CATHODIC PROTECTION SYSTEM

2018.07

TAEHEUNG CORROSION ENGINEERING Co., Ltd.

INDEX

1. Business Field

CONSTRUCTION

- Design & Engineering Service
- Maintenance & Repair Works
- Concrete Rebar (Posts, Beams, Buildings)
- Oil Storage Tanks, Steel-Pile Foundation (Bridges and soil foundations)
- Ships, Harbors, Offshore Platforms, Offshore Jackets, Barges

1. Business Field

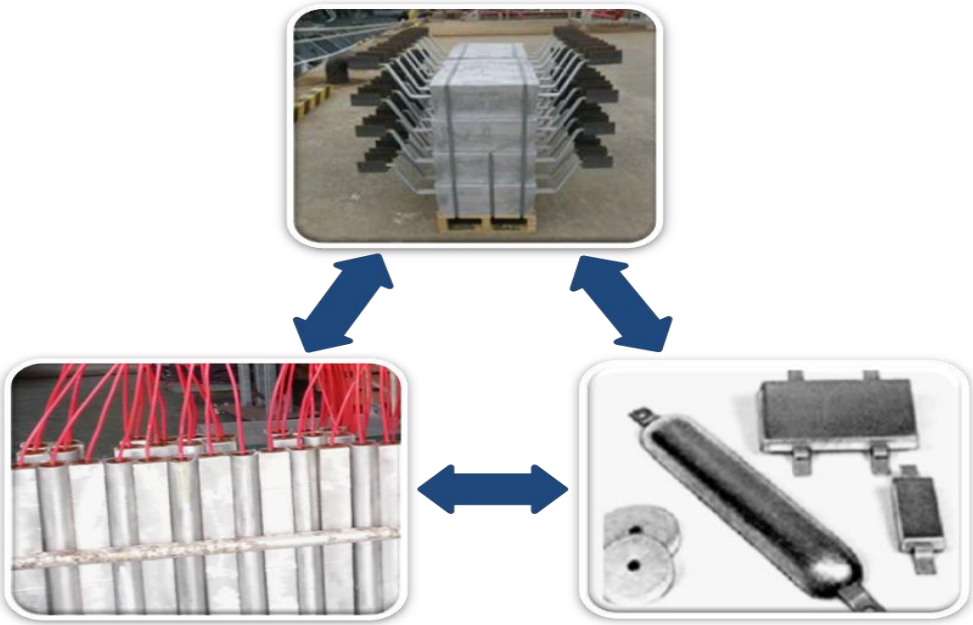
CONSTRUCTION

- DCVG(Direct Current Voltage Gradient)
  - Underground Pipelines
- U/G Pipe
  - Integrated waterworks, Oil P/L, LNG P/L, Gas P/L
- Subsea Pipelines, Discharge Pipelines
- Power Plants
  - S/ Condenser, Heater Exchanger, Piping Storage Tanks
- Petrochemical Plants

2. Material Supply - Sacrificial Anode System

2.1 Sacrificial Anode System

Type	Application range (Ω-cm)	Remark
Al-Anode	0-300	Seawater
Zn-Anode	0-2,000	Seawater & Sea soil
Mg-Anode	More than 10,000	Soil



Installation of Al-Anode

2. Material Supply - Sacrificial Anode System

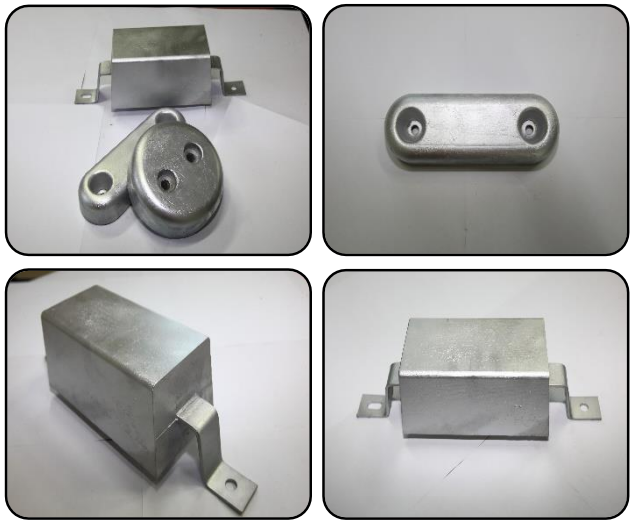
Al-Alloy Anode

Product Properties

Open Circuit Potential (Cu/CuSO4)	Effective Capacity	Theoretical Current Capacity	Current Efficiency	Consumption Rate
(-)1.10 Max.	2,600 A.Hr/Kg	2,890 A.Hr/Kg	90% Min.	3.37 Kg/A.yr

Nominal Dimension & Weight

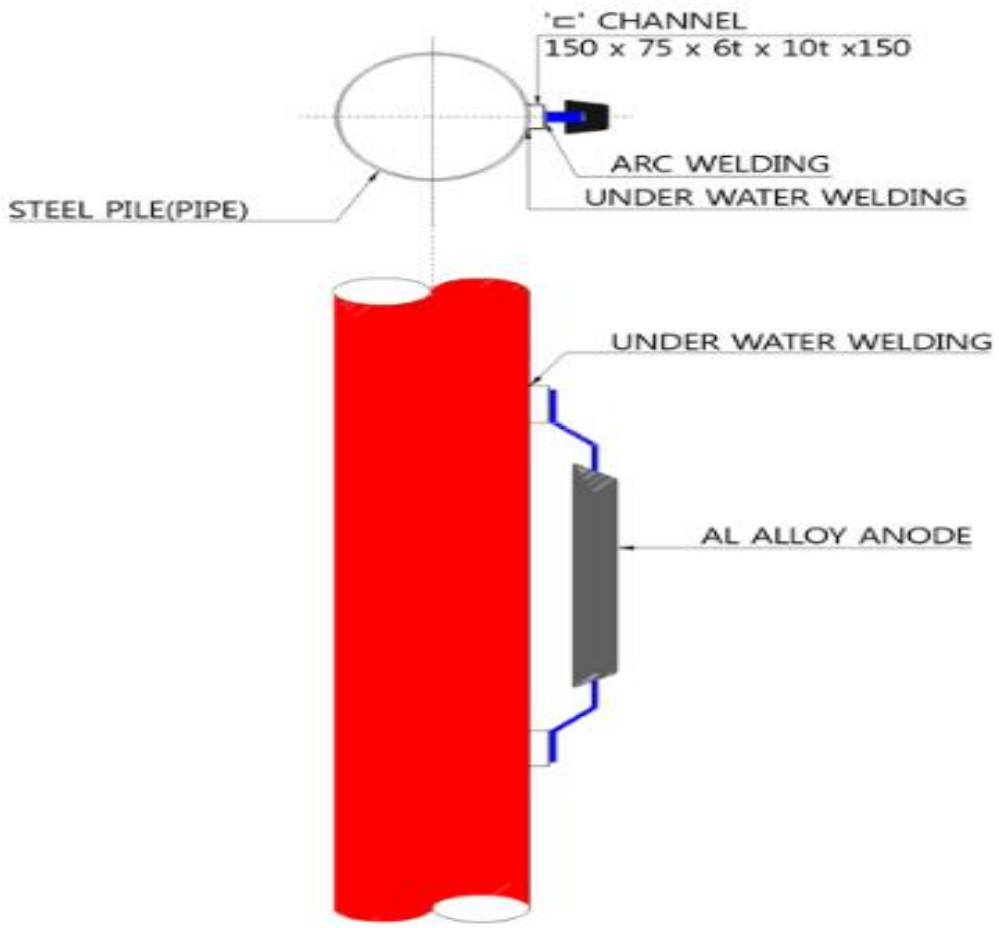
Type	Dimension	Nominal Weight (kg)	Output Current (Amp)	Lifetime (Year)
A1	(150+170) x 145 x 335	23.8	1.0	
A2	(135+170) x 130 x 585	34.8	1.5	
A3	(125+160) x 125 x 875	47.8	2.0	10
A4	(115+155) x 120 x 1,195	59.0	2.5	
A5	(120+155) x 110 x 1,555	71.3	3.0	
B1	(200+235) x 230 x 300	45.4	1.0	
B2	(190+225) x 205 x 510	64.4	1.5	
B3	(180+220) x 190 x 765	85.4	2.0	20
B4	(170+200) x 190 x 1,035	106.3	2.5	
B5	(165+195) x 180 x 1,340	126.5	3.0	



2. Material Supply - Sacrificial Anode System

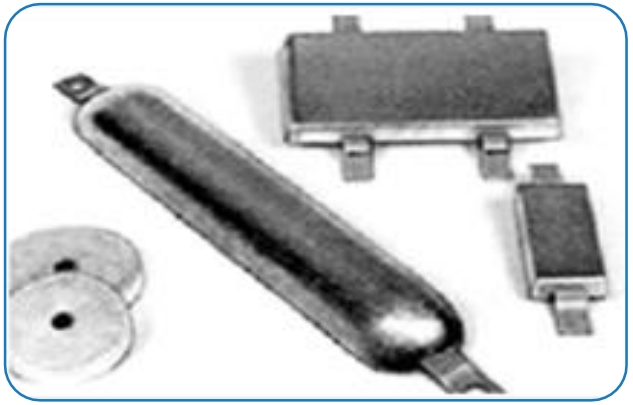
Al-Alloy Anode

- **Installation**



2. Material Supply - Sacrificial Anode System

Zn- Anode



Product Properties

Open Circuit Potential (Cu/CuSO4)	Effective Current Capacity	Theoretical Current Capacity	Current Efficiency	Consumption Rate
(-)1.10V Max.	780 A.Hr/Kg	820 A.Hr/Kg	95% Min.	11.23 Kg/A.yr

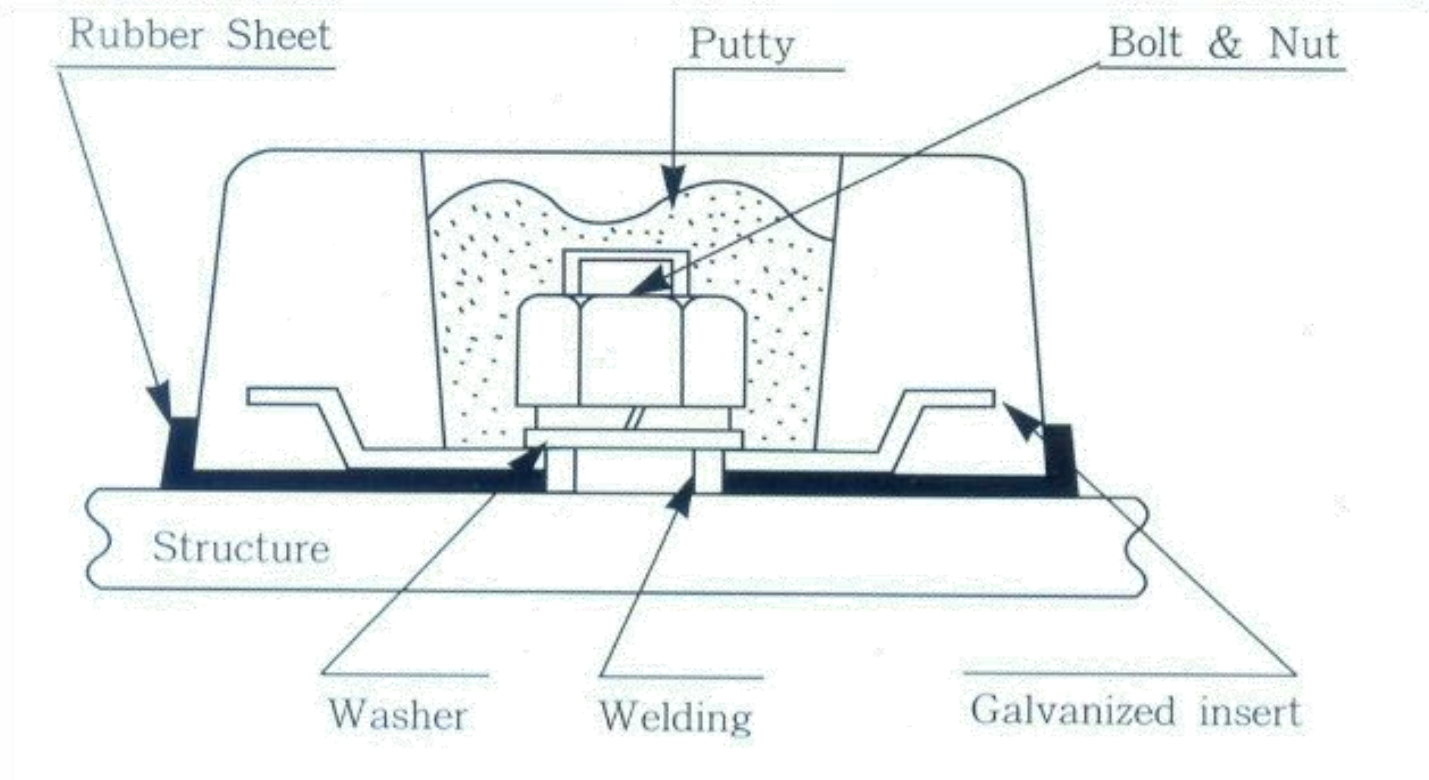
Nominal Dimension & Weight

Type	Dimension	Nominal Weight(kg)
THZ-B1 **THZ-B2** **THZ-B3**	300 x 150 x 30t 200 x 100 x 30t 200 x 100 x 20t	8.4 3.6 2.5
THZ-W1 **THZ-W2** **THZ-W3**	300 x 150 x 30t 200 x 100 x 30t 200 x 100 x 20t	9.3 4.1 2.9

2. Material Supply - Sacrificial Anode System

Zn- Anode

- **Installation**



2. Material Supply - Sacrificial Anode System

Mg- Anode

Product Properties

Open Circuit Potential (Cu/CuSO4)	Effective Current Capacity	Current Efficiency	Consumption Rate
(-)1.65V	1,100 A.Hr/Kg	50%	7.89 Kg/A.yr

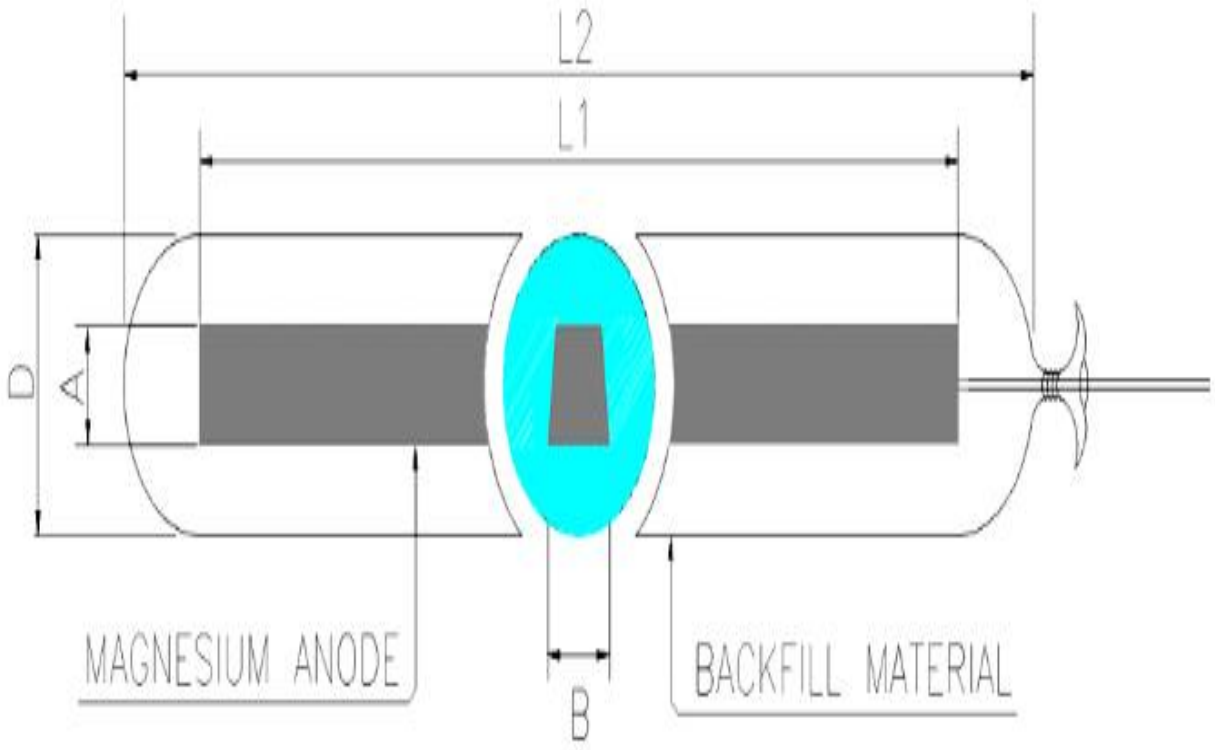
Nominal Dimension & Weight

Type	BARE (inch/mm)			BACKFILL (inch/mm)		Weight (Lb/kg)
	A	B	L1	D	L2	
9D2	2 ½ (63.5)	2 ½ (63.5)	26 3/8 (669.9)	6(152.4)	31(787.4)	9 / 4.08
9D3	3 ¾ (95.2)	3 ½ (88.9)	14 1/8 (358.8)	6(152.4)	17(431.8)	9 / 4.08
14D2	2 ½ (63.5)	2 ½ (63.5	41 ½ (1,054)	6(152.4)	46(1,168)	14 / 6.35
17D3	3 ¾ (95.2)	3 ½ (88.9	25 7/8 (657.2)	6 ½ (165.1)	29(736.6)	17 / 7.31

2. Material Supply - Sacrificial Anode System

Mg- Anode

- Detail



2. Material Supply - Impressed Current System

2.2 Impressed Current System

RECTIFIER

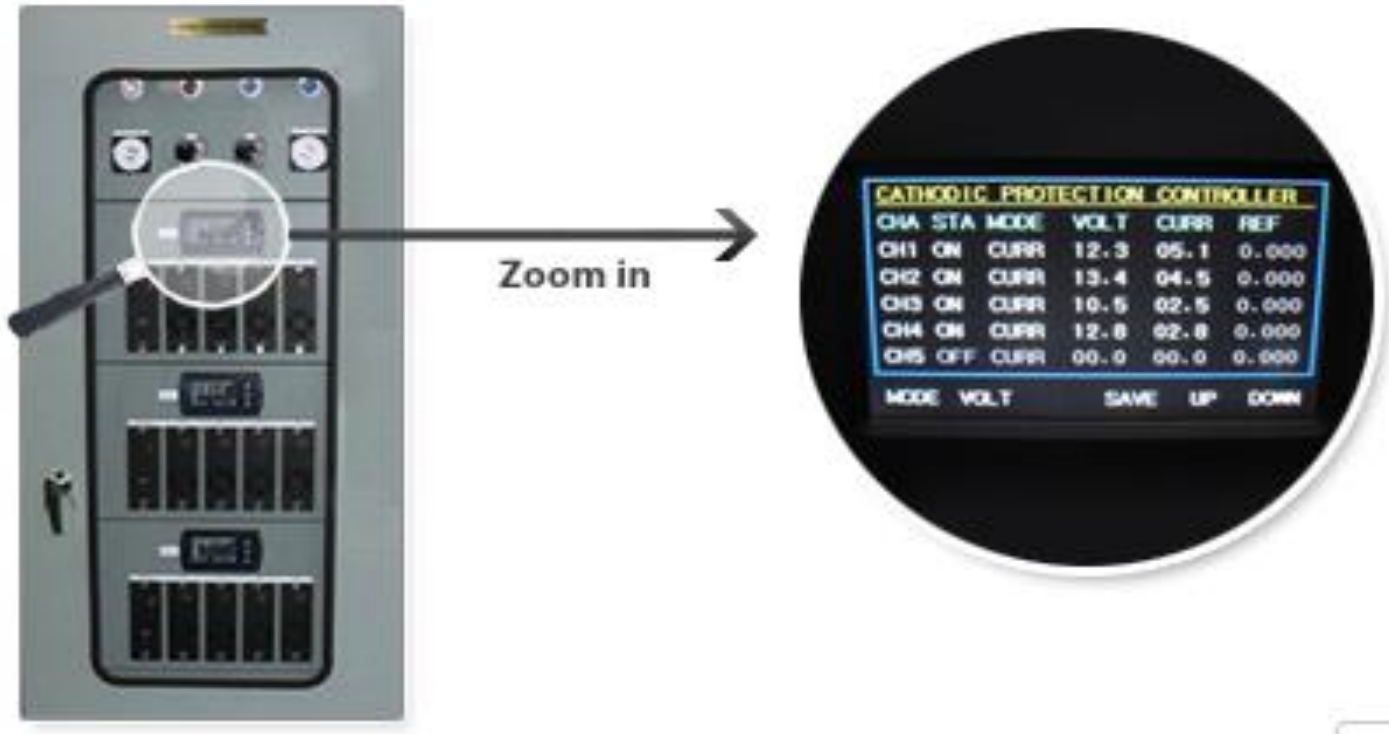
Dry type Auto/manual

Oil cooling type
Auto/manual

2. Material Supply - Impressed Current System

2.2 Impressed Current System

RECTIFIER



Condenser & Heat exchanger (multichannel)

2.2 Impressed Current System

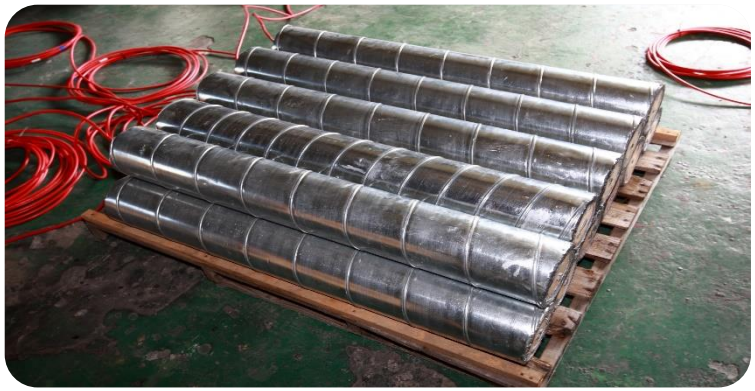
TEST BOX

Solar-cell type wireless communication system

Battery type
wireless communication system

2. Material Supply - Impressed Current System

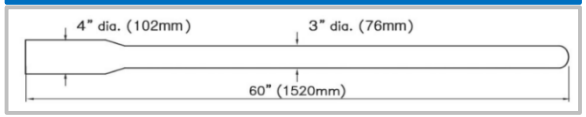
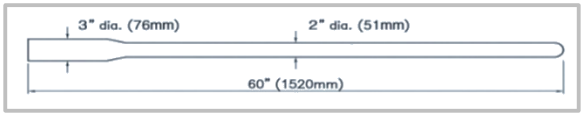
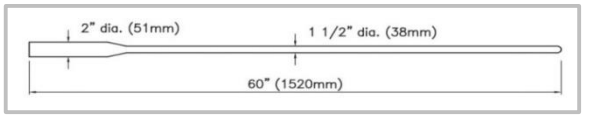
H.S.C.I Anode (High Silicon Cast Iron)



Mechanical & Physical Properties

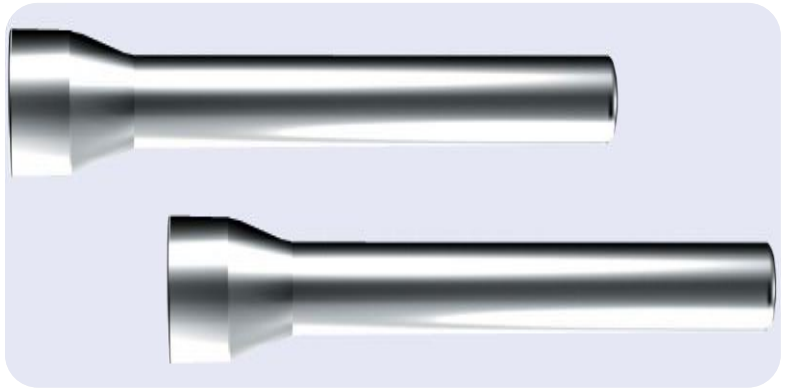
Tensile Strength	Over than 110 MPa
Compressive Strength	Over than 680 MPa
Hardness(HB)	520
Specific Gravity	7.0 g/㎤
Thermal Conductivity	0.125

Nominal Dimension & Weight

Nominal Dimensions	Weight
	50kgs
	20kgs
	12kgs

2. Material Supply - Impressed Current System

H.S.C.I Anode (High Silicon Cast Iron)

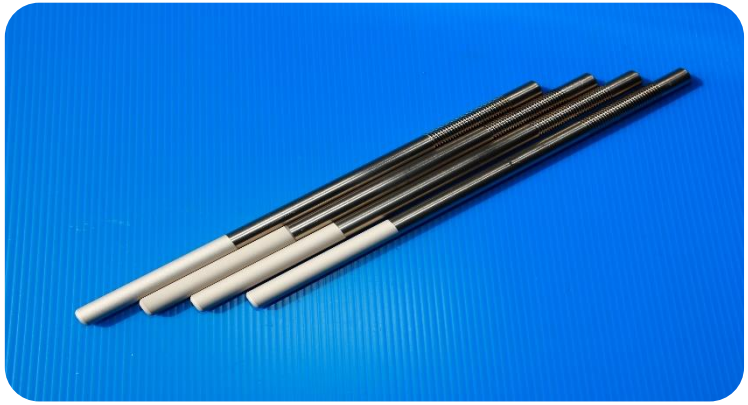


Chemical Composition

Silicon • 14.20 ~ 14.75 %	**Chromium** • 3.25 ~ 5.00 %
Carbon • 0.70 ~ 1.10 %	**Manganese** • 1.50 % max
Copper • 0.50 % max	**Molybdenum** • 0.20 % max

2. Material Supply - Impressed Current System

Pt-Ti Anode



Chemical Composition

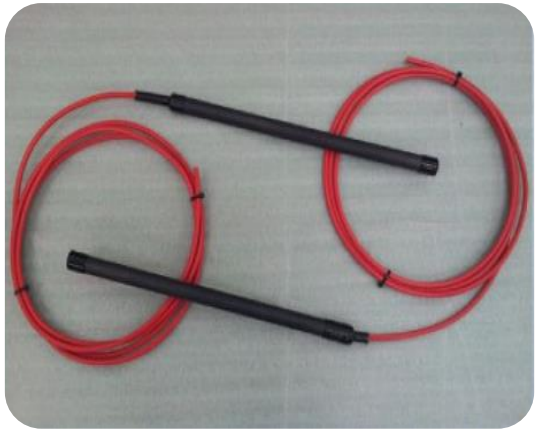
Oxygen • 0.18 % max	**Nitrogen** • 0.01 % max
Carbon • 0.01 % max	**Hydrogen** • 0.011 % max
Iron • 0.09 % max	**Titanium** • balance

Specification

Anode material	Consumption Rate [kg/A•yr]	Current Density (A/㎡)	Max.Voltage (V)
Pt-Ti	1×10^{-5} max	1,000	8

2. Material Supply - Impressed Current System

MMO Tubular Anode

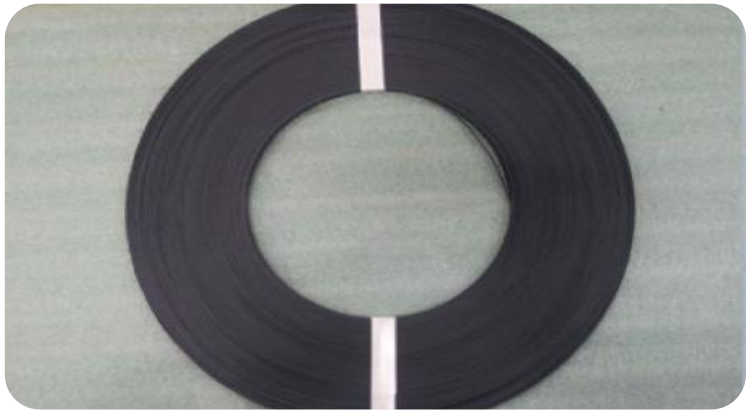


Nominal Dimension & Weight

Environment	Anode Size		Current Output (Amps)	Anode Life (Year)
	Diameter (mm)	Length (mm)		
• Calcined Petroleum Coke • Fresh Water • Brackish Water	25.4	500	4	20
	25.4	1000	8	20
• Sea water	25.4	500	25	20
	25.4	1000	50	20

2. Material Supply - Impressed Current System

MMO Ribbon Anode



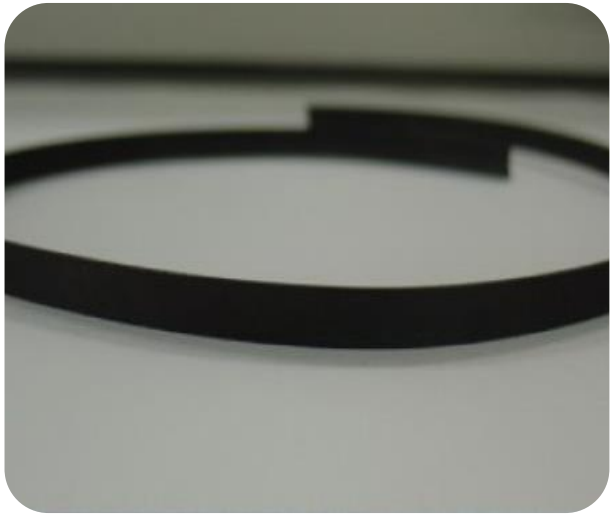
MMO Ribbon anode Specification

	¼" Ribbon	½" Ribbon
Width	6.35 mm	12.7 mm
Thickness	0.635 mm	0.635 mm
Surface Area	0.014 ㎡/m	0.0266 ㎡/m
Standard Coil Length	152 m	152 m
Standard Coil Weight	2.7 kg	5.5 kg

Anode Performances

- **Current Output of Ribbon in Find Sand**
  12.8mA/ft (42mA per m) when operating at an anode current density of 3A/㎡
- **Design Life**
  Over 50 years when operating at an anode current density of 3A/㎡

- **Current Output of Ribbon in Concrete**
  0.45mA/ft(1.5mA per m) when operating at an anode current density of 110A/㎡
- **Design Life**
  Over 100 years when operating at an anode current density of 110A/㎡

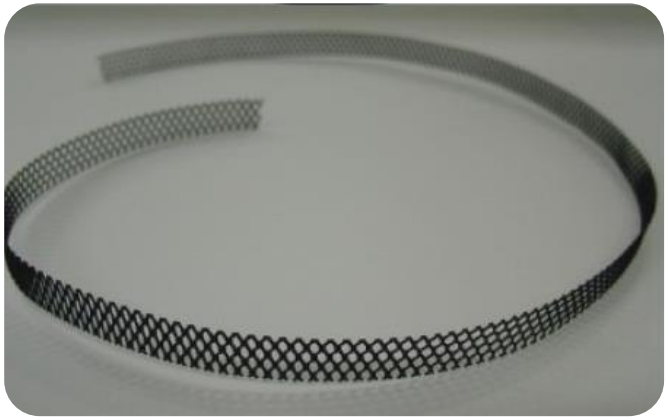


2. Material Supply - Impressed Current System

MMO Ribbon Mesh Anode

MMO Ribbon Mesh Anode Specification

	Ribbon mesh
Width	12.7 mm
Thickness	1.3 mm
Surface Area	0.032 ㎡/m
Standard Coil Length	76m/roll
Standard Coil Weight	1.8kg
Diamond Dimension	2.5(SW) x 4.6(LW) x 0.6(T)(mm)



Anode Performances

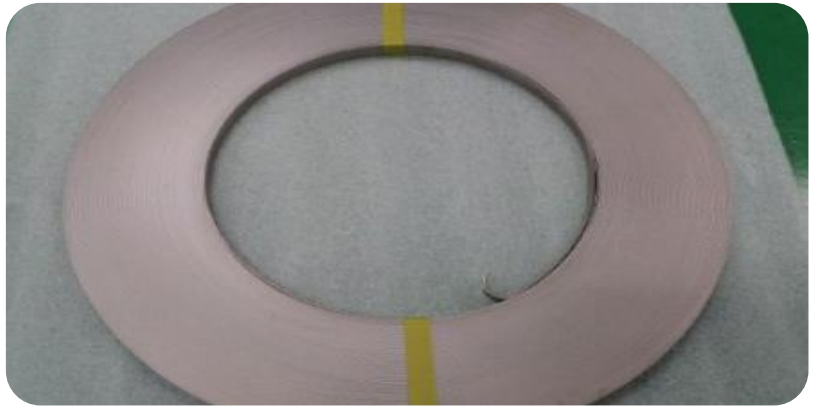
- **Current rating @ 110mA/㎡ :** 3.5mA/m
- **Design Life :** More than 100 year design life when operating at a current density of 110mA/ ㎡
- **Catalyst** : Iridium Based Mixed Metal Oxide

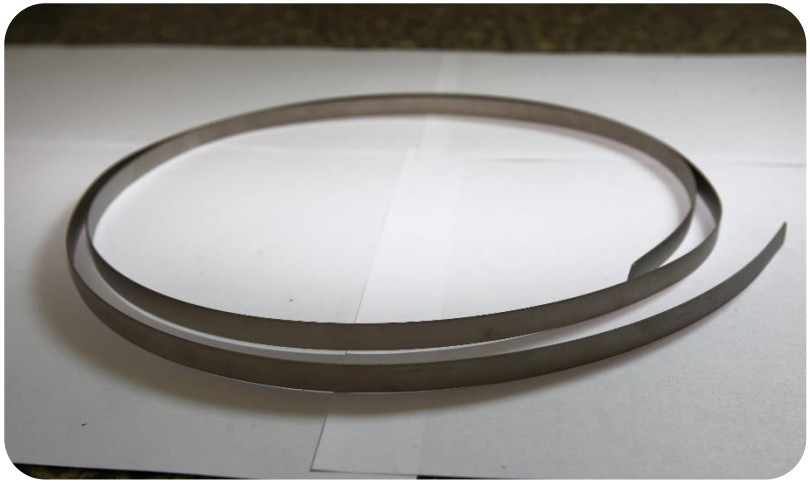
2. Material Supply - Impressed Current System

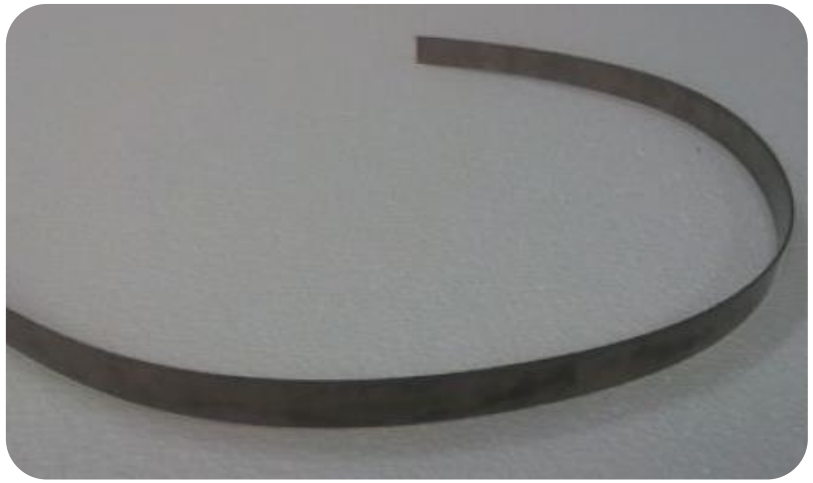
Conductor Bar

Conductor Bar Specification

Width	12.7mm
Thickness	0.9mm
Standard Coil Length	100m/roll
Standard Coil Weight	5.1kg







2. Material Supply - Testing & Adjusting Equipment

Cu/CuSO4 · Ag/AgCl Ref. Electrode

Cu/CuSO4 · Ag/AgCl Ref. Electrode Specification

- **Size :** 1"(25mm) Diameter x 8"(203mm) long.
- **Lead Wire :** 50' (15m) of #14 (2.5㎟) RHH-RHW Wire
- **Material :** High Impact ABS, Ceramic with Moisture Retention Membrane
- **Stability :** 5milivons with 3.0 microamps load.
- **Temperature Range** : -10℃ to 176℉ (-23 ℃ to 80 ℃)

Zinc Ref. Electrode

Zinc Ref. Electrode Specification

- **Size :** ϕ 20 x 100L (mm)
- **Material :** Pure Zinc
- **Instruction :** For condenser & Heat exchanger

2. Material Supply – Etc

Splice Kit 1way

Specification

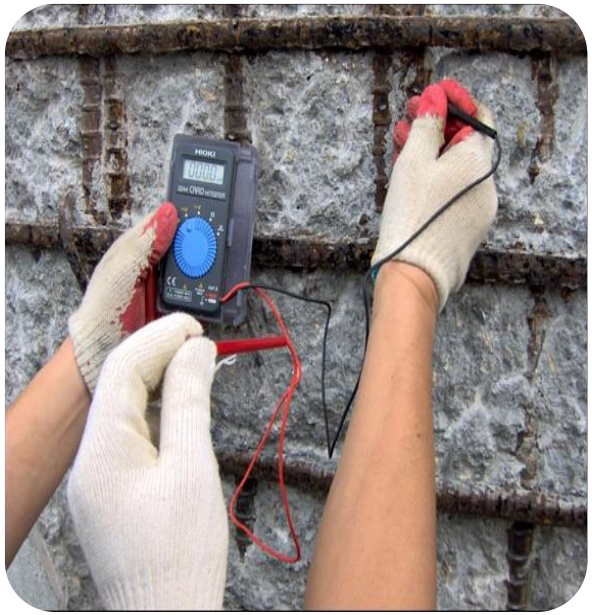
Splice Kit	for Cable connection
Electric maker	Radio control detector for test box

Splice Kit 3way

Electric maker

3. Cathodic Protection Application

CONCRETE (REPAIR WORKS)



Corrosion Investigation and Inspection

Cathode Ray Connection

Electrode Installation

3. Cathodic Protection Application

CONCRETE (NEW WORKS – Cathodic Protection Installation)

Installation of Rectcifier

Pull Box for Work Process

3. Cathodic Protection Application

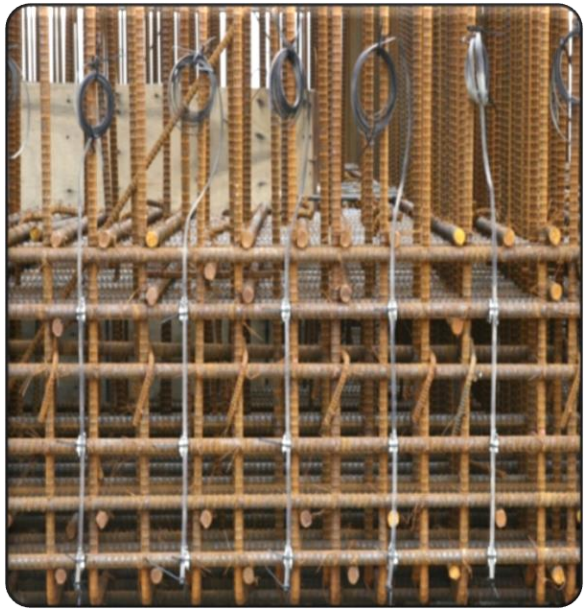
CONCRETE (NEW WORKS – Cathodic Protection Installation)

Ribbon Mesh Anode

Ag/AgCl Ref. Electrode

3. Cathodic Protection Application

CONCRETE (NEW WORKS – Cathodic Protection Installation)



Ribbon Anode Clip Installation

Installation of FRP Cover

Mold for Work Process

3. Cathodic Protection Application

U/G PIPELINE (NEW WORKS – Cathodic Protection Installtion)

Test box Installation

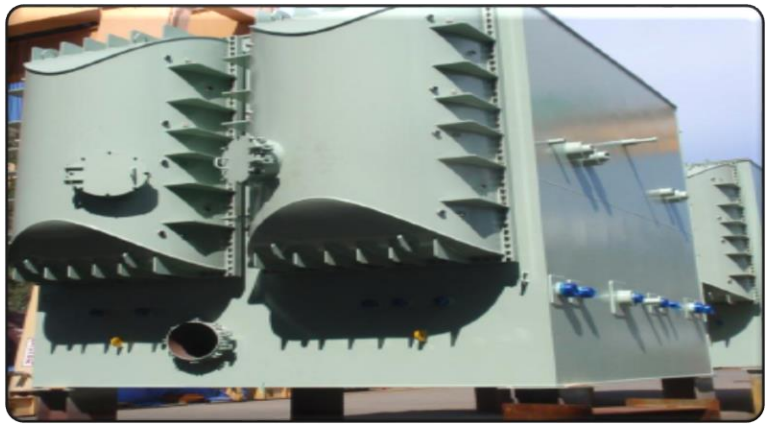
3. Cathodic Protection Application

U/G PIPELINE (NEW WORKS – Cathodic Protection Installtion)

Rectifier Installation

3. Cathodic Protection Application

POWER PLANTS (Cathodic Protection · Anode)

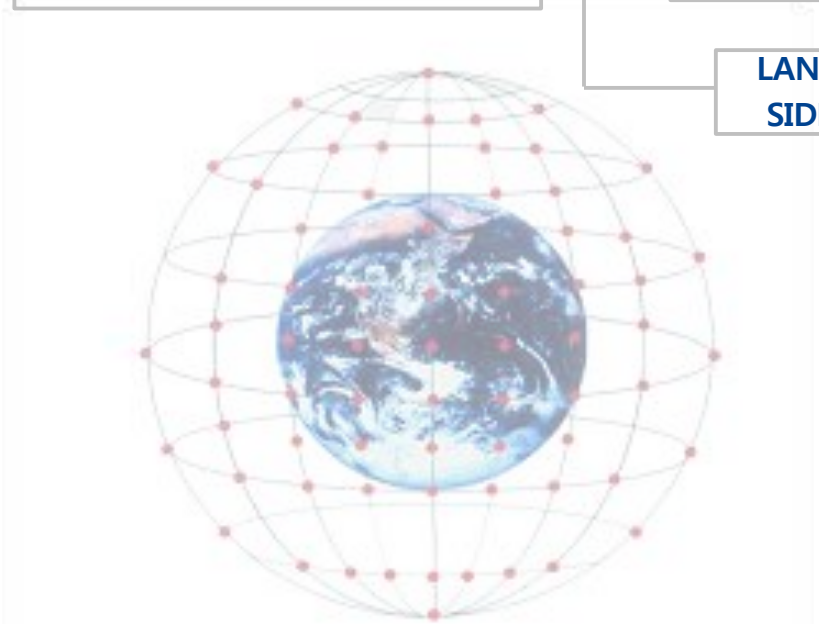


Surface Condenser · Heater Exchanger · Storage Tank

3. Cathodic Protection Application

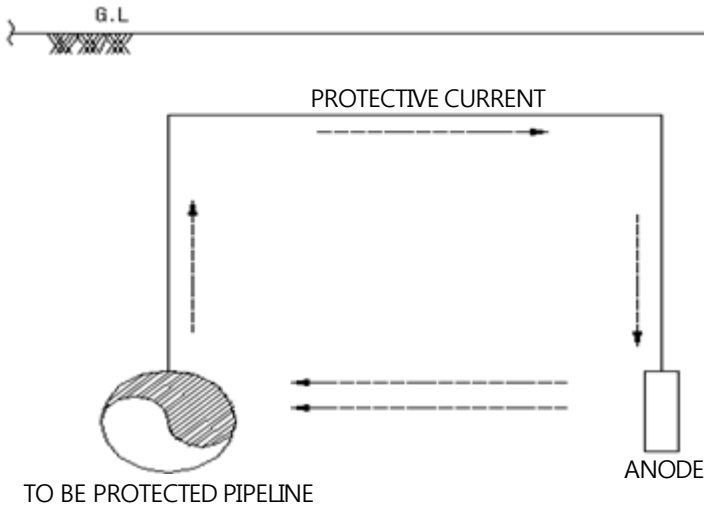
3.1 The Application of Cathodic Protection System

- CATHODIC PROTECTION SYSTEM
  - SACRIFICIAL ANODE SYSTEM
    - OFF-SHORE SIDE
      - Al-Anode
      - Zn-Anode
    - LAND SIDE
      - Mg-Anode
  - IMPRESSED CURRENT SYSTEM
    - Deep Well Bed Anode Type
    - Shallow bed Anode Type



3.2 Sacrificial Anode System (Galvanic Anode System)

The Theory of Sacrificial Anode system



The Condition of Installation for Sacrificial Anode system

Al Alloy-Anode	Seawater
Zn-Anode	Sea Soil & Fresh Water
Mg-Anode	Soil

3. Cathodic Protection Application

3.2 Sacrificial Anode System (Galvanic Anode System)

The Merit of Sacrificial Anode system

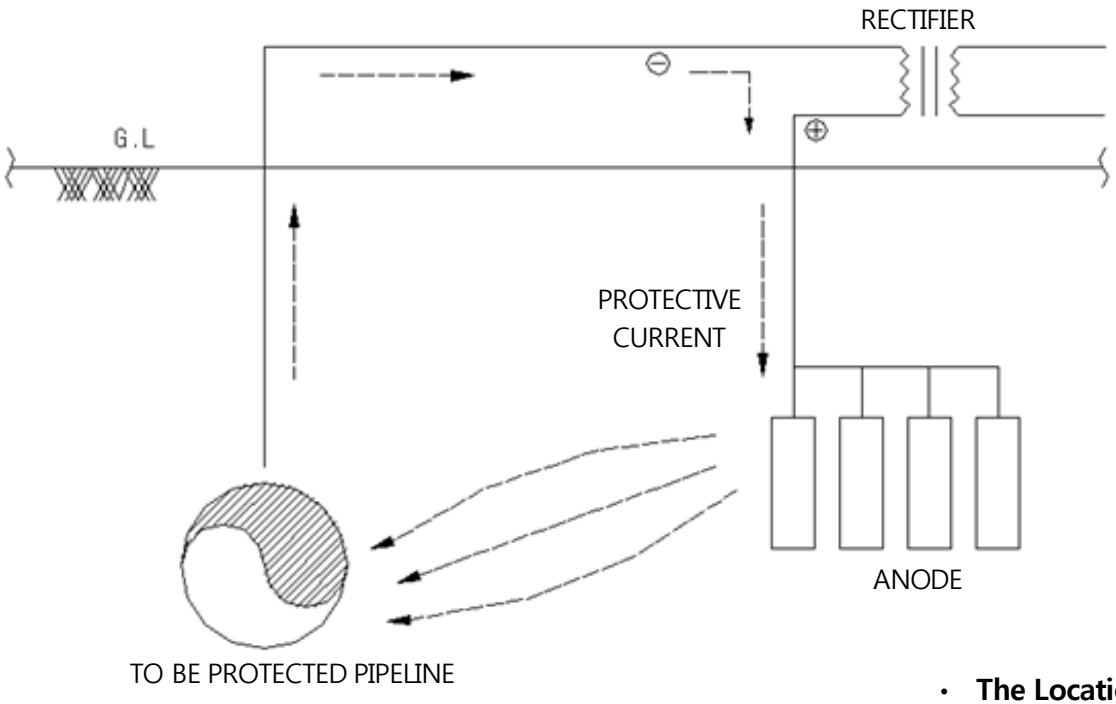
- They are Relatively simple to install
- They are Economical of the small structure for corrosion control
- They are less likely to affect any nearby neighbouring structures. Because the output at any one points is low
- They are stable for hydrogen over voltage
- The are Independent of any source of electrical power
- The expense of maintenance are less than impressed current system

The Demerit of sacrificial Anode system

- Their usefulness is generally restricted to the protection of structure. because of the limited current
- They aren't economical of the large structure for corrosion control
- Their output cannot be controlled
- Their usage is restricted to the protected structures in low resistivity of water and soil
- They may be required at a large number of positions. The cost of installation is higher

3.3 Impressed Current System

The theory of impressed current system

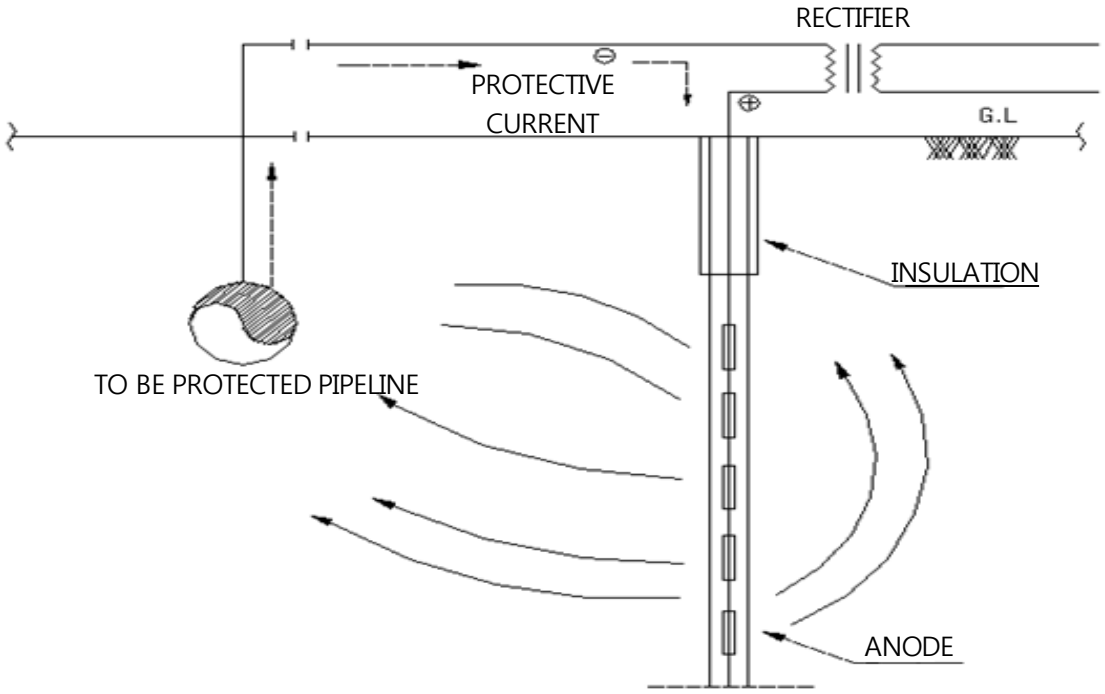


- **The Location of anode shall be in good distribution.**

SHALLOW ANODE BED TYPE

3.3 Impressed Current System

The theory of impressed current system



DEEP WELL ANODE BED TYPE

3. Cathodic Protection Application

Merit of Impressed Current System

- Can be applied to a wide range of structures
- Use is less restricted by the resistivity of soil or water
- Requires a small total

Demerit of Impressed Current System

- Requires a mains supply
- Need careful design neighboring structures for interference current
- They are expensive for operating & Maintenance

3.4 Installation Practices

Sacrificial Anode System

- Sea-Water : Al-Anode

Composition	Standard(%)	Remark
Zn	3.0-15.0	
Mg	0.5-5.0	
Sn	0.05-0.15	
In	0.004-0.02	
Si	0	
Cu	0	
Al	Remainder	

Specification for Al-Anode Composition

3. Cathodic Protection Application

Sacrificial Anode System

- Soil : Mg-Anode

Mg-Anode Installation

Mg Anodes should always be installed at least 3 feet below grade whenever possible.

The top of the anode should be at least as deep as the structure to be protected.

Anode lead wires should never be used to suspend, carry, or install the anode.

- Vertical.

Mg Anodes are commonly installed vertically in augered holes. If caving or unstable soil conditions are encountered, a thin metal (stovepipe) casing may be used. Anodes should be located on alternating sides of the pipe when possible to reduce interference and allow for even current distribution. **The cloth bag used with packaged anodes should be carefully handled as loss of backfill will result on reduced anode output.**

The anode lead cable should not be used to lower the anode into the hole as the anode-to-cable connection is easily damaged. Sufficient slack should be left in the anode cable to prevent strain on the cable.

All connections should be properly made and inspected before the installation is buried.

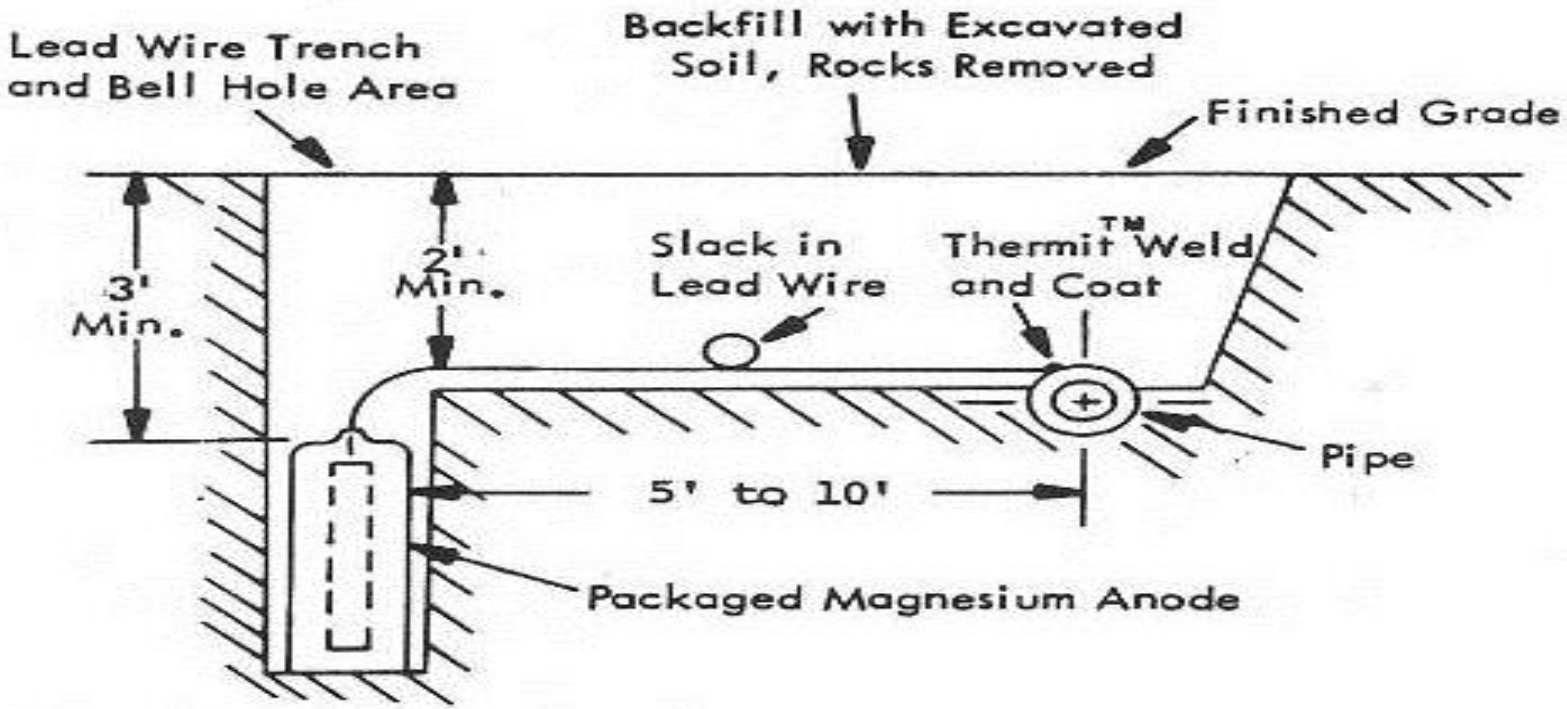
3. Cathodic Protection Application

Sacrificial Anode System

- Soil : Mg-Anode

Mg-Anode Installation

- Vertical.



Vertical Sacrificial Anode Installation

3. Cathodic Protection Application

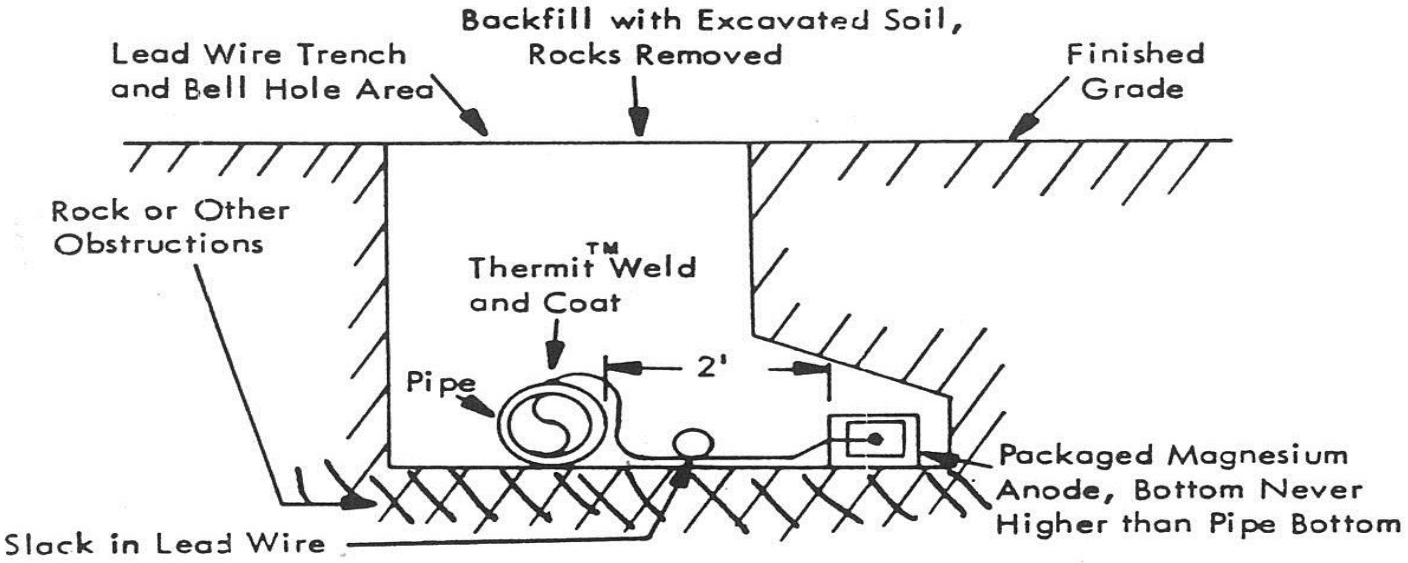
Sacrificial Anode System

- Soil : Mg-Anode

Mg-Anode Installation

- Horizontal.

Horizontal installation of Mg-Anodes is sometimes required due to obstructions or to limitations in right of way. Where obstructions are encountered, the anode may be installed as follows.



Horizontal Mg Anode Installation When Obstruction is Encountered

3. Cathodic Protection Application

Impress Current System

1) Impress Current Anode Installation for Shallow bed type

Selection of sites for the rectifiers, anode beds, test stations, and other components of an impressed current cathodic protection system should be made during the system design. As in the case of sacrificial anode systems, impressed current systems must be carefully installed in order to operate properly and reliably.

The most common type of impressed current anode installation is vertical. Horizontal installations are sometimes used if obstructions are encountered.

Deep well anode installations are used to reduce interference effects or to reach low resistivity soil. Anode lead wires should never be used to suspend, carry, or install anode.

- Vertical.

This is the most common type of impressed current anode installation.

HSCI anodes are brittle and must be carefully handled to prevent breakage. The anode cable is particularly prone to failure if the insulation is damaged in any way and particular care must be exercised in handling the anode leads.

As impressed current cathodic protection anodes are generally longer than sacrificial anodes, excavation of holes for them is often more difficult.

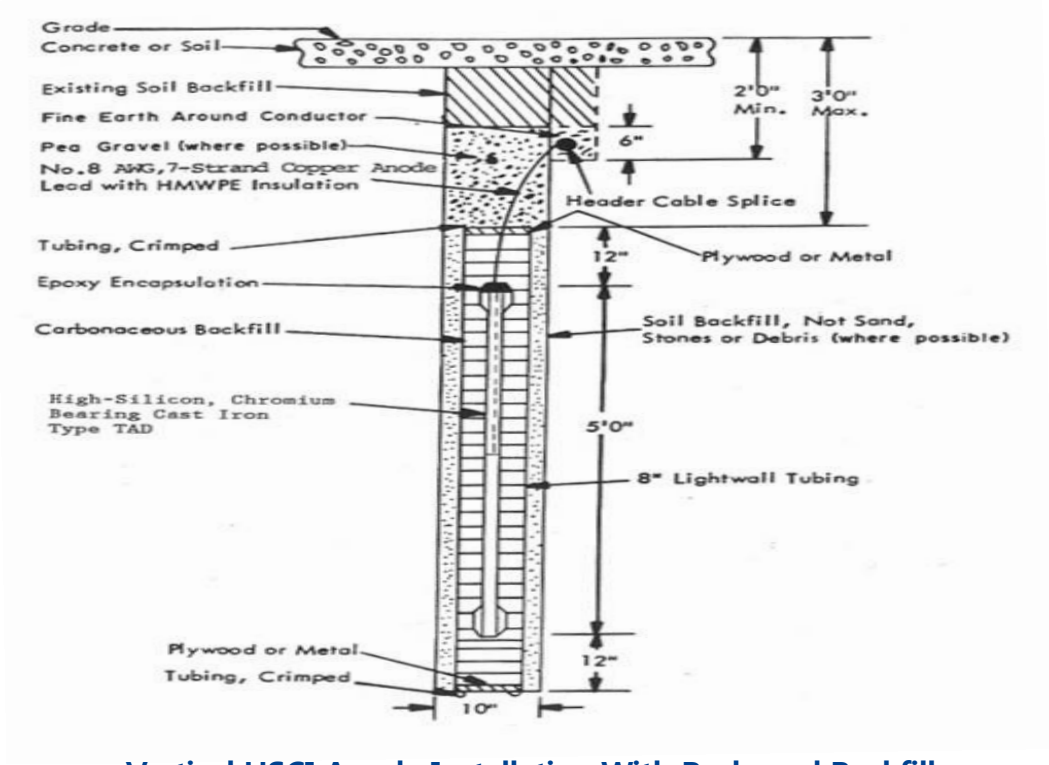
3. Cathodic Protection Application

Impress Current System

1) Impress Current Anode Installation for Shallow bed type

- Vertical.

A typical vertical anode installation using a bare HSCI anode with backfill is shown as follows.



Vertical HSCI Anode Installation With Packaged Backfill

3. Cathodic Protection Application

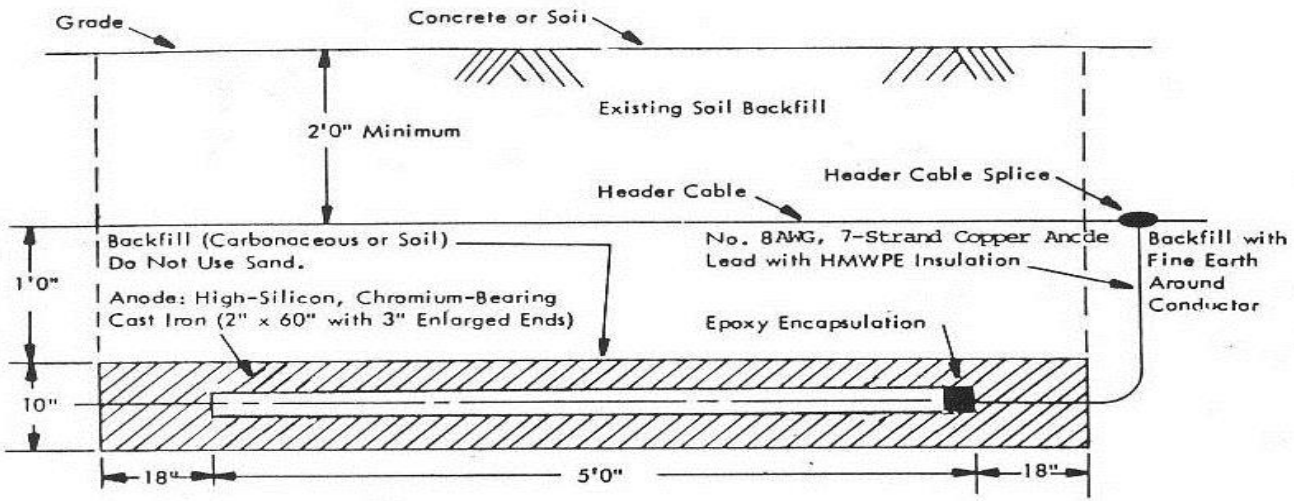
Impress Current System

1) Impress Current Anode Installation for Shallow bed type

- Horizontal.

Horizontal installation of impressed current anodes are less expensive than vertical anodes.

Horizontal installations may be necessary when obstructions or other soil conditions make augering of deep holes difficult. Horizontal installations are also used where soil resistivities are very low and the increased resistance of the horizontal installation is not significant. A typical horizontal installation of a HSCI anode is shown as follows.



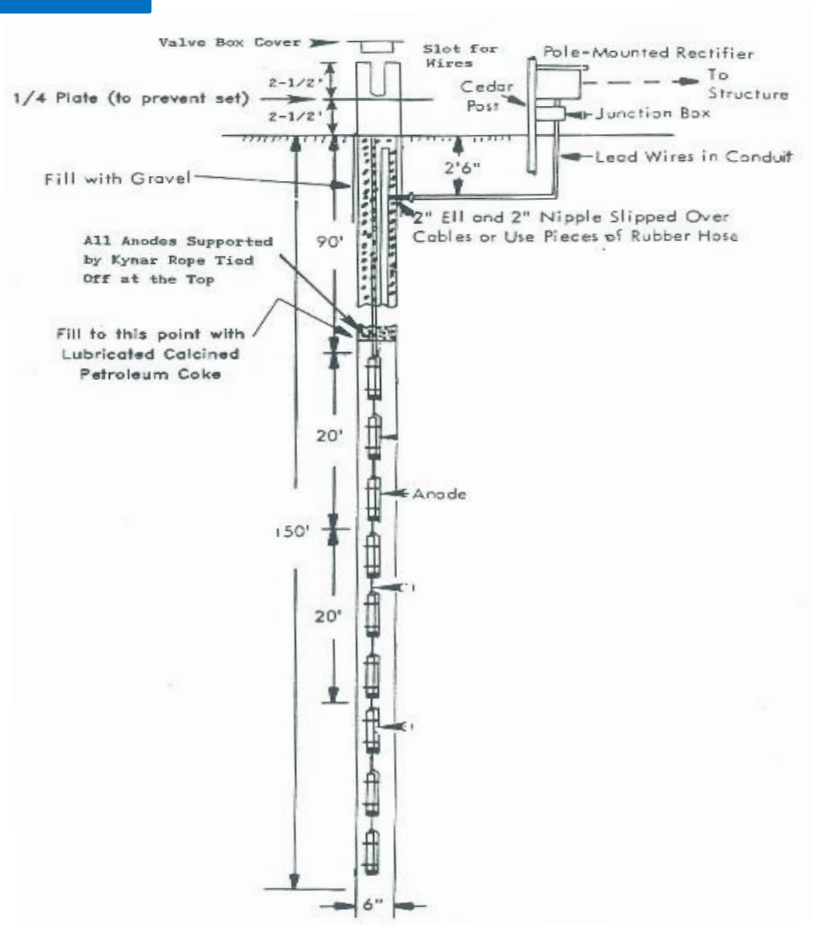
Horizontal HSCI Anode Installation

3. Cathodic Protection Application

Impress Current System

2) Impress Current Anode Installation for Deep Well Anode Bed Type

In some installations where interference problems are severe, anode beds are sometimes installed deep below the surface. This causes the current flow to become more vertical and reduces interference between horizontally displaced structures. **Deep anodes are also used where the resistivity of the soil near the surface is high.** Anodes installed deeper than 50 feet are called "deep" anodes. Specialized equipment and skill is required for the installation of such an anode array. Installation of deep anode systems is described in NACE standard RP-50-72. Newly developed deep anode systems using platinized anodes show considerable promise for such applications. A typical deep anode system using HSCI anodes is shown as follows.



Typical Deep Well Anode Bed Cathodic Protection Installation

THANK YOU VERY MUCH

TAEHEUNG CORROSION ENGINEERING Co., Ltd.