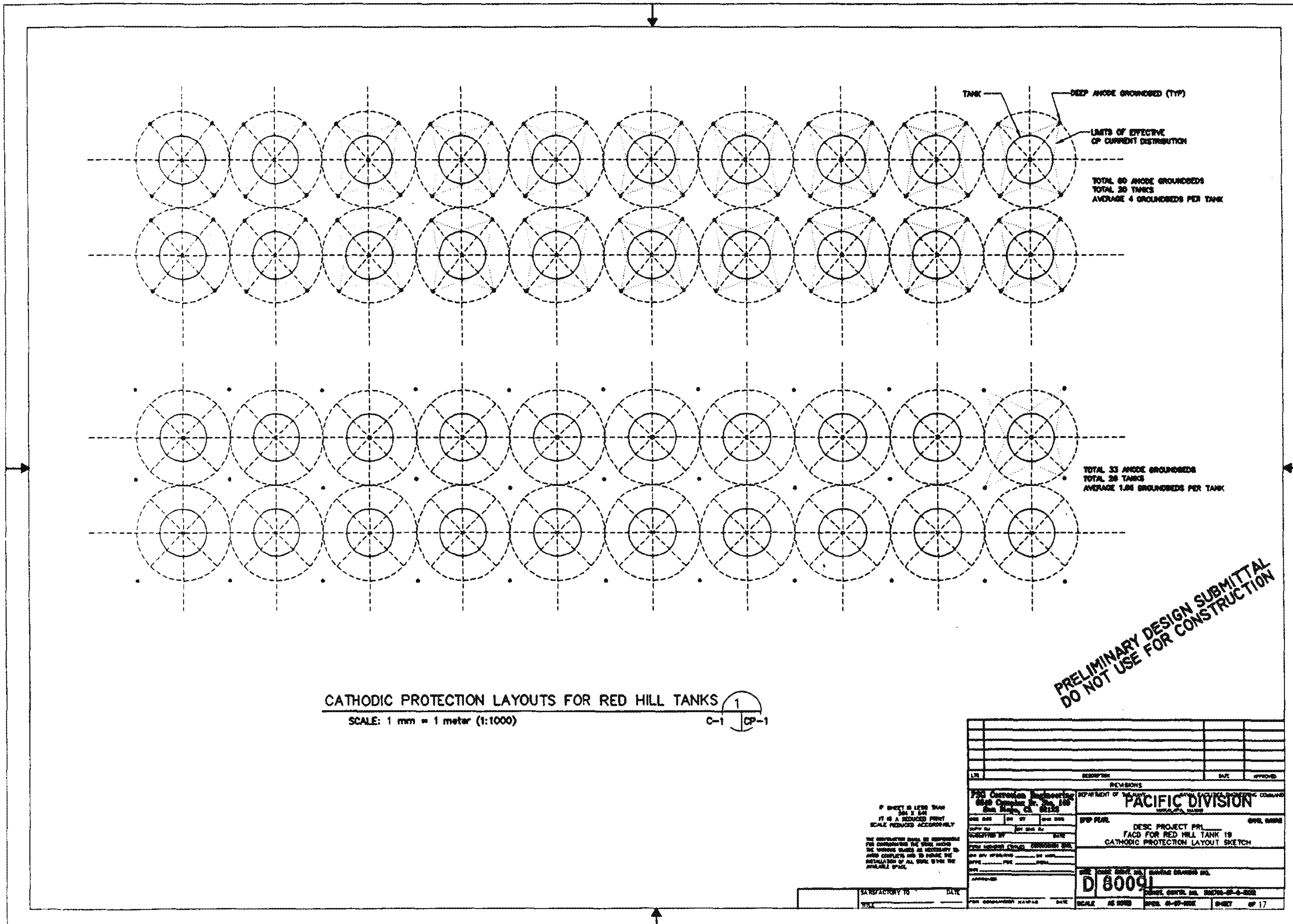
CATHODIC PROTECTION CONCEPT


TANK
DEEP ANODE GROUNDBED (TYP)
LIMITS OF EFFECTIVE
CP CURRENT DISTRIBUTION
TOTAL 80 ANODE GROUNDBEDS
TOTAL 20 TANKS
AVERAGE 4 GROUNDBEDS PER TANK
TOTAL 33 ANODE GROUNDBEDS
TOTAL 20 TANKS
AVERAGE 1.65 GROUNDBEDS PER TANK
PRELIMINARY DESIGN SUBMITTAL
DO NOT USE FOR CONSTRUCTION
CATHODIC PROTECTION LAYOUTS FOR RED HILL TANKS
SCALE: 1 mm = 1 meter (1:1000)
1
C-1
CP-1
REVISIONS
PACIFIC DIVISION
DESC PROJECT PRL____
FACD FOR RED HILL TANK 19
CATHODIC PROTECTION LAYOUT SKETCH
D
80091
SATISFACTORY TO
DATE
OF 17

PSG CORROSION ENGINEERING / SAN DIEGO (A Corrpro Company)
• 8840 Complex Drive, Suite 100 • San Diego, California 92123 • (619) 565-6580 • Fax 569-1743 •

TO: ENTERPRISE ENGINEERING
attn: **STEVE BROOKS**
Phone 907-563-3835, Fax 907-563-3817

FROM: Brendan Sheehan, PSG Corrosion Engineering/San Diego

DATE: Thursday, 07 May, 1998

PROJECT: SPECIAL PROJECT PRL 98-9 REPAIR TANK 19
RED HILL, FISC, PEARL HARBOR HAWAII.

SUBJECT: CONCLUSIONS AND BASIS OF DESIGN

FACD COMMENTS AND CONCLUSIONS

The following lists the main conclusions that I have following this FACD

A. From the 4 or 5 coupons cut from Red Hill tanks other than Tank 19 supplied by Tom Kitchen, it appears that the backside of the steel liners are suffering from two types of corrosion. The first type is a generalized corrosion attack that has resulted in broad areas of metal loss. These areas had corrosion pits of 1/2 to 1 1/2 inches in diameter. The second type of corrosion evident on the coupons is a very localized pitting with holes as small as 1/8 of an inch in diameter that had fully penetrated the 1/4 inch thick steel. The neighboring steel on the latter samples was virtually left fully intact.

B. Since the original construction of the Red Hill tanks incorporated a concrete bearing wall (minimum 4 feet thick) behind the 1/4 inch steel liner, the high pH of a quality concrete would normally provide an effective means of passisvating the steel. This passivation of the steel would continue for an indefinate amount of time as long as the integrity of the concrete at the steel/concrete interface remained intact and dry.

C. Several mechanisms could be contributing to the corrosion on the backside of the steel liners. The original concrete may have been mixed with seawater instead of fresh water. Beach sand may have been used in the concrete mix. Either of these items or any other mechanism that would allow chlorides into the concrete would result in several types of destructive processes. The reinforcing steel in the concrete, the hangers (tie backs) that fully penetrate the concrete, the strain gauges, and the grout tubes would corrode. The corrosion products expand to several times the original volume of the steel. This expansion process creates high tensile forces within the concrete and rather easily splits and cracks the concrete. Once the concrete has cracked, it would allow ground water to infiltrate to the interface between the concrete and steel liner. Also the presence of any significant chlorides in the concrete would act directly on the back side of the steel liner to corrode it.

D. Another corrosion mechanism that is possible is that the steel liner is not in contact with the concrete in all places. If water or high humidity were present in these voids it would set up a differential corrosion cell between the steel exposed to the humid air (anodic zone) and the steel covered by concrete. This type of process can be easily demonstrated by the way a steel bollard set in a concrete footing will corrode at the interface unless the concrete is crowned to facilitate quick water drainage away from the steel bollard.

E. A review of the 1949 Bectel report on the NSC Fuel System clearly reveals that even as far back as September, 1948 (See Appendices 1C, 1D, and 2A of this 1949 report) the integrity of the concrete behind the steel liner was broken. This letter describes how when compressed air was used to attempt to pressurize the tell tale piping system, very little or no back pressure could be achieved. They concluded "we believe that the most probable location of a leak not indicated by the tell tale system would be through the strain gage installation, because at this point, both the concrete and most of the gunnite is penetrated by a 1/2 inch pipe that extends thru the 1 1/4 inch pipe to the outer face of the 1/4 inch plate liner, detail "E". A leak occuring in or around any one of these 24 strain gage connections could easily find its way thru a porous or broken section of the gunite." This quite clearly demonstrates to me that there are multiple pathways for ground water to infiltrate through the massive reinforced concrete walls into the zone between the concrete and the back of the tank's steel liner. Altough this may not happen in most or even a lot of locations, all it takes is a few areas on a tank to develop the leak problems that are now being experienced.

F. Much of these conclusions have to be made based on review of old reports and "as-built" drawings, and a very small sampling of tank coupons taken out of different tanks. A survey using ultrasonic scanning equipment that is

PSG CORROSION ENGINEERING / SAN DIEGO (A Corrpro Company)
• 8840 Complex Drive, Suite 100 • San Diego, California 92123 • (619) 565-6580 • Fax 569-1743 •

able to provide complete coverage of an area (B-Scan or C-Scan) is needed for at least representative sections of the tank before any more reliable conclusions can be made. I believe that to this date, the only analysis for any of the Red Hill tanks that has been done is by personnel visually inspecting the internal side of the tank walls; looking for through wall corrosion penetrations or by very limited point to point ultrasonic testing (A-Scan). Therfore nobody knows as a fact whether the external skin of Tank 19's 1/4 inch thick steel tank liner is corroded 90% of the way through at 1, 10, 100, or 1,000 locations.

CATHODIC PROTECTION SYSTEM BASIS AND COMMENTS

A. Although the Red Hill tanks are located in a so called "rock" excavation, the possibilty of providing an effective cathodic protection system is not as unlikely as I first thought. The existing network of cathodic protection (CP) systems at Pearl Harbor was designed by PSG Corrosion Engineering (PSG) out of our San Diego, California office by contract N62755-87-C-0923. One of the 24 deep anode CP systems for this project is located only 200 feet from Red Hill's ADIT 6 next to the Tank 355. This CP systems protects the 16 inch fuel line from ADIT 6 to Pearl City Tank Farm. Although this area appears to be the same rocky formations that the Red Hill tanks were excavated in, the operating resistance of this CP system is only 1.2 Ohms (8.0 Volts/6.6 Amps). Similar fractured rock formations exist at the Pearl Harbor Upper Tank Farm and Middle Tank Farm where we I designed 8 other deep anode groundbeds. The only logical conclusion is that although the local geology is "rocky", it is fractured rock that is very permeable. The permeabilty must be allowing water to migrate though and thus electrical current is able to be efficiently distributed to these tanks and pipelines.

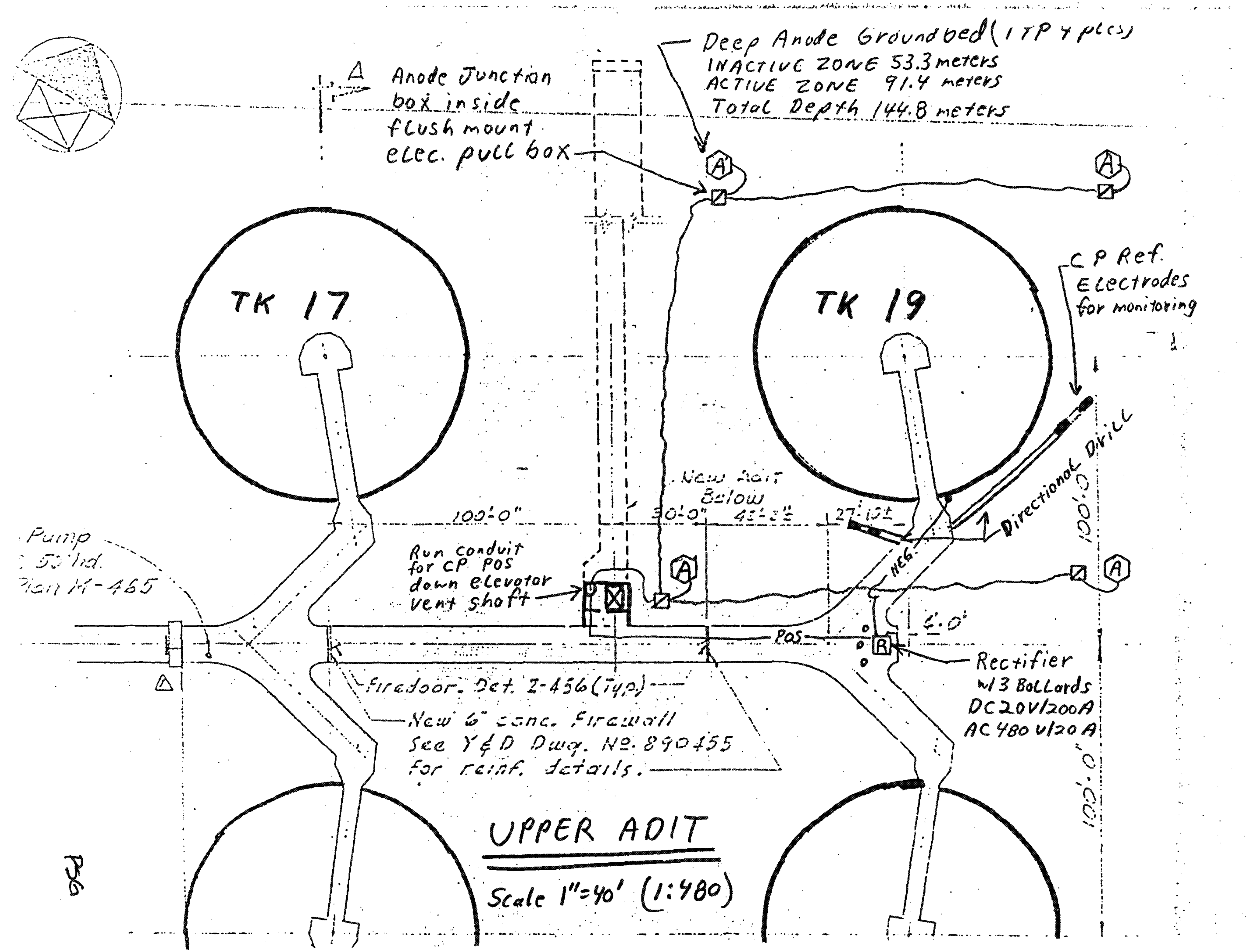
B. I am proposing to design 4 anode groundbeds for Tank 19; located at 90 degree radially positions. These deep anode groundbeds would be similar to the 24 other ones for FISC's fuel pipelines and tanks. The major construction difference is that since the tanks are so deep in the mountain, the holes have to be much deeper. I am proposing an active anode length of 300 feet and an inactive length of 175 feet; total hole depth 475 feet (145 meters). Each anode groundbed would have 12 mixed metal oxide anodes similar to the anodes already in use in the other CP systems.

C. For only Tank 19, a total of 4 anode groundbeds are required. If this CP concept for Tank 19 is later expanded to include Tank 20, then only 6 anode groundbeds (two more) would be required instead of 8. For Tanks 17, 18, 19, and 20, a total of 9 anode groundbeds would be required instead of 16. The point is that if the first CP installation for a single tank is the greatest per unit cost. As more tanks are included in the CP system, less anode groundbeds are required.

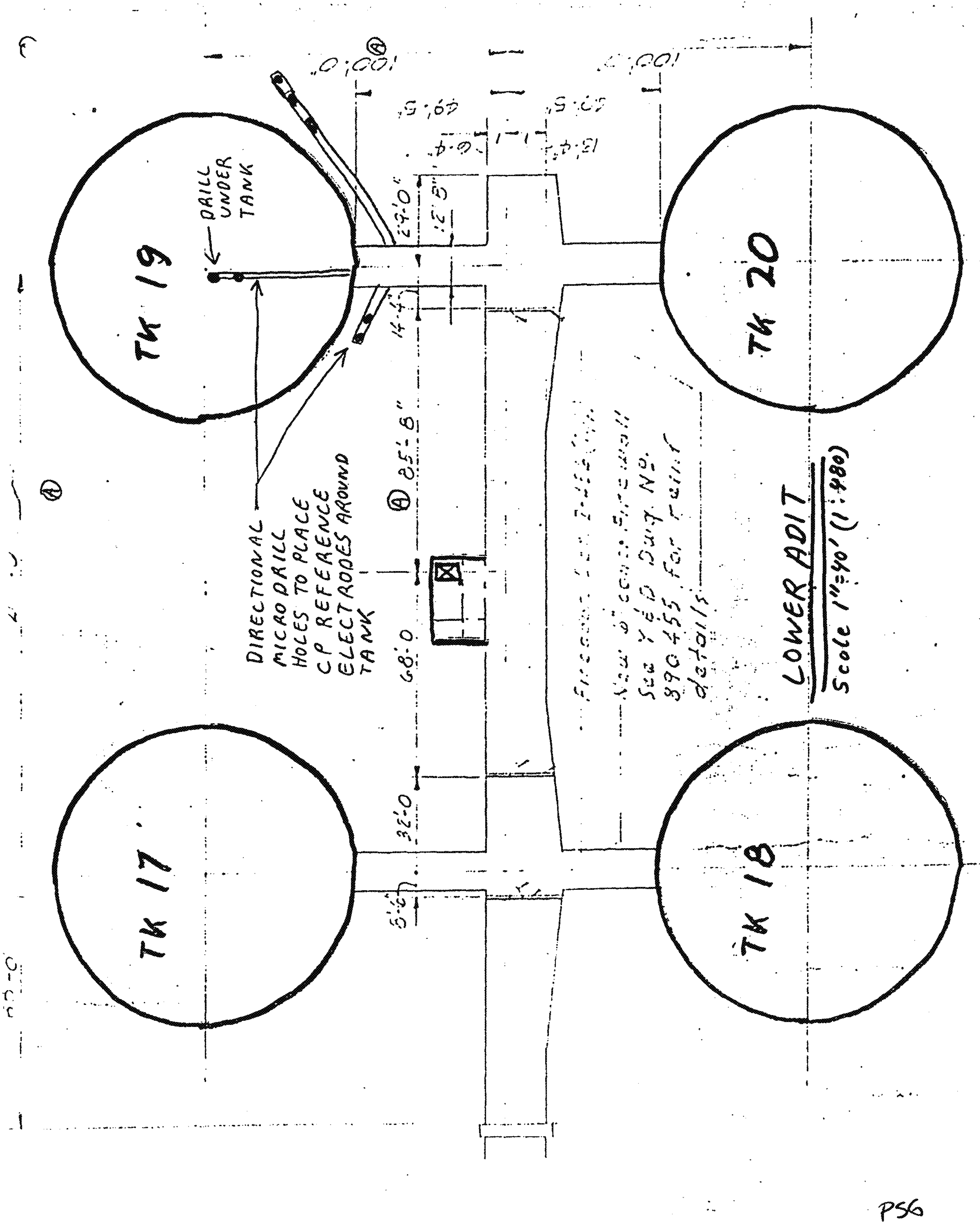
D. An important factor used in designing a cathodic protection system is the current density designed for expressed in mAmps per square meter or square foot. Although for steel pipelines in soil or water this criteria is typically 2 mA/Ft2, for steel in concrete this value ranges by a factor of 10 depending on chloride concentration in the concrete, ambient oxygen, and amount of moisture present. For new concrete coated steel piplines, we use values as low as 0.2 mA/Ft2. For reinforcing steel in bridge and pier decks that are contaminated with heavy chlorides, this value approached 3 mA/Ft2. If this project were to proceed to a design, it would be very helpfull to obtain representative samples of the concrete behind tank's steel liner. These concrete samples would be crushed into a powder and tested for total chloride concentration. This information would be used to adjust the cathodic protection system basis of design calculations that are attached with this.

E. The rectifier would be placed inside the upper adit tunnel instead of on top of Red Hill in order to avoid exposure to the elements, eliminate vandalism and allow more frequent monitoring.

F. This CP system must be designed with the ability to monitor its effectiveness. This is done by measuring DC Voltages (CP Potentials) between the steel liner and the concrete environment using reference electrodes that would be embedded in the concrete at the areas that would most likely be the most difficult to provide corrosion control to. These areas would be the furtherest away from the anode groundbeds. These reference electrodes would be placed in position by micro tunneling from inside the Upper Adit and Lower Adit tunnels.



RDHLCC0027629



PS6

RDHLCC0027630
BWS031170

PSG CORROSION

PSG Corrosion Engineering (a Corrpro Company)
8840 Complex Drive, Suite 100, San Diego, CA 92123
CA (619) 565-6580, HI (808) 531-3143, Fax (619) 569-1743

CATHODIC PROTECTION BASIS OF DESIGN CALCULATIONS

PR	FACD FOR RED HILL TANK 19
LOCATION:	FISC FUEL DEPT. PEARL HARBOR, HAWAII
CLIENT:	ENTERPRISE ENGINEERING/ PAC DIV NFEC
DATE:	7-May-98 EER: B. SHEEHAN
SUBJECT:	**TANK 19 CATHODIC PROTECTION SYS CALCS**

1.0 GENERAL CATHODIC PROTECTION DESIGN PARAMETERS

STEEL'S EXTERNAL COATING NONE

AVERAGE EFFECTIVE COATING EFFICIENCY: 0 %

ELECTROLYTE ENVIRONMENT CONCRETE

CP CURRENT DENSITY (dependant on concrete's chloride concentration):

Value used for this design = 1.5 mA/Sq Ft = 16 mA/m^2

New conc pipe	300 PPM	0.2 mA/Sq Ft =	2 mA/m^2
	1000 PPM	0.7 mA/Sq Ft =	8 mA/m^2
	2500 PPM	1.0 mA/Sq Ft =	11 mA/m^2
Heavy chlorides	5000 PPM	2.0 mA/Sq Ft =	22 mA/m^2

CP CURRENT LOST TO OTHER TANKS = 43%

2.0 SURFACE AREA OF ONE TANK

TANK BARREL DIA	100 Ft =	30.48 *m*
TANK BARREL LENGTH	150 Ft =	45.72 *m*
TANK BARREL SURF. AREA	47,124 Sq Ft =	4,378 m^2
TANK DOME RADIUS	50 Ft =	15.24 *m*
TANK DOME SUR. AREA	31,416 Sq Ft =	2,918 m^2
TOTAL TANK SURF. AREA	78,540 Sq Ft =	7,296 m^2

PSG CORROSION

PSG Corrosion Engineering (a Corrpro Company)
8840 Complex Drive, Suite 100, San Diego, CA 92123
CA (619) 565-6580, HI (808) 531-3143, Fax (619) 569-1743

CATHODIC PROTECTION BASIS OF DESIGN CALCULATIONS

PR FACD FOR RED HILL TANK 19
LOCATION: FISC FUEL DEPT. PEARL HARBOR, HAWAII
CLIENT: ENTERPRISE ENGINEERING/ PAC DIV NFEC
DATE: 7-May-98 **EER:** B. SHEEHAN
SUBJECT: **TANK 19 CATHODIC PROTECTION SYS CALCS**

3.0 - CP CURRENT REQUIREMENT CALCULATIONS

CP CURRENT REQUIREMENT EQUATION

$$I = SA \times (1 - EFF) \times CD \times SF + INSUL$$

HERE:

$I = Total\ CP\ Current\ \mathrm{Re}quired\ For\ Anode\ Capacity$

$SA = Submerged\ Surface\ Area$

$EFF = Coating's\ Dielectric\ Efficiency\ (For\ Bare\ Steel = 0)$

$CD = Emperically\ Derived\ CP\ Current\ Density\ Parameters$

$SF = Safety\ Factor$

$INSUL = Extra\ Current\ Allowance\ for\ Insulator\ Leakage$

TOTAL SUBMERGED AREA AT FUEL PIER (SA)	7,296 m^2
AVERAGE COATING EFFICIENCY (Eff)	0 %
CP SYSTEM CURRENT DENSITY (CD)	16.1 mA/m^2
CURRENT CAPACITY SAFETY FACTOR (SF)	1.0
OTHER TANKS AND INSULATOR LEAKAGE (Insul)	51.1 *DC Amps*
TOTAL CURRENT REQUIRED =	168.9 *DC Amps*

USE FOR CP SYSTEM CURRENT REQUIREMENT 170 DC AMPS

4.0 TUBULAR MIXED METAL OXIDE IMPRESSED CURRENT ANODES

ANODE TRADE NAME =	HARCO M754
ANODE LENGTH =	1.219 *m*
ANODE DIAMETER =	19.1 *mm*
ANODE SURFACE AREA =	0.073 m^2
MAX CURRENT DENSITY (Open Hole) =	90 *DC Amps/*m^2
MAX. ANODE CURRENT OUTPUT =	6.583 *DC Amps*
ANODES PER GROUNDBED =	12 *Anodes*
TOTAL ANODE GROUNDBEDS =	4 *Groundbeds*
TOTAL QUANTITY OF ANODES =	48 *Anodes*
TOTAL ANODE GROUNDBEDS MAX. AMPACITY =	316 *DC AMPS*
CP SYSTEM CURRENT REQUIREMENT =	170 *DC AMPS*

CATHODIC PROTECTION BASIS OF DESIGN CALCULATIONS

PR	FACD FOR RED HILL TANK 19
LOCATION:	FISC FUEL DEPT. PEARL HARBOR, HAWAII
CLIENT:	ENTERPRISE ENGINEERING/ PAC DIV NFEC
DATE:	7-May-98 EER: B. SHEEHAN
SUBJECT:	**TANK 19 CATHODIC PROTECTION SYS CALCS**

Note - The max. ampacity should be significantly greater than the CP system current requir

5.0 ANODE GROUNDBED DESIGN PARAMETERS

ANODE GROUNDBED TYPE =		DEEP ANODE GROUNDBEDS	
NUMBER OF ANODE GROUNDBEDS IN PARALLEL =		4	*Groundbeds*
NUMBER OF ANODES IN EACH GROUNDBED =		12	*Anodes*
TOTAL QUANTITY OF ANODES IN ALL GROUNDBEDS =		48	*Anodes*
ANODE GROUNDBED HOLE DIA. =	6.875 inch	175	*mm*
INACTIVE LENGTH OF ANODE HOLE	175 Ft =	53.3	*m*
ACTIVE LENGTH OF ANODE HOLE=	300 Ft =	91.4	*m*
TOTAL LENGTH OF ANODE HOLE=	475 Ft =	144.8	*m*

6.0 COKE BACKFILL CURRENT DENSITY CALCULATION CHECK

Anode groundbed backfill densities recommended by Elgard Corporation, Tech Paper
"Deep Anode Groundbed Design and Installation Guidelines", C.F. Schrieber, Jan, 1994

Dry Soil	*1.615 DC Amps/m²*
Partially Dry Soil - not in water table	*2.153 DC Amps/m²*
Moist Soil, down in a water table	*3.229 DC Amps/m²*
Open Hole	*4.952 DC Amps/m²*

ANODE GROUNDBED TYPE =	DEEP ANODE GROUNDBEDS	
NUMBER OF ANODE GROUNDBEDS IN PARALLEL =	4	*Groundbeds*
ACTIVE LENGTH OF ANODE HOLE=	91.44	*m*
DIAMETER OF DRILLED ANODE GROUNDBED HOLE =	174.6	*cm*
TOTAL ACTIVE SURFACE AREA OF ANODE GROUNDBEDS	2,006	*m^2*
ANODE BACKFILL DISCHARGE DENSITY (from table above) =	1.615	*DC Amps/m^2*
MAX ANODE GROUNDBEDS TOTAL CURRENT DISCHARGE	3,240	*DC AMPS*
CP SYSTEM CURRENT REQUIREMENT =	170	*DC AMPS*

Note - The max. current discharge should be greater than the CP system current requireme in order to avoid problems at the backfill/soil interface. Electro-osmotic force drives moistur away from the anodes and the anodic oxidation reaction produces gas and consumes mois

PSG CORROSION

PSG Corrosion Engineering (a Corrpro Company)
8840 Complex Drive, Suite 100, San Diego, CA 92123
CA (619) 565-6580, HI (808) 531-3143, Fax (619) 569-1743

CATHODIC PROTECTION BASIS OF DESIGN CALCULATIONS

PR FACD FOR RED HILL TANK 19
LOCATION: FISC FUEL DEPT. PEARL HARBOR, HAWAII
CLIENT: ENTERPRISE ENGINEERING/ PAC DIV NFEC
DATE: 7-May-98 EER: B. SHEEHAN
SUBJECT: **TANK 19 CATHODIC PROTECTION SYS CALCS**

7.0 ANODE GROUNDBED RESISTANCE TO SOIL CALCULATIONS

ANODE RESISTANCE – TO – EARTH FORMULA

$$R = \frac{\rho}{2\pi L}\left(\ln\frac{8L}{D} - 1\right)$$

$R = \text{Resistance-to-earth } (ohms)$

$\rho = \text{Soil Resistivity } (ohm \cdot cm)$

$L = \text{Length of Anode or Active Coke Column } (cm)$

$D = \text{Diameter of Anode or Active Coke Column } (cm)$

MAX. AVG. SOIL RESISTIVITY TO BE ENCOUNTERED (*P*) =	5,000	*Ohm-cm*
TOTAL ACTIVE LENGTH OF ANODE HOLE (L) =	9,144	*cm*
DIAMETER OF DRILLED ANODE GROUNDBED HOLE =	174.6	*cm*
CALCULATED RESISTANCE OF ONE NEW GROUNDBED =	0.44	*Ohms*
NUMBER OF ANODE GROUNDBEDS IN PARALLEL =	4	*Groundbeds*
CALCULATED RESISTANCE OF PARALLEL GROUNDBEDS	0.11	*Ohms*

8.0 RECTIFIER VOLTS AND AMPS SIZING CALCULATIONS

CP DESIGN CURRENT OUTPUT CAPACITY =	170	*DC Amps*
REQUIRED RECTIFIER MAX. VOLTAGE (V = I x R) =	18.6	*DC Volts*

NEAREST STANDARD RECTIFIER MAX. AMPS =	**200**	*DC Amps*
NEAREST STANDARD RECTIFIER MAX. VOLTAGE =	**20**	*DC Volts*

CP RECTIFIER INSPECTION FORM
FISC PEARL HARBOR, HAWAII

CORRPRO / PSG CORROSION
SAN DIEGO, CALIFORNIA

RECTIFIER 26 KEY Gate at bottom of hill and gate at Tank 355

LOCATION Red Hill, next to Slop Tank #355 TESTED BY B. SHEEHAN

Pipeline/Tanks: 16 inch JP-5 pipeline down to Aloha Stadium DATE 27-Jan-98

DEEP ANODE GROUNDBED INFORMATION

DEPTH OF ANODE GROUNDBED = 175 FEET. Total of 8 "LIDA ONE" mixed metal oxide tubular type anodes
Anodes provided with No. 8 AWG 65 mil HMW-PE/ 40 mil HALAR insulation

RECTIFIER RATINGS AND MANUFACTURER'S INFORMATION

MANUFACTURER	J A Electronics, Stafford, TX		MFD DATE:	1993		SERIAL NO.	93747
AC INPUT	496	VOLTS AC	0.09	AMPS AC		*1 PHASE*	*OIL COOLED*
MAX DC OUTPUT	30	VOLTS DC	30	AMPS DC		900	WATTS
TAP SETTINGS	5	COARSE	6	FINE		30	NO OF STEPS

ANNUAL RECTIFIER METER ACCURACY CHECK

		METER SWITCH OPERATION	OTHER NOTES AND TEST DATA
VOLTAGE AT POS & NEG TERMINALS =	8.0 Volts		
RECTIFIER VOLTMETER READING =	no reading	*WORKS OK*	Rectifier voltmeter is broken
mV MEASUREMENT AT SHUNT =	11.0 mV	SHUNT FACTOR INFO:	
CALCULATED CURRENT AT SHUNT =	6.6 Amps	50 mV	
RECTIFIER AMMETER READING =	6.0 Amps	30 AMPS	

ANNUAL INDIVIDUAL ANODE CURRENT OUTPUT MEASUREMENTS

Anode #	Anode Current	Anode #	Current	Anode #	Current
ANODE 1	0.51 Amps	ANODE 4	0.87 Amps	ANODE 7	0.40 Amps
ANODE 2	0.50 Amps	ANODE 5	0.73 Amps	ANODE 8	1.15 Amps
ANODE 3	0.51 Amps	ANODE 6	1.88 Amps	TOTAL	6.55 AMPS

RECOMMENDED RECTIFIER CURRENT OUTPUT

MAX = 8.00 Amps MIN = 5.00 Amps

PERIODIC RECTIFIER OUTPUT TESTING

DATE	INSPECTED BY:	DC VOLTS	DC AMPS	COARSE SETTIN	FINE SETTING	NOTES
1-Sep-94	B. Sheehan	7.6 Volts	8.30 Amps	COARSE = 2	FINE = 1	Initial activation
5-Feb-96	B. Sheehan	0.0 Volts	0.00 Amps	COARSE = 2	FINE = 1	AC off + 4" pipe removed
29-Oct-96	B. Sheehan	8.0 Volts	7.44 Amps	COARSE = 2	FINE = 1	Found Rect. OFF!
9-Apr-97	PWC Pearl	7.9 Volts	7.32 Amps	COARSE = 2	FINE = 1	
13-Aug-97	PWC Pearl	7.8 Volts	7.32 Amps	COARSE = 2	FINE = 1	
18-Dec-97	PWC Pearl	8.0 Volts	7.44 Amps	COARSE = 2	FINE = 1	
27-Jan-98	B. Sheehan	8.0 Volts	6.00 Amps	COARSE = 2	FINE = 1	Annual CP Survey

Date	GENERAL RECTIFIER INSPECTION NOTES
27-Jan-98	Cleaned/lubricated the rectifier locks and applied the FISC safety and phone number stic
27-Jan-98	The rectifier's voltmeter is broken and should be replaced.

May 7, 98

TCu / Miki Funahashi 1-800-733-7092

or 1-800-326-1953

L.M @ 9:45 Korea Project

Anode for Steel Pipe Pile

MMO Anode 2 FT

Coated piles

Each Bent has 3 Pile

Diego Garcia POL Pier

D.G. TARMAC is not helping Speegle

Speegle fired TARMAC ~~and~~ hired Southern C. P.

Joe Fogal

Rect are ~~only~~ operating in manual mode

dealing directly with Tom not Dwight

Replacing

They original sent a constant potential Rectifier not a constant current rectifier.

Red Hill Tank 19

0.2 mA/FT with no chlorides in the concrete

2. with Lots of chlorides in the concrete, might need 1.5 mA but since its underground with low oxygen conc. takes a long time to polarize and depolarize a conc. sample would go a long way to determine current density (by measuring chloride content

eg. ~~lb Cl/cubic yard~~ TOTAL chlorides

AAHSTO	2,500 PPM	=	1 mA/FT
AAHSTO	5,000 PPM	=	2 mA/FT
	1,000 PPM	=	0.7 mA/FT
Req. ACW conc.	300 PPM	=	0.2 mA/FT

May 7, 98

TC w/ John Waters

They use 0.2 mA/FT^2.

in moist conc, the current densities go up a lot to as much as 0.8 mA/FT^2

Might use up to 2 mA/FT^2

Size Rectifier <u>after</u> anode groundbeds are installed.

May 7, 98

TCw/ Frank Veneri 677-8181

they have primarily PR Drilling 2,000 FT drilling

Put [R] inside the tunnels

holes 200 FT

1,000 FT for $100,000 ← Geolabs was $120,000 w/ Rotory. Tri Cone 6 inch dia

one hole was cased

If ex soil is mudrock, the rotory drilling will build a wall and hole could be left open.

Red hill anode ground bed

They did not loose circulation.

use 130 $/FT

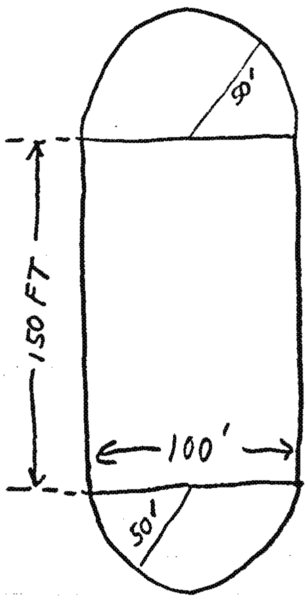
$10,000 to bring a drill rig over from the mainland (one way)

Foundation uses air drill rigs

CMC

PR

Corrpro Companies Incorporated "A Commitment to Excellence"	CLIENT	SHEET NO. OF
	PROJECT	DATE
	SUBJECT	BY



Surface Area of Barrell

$SA = \pi D L = \pi \; 160 \; 150$
$= 47,124 \; FT^2$

Surface Area of Top + Bottom Domes

$SA = 4\pi r^2 = \pi d^2 = \pi (100)^2$
$= 31,416 \; FT^2$

Total Surface Area = 78,540 FT^2

Design Current Density = 0.2 mA/FT^2
(from AWWA C300 pipeline projects)

Total Current Required = 15,708 mA
= 15.7 Amps

$2 r \pi (r + h) = 2\pi r^2 + 2 r \pi L$
$= 2\pi r^2 + \pi D L$

Corrpro Companies Incorporated "A Commitment to Excellence"	CLIENT	SHEET NO. OF
	PROJECT	DATE
	SUBJECT	BY

Tom Kitchen Re: TK's 16, 10, 8, 7, 6

Tank 16 most holes were in the dome
4 holes

Tank 10 10 holes

Inspection has been done only visually from inside.

original telltale sy
3/4" pipes were often clogged w/ NSFO
STD wall

1960 circa TKS 17-20 upgrade
Bottom water inside tank. 1½" SCH 80

Late 60's TK'S 5, 6, 12
1 ½" DIA SCH 80
Ran pipe through upper dome so they could be blown out.
Drilled new hole in botton of tank

1978 - Larry Goodwin
Bunker C fuel oil would go on fire as it oosed out of holes created ~~xx~~ by the 3/4" tell tale pipe which were removed.

B-273

RDHLCC0027640
BWS031180

Corrpro Companies Incorporated "A Commitment to Excellence"	CLIENT	SHEET NO. OF
	PROJECT FACD RED HILL TANK 19	DATE May 6, 98
	SUBJECT	BY

TANK OPTIONS FOR ALL SCENARIOS (TOFAS)

a.) Don't use upper dome area for fuel
b.) RECOAT BOTTOM DOME and install galvanic anodes
c.) Tank Gauging
D) Piping Repairs
E) No elevator required

Special options
Under tank monitoring tubes

RDHLCC0027641
BWS031181

	CLIENT	SHEET NO. OF
Corrpro Companies Incorporated "A Commitment to Excellence"	PROJECT	DATE 4 May, 98
	SUBJECT	BY

DEO Defense Energy Office

Ron Tanaka - "Repair" not just searching for leaks + patching.

Prevent future leaks
Make it Easier to Locate Leaks

JIM GAMMON -
8" Barbers Pt Line to be closed in 1999

Botom of TK 1 is 151 FT above sea level

notice Rock
6" Gunite
1/8" Grout
3 1/2 - 4' Reinforced Conc
1/4' Steel
Polyurethane coating

existing tank gauging system
± 0.001 FT — 58 gallons in the tank
doesn't compensate for temp. contraction/expansion

wood behind the gunite for tunnels was not removed.

angle plates were welded to the dome (by the low quality welders)

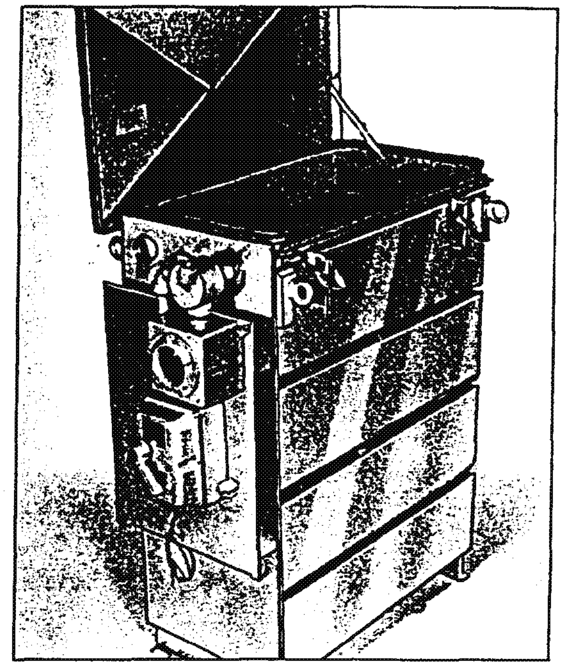
TK 19 NRC Polyurethane applied in early 1960's

Good-All Electric®

Standard Oil Rectifiers

For Aggressive Environments

Cathodic protection systems are often operated in volatile areas near gas and petroleum storage. For these environments Harco offers Standard Oil rectifiers manufactured by Good-All Electric. The rectifiers are made with the same quality components as other Good-All power supplies, including powerful transformers, long-lasting silicon stacks, and durable cabinets. They can be designed for single or three phase input and contain taps for 20 different DC output combinations. Surge protection is provided standard on AC input and DC output. Efficiency filters are also offered as an option to improve power conversion. To prevent the risk of explosion from sparks, all electrical components are immersed in an oil coolant. The coolant is protected from contaminants by specially built gaskets on the rectifier's cabinet. The explosion proof cabinet also features a quick opening and sure sealing cover, ample cooling capacity, and a rugged 11-gauge reinforced steel construction which will not deform under the weight of the oil coolant.



Good-All Standard Oil rectifiers are offered in NEMA 4 and 7 cabinets. On NEMA 4 rectifier units an external housing is provided for circuit breakers, meters, and shunt and output cable connections. This cabinet allows operators to test and make minor adjustments to the rectifier without touching the oil coolant. A phenolic panel in the box is provided to shield primary circuit components from accidental contact. Meters mounted to the panel are individually calibrated and are accurate to within 2 percent of full scale. On NEMA 7 power units, all electrical components are immersed in the oil coolant to satisfy NEC Class 1, Division 2 requirements for hazardous locations.

Typical Applications

Standard Oil rectifiers by Good-All are designed for hazardous areas containing explosive substances. Locations where the power units are typically used include tank farms, refineries, and chemical plants. The rectifier can be housed in NEMA four or seven cabinets which are Class 1, Division 2 rated. AC voltage of 120, 208, or 240 may be selected in single phase, and 240 or 480 in three phase rectification. The power supply is also available in a range of DC voltage and current output combinations. Maximum operating temperature for the unit is 113°F.

Options

- Bolt-on Lid
- Communication Interference Filter
- Continuous Reading Meters
- Continuous Signal Light
- Customer-Specified Finish
- Efficiency Filter
- Heavy Duty Wood Crating
- Interrupter Circuit
- Operating Temperature Above 113°F
- Over 20 Step Tap Adjustment

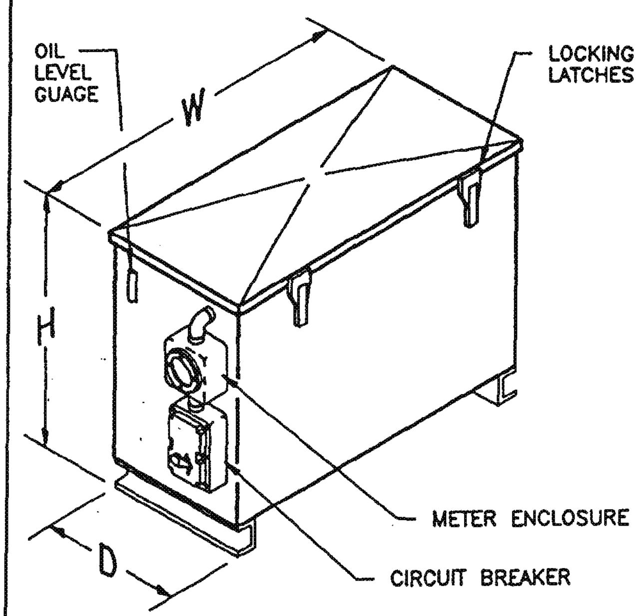
PSG

Good-All Electric®

Standard Oil Rectifiers

Ordering Procedure

Good-All Standard Oil rectifiers are manufactured according to customer specifications. To order this type of rectifier for your particular application, indicate that you need a Good-All Standard Oil rectifier and specify the quantity desired, the input voltage, the DC voltage rating, the DC current rating, the phase of operation, cabinet specifications, and any options. An example is provided to help illustrate this process.



Ordering Procedure Example

ITEM	EXAMPLE
Quantity	*1*
Product	*Good-All Standard Oil Rectifier*
Input Voltage	~~240 VAC~~ 480
Input Phase	~~Three~~ 3
DC Voltage	~~50 VDC~~ 20 V
DC Current	~~50 amps~~ 200 A
Cabinet Type	~~NEMA 7 Class 1~~ Division 2 ?
Options	~~Efficiency Filter~~

Standard Dimensions and Shipping Weights

NOMINAL DIMENSIONS in (cm) H	W	D	WEIGHT lbs (kg)
35 (88.9)	44 (111.76)	19 (48.26)	410 (185.98)

AC Input Ratings
120, 60 Hertz Single Phase
208, 60 Hertz Single Phase
240, 60 Hertz Single Phase
240, 60 Hertz Three Phase
480, 60 Hertz Three Phase

DC Output Ratings

VOLTS	AMPS
Specify	

HARCO CERTIFIED

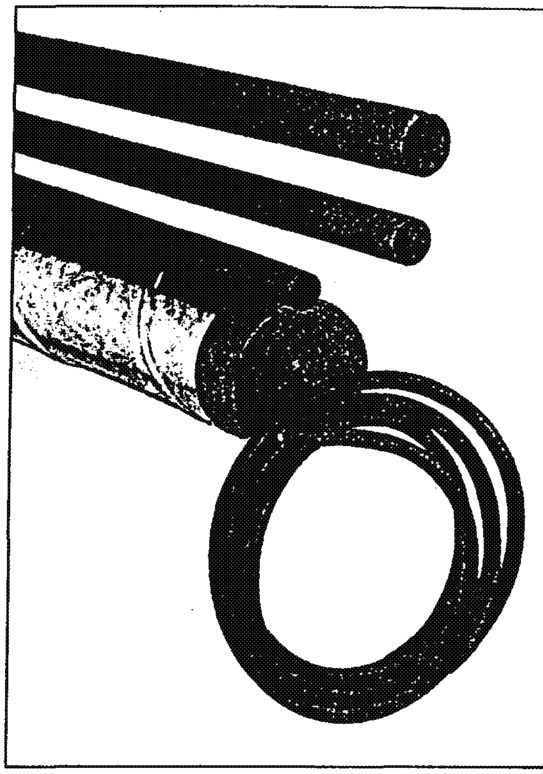
Mixed Metal Oxide

Tubular Anodes

Dimensionally Stable In All Environments

To obtain the highest level of protection from an impressed current cathodic protection system you need an anode with a very low consumption rate and high current capacity. With Harco's tubular mixed metal oxide line of anodes you get powerful protection and unsurpassed stability. The anodes are made using tubular titanium substrates which are coated with a mixed metal oxide catalyst. The catalyst is thermally applied to the titanium to form an extremely chemical resistant bond. This special composition brings together the stability of titanium with the conductive properties of the mixed metal oxide catalyst to achieve superior performance. In soil and fresh water applications the anodes have a recommended current density of approximately 10 amp/ft², and can be operated over 50 amp/ft² in sea water environments. Even at these relatively high discharge levels the anodes will be consumed at less than 1.0 mg/amp-yr.

The tubular design of these anodes also allows for numerous performance benefits. The tubular configuration provides a larger surface area, which in turn permits greater current output and lower anode-to-earth resistance. The tubular style also means lead wire connections can be made in the center of the anode. With Harco tubular anodes this connection consists of a brass wedge connector which grips firmly to the internal circumference of the anode. This connection is protected from moisture intrusion by a waterproofing sealant which fills the entire anode tube. The ends of the anode are then covered with shrink tubing for a completely sealed electrical connection.



Typical Applications

Mixed metal oxide anodes have proven to operate effectively in all types of environments, including areas with extremely low pH levels (under 1), and high chloride concentrations. While Harco tubular anodes can be used singularly, their unique configuration also makes them ideal for use in strings on offshore platforms or in deep groundbeds. In addition, the string anodes can be installed parallel to transmission pipelines, or used for other special applications.

CHEMICAL COMPOSITION

Substrate	Catalyst
ASTM B-338 Grade 1 Titanium	Mixed Metal Oxide

PSG

HARCO CERTIFIED

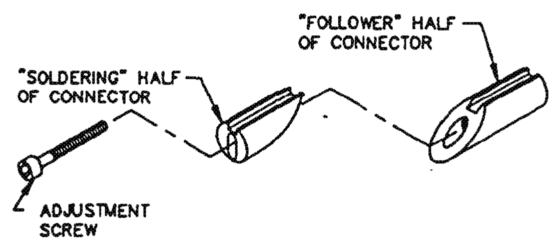
Mixed Metal Oxide

Tubular Anodes

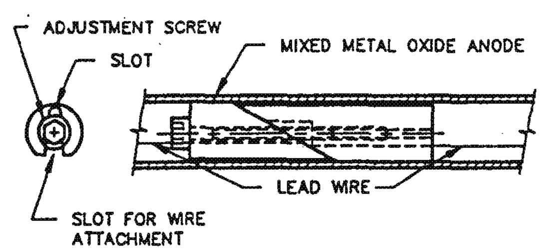
Ordering Procedure

Harco tubular mixed metal oxide anodes are available in several different dimensions. To order the required anode for your structure, indicate that you need a tubular mixed metal oxide anode and specify the quantity desired, the anode type, the lead wire length, size, and insulation, and whether it should be packaged or bare. An example is provided to help illustrate this process.

Ordering Procedure Example	
ITEM	**EXAMPLE**
Quantity	*200*
Anode Material	*Tubular Mixed Metal Oxide*
Anode Type	*M754*
Wire: Length	*20 ft*
Size (*#6 or #10=Standard)*	*#6 AWG*
Insulation *(EPR/CSPE=Standard)*	*EPR / CSPE*
Packaging *(Bare or Packaged)*	*Packaged*



CONNECTOR ASSEMBLY



CONNECTOR INSTALLATION

Standard Dimensions and Shipping Weights

ANODE TYPE	NOMINAL DIMENSIONS Ø in (mm)	NOMINAL DIMENSIONS LENGTH ft (mm)	NOMINAL WEIGHT BARE oz / ft (g / M)	NOMINAL WEIGHT PKGD. lbs (kg)	CURRENT RATING* amps
M752	0.75 (19.1)	2.0 (610)	3.4 (314)	23 (10.5)	23
M754	*0.75 (19.1)*	*4.0 (1,219)*	*3.4 (314)*	*25 (11.4)*	*45*
M103	1.0 (25.4)	3.3 (1,006)	3.8 (351)	25 (11.4)	50
M124	1.25 (31.8)	4.0 (1,219)	5.8 (538)	27 (12.3)	73

**Based on 15 years design life in saltwater.*

Loresco DW-1®, SC-2™, and SC-3™

Petroleum Coke Backfill

Low Resistivity For Deep Groundbeds

Coke breeze backfills are designed to lower anode-to-earth resistance. Loresco DW-1, SC-2, and SC-3 backfills not only possess the lowest resistivities on the market today, they also exhibit unique properties which make them ideal for deep groundbed applications.

The DW-1 backfill is composed of carbon particles ranging in size from 0.004 - 0.04 inches. It weighs 74 pounds per cubic foot and sinks readily in water or light mud. The fixed carbon content of DW-1 is over 99 percent. SC-2 is a "dust-free" sized and surface modified carbon product designed for impressed current systems. Particle size of the backfill is 0.04 inches. Loresco SC-3 is the finest backfill in the Loresco line. It utilizes the latest technological developments to enhance and maximize the effects of an earth contact backfill. These refinements include improved surface modifications and particle selection, and the "wetting" characteristics of surfactants. These enhancements permit better conductive and pumping properties to make it 40 percent less resistive than common metallurgical coke breeze.

DW-1, SC-2, and SC-3 are manufactured using the same quality standards as other Loresco backfills. They contain 99.77% fixed carbon contents and are packed in 100 pound woven polypropylene bags with polyethylene inner liners to protect against moisture.

CHEMICAL COMPOSITION

Element	Content %
Fixed Carbon	99.77
Ash	0.1
Moisture	0.0
Volatile Matter	0.0

Typical Applications

Loresco DW-1, SC-2, and SC-3 backfills can be used on both surface and deep groundbed applications. Because they exhibit excellent pumping characteristics, they are ideal for use in deep groundbed installations. All three backfills have been tested according to EPA leacherate standards and have been found to meet the quality requirements for materials utilized in underground burial.

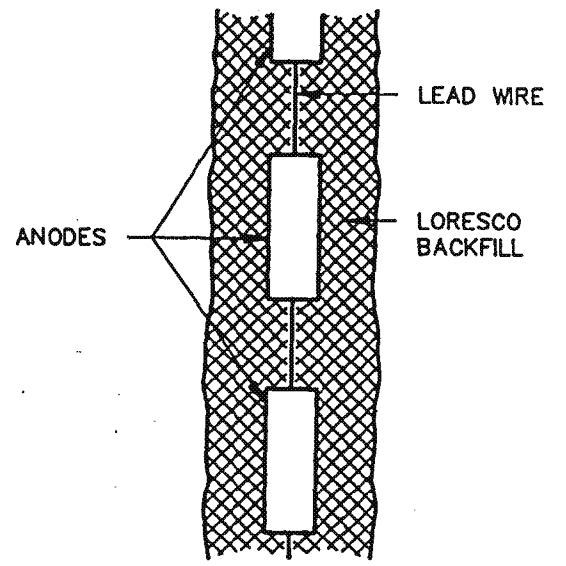
PSG

Loresco DW-1®, SC-2™, and SC-3™

Petroleum Coke Backfill

Ordering Procedure

DW-1, SC-2, and SC-3 compact without tamping to 74 lb/ft³. To order the required backfill for your structure, indicate that you need either the DW-1, SC-2, or SC-3 backfill and specify the total pounds required. Calculation of the total pounds necessary can be accomplished using the chart provided. An example is also included to help illustrate this process.



Calculation Example

ITEM	EXAMPLE
Backfill Material	*SC - 3*
Hole Diameter	*6 in*
Hole Depth	*10 ft*
Number of Holes	*10*
Total Backfill Wt.	*1,500 lbs*
Total Bags Req'd.	*15*

Standard Dimensions and Shipping Weights

BACKFILL	PARTICLE SIZE in (mm)	BULK DENSITY DENSITY lbs/ft³ (kg/m³)	SHIPPING WT PER BAG lbs (kg)
DW - 1	0.0039 - 0.039 (0.1 - 1.0)	74 (1188)	100 (45)
SC - 2	0.039 (1.0)	74 (1188)	100 (45)
SC - 3	0.039 (1.0)	74 (1188)	100 (45)

Calculation Chart

HOLE DIAMETER in	(mm)	BACKFILL REQUIRED lbs/ft (kg/M) DW-1 SC-2 SC-3	
6	(152)	15	(22.4)
8	(203)	26	(38.8)
9	(229)	33	(49.2)
10	(254)	41	(61.1)
12	(305)	58	(86.5)
14	(356)	79	(117.8)
16	(406)	103	(153.6)

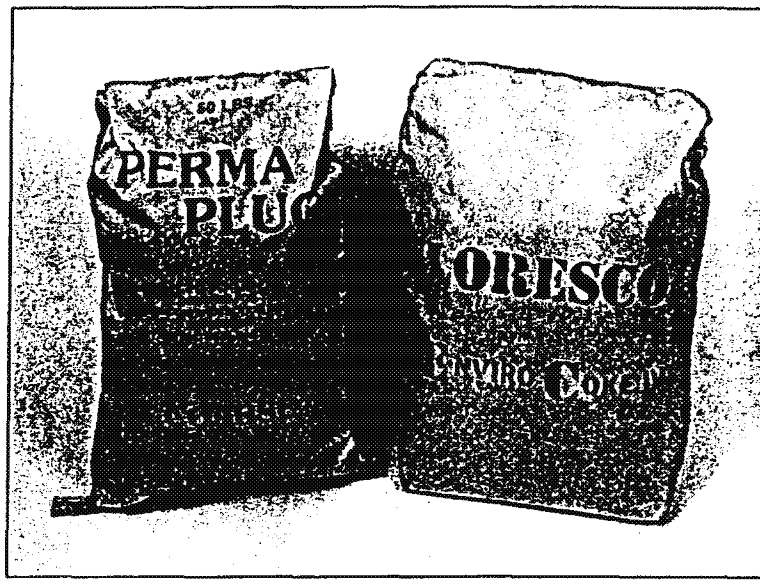
RDHLCC0027648
BWS031188

Loresco EnviroCoke IV™ and PermaPlug™

Specialty Backfills

Protection For Environmentally Sensitive Areas

Contamination of underground aquifers is a major concern in today's environmentally conscious society. To prevent deep groundbed cathodic protection systems from polluting ground water in environmentally sensitive zones, Harco supplies Loresco's EnviroCoke IV and PermaPlug specialty backfills.



EnviroCoke IV is a conductive carbon based cementitious backfill with an extremely low permeability. It is designed to surround the casing at the discharge zones of a cathodic protection system and prevent the intermixing of waters held in separate aquifers. The material mixes with water and can be easily pumped for placement around the well casing. After settling for 24 hours, the protective backfill becomes structurally stable.

PermaPlug is a non-conductive backfill designed to seal the entrance of a deep anode bed cathodic protection system. The backfill is made from naturally occurring bentonite rock, which swells when saturated with water to provide a leak-tight seal. This seal stops surface fluids from flowing into the well and contaminating potable water aquifers. The material does not require mixing and can be poured directly into the hole at the surface of the deep anode bed. Because the material completely seals the entrance of the cathodic protection system, it is strongly advised that a vent pipe be utilized to release gases and to provide access to the system so that water can be added if necessary.

CHEMICAL COMPOSITION

EnvironCoke IV	PermaPlug
49% Portland Cement	98% Bentonite
48.9% Fixed Carbon	2% Wetting Agents
0.1% Ash	—
0.0% Moisture	—
0.0% Volatile Matter	—

Typical Applications

EnviroCoke IV and PermaPlug specialty backfills are designed for use in deep groundbed cathodic protection systems located in environmentally sensitive zones. Used in conjunction, the two backfills effectively protect underground aquifers from contamination. Both products have been tested according to EPA leacherate standards and have been found to meet all quality requirements for materials utilized in underground burial. The backfills should be stored in a dry area prior to use.

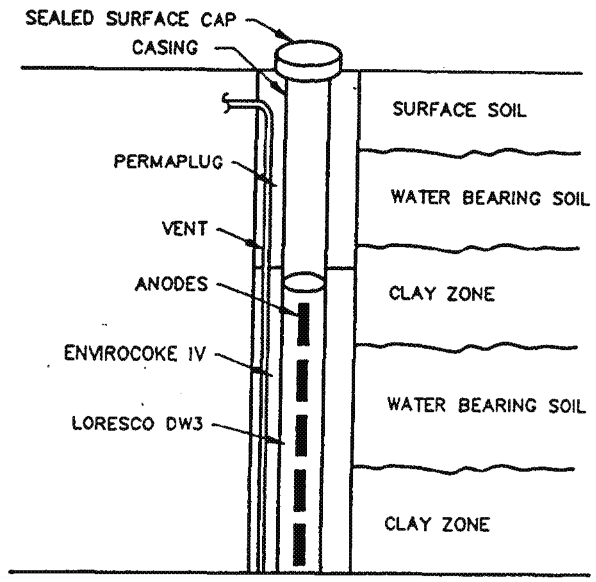
PSG

Loresco EnviroCoke IV™ and PermaPlug™

Specialty Backfills

Ordering Procedure

EnviroCoke IV and PermaPlug are supplied in 100 lb and 50 lb bags respectively. To order the required material for your installation project, indicate that you need EnviroCoke IV and/or the PermaPlug backfill and specify the total pounds required. A chart has been provided to assist in calculating the total pounds necessary for various types of installations. An example is also included to help illustrate the ordering process.



Calculation Example

ITEM	EXAMPLE
Backfill Material	*EnviroCoke*
Hole Diameter	*6 in*
Hole Depth	*10 ft*
Number of Holes	*10*
Total Backfill Wt.	*1,430 lbs*
Total Bags Req'd.	*15*

Standard Dimensions and Shipping Weights

BACKFILL	BULK DENSITY lbs/ft³ (kg/m³)	SHIPPING WT PER BAG lbs (kg)
EnviroCoke	75 (1204)	75 (34)
PermaPlug	70 (1124)	50 (22.7)

Calculation Chart

HOLE DIAMETER in	(mm)	BACKFILL REQUIRED lbs/ft (kg/M) ENVIROCOKE IV		PERMAPLUG	
4	(102)	6.4	(9.5)	6.1	(9.1)
6	(152)	14.3	(21.3)	13.7	(20.4)
8	(203)	25.5	(38.0)	24.4	(36.4)
10	(254)	39.8	(59.4)	38.2	(57.0)
12	(305)	57.2	(85.3)	54.9	(81.9)

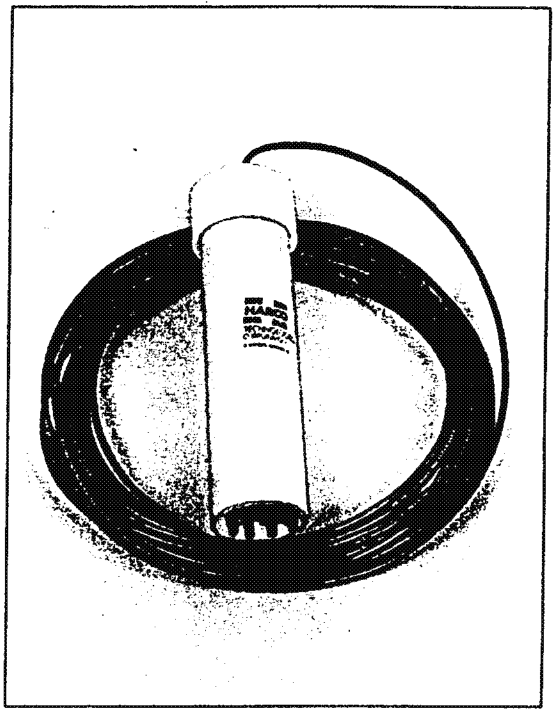
Permacell® 804

Permanent Reference Cell

For Buried Structures In High Chloride Areas

Chloride ions affect the stability of copper reference cells. For protected structures located in areas with high chloride ion concentrations Harco offers the Permacell 804 silver/silver chloride reference electrode. This specially designed cell is not susceptible to chloride contamination and will deliver accurate potential measurements for up to 15 years. It is composed of a silver element which is immersed in a glass tube containing a super-saturated gel of silver chloride. This entire component is then housed in a durable non-conductive tube which is further surrounded by a dense mixture of silver and chloride. From this multiple layer construction, cell purity is maintained through the restriction of ions in and out of the cell. Each cell is also tested for electrical potential and resistance prior to shipping. The measurements obtained from these tests are recorded and included with each cell, and cells which do not meet or exceed established performance thresholds are rejected. Completion of these quality procedures provides Harco's 804 cell with an accuracy of plus or minus 5 millivolts.

Proper installation of the 804 cell is simple and easy. The cell is pre-packaged in a cloth sack containing a low resistance backfill and is ready for immediate installation. Plastic centering rods attached to the cell ensure the backfill is evenly positioned around the cell for a low resistance groundbed. The cell is also provided with 15 feet of #14 AWG wire containing HMWPE insulation. Once all wire connections have been made and the ground around the cell is moistened, the installation is complete.



Typical Applications

The Permacell 804 permanent reference electrode is designed for use in high chloride electrolytes. It is ideal for taking potential measurements on pipelines, tanks, and other structures buried in coastal areas. It can also be used to test reinforced concrete structures. With this type of application, the cell is provided without a backfill. Operation of the cell is limited to electrolytes with temperatures between 33° and 140°F. The cell should not be installed in areas with high sulfide or bromide concentrations.

PSG

Permacell® 804

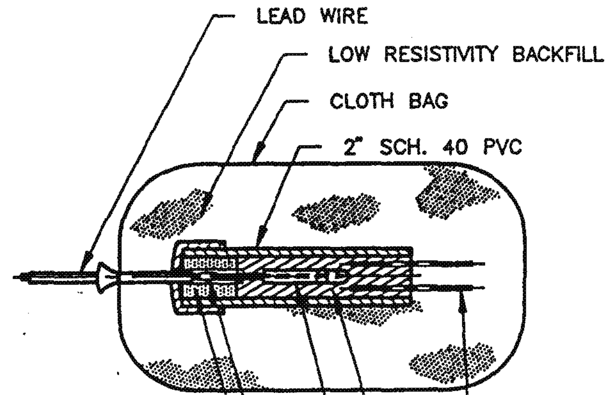
Permanent Reference Cell

Ordering Procedure

Harco's Permacell 804 is provided standard with backfill and 15 feet of #14 AWG lead wire. To order this cell for your particular application, indicate that you need a Permacell 804 silver/silver chloride permanent reference cell and specify the quantity desired, whether it is to be used in soil or concrete, and the lead wire length, size, and insulation if different from the standard provided. An example is included to help illustrate this process.

Ordering Procedure Example

ITEM	EXAMPLE
Quantity	*20*
Product	*Permanent Reference Cell*
Permacell Model	*804*
Application	*Soil*
Lead Wire: Length *(15 ft=Standard)*	*15 ft*
Size *(#14 AWG=Standard)*	*14 AWG*
Insulation *(HMWPE=Standard)*	*HMWPE*



Product Specifications

	NOMINAL DIMENSIONS in (mm) Ø	LENGTH	WT lbs (kg)	ELECTRICAL STABILITY	DESIGN LIFE
Bare	1 (25.4)	10 (254.0)	4 (1.82)	±5 millivolts with 8.0 microamp load	15 years
Pkgd.	8 (203.2)	16 (406.4)	23 (10.43)		

RDHLCC0027652
BWS031192