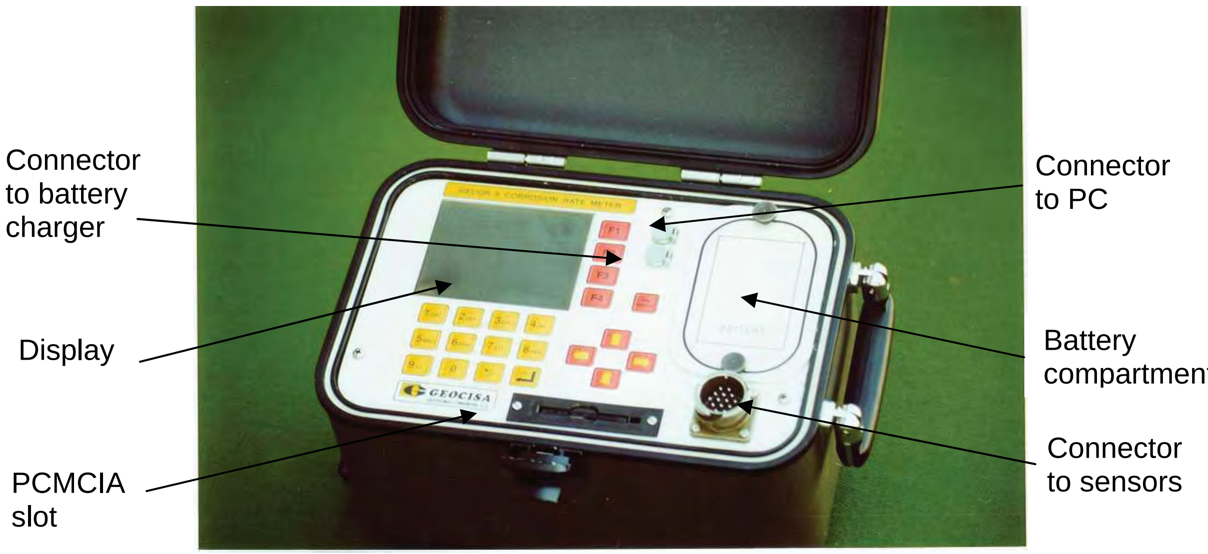


Figure 1.- GECOR8 rate meter

2.2 SENSOR A

(See Figure 2 and Figure 3)

The maximum depth of the sensor reading is approximately one meter.

- **Elements:**
  - Central reference electrode ($Cu/CuSO_4$ or Ag/AgCl)
  - Confinement reference electrodes ($Cu/CuSO_4$ or Ag/AgCl)
  - Stainless steel counter electrodes
  - Methyl methacrylate body
  - Three $CuSO_4$ solution reservoirs with 8 ml of capacity each one (on $Cu/CuSO_4$ sensors)
- **Dimensions:** 18 cm (diameter) x 2.5 cm (high)
- **Weigh:** 1 Kg

Figure 2.- Sensor A ($Cu/CuSO_4$)

Figure 3.- Sensor A (Ag/AgCl)

2.3 SENSOR B

(See Figure 4)

- **Elements:**
  - Reference electrode ($Cu/CuSO_4$ or Ag/AgCl)
  - Stainless steel counter electrode
  - Methyl methacrylate body
  - One $CuSO_4$ solution reservoir with 12 ml of capacity (on $Cu/CuSO_4$ sensors)
- **Dimensions:** 4 cm (diameter) x 14cm (high)
- **Weight:** 160 gr

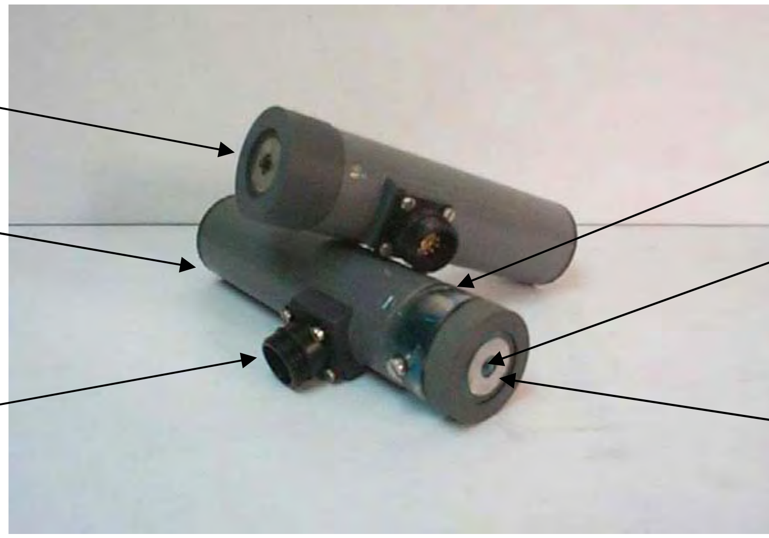


Figure 4.- Sensors B

2.4 SENSOR C

(See Figure 5)

- **Elements:**
  - Four reference electrodes ($Cu/CuSO_4$)
  - Stainless steel counter electrode
  - Methyl methacrylate body
  - Four $CuSO_4$ solution reservoirs with 10 ml of capacity each one
  - Rubber band.
- **Dimensions:** 7 x 23 x 2.5 cm
- **Weight:** 1 Kg

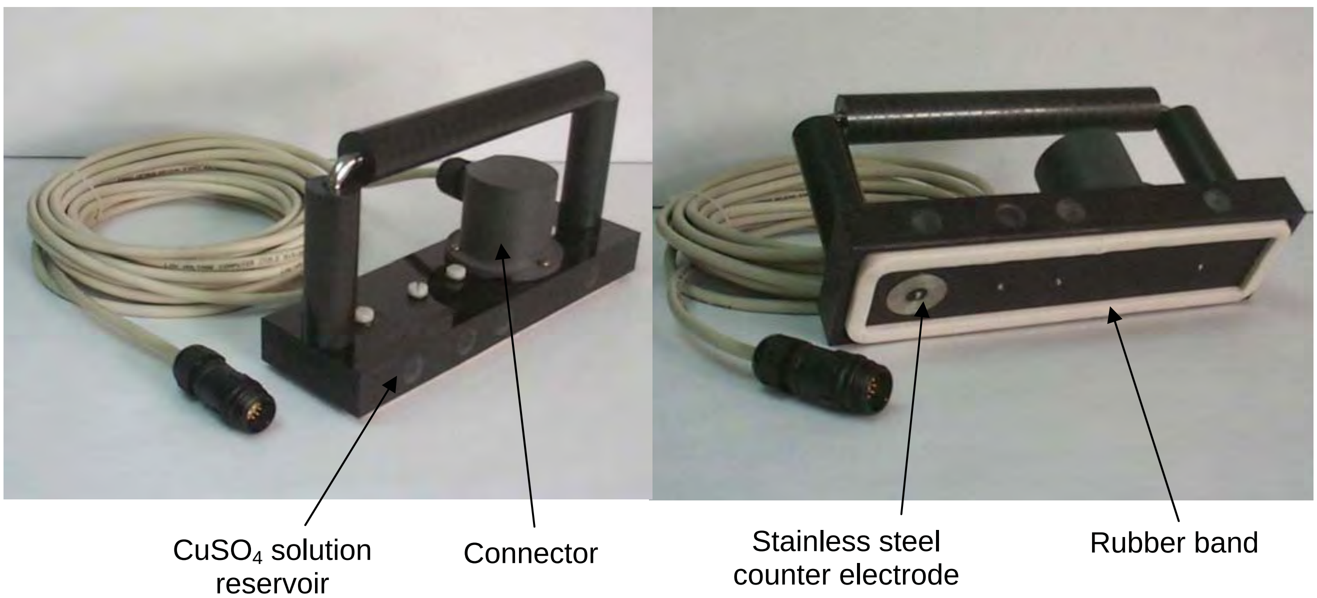


Figure 5.- Sensor C ($Cu/CuSO_4$)

2.5 ACCESSORIES

- 8 m cable for sensor to rate meter connection (additional 30 m cable)
- Dummy cell (see Figure 7)
- Nickel-metal hydride battery fast charger: (see Figure 8)
  - 13.7 V 5 Ah
  - 110/220 VAC power
  - A Fast charge
  - A Trickle charge
  - Voltage slope and timer fast charge cut-off
  - 150 minutes fast charge maximum
- RS232 interface cable
- Software for downloading data to host computer (RX8)

- Pre-post processing software (BASEGECOR) (optional)

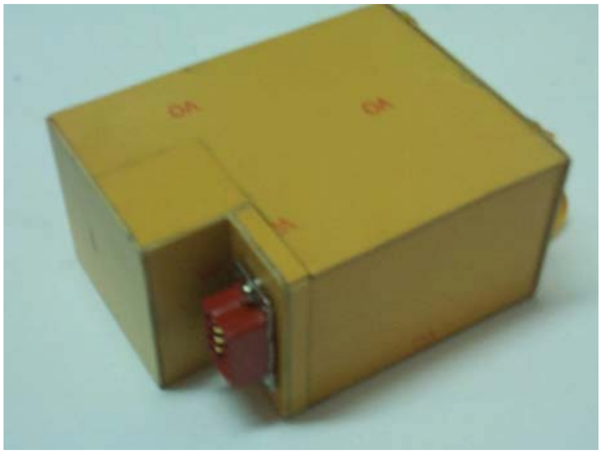


Figure 6.- Battery pack

Figure 7.- Dummy cell

Figure 8.- Battery charger

3 INSTRUCTIONS FOR OPERATION

3.1 SET-UP PROCEDURE

3.1.1 SELECTING MEASUREMENT LOCATIONS

Before starting a corrosion survey it is important to select the number and location of points where corrosion rates will be measured. The number of points will depend upon the available time, access, size of structure and the information available either prior to the survey or collected from the survey. In any case, the objective is always the determination of the state of corrosion of the structure, identifying areas with risk of corrosion and quantifying on each case the level of corrosion.

Each reading takes different times depending upon the type of measuring required. But the operator has to also consider the time taken to get access to each location, other measurements taken and other logistical elements associated with site work. This will control the total number of readings that can be taken.

Obviously experience is important in being able to collect the most useful data for a defined time and effort. Chloride concentration, staining, cover size, carbonation depths, etc… can also be used where appropriate.

Before starting corrosion rate measurements in aerial structures with sensor A, previous information can be obtained with the sensor B (**mapping**) in order to have an understanding of the global condition of the structure. These measurements can be taken on a grid on the surface of the concrete to identify areas with risk of corrosion. The distance between the sensor and the rebar has to always be more than 5 cm (two times the counter electrode diameter). Resistivity and Corrosion Potential are measurements take only 2 to 5 seconds and a combination of these two parameters is also given by GECOR8.

Measurements in aerial structures (non submerged structures) with sensor A take 2-3 minutes depending upon the actual corrosion conditions. There is also a set up time of 2-5 minutes so the operator must allow 4-8 minutes per location.

Sensor C is required for **measurements in submerged or very wet structures**. Each measurement takes around 2-3 minutes and preparation time depends on the measurement location.

For **measurements in structures with cathodic protection** sensor A must be use because the PVT needs the modulated confinement. Each measurement takes around 10-12 minutes and other 2-3 minutes for set-up and stabilisation. Measurement points should be representative as is usually suggested. Near the location of the anodes the PVT measures their efficiency. Therefore, it is suggested to start by measuring near the anodes and at different farther distances when the checking of the critical distances of protection is of interest.

In general, measurement planning can be made following three different ways

A.- Regular grid of Measurement points

This mode of operation is recommended for structures or elements that have to be thoroughly studied, either because they could suffer localized damage or because the consequences of a structural failure.

In this case, measurement locations have to be regular and geometrical, attending generally to a grid on which the vertexes are the measurement points. The distances between points will depend upon the element size and spacing of reinforcements. Typically this could be 20 to 100 cm.

Example 1: Wall on a basement affected by possible seawater leakage because of a punch on the external waterproof layer. On this example, the element has large dimensions and it is exposed to aggressive agents only on very localized areas. Depending on the wall dimensions it will be appropriate a measurement grid of 1m x 1m spacing.

Example 2: A beam of a bridge of ... in span. The grid should follow the geometry and recommended distance may be 20-30cm.

B.- Statistical distribution

It is indicated for large structures, with different and repetitive structural elements.

On this case, measurements must be located over a percentage of the elements, increasing the number of measurement points when active situations are detected.

Example 3: 3 Km long bridge with 80 spans and slab composed by 8 beams.

On this example the number of measurement points of the sampling will depend on the apparent damages detected by a visual inspection.

C.- Measurement points disposed on relevant areas

Point locations are selected as a representative state of the structure even in areas affected and non-affected by corrosion damages. Sampling must be made on significant points because of the apparent damage level (with or without damages) and the exposure level or corrosion risk (submerged areas or edges)

This sampling can be made in all types structures; being specially indicated to be used with other different concrete inspection techniques as visual inspection, chemical analysis, ultrasound, drilled core, etc…

Example 4: Bridge with 3 spans, with slab with 4 beams and 3 columns, partially submerged.

Depending on the visually observed damages, 10 or 15 points could be enough. These points must be close to the concrete samples drilled to determine aggressive contents and close to damaged areas. A few points should be located on edge beams and drain areas. Any measurement should be made on the wet zone of columns.

3.1.2 ENVIRONMENTAL CONDITIONS

The corrosion rate meter like any device having electronic components will not work in extreme conditions of temperature or humidity. The device should not be operated in temperatures below 0ºC (32 F), or allowed to get over 50ºC (122 F). The relative humidity should not exceed 90% inside the unit.

If the environment exceeds these limits, then the meter can be operated from within an air-conditioned enclosure or vehicle. An additional 30m (l00 ft) cable can be provided with GECOR8 for this purpose.

It should be noted that below freezing, the water in the sponge pad may freeze giving misleading or unstable readings. If it is essential to collect data under these conditions then an alcohol solution (10-30% of alcohol by volume) will reduce the freezing point. It should also be noted that the concrete pore water may also freeze and the corrosion rate reduce to negligible proportions giving misleadingly low corrosion rate measurements at low temperatures.

3.1.3 SURFACE PREPARATION

There must not be a metallic (electronic) short circuit from the bar to the surface caused by tie wire, nails etc., as these will distort the reading. The surface must be cleaned and free of any electrical insulating or impermeable material. If there is any finishing layer in the concrete surface it is recommended to remove it (only under the sensor). Any local unevenness or insulating layers have to be avoided or removed by grinding or choosing another location or they can be "ironed out" by using additional sponge pads. On very wet or submerged structures molluscs or moss must be removed. There must be complete electrical (ionic) contact between the electrodes and the counter electrodes in the sensor and the concrete surface.

The surface can be wetted (but not saturated) prior to applying the sensor. Ordinary drinking water without further addition (other than alcohol in freezing conditions as describes above) is recommended to avoid contaminating the half-cells. Deionized or distilled water is not recommended.

Major voids, delaminations or cracks within the concrete should be avoided. This will cause the signal to deviate from the required path, giving misleading readings.

3.1.4 CONNECTIONS BETWEEN EQUIPMENT AND STRUCTURE

A) Reinforcement contact

In order to complete the circuit an electrical connection must be made to the reinforcement. It should be made without creating excessive damage, using rebars that are not covered or removing light concrete cover along a section of rebar (1 or 2 cm of rebar).

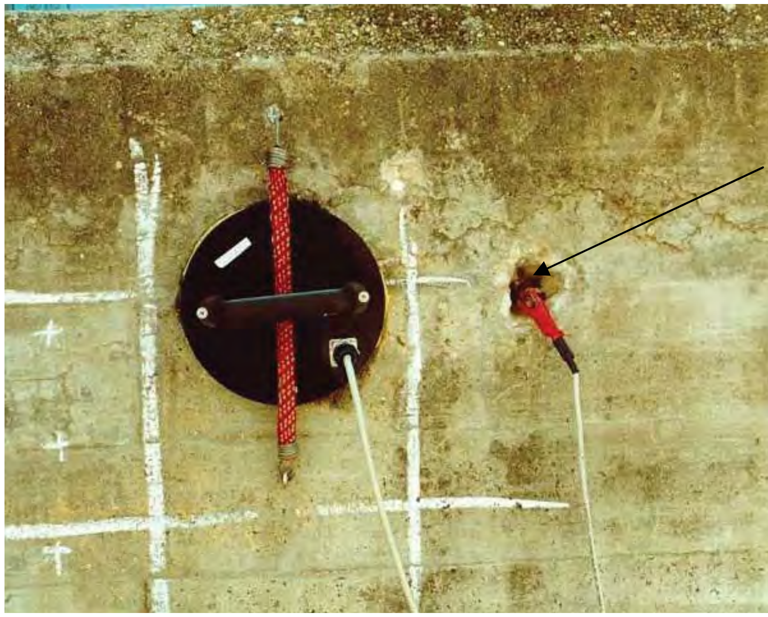


Figure 9.- Connections between the equipment and the structure

Generally, reinforcement inside one concrete element is electrically connected, and one connection will be enough for different measurements, even if points are far from the contact. When one element has separated points by a long distance (more than 30 m.), it is recommended to make more than one contact with the rebar. Besides, the measurement signal has a very low intensity for avoiding alterations on the reinforcement. Thus, it can vanish along the concrete because of the high resistivity of the material.

Finally, contact has to be made by fitting the crocodile claw (alligator clip) of the wire connection and cleaning the pincer and the rebar surface of any oxide or concrete. The connection must be checked with a multimeter.

In case of periodical measurements at the same points (evolution with time of corrosion rate) it could be useful to make permanent electrical contact on the structure, connecting a wire that could be checked externally and closing the concrete surface with a mortar.

In submerged or very wet structures, electrical contact should be in the aerial zone of reinforcement if it is possible. If not, an isolated contact is necessary.

B) Sensor location

Before placing the sensors it is necessary to know the rebar location in the measurement area using a rebar locator.

The preferred location for sensor A and sensor C is directly over a rebar, either a single bar or at a cross over. With the confinement method with sensor A, rebar diameter must be known. In case of sensor C, reinforcement on a reference area (usually $1m^2$) must be known.

On mapping measurements with sensor B, distance between sensor and reinforcement must be more than 50 mm (two times the counter electrode diameter). Thus, if the concrete cover is less than 50 mm, it is better to place the sensor away from the bar position.

The sensors have to be kept against the surface with the electrodes and counter electrodes in full contact with the surface throughout the measurement. In case of sensors A or B, the sponge and the concrete surface must be wetted.

In measurements with sensor A or C, it is recommended to fix the sensor with any external element (belts, props...) because a small oscillation can make fluctuations in measurement that make it difficult. Sensor B must be manually placed perpendicular to the surface of the concrete.

There are conditions when the contact side of sensor A or C cannot be in full contact with the concrete, as described below:

- **Measurements on corner reinforcing steel**

  If measurement is made on aerial structures (with Sensor A), rotate the sensor so that the three reference electrodes (half-cells) are perpendicular to the edge. In both, sensor A or C, all reference electrodes must be in contact with the concrete.

- **Measurements on narrow elements (beams)**

  Ensure that the reference electrodes are in contact with the concrete, aligned over the rebar to be measured.

- **Uneven or curved surfaces**

  Additional damp sponges may be applied with sensor A to ensure a good ionic contact between the sensor and the surface.

Sensor C must work with their $Cu/CuSO_4$ solution reservoirs full and not very long submerged periods are recommended. There is no experience in measurements on very deep locations.

Figure 10.- GECOR8 device with sensor A

Figure 11.- GECOR8 device with sensor B

3.2 TAKING A MEASUREMENT

3.2.1 NOMENCLATURE

Following nomenclature will be used along this chapter:

- The different screens shown by the equipment will be referred in cursive and between angular brackets.

<Main screen>

- Execution process of the program without the user action: parenthesis will be used to describe how to go from one screen to another automatically.

<System test>()<stability>

- Execution process of the program with the user action: The sequence necessary to go from one screen to another pressing a key will be represented as follows, where the actionable icon is shown.

<Main screen SETUP *<set-up>*

Icons that appear in the screens are activated pressing its nearest key in the keyboard (F1 to F4 and 1 to 3). The keys of the keyboard will be represented framed along this manual.

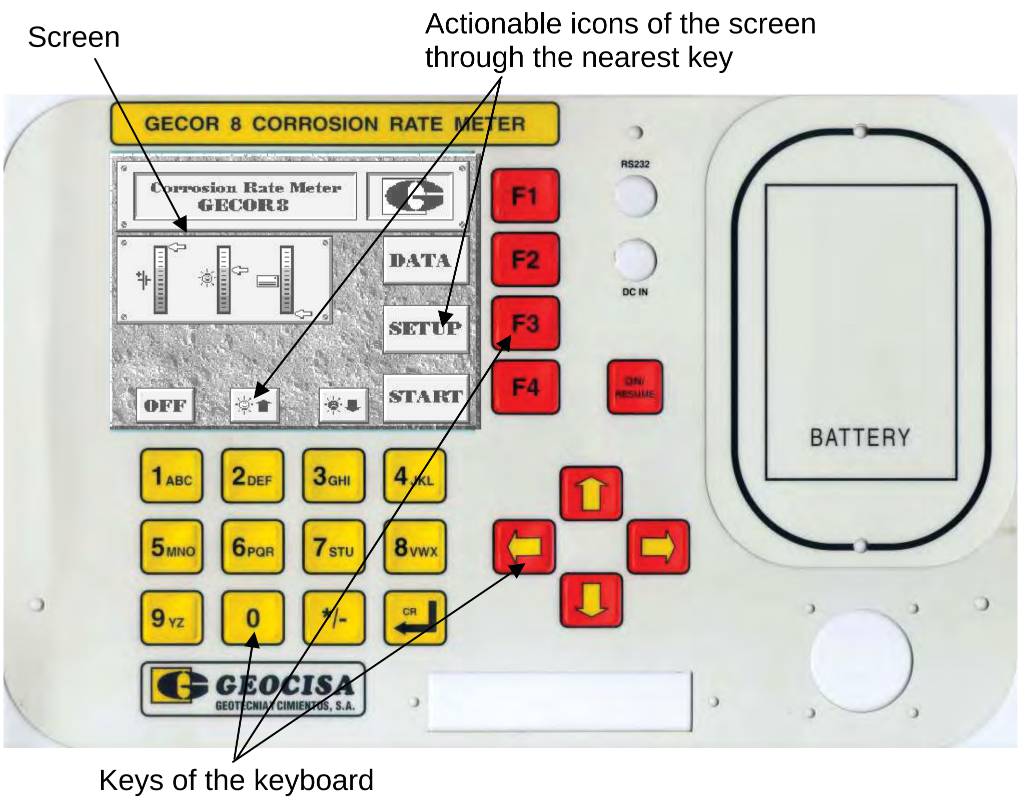
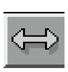


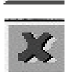
Figure 12.- Front part of GECOR8 rate meter

<u>More common icons</u>:

 To save the modifications and go to the next screen

 To delete

 To change the value of some alphanumeric parameter

 To cancel all changes and go back to the main screen.

<u>Types of parameters</u>:

- Alphanumeric: the same key has to be pressed to get the suitable character (key 1_{ABC} will show successively characters 1, A, B, C). To write the next character press →.

  In some cases user can choose in a menu among different values activating  icon with his nearest key on the keyboard. (This parameter will be marked with the symbol “<>”).

- Numerical: press the corresponding key successively. Decimal point will be written by key *.

The equipment has default values for each parameter that are shown in the data screens.

Each parameter has a valid range of values. If a number out of bounds is written, a message appears during a few seconds informing about the established bounds in the parameter and the equipment does not let to continue with next field pressing CR when numerical limits are exceeded.

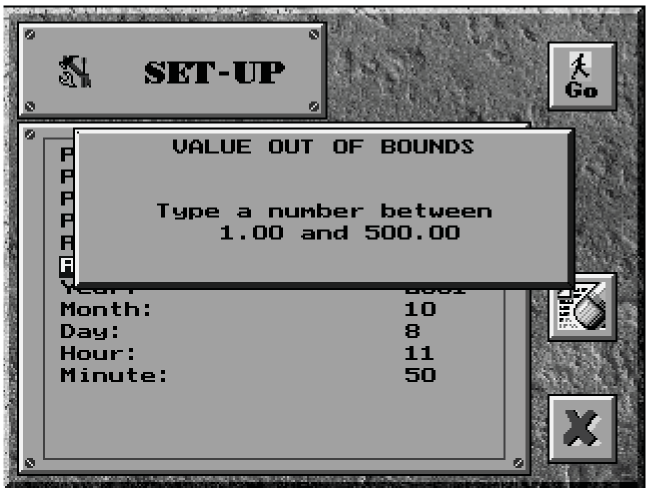


Figure 13.- Warning message indicating a value out of bounds

Each parameter has a maximum number of characters and a whistle warns when more characters are introduced.

3.2.2 MAIN SCREEN

When the equipment has been connected pressing ON and when the starting process is finished "*Main screen*" appears (Figure 14). To access the various options:

icon is activated pressing F2 to see all the files registered in the PCMCIA and to select, delete or transmit them. (see chapter 4)

icon is activated pressing F3 to access to the configuration screen. (See chapter 3.2.3)

icon is activated pressing F4 to start a measuring. (See chapter 3.2.4)

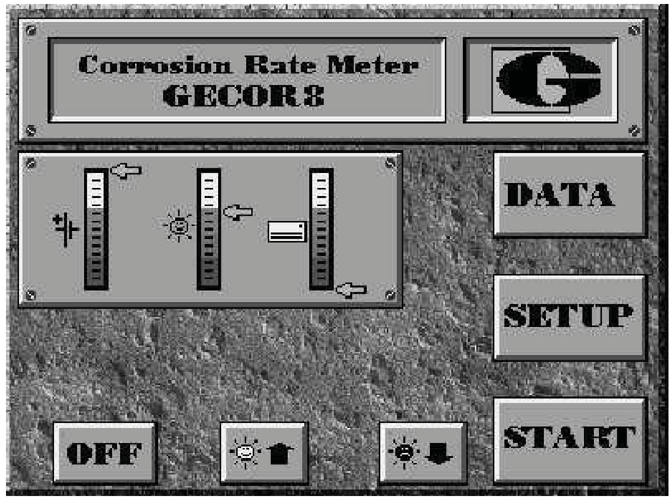


Figure 14.- “*Main screen*”

Moreover, this screen displays information about the battery level, contrast level of the screen and free memory at of the PCMCIA card. Battery level is high when arrow is on the top. Contrast level can be modified activating [button] and [button]. When all space is free on PCMCIA card, the arrow will be on the top.

3.2.3 SET-UP

The screen of the configuration parameters appears with the following sequence:

<Main screen> SETUP *<Set-up>*

“*Set-up*” screen (Figure 15) shows different parameters that can be change by the user.

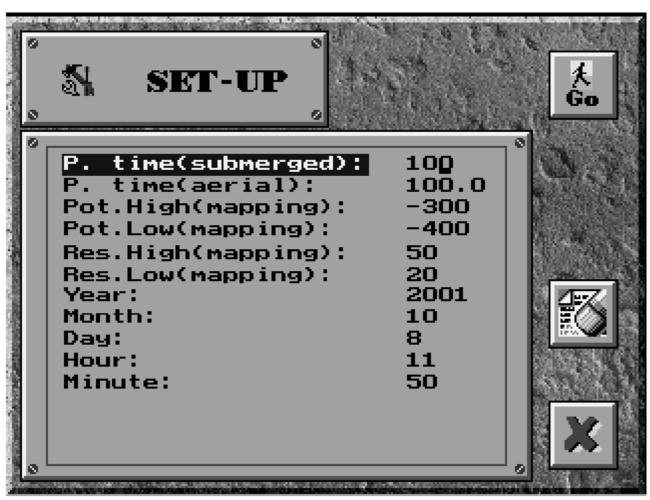


Figure 15.- “*Set-up*” screen

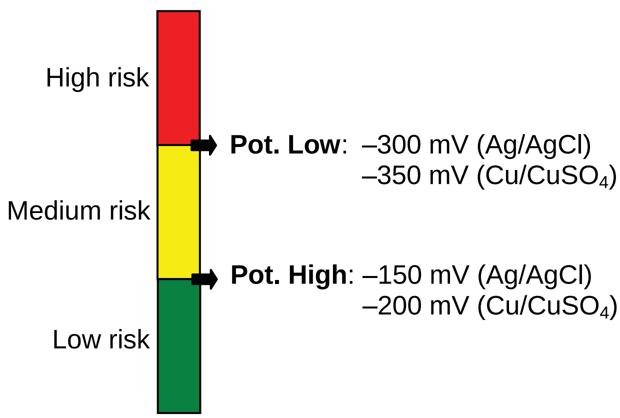
Initially it is shown the value stored on the internal memory of the equipment. To select a new parameter (dark framed) use keys ↑ ↓ or CR. To change the values of the parameters see chapter 3.2.1.

The parameters, units, bounds and default values shown on "*Set-up*" screen are the following:

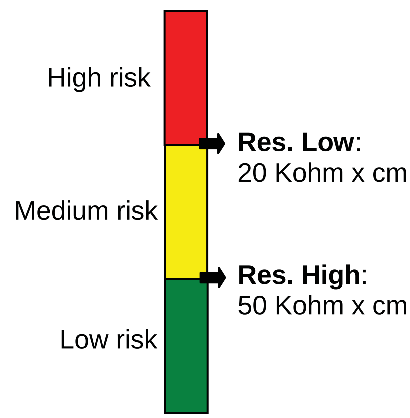
Mapping (see chapter 3.2.5)

- Threshold default values:

Corrosion potential



Concrete resistivity



- Bounds of values of the equipment:

  Corrosion potential: -2000 to -1

  Concrete resistivity: 1 to 500

Measurements in aerial structures (non submerged structures) (see chapter 3.2.6)

- **P. Time** (aerial): Polarization time
  - Units: seconds
  - Bounds: 2 to 1000
  - Default value: 100 s

Measurement in submerged or very wet structures (see chapter 3.2.7)

- **P. Time** (submerged): Polarization time
  - Units: seconds
  - Bounds: 2 to 1000
  - Default value: 80 s

Parameters needed for the updating of the internal watch are also included in "*Set-up*" screen (Figure 15).

3.2.4 TASK AND METHOD SELECTION

A task is a type of measurement to be made in one point of the structure. There are two types of tasks: predefined and non-predefined.

<u>Predefined tasks</u> can either be defined in a PC with a standard text-processing program or with the optional pre-post processing software (BASEGECOR) (see Ref (9) on page 8). They do not need to select the method with the equipment because it is already predefined.

<u>Non-predefined tasks</u> are made directly with the equipment and the method has to be selected as it is explained next.

Following the sequence:

< *Main screen*> 

< *Task selection*>

"*Task selection*" screen (Figure 16) appears where tasks saved on PCMCIA are shown.

Figure 16.- "*Task selection*" screen

When a task is selected the description appears at the right of the screen and when a task has been made an indicator (*) appears at the left of its name.

When there are more than 12 predefined tasks on PCMCIA, it is not possible to see all of them at the screen on the same time. The List can be moved up and down when the selection bar is placed on the upper or lower line. "New task" line is always the last of the list.

GECOR8 is able to show at maximum 199 different tasks saved on the PCMCIA and it allows to move thorough them in groups of 50 tasks. To select the group in which you are moving activate icons  or  with keys ← or →.

Each task corresponds to a point and a type of measurement. On the "*Results*" screen of each type of measurement (except in mapping) an icon for repeating the measurement is available. This option allows saving different measurements with the same task name. It has to be used only for measurements made on the same point.

To carry out a task that appears on the list (predefined task), move the task selection bar with the keys ↑ ↓ and press CR to start. In this case it is not necessary to choose the measurement method.

To carry out a task that is not included on the list (non-predefined task), place the selection bar at the line "New task" and press CR.

<Main screen 

<Task selection> CR *<Method selection>*

Then "*Method selection*" screen (Figure 17) appears where you can select one of the four available methods pressing icons  with keys F1 to F4

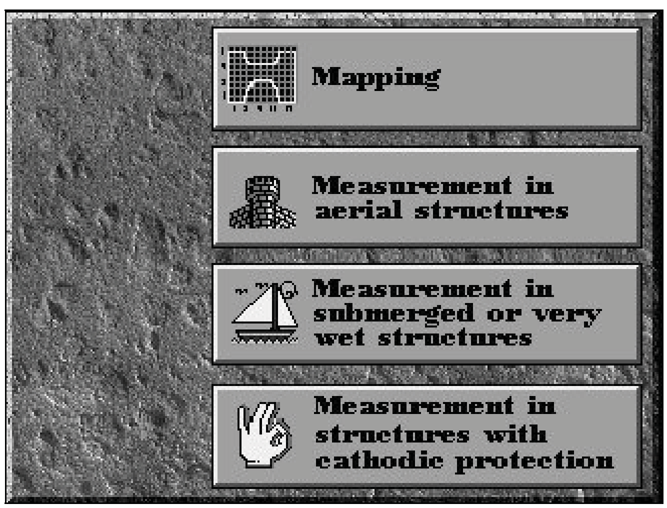


Figure 17.- "*Method selection*" screen

After selecting a predefined task or after selecting the measurement method in case of non-predefined tasks, GECOR8 makes a check to detect the connected sensor. If it is not the correct sensor for the selected method (see Table 1) a warning message (Figure 18, Figure 19 and Figure 20) appears to require the correct sensor.

GECOR8 is compatible with sensor A and sensor B of GECOR6 (the former version), but these sensors cannot be detected by GECOR8 so the warning messages requiring the correct sensor will always appear on that cases. If you are sure that it is the correct sensor for the selected method, activate  icon to continue with the measurement.

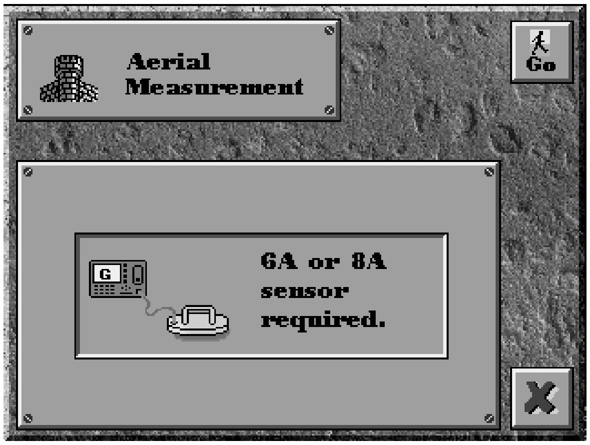


Figure 18.- “*Sensor A*” screen

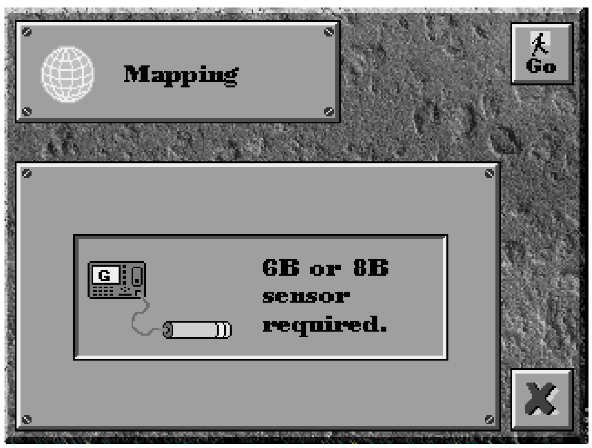


Figure 19.- “*Sensor B*” screen

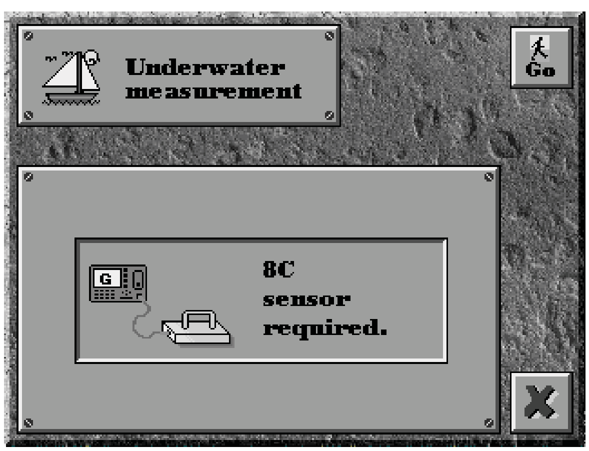


Figure 20.- “*Sensor C*” screen

3.2.5 MAPPING

3.2.5.1 Previous remarks

Mapping gives numerical values of corrosion potential and concrete resistivity and the identification of the risk level of corrosion (green, orange or red colour) at each point.

Risk level of corrosion is obtained as a combination of the two measured parameters. There are established threshold values for Ecorr and ρ that provide the risk level results. These values can be changed by the operator on "*Set-up*" screen (see Figure 15), but there are recommended values (see chapter 3.2.3) and changes to them can give incoherent results of the risk level results. There are different recommended threshold values of Ecorr for $Cu/CuSO_4$ and Ag/AgCl. Thus, before starting a measurement it is recommended to assure that they are the correct values for the sensor in use.

The parameters displayed on the screen and saved on the mapping file for each measurement point are the following:

- **Corrosion potential** (Ecorr), mV.
- **Resistivity** (ρ), KΩ.cm. Resistivity value provided by GECOR8 is the averaged value of four measurements taken automatically by the equipment.
- **Risk level**: It is a colour code of the combination of the two previous parameters. The three established levels of corrosion risk are:
  - Green: Low risk
  - Orange: Medium risk.
  - Red: High risk.

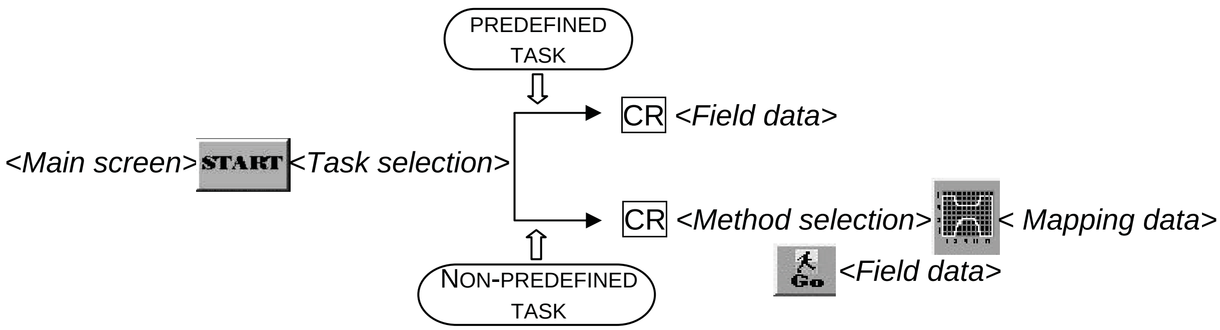
Sometimes it can be useful to measure Icorr (with sensor A) in a mapping point. GECOR8 allows predefining a task during a mapping in different points. For each marked point the equipment will predefine a task. After having finished the mapping you can go to the "*Task selection*" screen (Figure 16) and make the CORROSION measurement changing to the sensor A (see chapter 3.2.5.6). GECOR8 automatically save the Icorr result in the appropriate point of the mapping file. User has the responsibility of making the measurement in the point of the selected mapping.

The parameter displayed on the screen of CORROSION measurement is the following:

- **Corrosion rate** (Icorr), $\mu A/cm^2$ (with sensor A)

3.2.5.2 Starting a measurement

To start a measurement there are two possibilities to chose in the <*Task selection*> screen (Figure 16) as it is explained in chapter 3.2.4: *predefined* or *non-predefined task*.



In case of <u>*predefined tasks*</u> (see chapter 3.2.4), “*Field data*” screen (Figure 21) appears directly after selecting the task in “*Task selection*” screen (Figure 16).

On “*Field data*” screen, the user can introduce data from the visual inspection of the structure and environmental conditions to help the interpretation of the obtained results. This information is not necessary for the measurement.

The parameters shown on “*Field data*” screen are the following:

- Sensor position (alphanumeric): “Horizontal“, “vertical“ or “reverse“.
- Visual condition of the concrete (alphanumeric):
  - “Wet“ or “dry“
  - “Cracked“ or “uncracked“
  - “Complete cover“ or “spalled cover“
  - “Clean“ or “stain spots“
- Weather (alphanumeric):
  - “Dry or sunny“ or “wet or raining“
  - “hot“ (>25ºC), “fine“ or “cool“ (<5ºC)

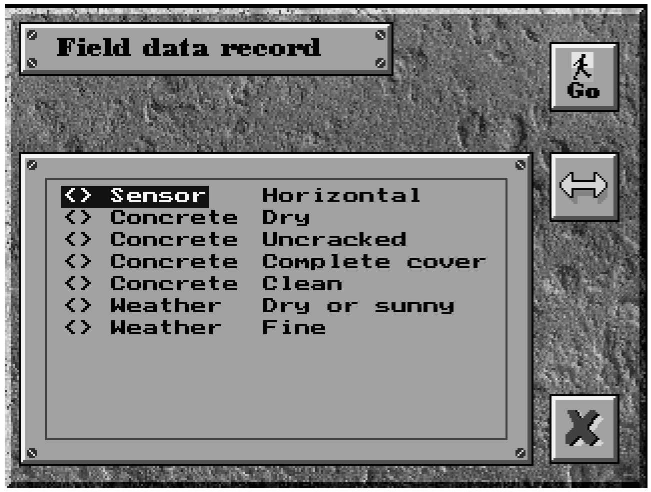
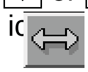


Figure 21.- “*Field data*” screen

To move from one parameter to another press keys ↑ ↓ or CR and to choose in the menu among different values for each parameter activate ic 

In case of *non-predefined tasks* and after selecting the *Mapping* option in “*Method selection*” screen (Figure 18), “*Mapping data*” screen (Figure 22) appears. The parameters that define the mapping measurement are the following and they can be modified as it is explained in chapter 3.2.1.

- Task name (alphanumeric): 8 characters.
- Grid step X (numerical): spacing between consecutive points along X-axis. User units.
- Grid size X (numerical): total length on X-axis. User units.
- Grid step Y (numerical): spacing between consecutive points along Y-axis. User units.
- Grid size Y (numerical): total length on Y-axis. User units.
- Grid path (alphanumeric): Random (measurement point is chosen by the operator moving the cursor through the grid) or Regular (cursor is placed automatically by the equipment from down to up and left to right). It is possible to map irregular perimeters if they have been introduced into a predefined task (see files format in Annex 1).

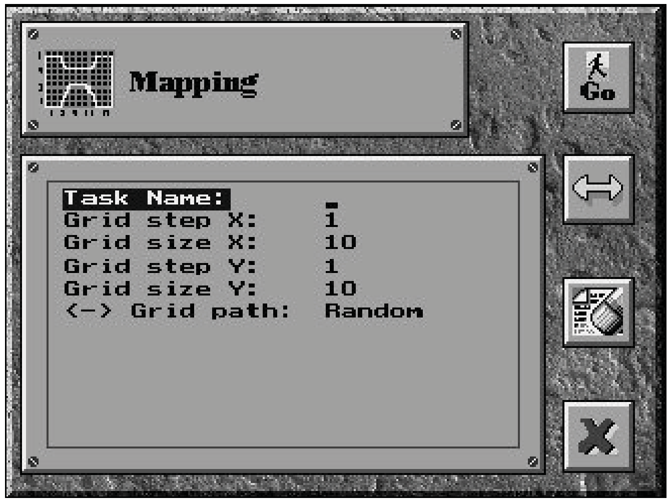


Figure 22.- “*Mapping data*” screen

After introducing these parameters and activating 

icon, “*Field data*” screen appears (Figure 21).

To start the measurement activate 

icon in “*Field data*” screen (Figure 21) and “*Mapping measurement*” screen appears (Figure **23**).

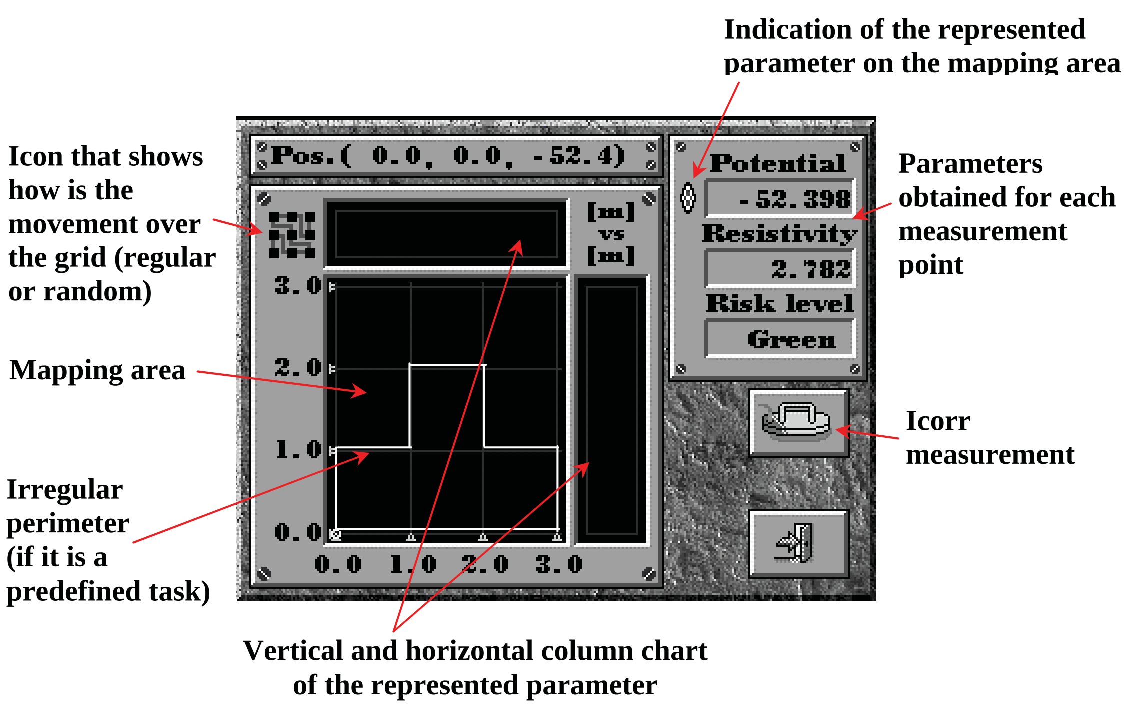


Figure 23.- “*Mapping measurement*” screen

3.2.5.3 Mapping grid

On the grid representation (Figure **23**) there are three different zones:

- Centre: view of the mapping area, with co-ordinates (x, y) in user units. Over this area the cursor is moved indicating the point on which measurement is made. To make a zoom of the represented area, press keys [5] and [8]. If an irregular perimeter has been associated to a predefined task (see file formats on Annex 1), it is shown on mapping area.
- Right: Shows the column chart of the represented parameter of the points on which the co-ordinate x has the same position than the cursor.
- Upper: Shows the column chart of the represented parameter the points on which the co-ordinate y has the same position than the cursor.

Text at the upper left corner shows three values (x, y, value) where x and y are the coordinates of the cursor position and value is the result of the value obtained during the measurement process on this point of the represented parameter.

At the upper right corner of the screen, two numerical values obtained on each point (corrosion potential and concrete resistivity) and the identification of the risk of corrosion (green, orange or red colour) is displayed.

The parameter that is shown on the column chart is selected pressing keys [1] or [2]. The represented parameter is marked with a symbol (➊) on the right of the value.

3.2.5.4 Movement through the grid

Before placing the sensor a regular whistle sounds. Measurements automatically start when placing the sensor over the concrete surface. The equipment takes measurement automatically and it is stored for the measurement point indicated by the cursor in the screen. When the measurement is finished it sounds a long whistle and at the same time the results of this point are displayed in the screen. Then you have to remove the sensor from the structure, cursor is displaced to the next position and the regular whistle begins again until the sensor is placed again in the concrete surface.

It is the responsibility of the operator to place the sensor on the right position over the structure, with regard to the position of the cursor in the grid.

The cursor is displaced automatically to the next measurement point if “regular” option has been selected in “*Mapping data*” screen (Figure 22). This movement of the cursor thought the grid is made from down to up and from left to right. If “random” option has been selected the cursor has to be moved with keys ← ↑ → ↓ to the suitable position.

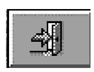
Icon on the upper left corner of the grid representation shows how the movement is over the grid (regular or random).

In case of predefined tasks with a defined perimeter; they will appear on the mapping area (

Figure **23**) and it will be not possible to move the cursor out of the bounds of this perimeter. If a perimeter file does not exist, it will be possible to move the cursor inside the rectangle that is defining the mapping area.

When Icorr measurement associated to a measurement point in the mapping process is required , then activate  icon and a task for Icorr measurement (sensor A) is predefined for this point (see chapter 3.2.5.6).

3.2.5.5 Saving data

Mapping process finishes when all the measurement points have been gone over or when process is aborted activating  icon. Then “*Save da*ta” screen (Figure 24) appears.

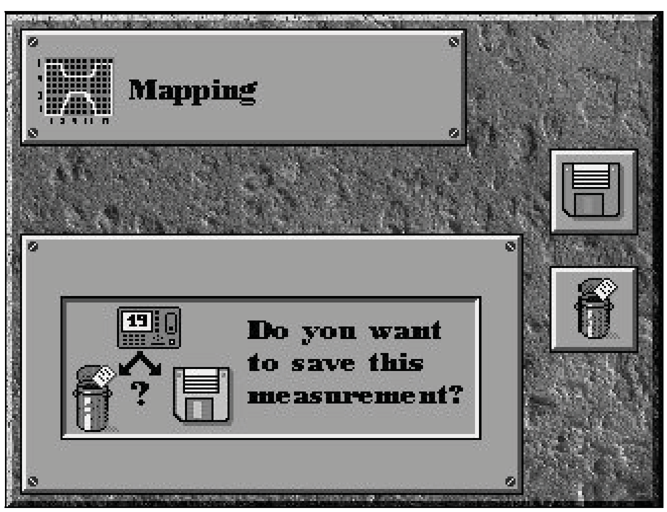
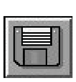


Figure 24.- “*Save data*” screen

Activating  icon data is stored on the PCMCIA and with  icon data is refused.

The mapping file with the results has the task name and the extension .MAP. Data files format is shown in Annex 2.

When task is finished, the task file is updated indicating the actual date. This parameter is the one that is shown on the "*Task selection*" screen (Figure 16) if the task has been made.

After deciding if data is stored or not, the equipment returns to the "*Main screen*" (Figure 14).

3.2.5.6 Icorr measurement

After having finished the mapping and if  icon has been activated in "*Mapping measurement*" screen (

Figure **23**), you can go to the "*Task selection*" screen (Figure 16) and make the CORROSION measurement, changing to the sensor A.

The task defined by the equipment has the name of the mapping task preceded by a dash.

GECOR8 automatically save the Icorr result in the appropriate point of the mapping file. User has the responsibility of making the measurement in the point of the selected mapping.

3.2.6 MEASUREMENT IN AERIAL STRUCTURES (non submerged structures)

3.2.6.1 Previous remarks

Polarization time has a default value shown in "*Set-up*" screen (Figure 15) and the user can change it as it is explained in chapter 3.2.3. This is the time used for the final part of the polarization resistance measurement. Its default value is 100s.

Reinforcement area affected by the signal has to be introduced by the user in the "*Aerial data*" screen (Figure 25). This area corresponds to the steel bars with electrical contact between them of the reinforcement layer close to concrete surface below a 105 mm diameter circle centered on the sensor. For a single rebar of diameter "D", with the sensor located centered over it, the area in square centimetres is:

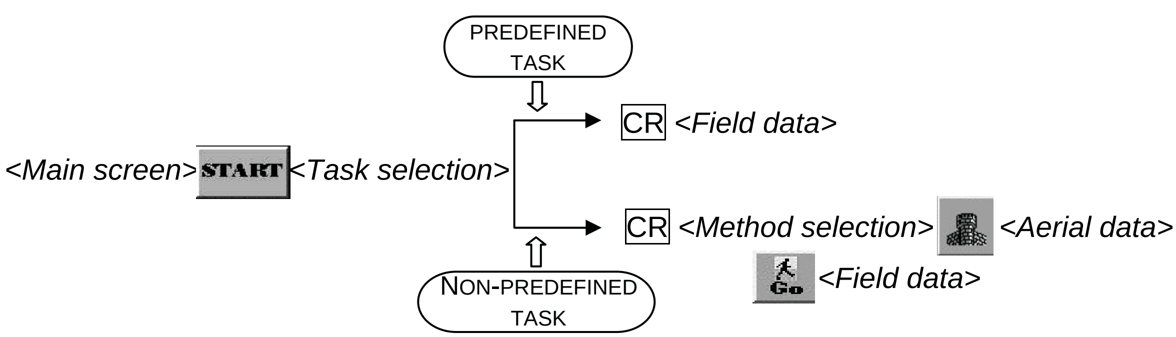
$$A = 3.142 \times D \times 10.5 cm^2$$

Results (see chapter 3.2.6.3) obtained with sensor A for measurement in aerial structures are displayed on "*Aerial results*" screen (Figure 29) and saved on the aerial file (see chapter 3.2.6.4).

Apart from these parameters sometimes it is necessary to measure the concrete resistivity. GECOR8 allows predefining tasks for resistivity measurements (with sensor B) on the "*Aerial results*" screen (see Figure 29) activating icon. After having finished the aerial measurement, you can go to the "*Task selection*" screen (Figure 16) and make the resistivity measurement changing to the sensor B (see chapter 3.2.6.5).The resistivity value will be saved in the appropriate point of the aerial file.

3.2.6.2 Starting a measurement

To start a measurement there are two possibilities to chose in the <*Task selection*> screen (Figure 16) as it is explained in chapter 3.2.4: *predefined* or *non-predefined task*.



In case of predefined tasks (see chapter 3.2.4), "*Field data*" screen (Figure 21) appears directly after selecting the task in "*Task selection*" screen (Figure 16).

In case of _non-predefined tasks_ and after selecting the *Measurement in aerial structures* option in “*Method selection*” screen (Figure 18), “*Aerial data*” screen (Figure 25) appears. The parameters that define the aerial measurement are the following and they can be modified as is explained in chapter 3.2.1.

- Task name (alphanumeric): 8 characters.
- Reinforcement area (numerical): Units: cm^2. (See chapter 3.2.6.1)

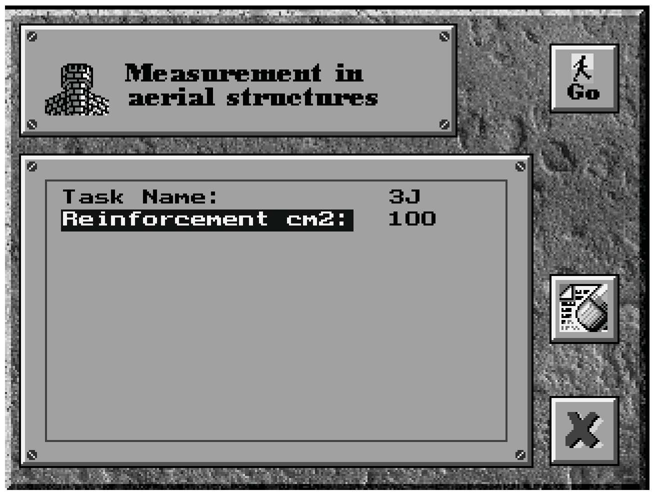


Figure 25.- “*Aerial data*” screen

After introducing these parameters and activating icon, “*Field data*” screen appears (Figure 21).

The parameters shown on “*Field data*” screen are described in chapter 3.2.5.

To start the measurement activate icon on “*Field data*” screen (Figure 21) and “*Cheeking system*” screen (Figure 26) appears. The sequence is:

<Main screen> START *<Task selection>* CR *<Method selection>* *<Aerial data>* Go *<Field data>* Go *<Checking system>*

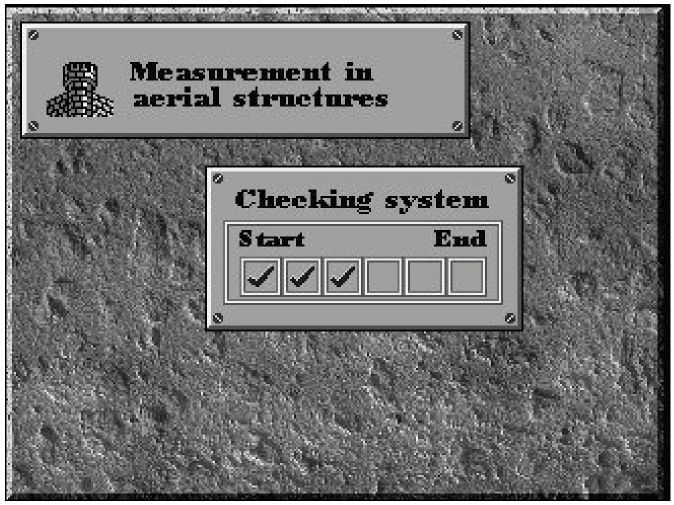


Figure 26.- “*Checking system*” screen

The state of the internal checking is shown in the “*Checking system*” screen (Figure 26). On this screen it is not necessary for any action by the user. If the equipment detects any mistake in the checking, a warning number and its description will appear in a message on the screen. Depending on the warning the measurement can continue but possible invalid results can be obtained. Chapter 7 shows the summary of warnings that can appear on the equipment.

When the internal checking of the system has finished “*Electrodes stability*” screen (Figure 27) appears automatically.

<Main screen> START *<Task selection>* CR *<Method selection>* *<Aerial data>* Go
<Field data> Go *< Checking system>* () *<Electrodes stability>*

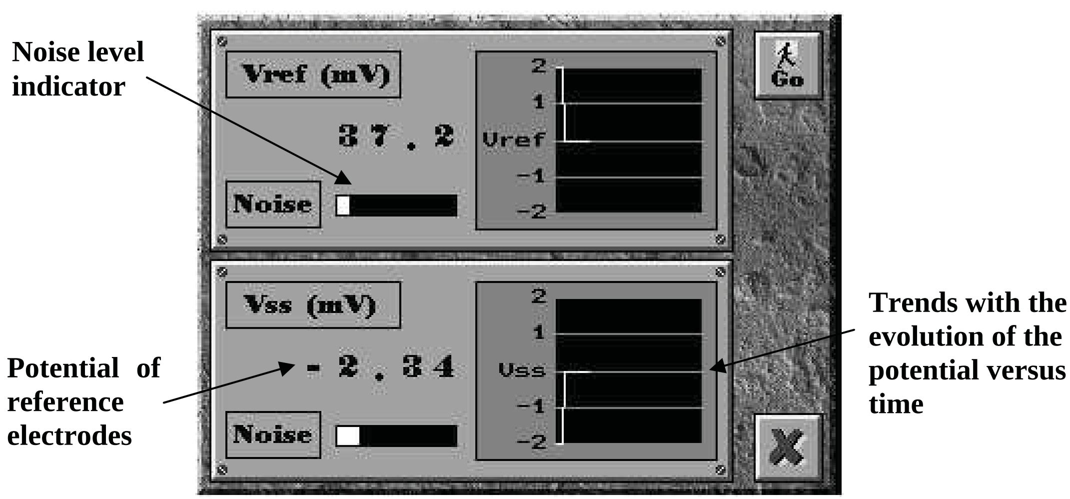


Figure 27.- “*Electrodes stability*” screen

To obtain good measurements, stable lectures from the reference electrodes are needed. Mistakes on the reference electrodes stability could be produced by bad contact between sensor and sponge, too dry sponge, bad contact between rebar and wire, etc.

This screen not only displays information about the potential value but also offers an indication of the potential changing on consecutive measurements (noise) by means of a bar that changes with the noise level (more noise = longer bar). Finally, this screen has a graph with the evolution of the potential versus time. This graph has an auto scale when the potential value changes more than 2 mV respects to the initial value.

When it is consider that the measurement is stable, the user can continue the measurement activating icon and "*Aerial measurement*" screen (Figure 28) appears or cancel the measurement with icon.

<Main screen> START *<Task selection>* CR *<Method selection>* *<Aerial data>* *<Field data>* *< Checking system>* () *<Electrodes stability>* *<Aerial measurement>*

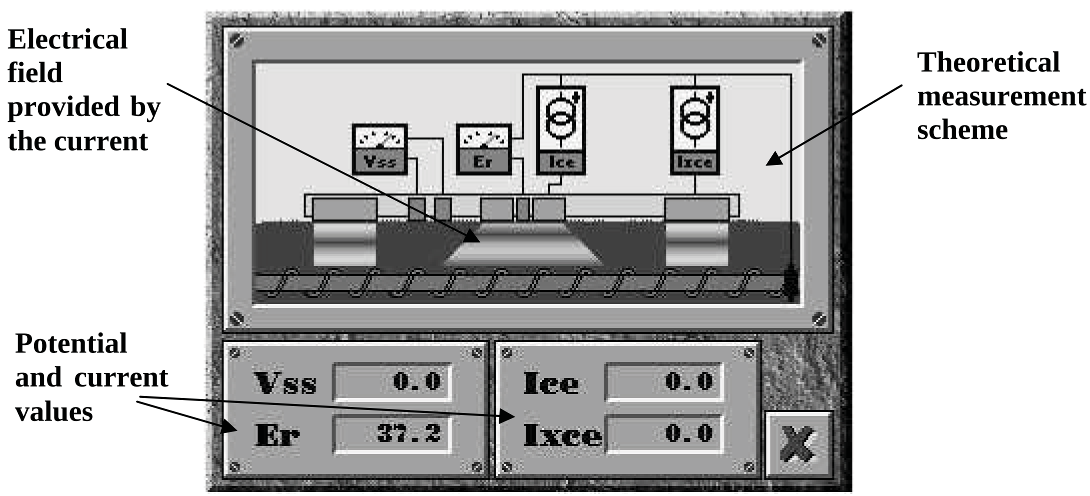


Figure 28.- "*Aerial measurement*" screen

"*Aerial measurement*" screen only needs the intervention of the operator if the measurement wants to be cancelled.

3.2.6.3 Results

When measurement is finished, results appear on the "*Aerial results*" screen (Figure 29).

<Main screen> START *<Task selection>* CR *<Method selection>* *<Aerial data>*
<Field data *< Checking system>* () *<Electrodes stability*
<Aerial measurement> () <Aerial results>

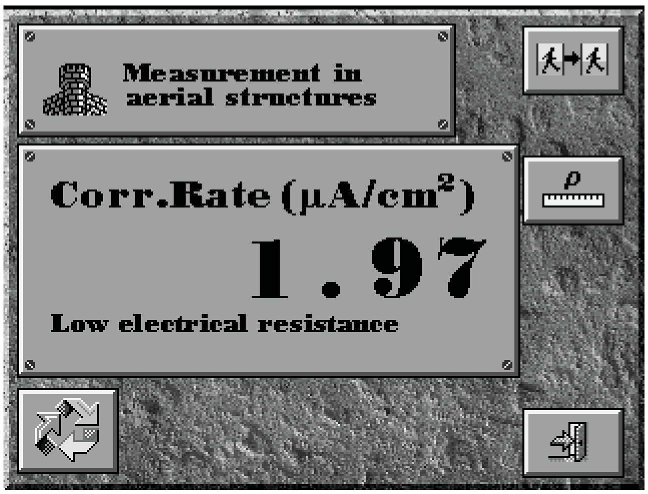


Figure 29.- “*Aerial results*” screen

The parameters displayed on the screen are the following:

- **Corrosion rate** (µA/cm^2)
- **Corrosion potential** (mV)
- **Concrete electrical resistance** (KΩ)
- Reinforcement area (cm^2)

Different values are available activating icon with key 1. Reinforcement area is not a result but a data introduced by the user in “*Aerial data*” screen (Figure 25).

Measurement quality is determined by the confinement percentage. If this value is lower than 50%, a message indicating the incomplete confinement is shown on the screen and repetition of the measurement is recommended. In this case, improve the quality of the measurement by means of wetting the concrete surface and the sponge and cleaning the electrical contact.

Confinement not fully achieved

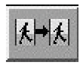
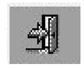
Percentage confinement <50%

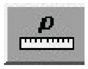
Please repeat

If electrical resistance obtained is very low (very wet structures) a message is shown and it is recommended to repeat the measurement by means of the method for submerged or very wet structures.

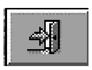
Low electrical resistance

Please try with method for measurement in submerged or verv wet structures

To repeat the measurement activate  icon with key F1 and the equipment returns to the "*electrodes stability*" screen). To finish activate  icon with key F4.

When ρ measurements associated to measurements in aerial structures are required, then activate  icon on "*Aerial results*" screen (Figure 29) and a task for ρ measurement (sensor B) is predefined for the measurement point (see chapter 3.2.6.5).

3.2.6.4 ***Saving data***

Activating  icon in "*Aerial results*" screen (Figure 29); "*Save da*ta" screen appears (Figure 30).

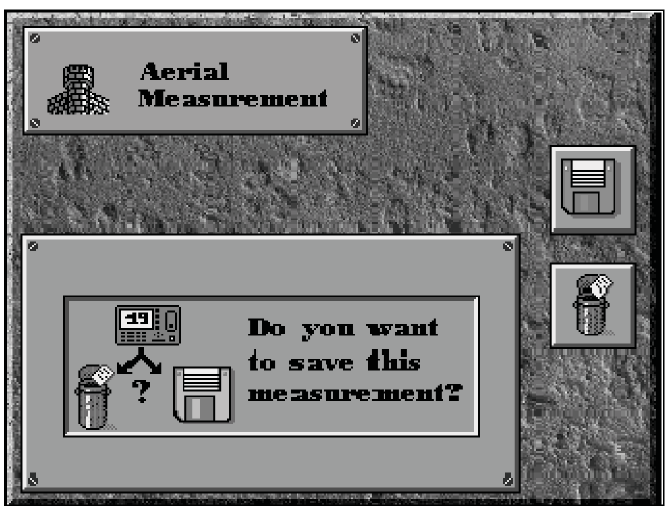
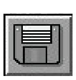


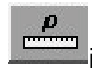
Figure 30.- "*Save data*" screen

Activating  icon data are stored on the PCMCIA and with  icon data are refused.

The aerial file with the results has the task name and the extension .E06. Data files format is shown in Annex 2.

After deciding if data are stored or not, the equipment returns to "*Main screen*" (Figure 14).

3.2.6.5 Resistivity measurement

After having finished the aerial measurement and if  icon has been activated in "*Aerial measurement*" screen (Figure 28), you can go to the "*Task selection*" screen (Figure 16) and make the resistivity measurement changing to the sensor B. Then the following screen (Figure 31) appears:

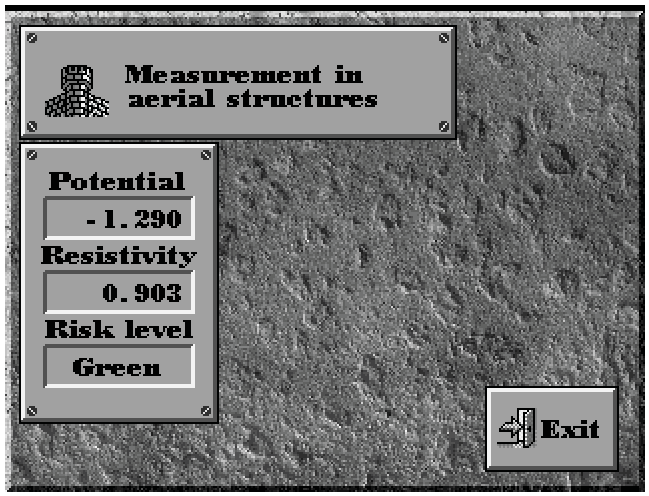


Figure 31.- "Resistivity measurement" screen

The task defined by the equipment in the aerial measurement has the name of the aerial task preceded by a dash.

GECOR8 automatically save the resistivity result in the appropriate point of the aerial file. The user has the responsibility of making the measurement in the point of the selected aerial measurement.

3.2.7 MEASUREMENT IN SUBMERGED OR VERY WET STRUCTURES

3.2.7.1 Previous remarks

Polarization time has a default value shown in "*Set-up*" screen (Figure 15) and the user can change it as it is explained in chapter 3.2.3. This is the time used for the final part of the polarization resistance measurement. Its default value is 80s.

The surface ratio between steel bars and concrete in a reference surface of concrete is needed for the measurement. Steel bars on the first layer close to the concrete surface and inside the reference surface must only be considered.

Data introduced by the user is the reference surface in "*Submerged data*" screen (Figure 32) and diameter and length of each steel bar contained in this reference surface in "*Bars dimensions*" screen (Figure 33).

The recommended value for the reference surface is 1 m^2. If one dimension is lower than 1 m (beams...), the other will be considered 1 m lengths for calculating the reference surface.

For small elements (less than 1 x 1 m) this method is not recommended because invalid results can be obtained.

Superficial relationship between steel bars and concrete is calculated by the equipment and shown with the results in the "*Submerged results*" screen (Figure 37). As an example, the superficial relationship (Sup.Rel.) for a surface reference of 1 m^2 that includes 5 steel bars of D mm diameter is the following:

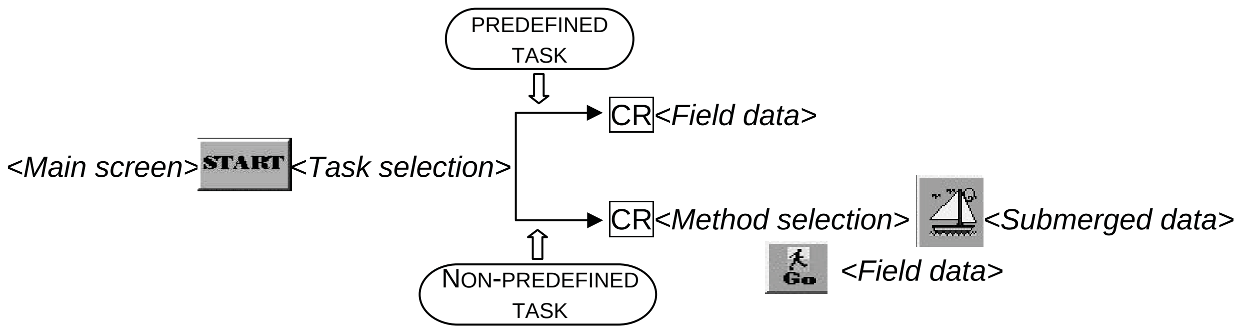
$$Sup.Rel. = \frac{(3.142 \times D \times 1) \times 5}{1m^2}$$

GECOR8 always considers that there are steel bars in two directions on the structure and as in most of the cases there are an electrical contact between all of them so this is a bidimensional model. In the particular cases of steel bars without electrical contact, the corrosion rate value has to be recalculated by activating 

icon with key F2 (unidimensional model) in "*Submerged results*" screen (Figure 37). In these cases only one bar has to be consider and although it is necessary to pass threw the bidimensional calculus, in the results file only the unidimensional corrosion result appears. The appearance of the message 'non-isolated rebar' is due to this button not being pressed at the appropriate time.

3.2.7.2 Starting a measurement

To start a measurement there are two possibilities to chose in the <*Task selection*> screen (Figure 16) as it is explained in chapter 3.2.4: predefined or non-predefined task.



In case of *predefined tasks* (see chapter 3.2.4), "*Field data*" screen (Figure 21) appears directly after selecting the task in "*Task selection*" screen (Figure 16).

In case of *non-predefined tasks* and after selecting the *Measurement in submerged or very wet structures* option in "*Method selection*" screen (Figure 18), "*Submerged data*" screen (Figure 32) appears. The parameters that define the submerged measurement are the following and they can be modified as it is explained in chapter 3.2.1.

- Task name (alphanumeric): 8 characters
- Bars (numerical): number of steel bars under the sensor.
- Ref. surface (numerical): reference surface of concrete. Recommended value: 1. Units: m^2. (See chapter 3.2.7.1)

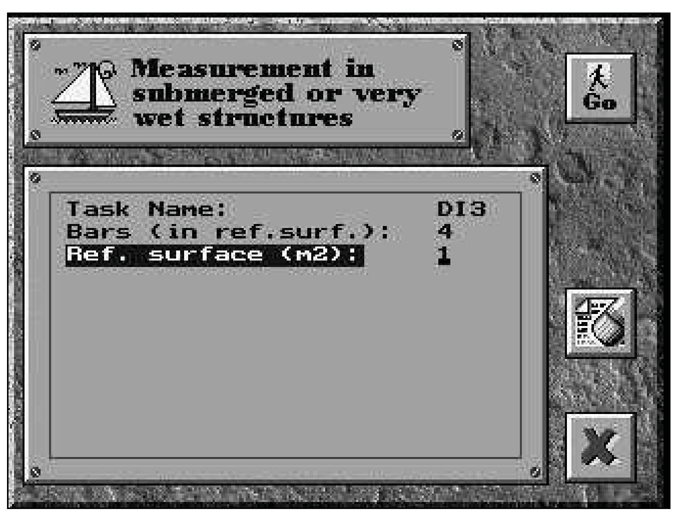


Figure 32.- "*Submerged data*" screen

After introducing these parameters and activating  icon, "*Bars dimension*" screen appears (Figure 33) with the following parameters for each steel bar:

- Diameter (numerical): diameter of steel bar. Units: mm
- Length (numerical): length of steel bar limited by the reference surface. Units: mm

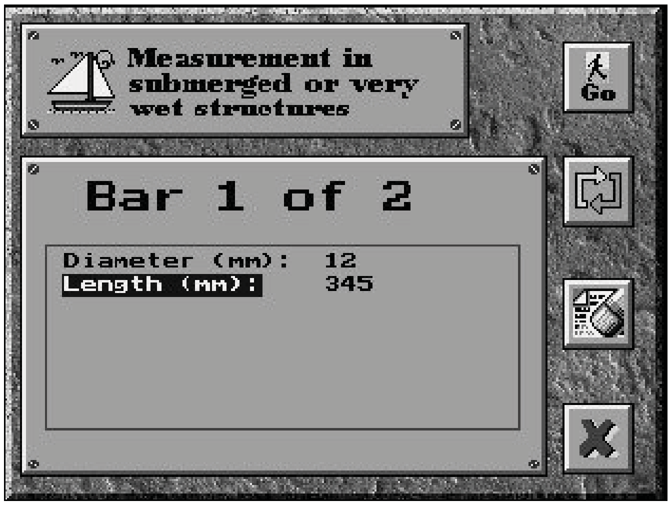


Figure 33.- “*Bars dimensions*” screen

To go from one bar to another activate icon. It is necessary to go over all the bars.

After introducing these parameters and activating icon, “*Field data*” screen appears (Figure 21).

The parameters shown on “*Field data*” screen are described on chapter 3.2.5.

To start the measurement activate icon on “*Field data*” screen (Figure 21) and “*Checking system*” screen (Figure 34) appears. The sequence is:

<Main screen> START *<Task selection>* CR *<Method selection>* *< Submerged data>* *<Field data>* *< Checking system>*

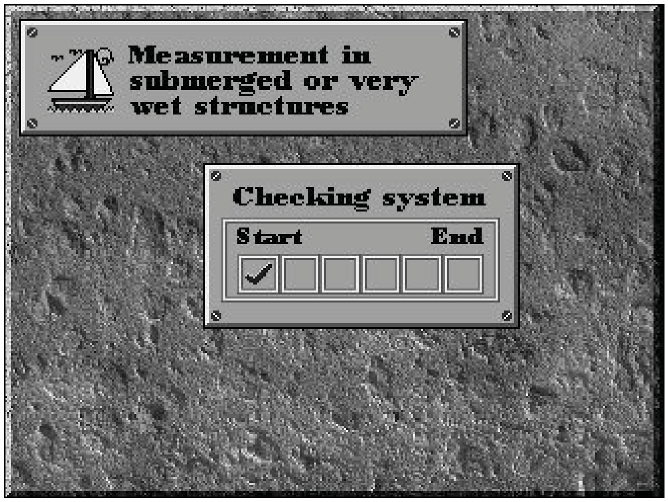


Figure 34.- “*Checking system*” screen

The state of the internal checking is shown in the “*Checking system*” screen (Figure 34). On this screen it is not necessary any action by the user. If the equipment detects any mistake on the checking, a warning number and its description will appear in a message on the screen. Depending on the warning the measurement can continue but possible invalid results can be obtained. Chapter 7 shows the summary of warnings that can appear on the equipment.

When the internal checking of the system has finished “*Electrodes stability*” screen (Figure 35) appears automatically.

<Main screen> *<Task selection>* CR *<Method selection>* *< Submerged data>* *<Field data>* *< Checking system>* () *<Electrodes stability>*

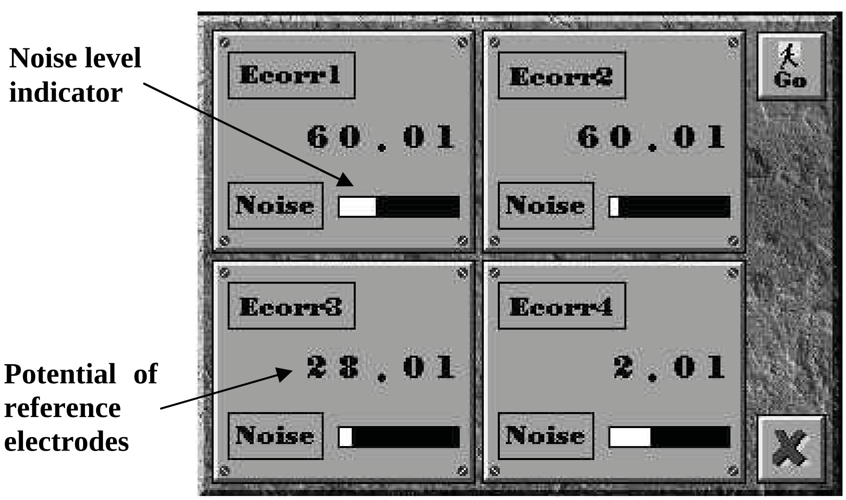


Figure 35.- “*Electrodes stability*” screen

To obtain good measurements, stable readings from the reference electrodes are needed. Mistakes on the reference electrodes stability could be produced by bad contact between sensor and sponge, too dry sponge, bad contact between rebar and wire, etc.

This screen not only displays information about the potential value but also offers an indication of the potential changing on consecutive measurements (noise) by means of a bar that changes with the noise level (more noise=longer bar).

When it is consider that the measurement is stable, the user can continue the measurement activating icon and "*Submerged measurement*" screen (Figure 36) appears or cancel the measurement with icon.

<Main screen> START *<Task selection>* CR *<Method selection>* *< Submerged data>* *<Field data>* *< Checking system>* () *<Electrodes stability>* *<Submerged measurement>*

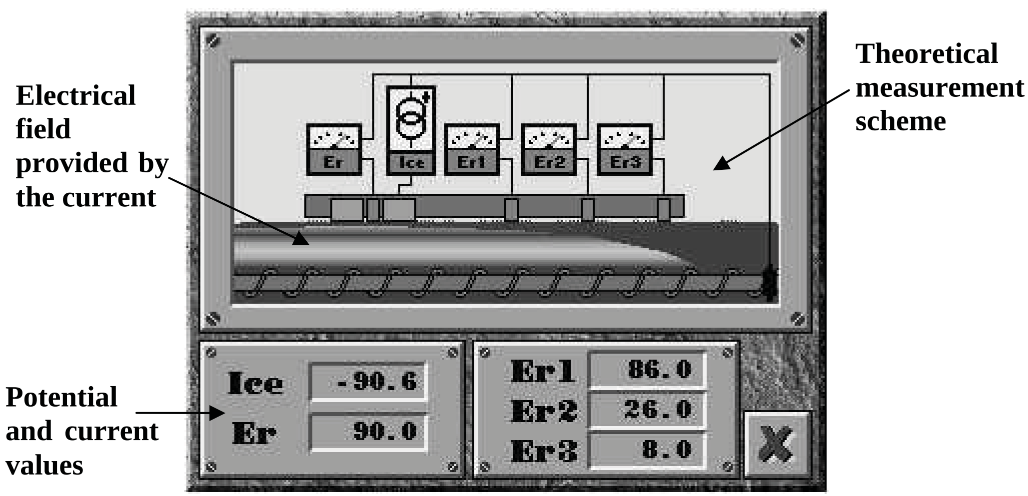


Figure 36.- "*Submerged measurement*" screen

"*Submerged measurement*" screen only needs the intervention of the operator if the measurement wants to be cancelled.

3.2.7.3 Results

When measurement is finished, results appear on the "*Submerged results*" screen (Figure 37).

<Main screen> START *<Task selection>* CR *<Method selection>* *< Submerged data>* *<Field data>* *< Checking system>* () *<Electrodes stability>* *<Submerged measurement>* () *<Submerged results>*

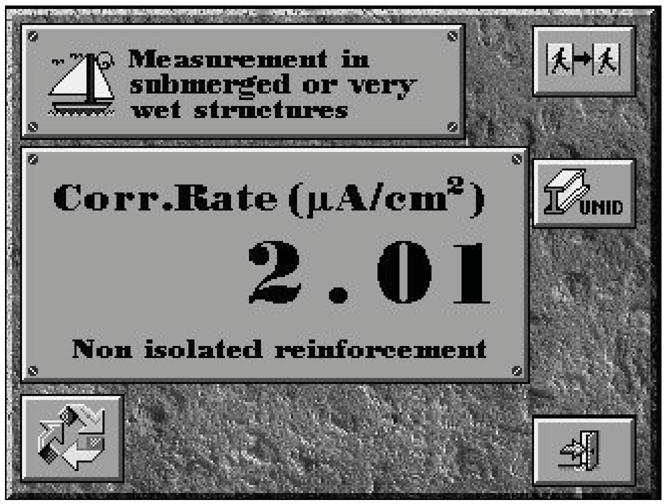


Figure 37.- "*Submerged results*" screen

The parameters displayed on the screen are the following:

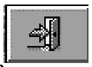
- **Corrosion rate** (µA/cm^2).
- **Corrosion potential** (mV).
- **Concrete electrical resistance** (KΩ).
- **Resistivity** (KΩx cm).
- Superficial relationship between steel bars and concrete (see chapter 3.2.7.1).

Different values are available activating icon with key 1.

To repeat the measurement activate icon with key F1 and the equipment returns to the "*Electrodes stability*" screen (Figure 34). To finish activate icon with key F4.

Activating with key F2 corrosion rate value can be recalculated as a unidimensional model (see chapter 3.2.7.1).

3.2.7.4 Saving data

Activating  icon in "*Submerged results*" screen (Figure 37); "*Save da*ta" screen appears (Figure 38).

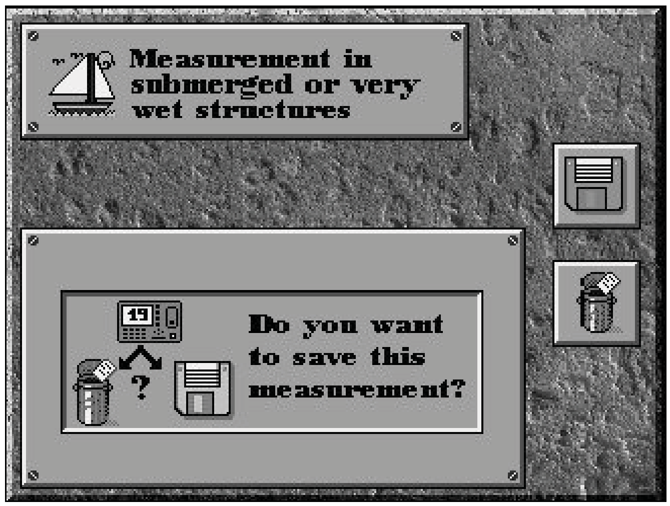
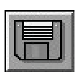


Figure 38.- "*Save data*" screen

Activating  icon data are stored on the PCMCIA and with  icon data are refused.

The submerged file with the results has the task name and the extension .E05. Data files format is shown in Annex 2.

After deciding if data are stored or not, the equipment returns to "*Main screen*" (Figure 14).

3.2.8 MEASUREMENT IN STRUCTURES WITH CATHODIC PROTECTION

3.2.8.1 Previous remarks

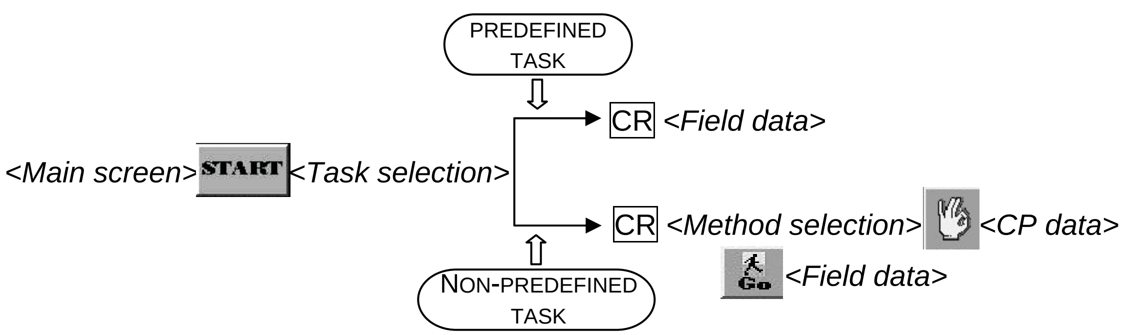
The checking of the efficiency of cathodic protection without switching-off the current is made through the **Passivity Verification Technique (PVT)** (see chapters 3.2.8.2, 3.2.8.3 and 3.2.8.4). GECOR8 gives the corrosion potential and an indication on the efficiency of the CP (well protected, protected or non protected).

GECOR8 also includes the **Instant off technique (IOT)** (see chapter 3.2.8.5) to measure the efficiency of cathodic protection by switching-off the current. With this method GECOR8 allows you to get a potential value on the measurement point at three different times:

- Before switching off the current.
- After finishing the potential drop that corresponds to the structure's ohmic drop.
- 60 second after switching-off the protection.

3.2.8.2 Starting a measurement

To start a measurement there are two possibilities to chose in the <*Task selection*> screen (Figure 16) as it is explained in chapter 3.2.4: *predefined* or *non-predefined task*.



In case of *predefined tasks* (see chapter 3.2.4), "*Field data*" screen (Figure 21) appears directly after selecting the task in "*Task selection*" screen (Figure 16).

In case of *non-predefined tasks* and after selecting the *Measurement in structures with cathodic protection* option in "*Method selection*" screen (Figure 18), "*CP data*" screen (Figure 39) appears. The parameter that defines the CP measurement is the following and it can be modified as it is explained in chapter 3.2.1.

- Task name (alphanumeric): 8 characters.

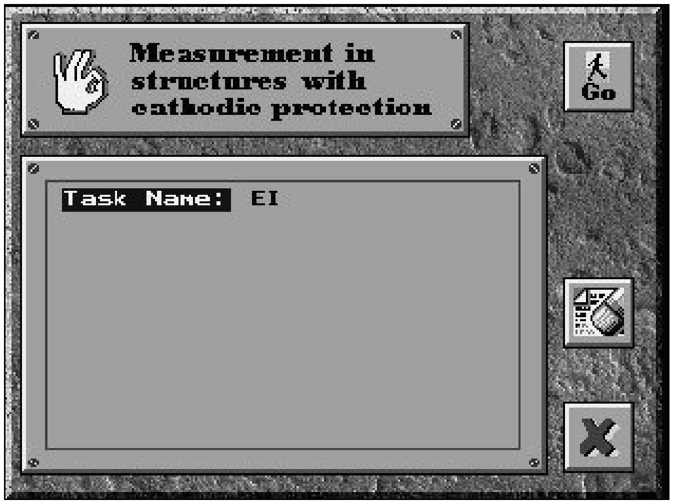


Figure 39.- “*PC data*” screen

After introducing this parameter and activating Go icon, “*Field data*” screen appears (Figure 21).

The parameters shown on “*Field data*” screen are described on chapter 3.2.5.

To start the measurement activate Go icon on “*Field data*” screen (Figure 21) and “*Checking system*” screen (Figure 40) appears. The sequence is:

<Main screen> START *<Task selection>* CR *<Method selection>* *<CP data>*
Go *<Field data>* Go *< Checking system>*

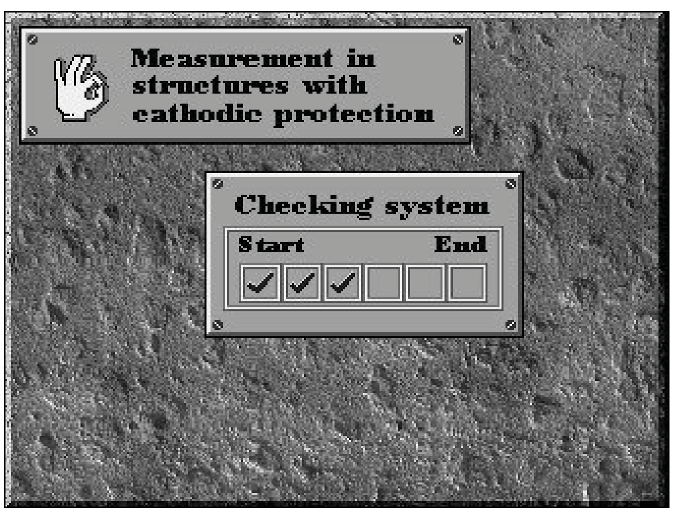


Figure 40.- “*Checking system*” screen

The state of the internal checking is shown in the “*Checking system*” screen (Figure 40). In this screen it is not necessary for any action by the user. If the equipment detects any mistake on the checking, a warning number and its description will appear in a message on the screen. Depending on the warning the measurement can continue but possible invalid results can be obtained. Chapter 7 shows the summary of errors that can appear on the equipment.

When the internal checking of the system has finished "*Electrodes stability*" screen (Figure 41) appears automatically.

<Main screen>  *<Task selection>* CR *<Method selection*  *< CP data>*  *<Field data>*  *< Checking system>* () *<Electrodes stability>*

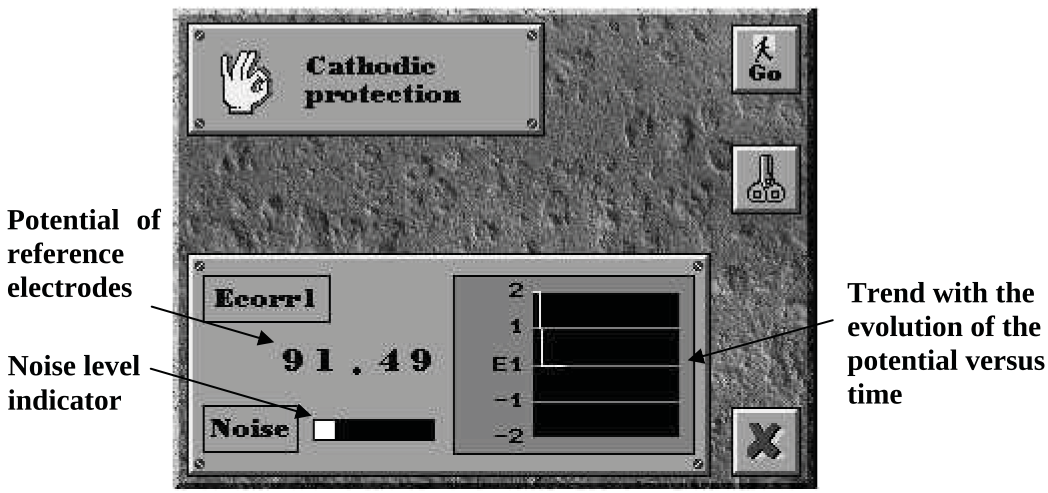
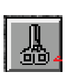


Figure 41.- "*Electrodes stability*" screen

To obtain good measurements, stable readings from the reference electrodes are needed. Mistakes on the reference electrodes stability could be produced by bad contact between sensor and sponge, too dry sponge, bad contact between rebar and wire, etc.

This screen not only displays information about the potential value but also offers an indication of the potential changing on consecutive measurements (noise) by means of a bar that changes with the noise level (more noise=longer bar). Finally, this screen has a graph with the evolution of the potential versus time. This graph has an auto scale when the potential value changes more than 2 mV respects to the initial value.

When it is considered that the measurement is stable, there are two options; continue the CP measurement activating  icon or start an **Instant-off measuring** activating  icon (see chapter 3.2.8.5).

To cancel the measuring activate  icon.

If icon is activated the CP measurement continue and “*Time warning*” screen (Figure 42) appears. This screen is a warning of the measuring time (10 minutes approximately).

<Main screen> START *<Task selection>* CR *<Method selection>* *<CP data>*
Go *<Field data>* Go *< Checking system>* () *<Electrodes stability>* Go *<Time warning>*

Figure 42.- “*Time warning*” screen

To continue the measurement activate icon and “*CP measurement*” screen (Figure 43) appears or cancel the measurement with icon.

<Main screen> START *<Task selection>* CR *<Method selection>* *<CP data>*
Go *<Field data>* Go *< Checking system> () <Electrodes stability>* Go
<Time warning> Go *<CP measurement>*

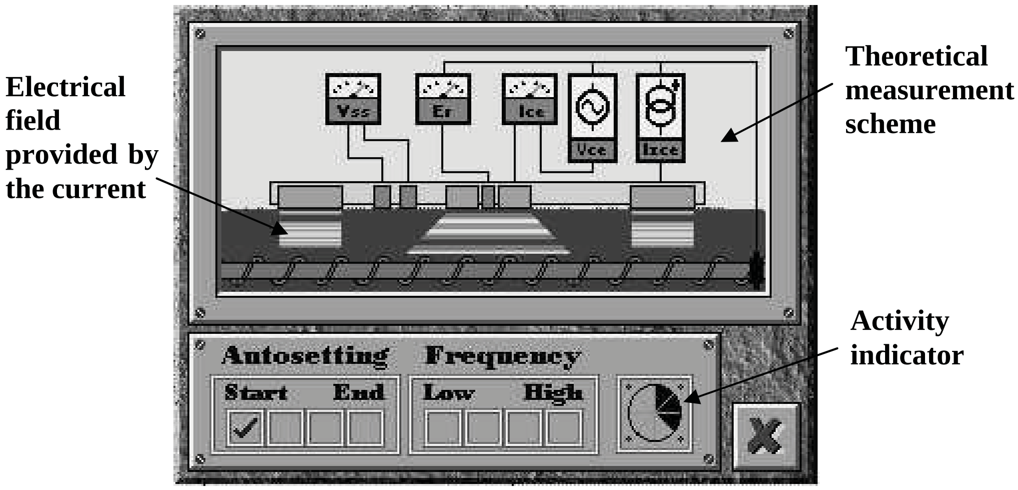


Figure 43.- “*CP measurement*” screen

“*CP measurement*” screen only needs the intervention of the operator if the measurement wants to be cancelled.

3.2.8.3 Results

When measurement is finished, results appear on the “*CP results*” screen (Figure 44).

<Main screen> *<Task selection>* CR *<Method selection>* *<CP data>*
<Field data> *< Checking system>* () *<Electrodes stability>*
<CP measurement> () *<CP results>*

Figure 44.- “*CP results*” screen

The parameters displayed on the screen are the following:

- **Corrosion potential** (mV)
- **Level of protection**: - Well protected
  - Protected
  - Not protected

Different values are available activating icon with key 1.

To repeat the measurement activate icon with key F1 and the equipment returns to the "*Electrodes stability*" screen (Figure 41). To finish activate icon with key F4.

3.2.8.4 *Saving data*

Activating icon "*Save da*ta" screen appears (Figure 45).

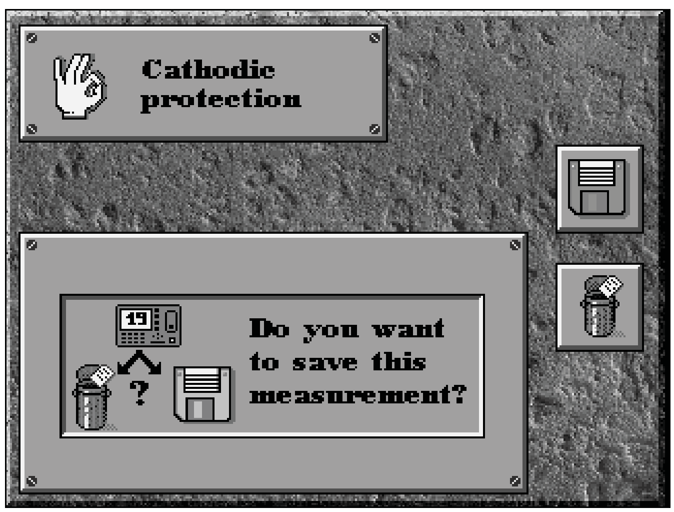


Figure 45.- "*Save data*" screen

Activating icon data are stored on the PCMCIA and with icon data are refused.

The CP file with the results has the task name and the extension MPC. Data files format is shown in Annex 2.

After deciding if dates are stored or not, the equipment returns to "*Main screen*" (Figure 14).

3.2.8.5 *Instant-off measurement*

Following the sequence:

<Main screen> START *<Task selection>* CR *<Method selection>* *< PC data>*

<Field data> *< Checking system> () <Electrodes stability>*

< Switch off CP current>

"*Switch off CP current*" screen appears. This screen is a warning of the necessity to switch off the current in the next screen.

To continue the measurement activate icon and "*IO measurement*" screen (Figure 46) appears or cancel the measurement with icon.

<Main screen> *<Task selection>* CR *<Method selection>* *< PC data>*
<Field data> *< Checking system> () <Electrodes stability>*
< Switch off CP current> *<IO measurement>*

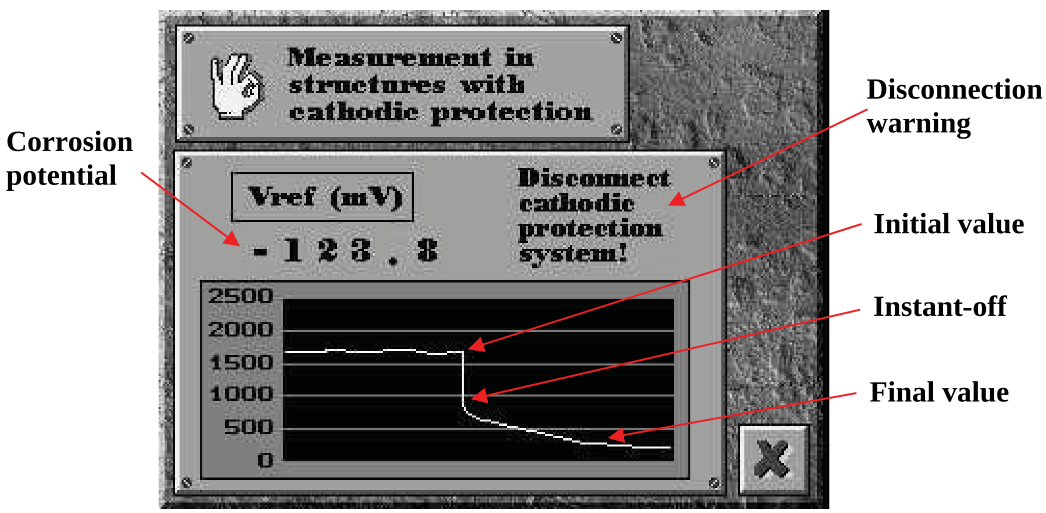


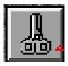
Figure 46.- "*IO measurement"* screen

Instant off measurement has two different phases; on the first one, GECOR8 waits to detect the potential drop caused by switching off the current. Second phase consists of 60 seconds of countdown.

"*IO measurement*" screen only needs the intervention by the operator if the measurement wants to be cancel.

When measurement is finished, results appear on the "*IO results*" screen (Figure 47).

<Main screen> *<Task selection>* CR *<Method selection>* *< PC data>*
<Field data> *< Checking system> () <Electrodes stability>*



< *Switch off CP current*>

<*IO measurement*> () <*IO results*>

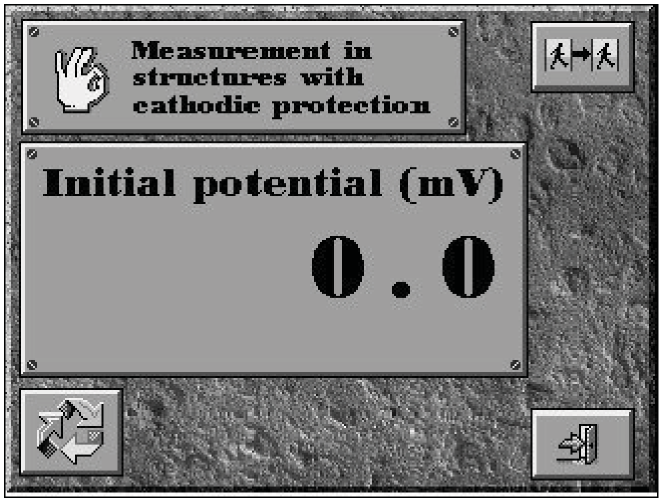
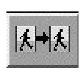


Figure 47.- “*IO results*” screen

The parameters displayed on the screen are the following:

- **Initial potential** (mV)
- **Potential “instant off”** (mV)
- **Final potential** (mV)

Different values are available activating  icon with key 1.

To repeat the measurement, activate  icon with key F1 and the equipment returns to the “*Electrodes stability*” screen (Figure 41). To finish activate  icon with key F4 and then “*Save da*ta” screen appears (Figure 48).

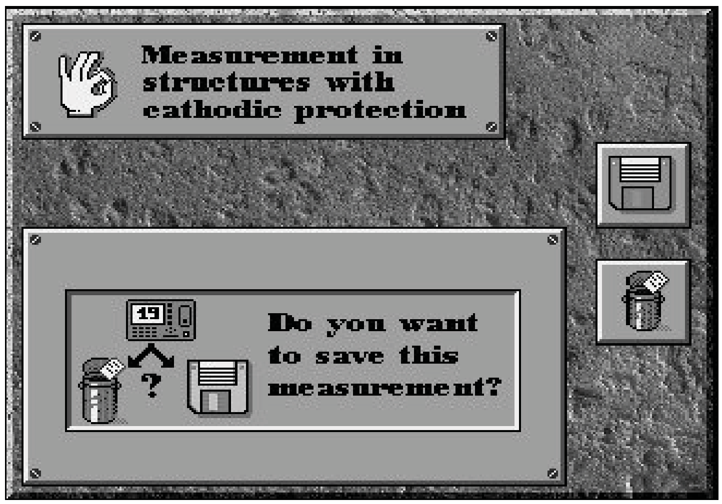
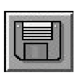


Figure 48.- “*Save data*” screen

Activating  icon data are stored on the PCMCIA and with  icon data are refused.

The IO file with the results has the task name and the extension .MIO. Data files format is shown in Annex 2.

After deciding if data are stored or not, the equipment returns to “*Main screen*” (Figure 14).

4 TRANSMITTING DATA TO A HOST COMPUTER

The PCMCIA memory card is needed to store data in GECOR8. Transmitting of data between the equipment and PC can be made through the PCMCIA interface if user has a PC with PCMCIA reader or through the standard RS232 interface and RX8 software available with the equipment. RX8 allows interchange of data through the RS232 interface from PC to GECOR8 (***predefined tasks***) or from GECOR8 to PC (***result files***).

GECOR8 stores the results in the PCMCIA on files ordered by date and method. Name of ***result files*** are the date of the measurement and extension of result files depending on the measurement method:

- Mapping files: **.MAP**
- Aerial files: **.E06**
- Submerged files: **.E05**
- CP files: **.MPC**
- IO files: **.MIO**

File of predefined tasks is named **TASK.TXT** and it includes a list with all the parameters necessary to make a measurement. The equipment automatically stores this one when measurements are completed.
File formats are shown in Annex 1.

Before starting data transmission through the RS232 interface it is necessary to connect PC and GECOR8 with the PCMCIA inserted (see connector to PC in Figure 1). It is also necessary to install the RX8 software in the PC.

- Transmitting data from GECOR8 to PC.

Following the sequence on GECOR8:

<Main screen> 

< *Files management*>

< *Files management*> screen appears (Figure 49) where saved files on PCMCIA are shown.

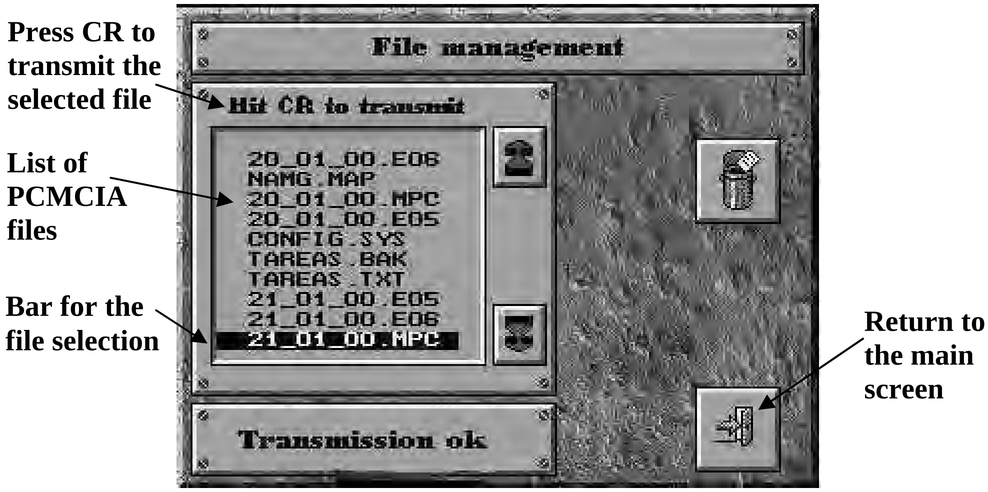


Figure 49.- “*Files management”* screen

Open RX8 software on PC and Main menu appears (Figure 50). Indicate the port number of the PC on which the RS232 interface has been connected on *PortNumber* menu (from COM1 to COM4).

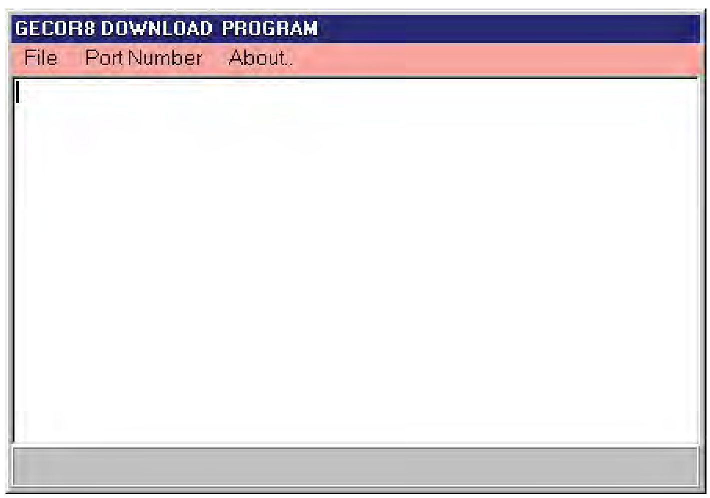


Figure 50.- Main menu of RX8

- In the main menu of RX8 program (Figure 50), select the menu “*File -> Receive data file*”. At the bottom of the window “Waiting data transmission” message appears.

- Select a file to transmit on “*Files management”* screen (Figure 49) of GECOR8 and press CR.

- Wait to the end of the transmission. At the bottom of the window of RX8 “Transmission successfully completed” message appears and “Transmission OK” message appears on “*Files management”* screen of GECOR8.

- To save the information on PC select the menu “*File -> Save data to file*”.

Transmitting data from PC to GECOR8:

- Go to <*Main screen*> (Figure 14) of GECOR8.
- In the main menu of RX8 program (Figure 50), select the menu "*File -> Send file*" and select a file to transmit. At the bottom of the window "Sending file" message appears.
- "Rs 232 link" message appears on the main screen of GECOR8
- If a task.txt is sent from PC to GECOR8, and there is another task.txt file on PCMCIA, it is possible to update the file.

General Instruction to Assist in Uploading

'unknown' problems persist in occurring as you attempt to upload data from your instrument to the P.C., please try the following:

1. Try a different P.C. Often P.C. have conflicts with serial ports which are undetected as the serial port is not used. This can typically be remedied by trying a different brand P.C. Sometimes two different brands fail for this reason.
2. Attach the serial cable to the P.C. before powering the instrument. This can help with a lot of strange ground problems and aid with proper handshake protocol between P.C. and the external RS232.
3. Jumper pins 4 and 5 of the serial connector and run the serial port test. This verifies the instrument is working properly.

5 MAINTAINING YOUR EQUIPMENT

5.1 BATTERY

GECOR8 battery (see Figure 6) is composed by a pack of 11 nickel-metal hydride batteries that provides on complete charge the tension of 13.7 volts with a capacity of 5Ah.

Battery pack has a connector that must be inserted on the one situated on the bottom of the battery compartment which is located under the lid on the right front of the equipment (see Figure 1).

Battery provides a minimum autonomy of 8 hours working and its level is shown on "*Main screen*" (Figure 14).

If the maintenance and work with the GECOR8 device is correct battery life will be about 5 years.

Charging the battery:

The battery can be recharged with the battery charger provided with the equipment (Figure 8). Charging has to be made with the battery pack installed inside the rate meter and connecting the battery charger through the connector placed on the frontal part of GECOR8 (see Figure 1).

The battery charger is a fast charger, and it is adjusted for charging the battery pack in less than three hours. Additionally it can be used as an external feeder if there is a current point available on the measurement area.

It is possible to recharge the battery outside the equipment, but an adapter is needed. To extract battery pack, unscrew and remove the lid of the equipment. Battery pack appears under this lid. Pull soft but firmly on the strips for unplugging the battery. To place again the battery on the right position, check that both connectors, the one on the battery pack and the other on the bottom of the battery compartment are one against the other. Push firmly for fitting connectors correctly.

5.2 SENSORS

5.2.1 GENERAL

No specific recommendations for maintenance of sensors with **Ag/AgCl electrodes** are needed. They do not need to be removed for transport or storage. They only have to be replaced when internal gel is dry or finished. Otherwise it is recommended to change these electrodes once a week.

The rest of the chapter 5.2 is dedicated to the sensors with **$Cu/CuSO_4$ electrodes**.

The $Cu/CuSO_4$ sensors require careful maintenance, as the $CuSO_4$ solution can be corrosive. The solutions can damage the sensors if they are not properly maintained.

Reference electrode condition must be checked at the beginning of each measurement session. The $CuSO_4$ solution reservoirs must be checked and refilled (see chapter 5.2.3).

5.2.2 CLEANING OF CU/CUSO$_4$ SENSORS

Keep the sensors clean. Leakages of CuSO4 solution and dried crystals have to be removed when storing and operating the equipment.

Clean any $CuSO_4$ crystals off the counter and reference electrodes. Avoid the leakage of excess solution around the stoppers as this could generate continuity between the half-cells.

Keep the connecting sockets and leads dry and away from contact with the solution and other oxidising agents.

5.2.3 REFILLING OF CuSO$_4$ SOLUTION RESERVOIRS

When the $CuSO_4$ solution level is low in the reservoirs it may be necessary to clean the reservoir and remove deposits around the electrodes and the stoppers:

1. Remove the stoppers
2. Clean around the stoppers
3. Refill with $CuSO_4$ solution made with deionized water and crystals of reagent grade copper sulphate, with excess crystals in the solution.

Refilling of reservoirs has to be done slowly and with care to ensure that they are filled with no trapped air in them. The way to refill the reservoirs is shown in Figure 51. In case of B sensors the refilling has to be made through its lateral drill.

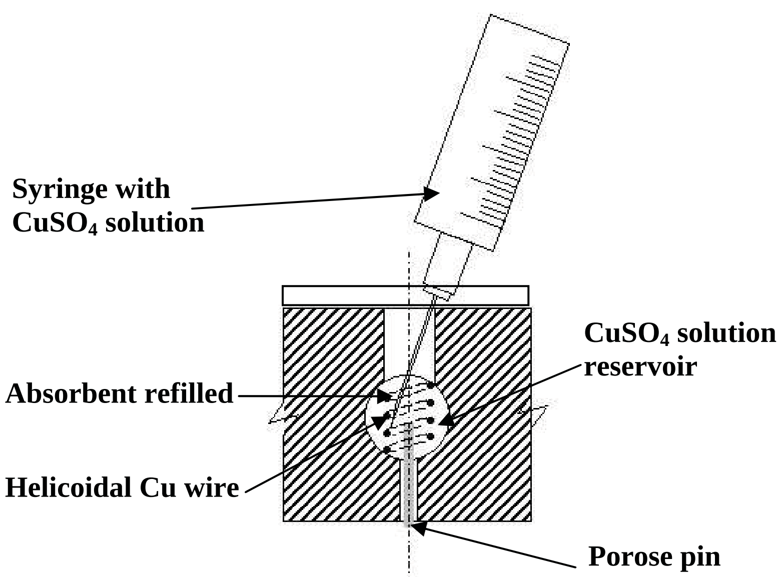


Figure 51.- Refilling of $CuSO_4$ solution reservoirs of sensors A and C.

5.2.4 SPONGE PADS

The sponge pad on the electrode face has to be kept clean and in good condition. It must be replaced when worn or broken. It is kept damp with tap water during operation of the unit. The pad on sensor B is held in place with a circular-retaining piece (see Figure 4).

5.2.5 TRANSPORT AND STORAGE

When equipment is not working, it is recommended to leave the sensors with the reference electrodes up, and remove the sponge pad whenever not in use as the pad absorbs copper sulphate solution. Keep the solution off the stainless steel elements. Keep the elements clean and dry. For transporting or longer-term storage, empty and clean the reservoirs and protect the steel electrodes and half-cell tips.

5.3 UPDATING SOFTWARE

GECOR8 hardware is based on an EPSON 486 card that behaves like a compatible computer. This compatibility allows the execution of MS-DOS programs. GECOR8 allows executing any executable file (*.EXE).

After switching on the equipment, a program checks the PCMCIA card and if an executable file is detected, "*PCMCIA contents*" screen (Figure 52) appears where a list with the files detected is shown. To execute any of them select it.

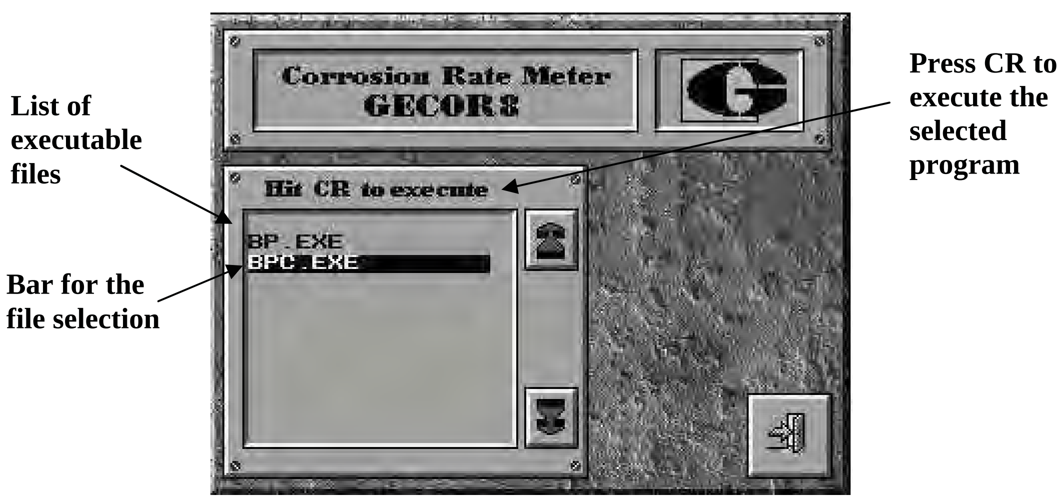


Figure 52.- "*PCMCIA contents*" screen

On the other hand, PCMCIA can contain a new version of GECOR8 software supplied by the maker. If the equipment detects it "*Updating Software*" screen appears (Figure 53).

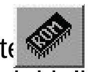
To update GECOR8 memory with the new software version, activate  icon. Updating process will take a couple minutes, and the equipment must not be reinitialised for going on.

Figure 53.- "*Updating Software*" screen

6 CHECKING YOUR EQUIPMENT

All maintenance operations that are described in this chapter must be always made before starting the measurements when the equipment has been stored during more than one month. The equipment must be also checked when it is necessary to verify the correct function (wet, hit, fall...), or when the user considers a wrong equipment operation.

6.1 BATTERY

Battery level must be checked on "*Main screen*" (Figure 14). If battery is too low it must be recharge. (See chapter 5.1)

6.2 EQUIPMENT

GECOR8 includes a dummy cell (see Figure 6) that verifies the correct equipment operation. Inside this cell an electrical circuit simulates the structure behaviour.

Dummy cell has to be connected to the equipment replacing the sensor and closing the circuit joining the crocodile claw (alligator clip) with the electrical connection in the dummy cell.

Make the average of 15 measurements with dummy cell and then test the possible error between these ones and the values provided with the equipment. The admissible ranges of variability for the Corrosion Rate values ($\mu A/cm^2$) to verify the equipment is $\pm$ 10 %.

It is only necessary to make measurements with the measurement methods that appear in this table to check the equipment (measurement in aerial structures or measurement in submerged or very wet structures in active or passive position).

The parameters that must be introduced on these measurements are:

	ACTIVE	PASIVE
AERIAL	Reinforcement area (*) = 100 cm^2	
SUBMERGED	Sup.Rel.(**) = 0.3	Sup.Rel.(**) = 1.5

Table 2.- Parameters for checking with dummy cell

(*) See chapter 3.2.6.1
(**) See chapter 3.2.7.1

On case of measurement in submerged or very wet structures it is not necessary to recalculate the result as a unidimensional model.

GECOR8 DEVICE

MODEL: 08
SERIAL NUMBER: *DATE:*

DUMMY CELL PARAMETERS

AERIAL METHOD

Switch Position	Reinforcement area (cm^2)	Icorr ($\mu A/cm^2$)	El. Resist. (kohm)
A (Active)	100	1.78	0.15
B (Passive)	100	0.03	1.13

SUBMERGED METHOD

Switch Position	Number of bars	Length (mm)	Diameter (mm)	Icorr ($\mu A/cm^2$)	El. Resist. (kohm)	Resistivity (Kohm*cm)	Sup. Rel.
A (Active)	15	200	32	1.86	0.14	0.84	0.30
B (Passive)	15	1000	32	0.03	0.98	5.88	1.51

MADE BY: DATE :	CHECKED BY: DATE :

Note: This is only a sample,
Number from dummy cell have a
range of +/- 10.

6.3 SENSORS

In $Cu/CuSO_4$ sensors check that reservoirs are full. In addition, check that reservoirs do not lose $CuSO_4$ solution, but maintaining porous point always wet.

On Ag/AgCl sensors, electrodes are detachable so, when reference potential is not stable or the user thinks that could be any problem with the potential value, these electrodes have to be changed. Service life of these electrodes depends on the type of measurements, but normally it can be at least one week.

Potential of each electrode respect of saturated calomel reference electrode must be between 60 and 80 mV in $Cu/CuSO_4$ sensors and between 10 and 30 mV in Ag/AgCl sensors (depending on the humectation level).

To check the reference potentials use a multimeter and a calomel reference electrode (see Figure 54) placing calomel electrode over each electrode point of the sensor, making contact with the correspondent pin (see Table 3).

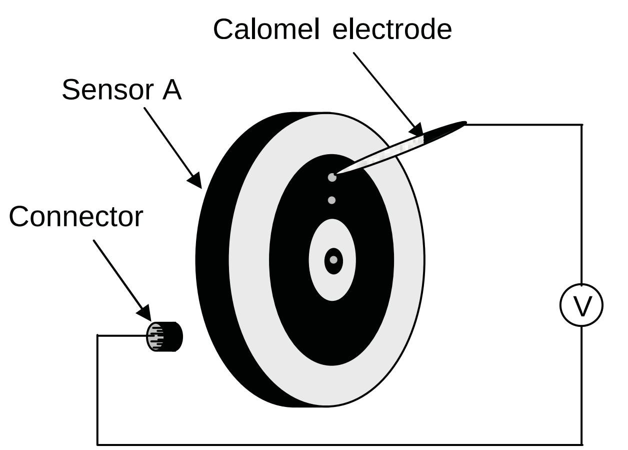


Figure 54.- Checking electrodes potential of sensor A

In sensors A and C verify that there is not electrical continuity neither between the different reference electrodes nor between the counter electrodes. To check the isolating of each electrode with the others, place calomel on each of them and make contact on pins of the others. Difference potential between electrodes has to be close to zero.

Cable can be also checked testing the different correspondence between pins of sensor connector and equipment connector (see Table 3).

Equipment Connector (14 pins)	Sensor Connector	Signal description			
		Sensor A	**Sensor B**	**Sensor C**	**Cable**
A	1	Central counter electrode	Counter electrode	Counter electrode	--
B	2	External counter electrode	--	--	--
C	3	Reference electrode	Reference electrode	Reference electrode 1	--
D	4	Internal confinement reference electrode	--	--	--
E	5	External confinement reference electrode	--	--	--
F	6	--	--	Reference electrode 2	--
G	7	--	--	Reference electrode 3	--
H	8	--	--	Reference electrode 4	--
I	9	Screen	Screen	Screen	--
J	Non applicable	--	--	--	Crocodile claw (alligator clip)
K	Non applicable	--	--	--	Crocodile claw (alligator clip)
L	Non applicable	--	--	--	Crocodile claw (alligator clip)
M	Non applicable	--	--	--	Crocodile claw (alligator clip)
N	Non applicable	--	--	--	Crocodile claw (alligator clip)

Table 3.- Correspondence of pins on sensor and equipment

7 TROUBLE SHOOTING

- If equipment does not switch on, probably battery level is too low for starting. Please try it again connecting battery charger on the correspond connector.

- Warnings can appear during measurements on the screen and then obtained results may not be valid. List of warnings that may appear for each measurement method is shown in Table 4.

Warning number	**Warning message**	
	Aerial	**Submerged or CP**
B0	Converter over range	Converter over range
B1	Ce range limit	Ce range limit
B2	Converter over range	Unstable Er1 reading
B3	Xce range limit	Bad Ce contact
B4	Unstable Er1 reading	Concrete too dry
B5	Unstable Er2 reading	Ice drop <= 0
B6	Unstable Er3 reading	Ohmic drop <= 0
B7	Bad Ce contact	Polarisation drop <= 0
B8	Unstable Er1 reading	Calculus error
B9	Unstable Er2 reading	--
B10	Unstable Vss reading	--
B11	Concrete too dry	--
B12	Bad Xce contact	--
B13	Unstable Er1 reading	--
B14	Unstable Er2 reading	--
B15	Unstable Vss reading	--
B16	High conf. const. Ce	--
B17	Low conf. const. Ce	--
B18	High conf. const. Xce	--
B19	Low conf. const. Xce	--
B20	Ohmic Resistance error	--
B21	Er1 unstable	--
B22	Er2 unstable	--
B23	Er3 unstable	--
B24	Ixce range limit	--
B25	Ice drop <= 0	--
B26	Ohmic drop <= 0	--
B27	Polarisation drop <= 0	--
B28	No initial Vss response	--
B29	Over balancing system	--

Table 4.- List of warnings

Where:

Ce: internal counter electrode
Xce: external counter electrode
Er1: central reference electrode
Er2: internal confinement reference electrode
Er3: external confinement reference electrode
Vss: difference between confinement reference electrodes
Ice: Current in the internal counter electrode
Ixce: Current in the external counter electrode

- Warning message corresponding to the numbers B0, B2, B25 in the aerial method (and for the corresponding number in submerged or CP method) can appear because of a wrong condition of the cable or a bad electrical connection with the rebar. Check the contact and clean with a metallic brush the rebar.

- Warning message corresponding to the numbers B1, from B3 to B10, from B12 to B29 for the aerial method (and for the corresponding number in submerged or CP method) can appear because of a failure on the sensor. Check the contact between concrete surface and sensor through the sponge. If not stable lectures from the electrodes appear in "*Electrodes stability*" screen, sensor must be moved and started again the measure. Verify a right work of sensor as indicates chapter 6.

- Warning message corresponding to the numbers B11 and B25 for the aerial method (and for the corresponding number in submerged or CP method) can appear because of very dry concrete. Wet the surface and wait the humidity seeped through the concrete. Check the contact between concrete surface and sensor through the sponge. If not stable lectures from the electrodes appear in "*Electrodes stability*" screen, sensor must be moved and started again the measure.

- Stray currents can also cause bad Potential stabilisation on reference electrodes. The flow of external (stray) currents into and out of the reinforcing network can change the polarisation of the rebar giving fluctuating half-cell readings. This can occur near DC power lines or rails (railways, underground or tram systems), cathodic protection systems or other DC power sources. Corrosion rate measurements can only be made if the stray currents can be isolated from the measurement location. On case of cathodic protection systems, use the method available in GECOR8 (see chapter 3.2.8)

- In case of any strange behaviour, turn off the equipment and try it starting again.

Annex 1 FORMAT OF TASK FILES

This file of predefined tasks (TASK.TXT) allows GECOR8 to make automatically measurements without introducing any parameter. This file is also automatically created by GECOR8 when measurements are made and it includes all the tasks realised with the parameters used for each one.

The file of predefined tasks can be made with a common text program or with the optional pre-post processing software (BASEGECOR) developed for GECOR8.

This file has text format and each line define a specific task. Each line has 13 different fields separated by commas. These fields are:

- **Task name.** Maximum eight characters and with the usual limitations for MS-DOS valid name files.
- **Measurement method.** Texts used are, on capital letters, MAPPING, PC, UNDERWATER or AERIAL. These names correspond to the different measurement methods in GECOR8.
- **Planned data.** Planned data on office for task execution.
- **Actual data.** Data when the task has been made.
- **Measurement parameters (1 to 6).** (See Figure 55). Parameter number and meaning depends on type of measurement.
- **Measurement point identification (three fields).** Only for predefined tasks with BASEGECOR program. Identification that allows BASEGECOR program to reallocate the results file in the correct point of the project.

METHOD	Param.1	Param.2	Param.3	Param.4	Param.5	Param.6
Mapping	Grid step X ([1])	Grid size X ([1])	Grid step Y ([1])	Grid size Y ([1])	Grid path ([1])	File of mapping perimeter ([4])
Aerial	Reinforcement area ([2])					
Submerged	Sup.Rel. ([3])					
CP						

Figure 55.- Parameters of task files

([1]) See chapter 3.2.5.2.

([2]) Reinforcement area affected by de signal. (See chapter 3.2.6.1).

([3]) Superficial relationship between steel bars and concrete included in the reference surface (see chapter 3.2.7.1).

Fields that are not used can be empty or filled with zeros, but must be respected the separators commas.

An example of task files is:

VA01,AERIAL,25/01/2002,,10.00,,,,,,Project1,1,1

VA02,SUBMERGED,25/01/2002,,0.0000,,,,,,Project1,2,2

VA03,CP,25/01/2002,,,,,,,,Project1,3,3

VA04,MAPPING,05/01/2002,,0.5,8,0.5,6,1,Form2.ini,Project1,1,1

([4]) File of mapping perimeter

Mapping area must be continuing. It is gone over from down to up and from left to right. When the top limit of the perimeter is found next measurement point is down and right. If it is defined an upper zone, this will not be gone over. On this case, divide on different mapping areas as it is shown in Figure 56.

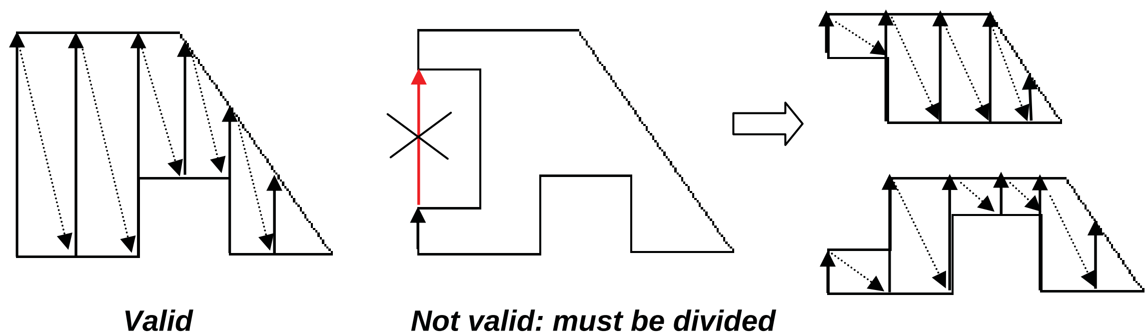


Figure 56.- Mapping perimeter

File of mapping perimeter has the extension .INI and the following parameters:

- VERTEX: Vertex number (maximum 99).
- P_INTERNAL: Co-ordinates of an internal point.
- P_STARTED: Co-ordinates of the started point.
- V_i: (x, y) co-ordinates from vertex i.

An example of file of mapping perimeter is the following:

```
VERTEX= 16
P_INTERNAL= (3; 3)
P_STARTED= (0; 0)
V_0= (0; 0)
V_1= (5; 0)
V_2= (5; 2)
V_3= (6; 4)
V_4= (8; 6)
V_5= (11; 7)
V_6= (14; 7)
V_7= (17; 6)
V_8= (19; 4)
```

V_9= (20; 2)
V_10= (20; 0)
V_11= (25; 0)
V_12= (25; 5)
V_13= (20; 10)
V_14= (5; 10)
V_15= (0; 5)

Annex 2 FORMAT OF RESULT FILES

Format of results files is ASCII format. They can be opened with any text editor.

Each measurement is registered with the parameters defined on "*Field data"* screen (Figure 21). To simplify the presentation, abbreviations of the alphanumeric values are saved in the same order than they appeared on the screen:

- Sensor position: "Horizontal", "vertical" or "reversed". (H, V, R)
- Visual condition of the concrete:
  - "Wet" or "dry". (W, D)
  - "Cracked" or "uncracked". (C, UC)
  - "Complete covers" or "spelled cover". (CC, SC)
  - "Clean" or "stain spots". (S, NS)
- Weather:
  - "Dry or sunny", "wet or raining" (D, W)
  - "hot" (>25ºC), "fine" or "cool" (<5ºC). (H, F, C)

<u>Mapping</u>.

Each complete mapping is saved on an independent file that has the name assigned to the task and the extension .MAP

This file contents the following information:

- Task name
- Identification that allows BASEGECOR program to reallocate the results file in the correct point of the project (only for predefined tasks with BASEGECOR program).
- Planned date and actual date and time measurement
- Field data
- Threshold values for corrosion potential and resistivity that provide the risk level results.
- (x, y) co-ordinate point, corrosion potential, resistivity, corrosion rate and risk level.

```
Task name          : ESTR1c25    nave 1 4
Planned date       : 17/10/01 Actual date: 17/10/01  Time: 13:14:42
Field Data         :  H  D NF CR NS  D  F
Potential threshold  :  -200.00 -350.00
Resistivity threshold :    50.00   20.00
     X      Y     Pot.      Res.     Risk      Icorr
    0.0    0.0    -1.09     1.70    green
    0.0    1.0    -0.62     0.75    green
    0.0    2.0    -1.01     1.71    green
    1.0    0.0    -1.05    -4.22    green
    1.0    1.0    -0.90     0.76    green
    1.0    2.0    -1.29     3.53    green
    2.0    0.0    -1.02     0.00    green
```

2.0	1.0	-508.83	0.00	green
2.0	2.0	-626.97	0.00	green

Aerial measurement.

Measurements are saved in a daily file. This file has the name of the date of measurements, the extension .E06 and the following information:

- Task name.
- Time
- Corrosion rate.
- Corrosion potential.
- Concrete electrical resistance.
- Resistivity
- Reinforcement area.
- Warning code (binary code that BASEGECOR program automatically convert into the warning numbers of the Table 4)
- Field data
- Identification that allows BASEGECOR program to reallocate the results file in the correct point of the project (only for predefined tasks with BASEGECOR program).

Task name	*Time*	*Cor_Rate*	*Cor_Potent*	*El_Resist*	*Resistivity*	*Reinf_Area*	*Warning_Code*	*Field data*
ESTR1c21	*12:51:27*	*0.035*	*-0.471*	*1.006*	*0.000*	*100.000*	*00000008*	*H D NF CR NS D F nave 1 1*
ESTR1c21	*12:54:20*	*0.035*	*-1.422*	*0.992*	*0.000*	*100.000*	*00000008*	*H D NF CR NS D F nave 1 1*
ESTR1c22	*12:57:57*	*0.035*	*-1.513*	*1.007*	*0.000*	*100.000*	*00000008*	*H D NF CR NS D F nave 1 2*
ESTR1c22	*13:02:37*	*0.027*	*-0.423*	*1.176*	*0.000*	*100.000*	*00000008*	*H D NF CR NS D F nave 1 2*

***Submerged measurement*.**

Measurements are saved in a daily file. This file has the name of the date of measurements, the extension .E05 and the following information:

- Task name.
- Time.
- Corrosion rate.
- Corrosion potential.
- Concrete electrical resistance.
- Resistivity.
- Superficial relationship between steel bars and concrete on non isolated (NI) bars (bidimensional model) or steel diameter on isolated (I) bar (unidimensional model).
- Warning code (binary code that BASEGECOR program automatically convert into the warning numbers of the Table 4)
- Field data
- Identification that allows BASEGECOR program to reallocate the results file in the correct point of the project (only for predefined tasks with BASEGECOR program).

Task	Time	Cor_Rate	corr_pot.	Elec_resist.	Resistiv	S.ratio/Diam.	Warning code	Field data

0P1	12:24:27	0.052	-0.393	0.940	5.643	30I	00000000	H D NF CR NS D F	*nave 1 3*
0P1	12:26:21	0.053	-0.500	0.933	5.597	30I	00000000	H D NF CR NS D F	*nave 1 3*
0P1	12:27:45	0.044	-0.683	0.932	5.593	1.131NI	00000000	H D NF CR NS D F	*nave 1 4*
0A1	12:31:50	0.477	-1.520	0.146	0.874	1.131NI	00000000	H D NF CR NS D F	*nave 1 4*

Cathodic protection.

Measurements are saved in a daily file. This file has the name of the date of measurements, the extension .MCP and the following information:

- Task name
- Time
- Corrosion potential
- Level of protection
- Warning code (binary code that BASEGECOR program automatically convert into the warning numbers of the Table 4)
- Field data
- Identification that allows BASEGECOR program to reallocate the results file in the correct point of the project (only for predefined tasks with BASEGECOR program).

Task name	Time	Potential	Level of protection	Warning Code	Field data
ESTR1P14	15:41:23	-124.12	Moderately protected	00000000	H D NF CR NS D F nave 1 1
ESTR1P14	15:41:23	-124.12	Moderately protected	00000000	H D NF CR NS D F nave 1 1

Instant-off

Measurements are saved in a daily file. This file has the name of the date of measurements, the extension .MIO and the following information:

- Task name
- Time
- Initial potential
- Potential “instant off”
- Final potential
- Field data
- Identification that allows BASEGECOR program to reallocate the results file in the correct point of the project (only for predefined tasks with BASEGECOR program).

Task name	*Time*	*Ini.Pot.*	*IOff.Pot.*	*Fin.Pot.*	*Field data*
ICU	*15:42:04*	*-2609.755*	*-951.633*	*249.896*	*H D NF CR NS D F* nave 1 1
ICU	*15:42:04*	*-2609.755*	*-951.633*	*249.896*	*H D NF CR NS D F* nave 1 1