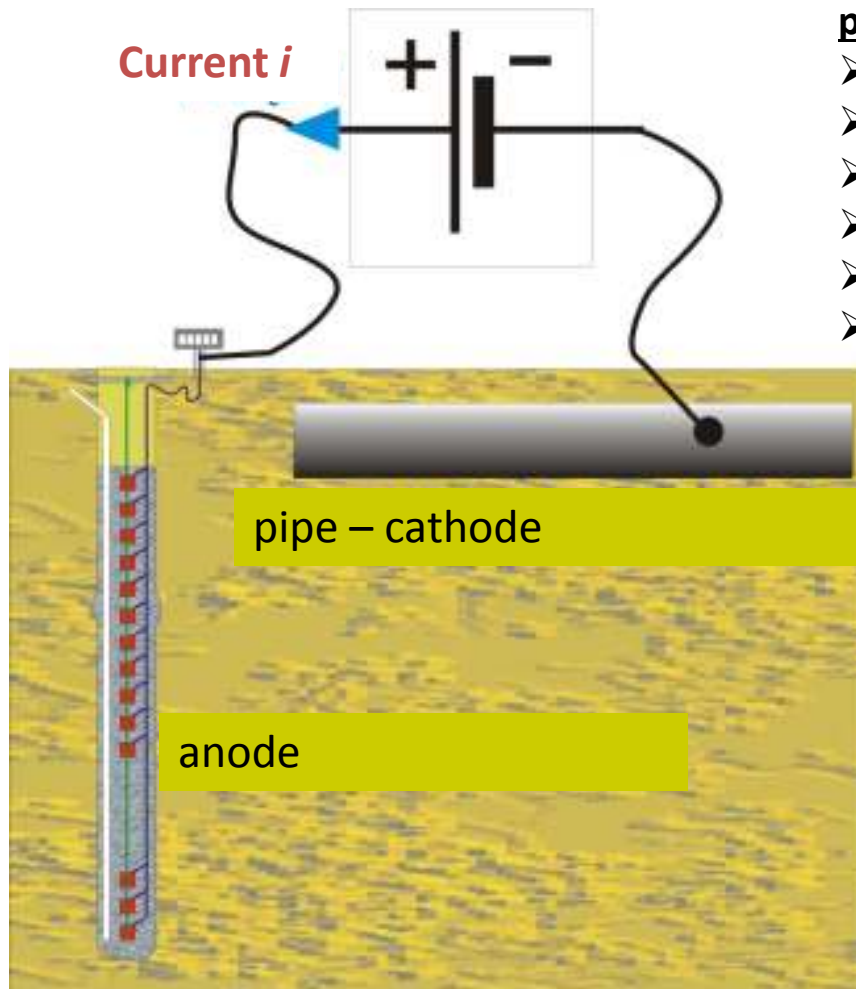


Corrosion Protection



Jacek Banaś

Cathodic protection



Structures that are commonly protected by cathodic protection are the exterior surfaces of:

- Pipelines
- Ships' hulls
- Storage tank bases
- Jetties and harbour structures
- Steel sheet, tubular and foundation pilings
- Offshore platforms, floating and sub sea structures

Cathodic protection is also used to protect the internal surfaces of:

- Large diameter pipelines
- Ship's tanks (product and ballast)
- Storage tanks (oil and water)
- Water-circulating systems

However, since an internal anode will seldom spread the protection for a distance of more than two to five pipediameters, the method is not usually practical, or suitable, for the protection of small-bore pipework.

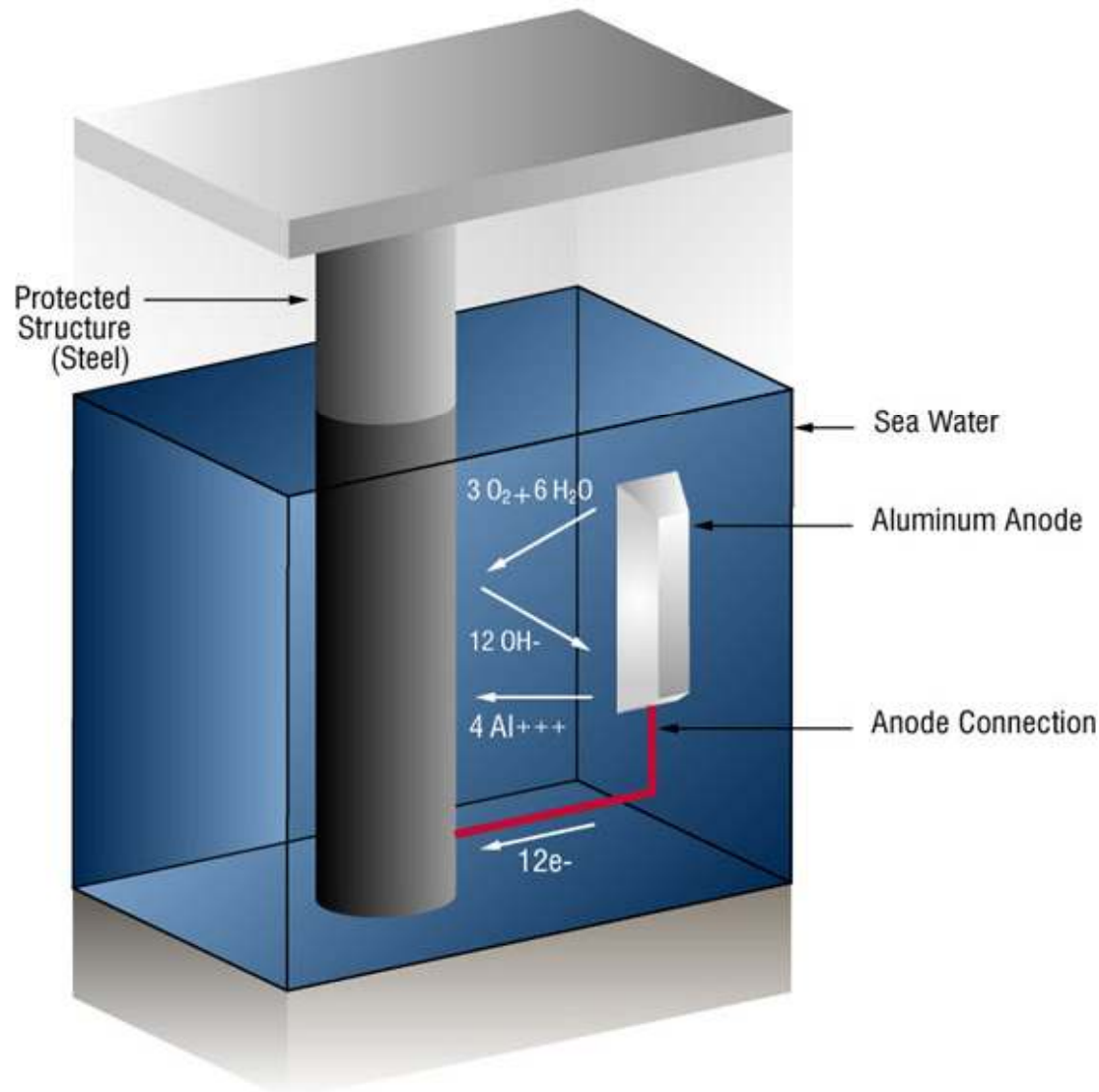
Cathodic protection



The first application of cathodic protection (CP) can be traced back to **1824**, when [Sir Humphry Davy](#), in a project financed by the British Navy, succeeded in protecting copper sheathing against corrosion from seawater by the use of iron anodes.

Cathodic protection

Sacrificial anode system in seawater



Protected surface (cathode):

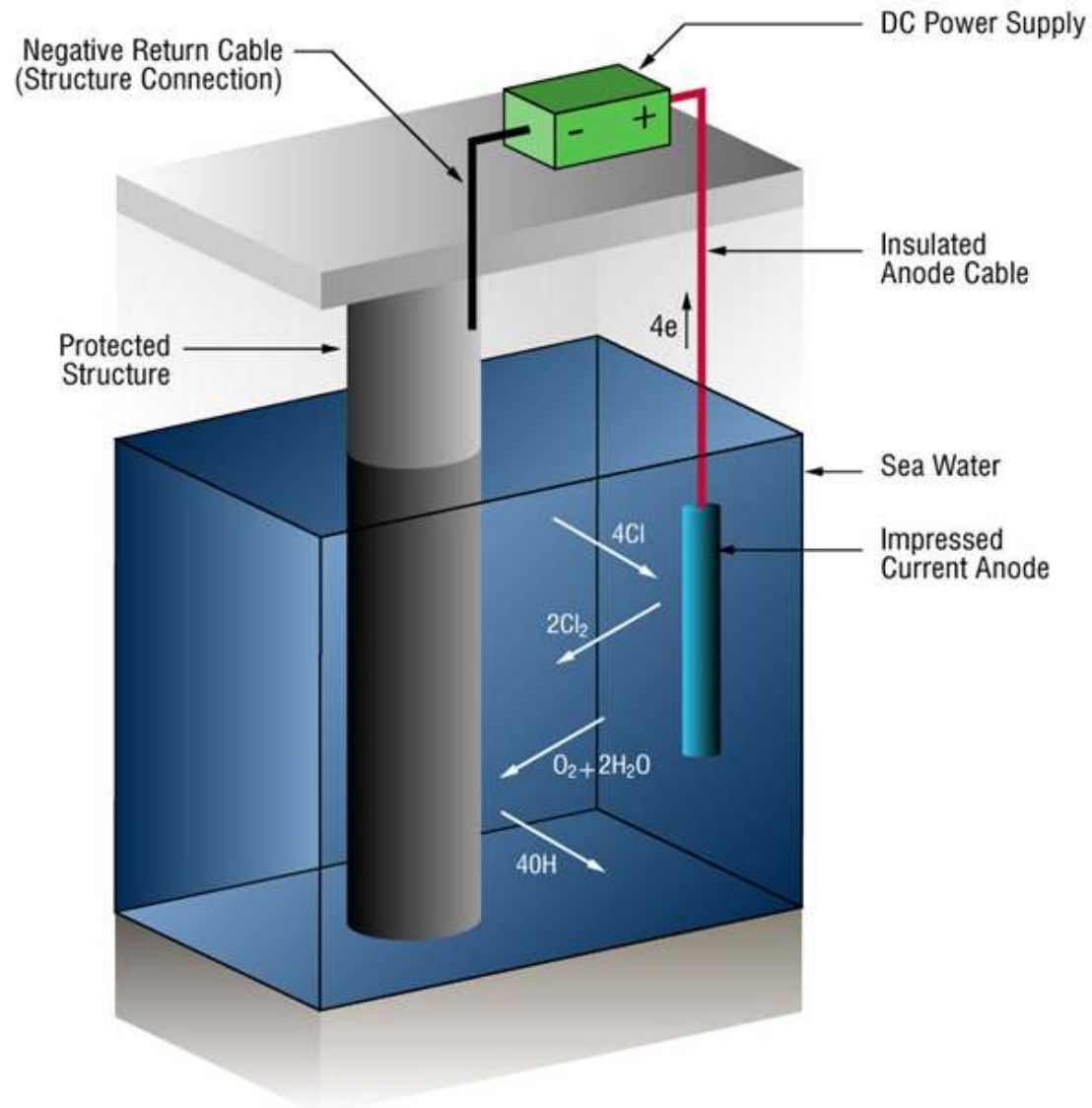


Sacrificial anode:

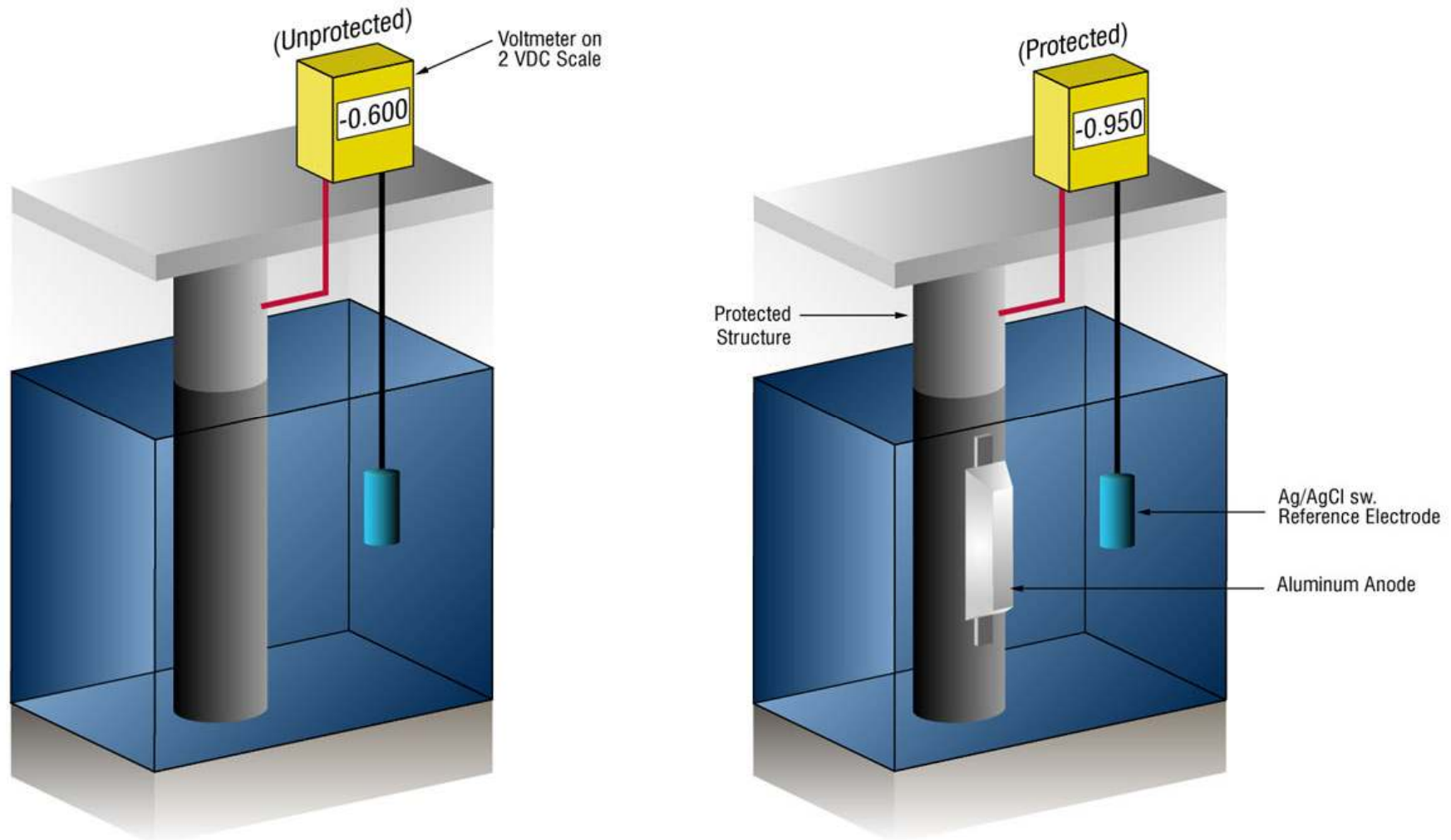


Cathodic protection

Impressed Current Cathodic Protection Systems (ICCP Anode Systems)



Cathodic protection



Protected vs Unprotected structures as verified by cathodic protection potential

SILICON IRON ANODE DATA

CHEMICAL COMPOSITION

	Normal	Chrome
Silicon	14.50%	14.50%
Manganese	0.75%	0.75%
Carbon	0.85%	0.95%
Chromium	-	4.50%
Iron	Remainder	Remainder

CONSUMPTION RATES

Typical Rates	
Normal Alloy	0.5 kg/Amp/year
Chrome Alloy	0.2 kg/Amp/year

CANISTERED ANODES

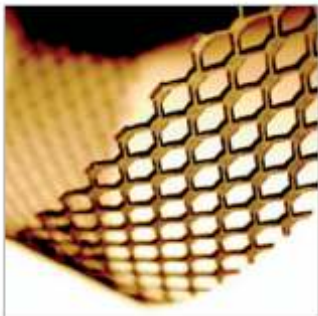


MIXED METAL OXIDE ANODES

- Substrate Titanium ASTM B338 Grade 1 or 2
- Coating IrO₂/Ta₂O₅
- Coating Method Multi pass thermal decomposition of precious metal salts technique
- Diameter 25.4mm
- Wall Thickness 0.90mm
- Rate 0.5 - 4.0 mg/A/yr depending upon CP application conditions
- Utilisation Factor Dimensionally Stable
- Working Environment Suitable for Cl₂ & O₂ or combination of both

Operating Characteristics

Environment	Max Current Density (A/m ²)	Life (Years)
Carbonaceous Backfill	50	20
Calcined Petroleum Coke	100	20
Freshwater	100	20
Brackish Water	100-300	20
Seawater	600	20

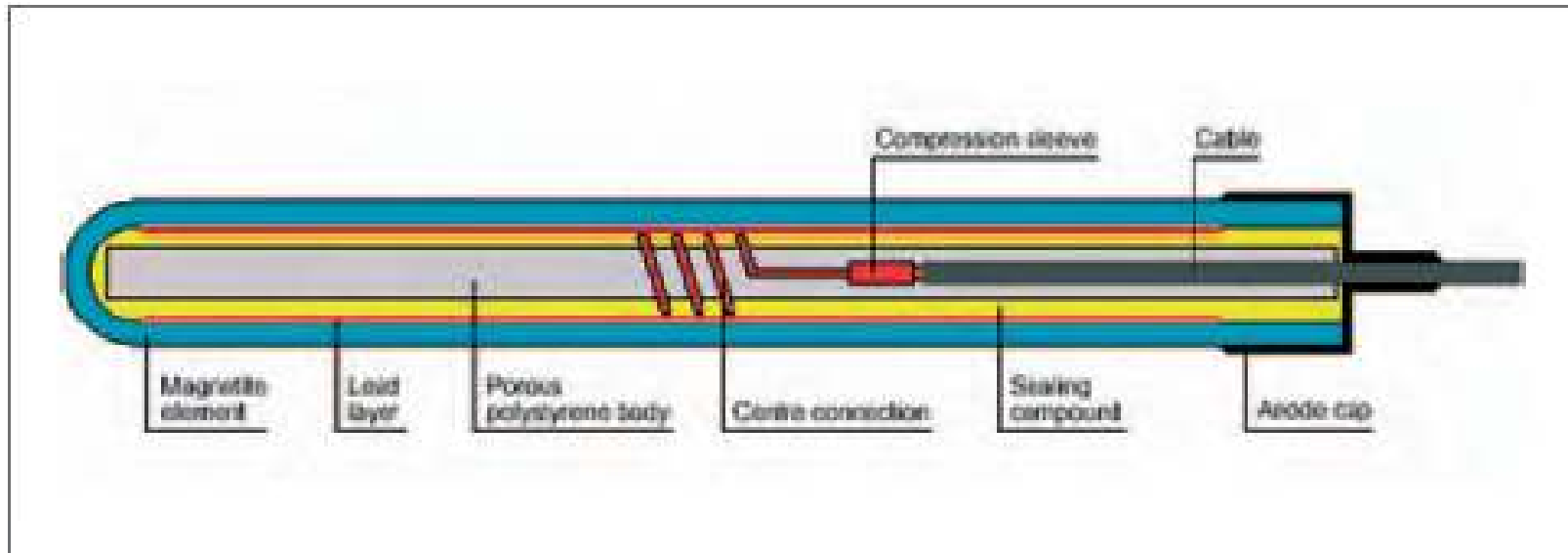


MESH STRIP ANODES



TUBULAR MMO ANODE

MAGNETITE ANODE



FeO	28 - 32%
Fe ₃ O ₄	60 - 64%
Balance	4 - 12%

GRAPHITE ANODE

Environment	Current Density Amps/M ²	Consumption Rate kg/Amp/Year
Fresh Water	2.5 - 3	0.1 - 0.3
Sea Water	10	0.3 - 0.5
Carbonaceous Backfill	10	0.1 - 0.3



PLATINISED TITANIUM ANODES

Max current density A/dm ²	30
Usual current density A/dm ²	1.0 - 10.0
Consumption rate g/A/yr	0.01 (at current density 5.50A/dm ²)



Zinc Anodes



ANODE INSTALLATION EXAMPLES



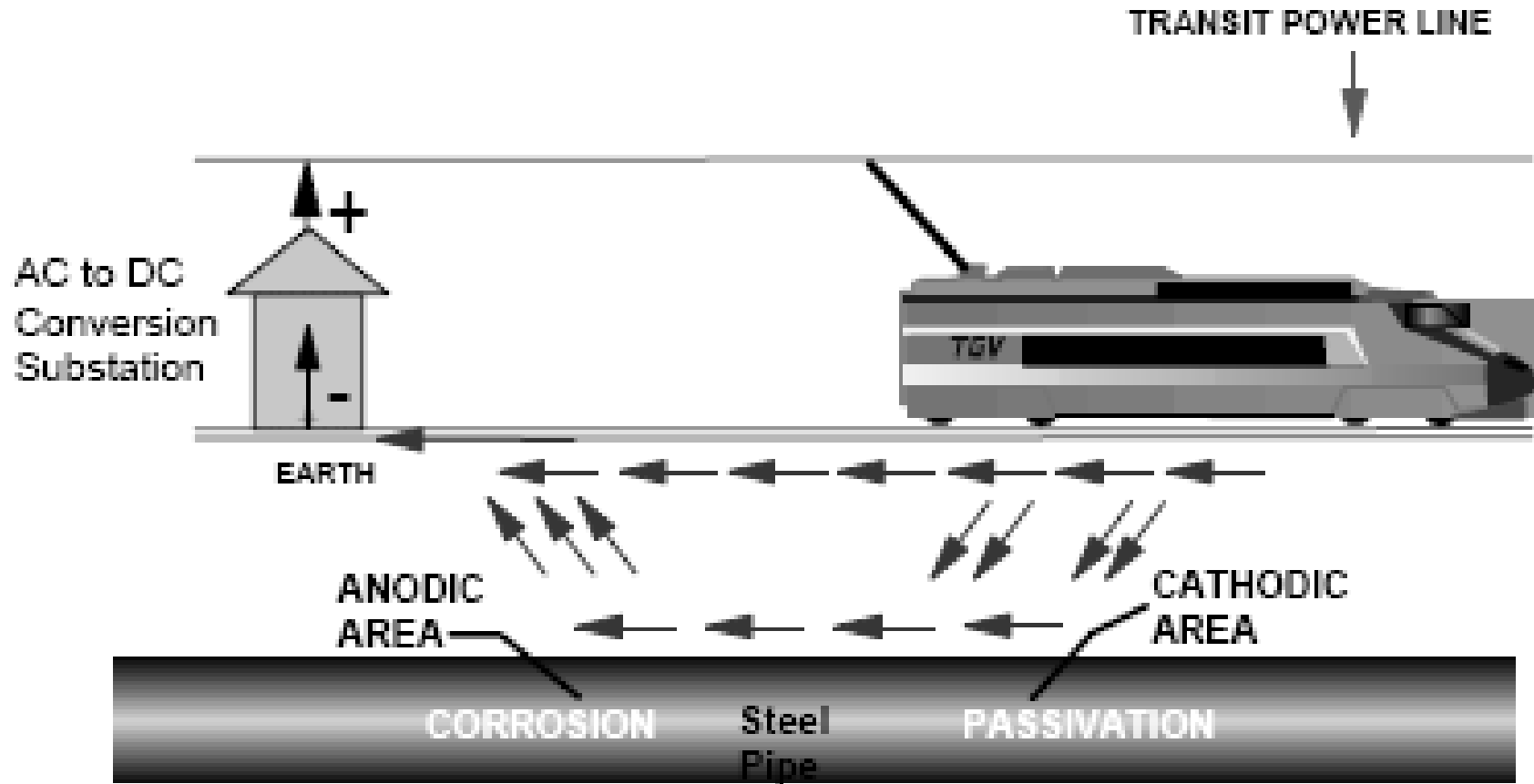
Solar units can be used as a source of energy for cathodic protection



STRAY CURRENT CORROSION

Stray currents are currents flowing in the electrolyte from external sources. Any metallic structure, for example a pipe line, buried in soil represents a low resistance current path and is therefore fundamentally vulnerable to the effects of stray currents

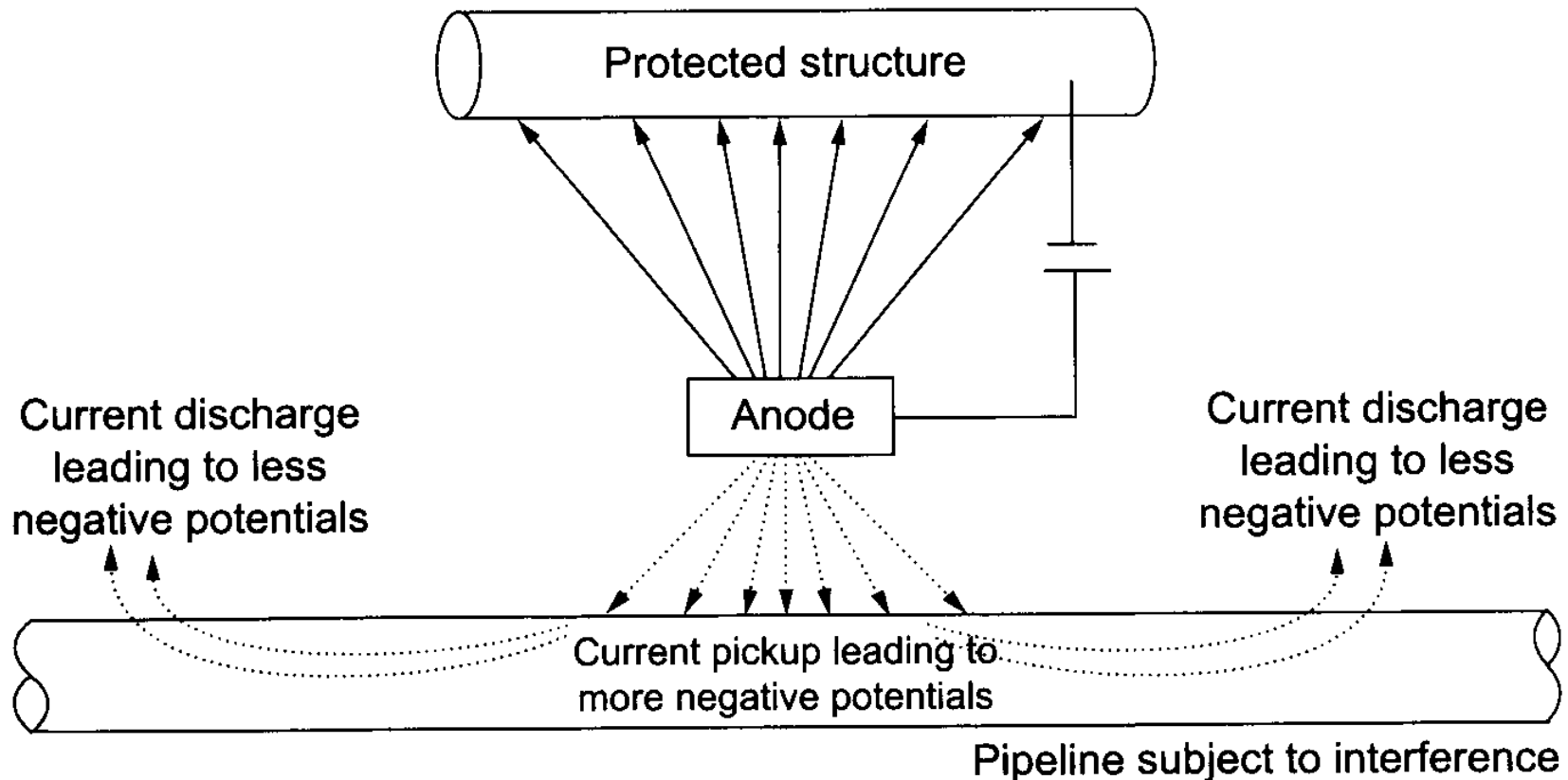
STRAY DIRECT CURRENT CORROSION



Anodic Interference

It is found in relatively close proximity to a buried anode.

At location close to anode the pipeline will pick up current. This current will be discharged at a distance farther away from the anode.



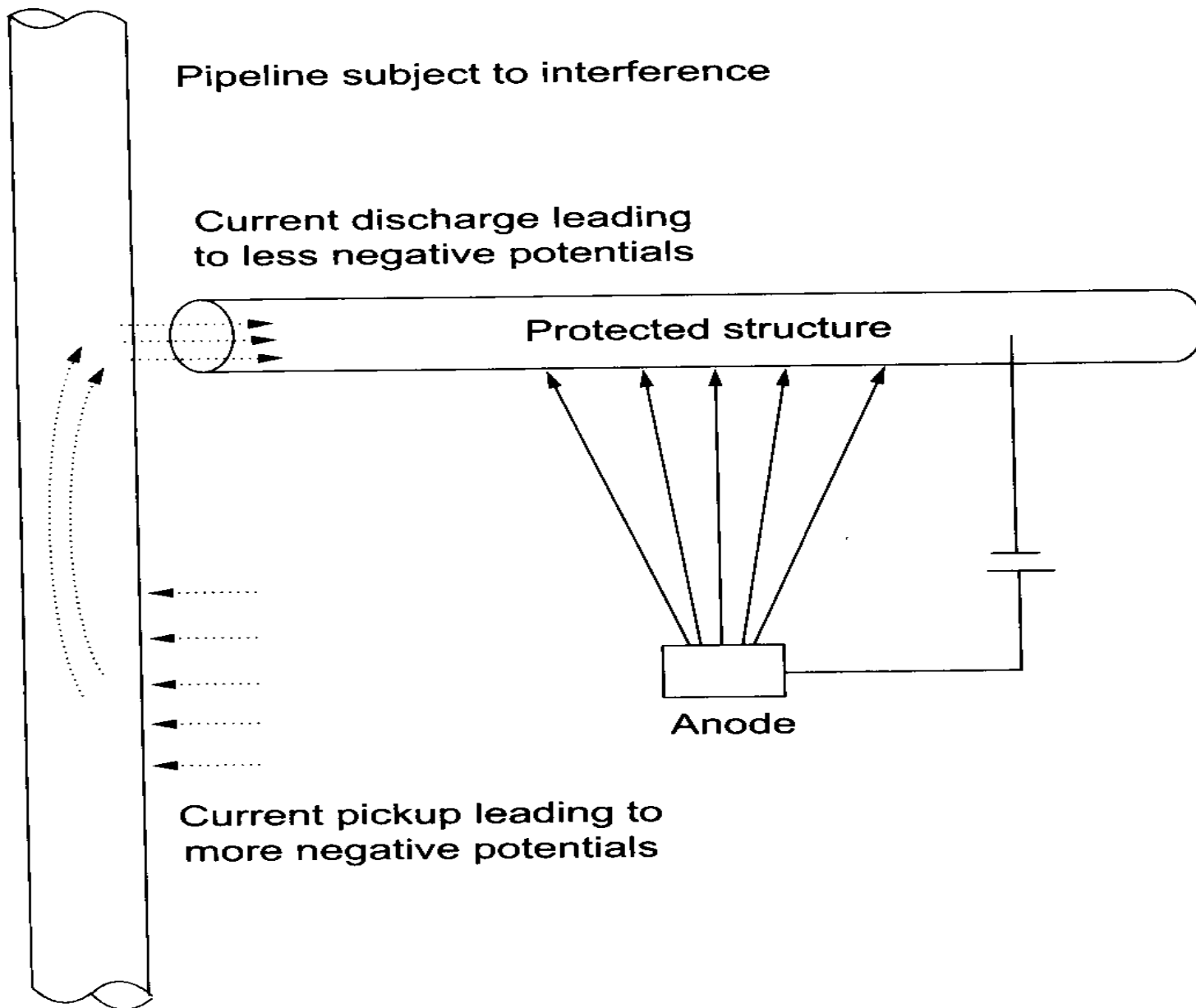


Figure 11.13 Cathodic interference example (schematic).

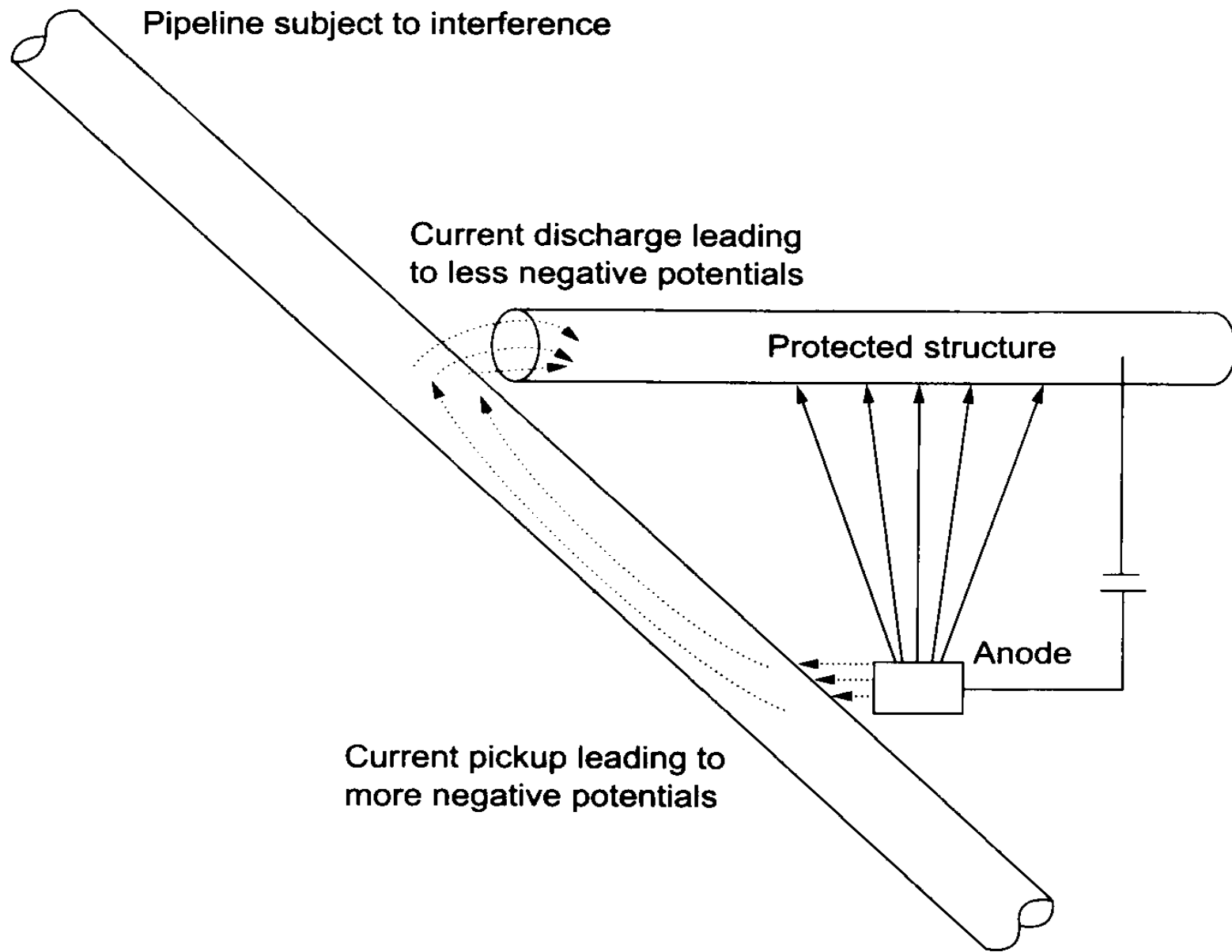


Figure 11.14 Combined anodic and cathodic interference example (schematic).

- Stray current tends to enter a buried structure in a certain location and leave it in another. It is where the current leaves the structure that severe corrosion expected.
- Overprotection might also occur at a location where the high current density of stray current enter a structure.
- There are a number of source of undesirable stray currents, including foreign cathodic protection installations, dc transit systems such as electrified railways, subway systems, and streetcars, welding operations, and electrical power transmission systems.

Use of a drainage bond

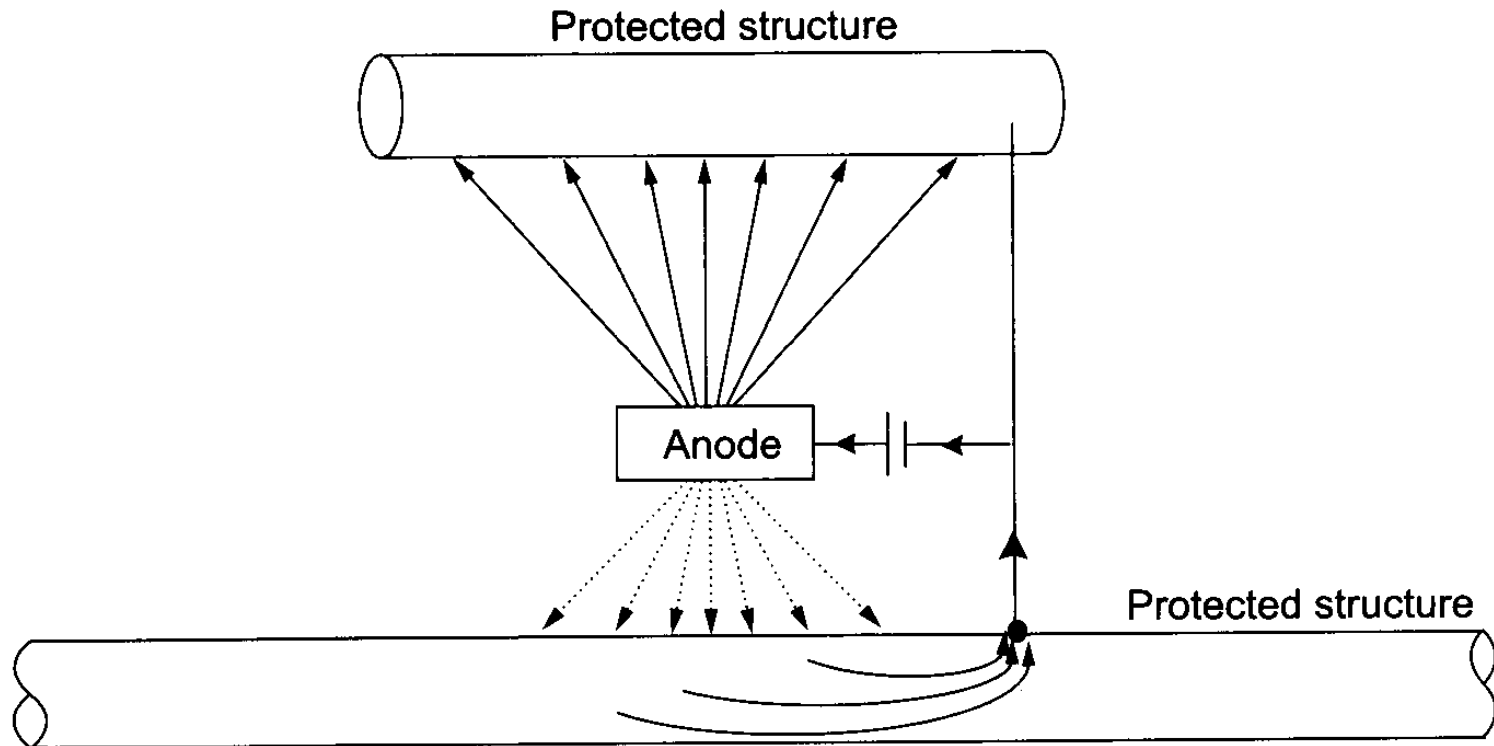


Figure 11.15 Use of a drainage bond to mitigate stray current discharge from the pipeline (schematic).

Cathodic shielding

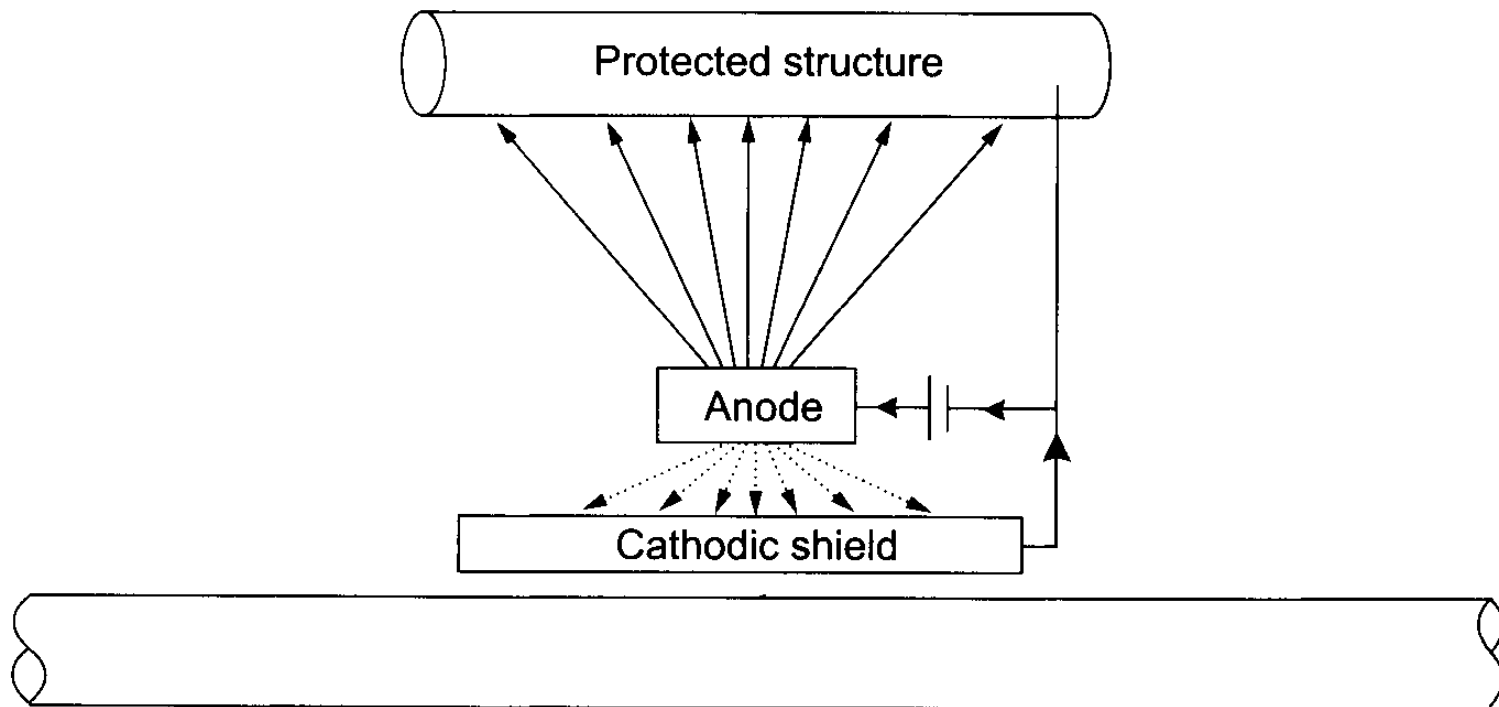
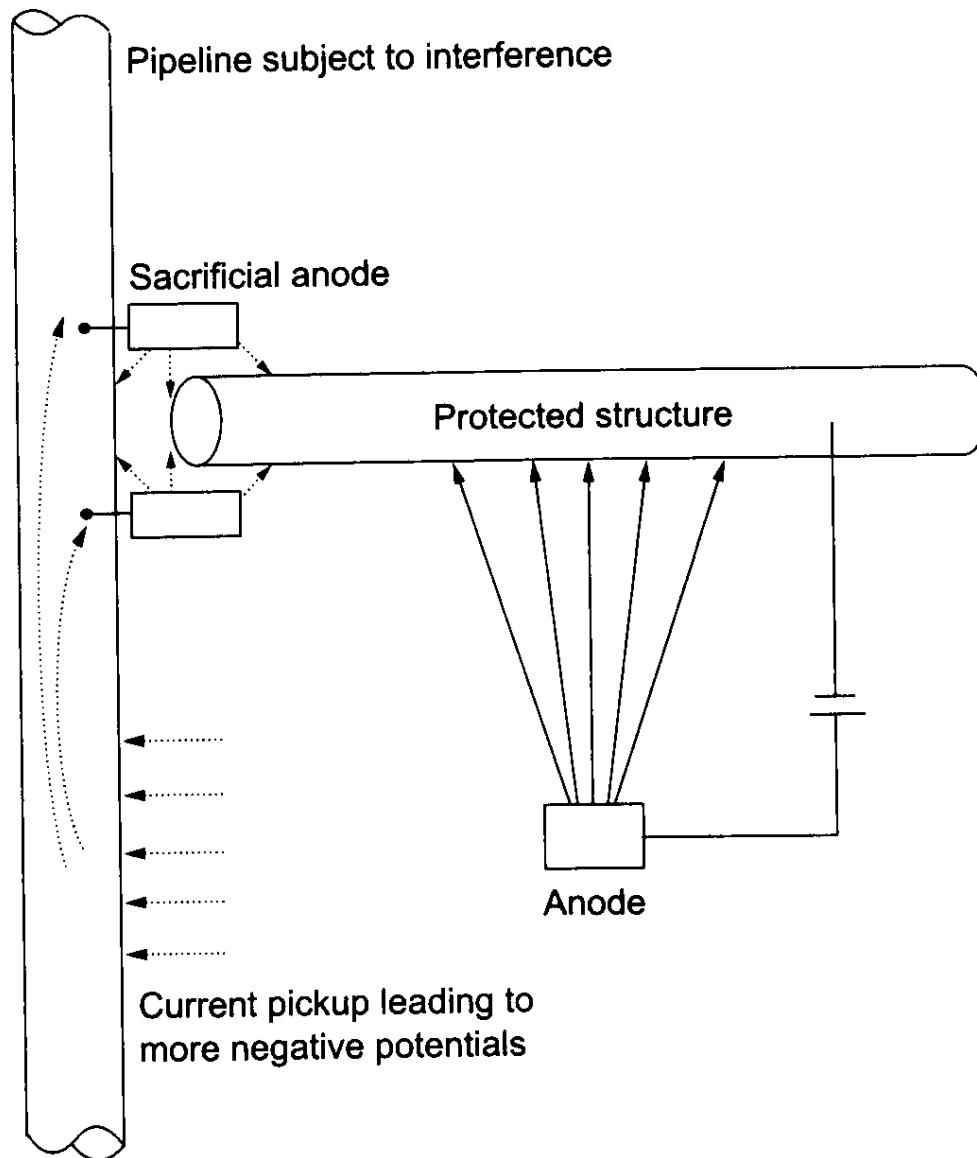


Figure 11.16 Principle of a cathodic shield to minimize anodic interference (schematic).

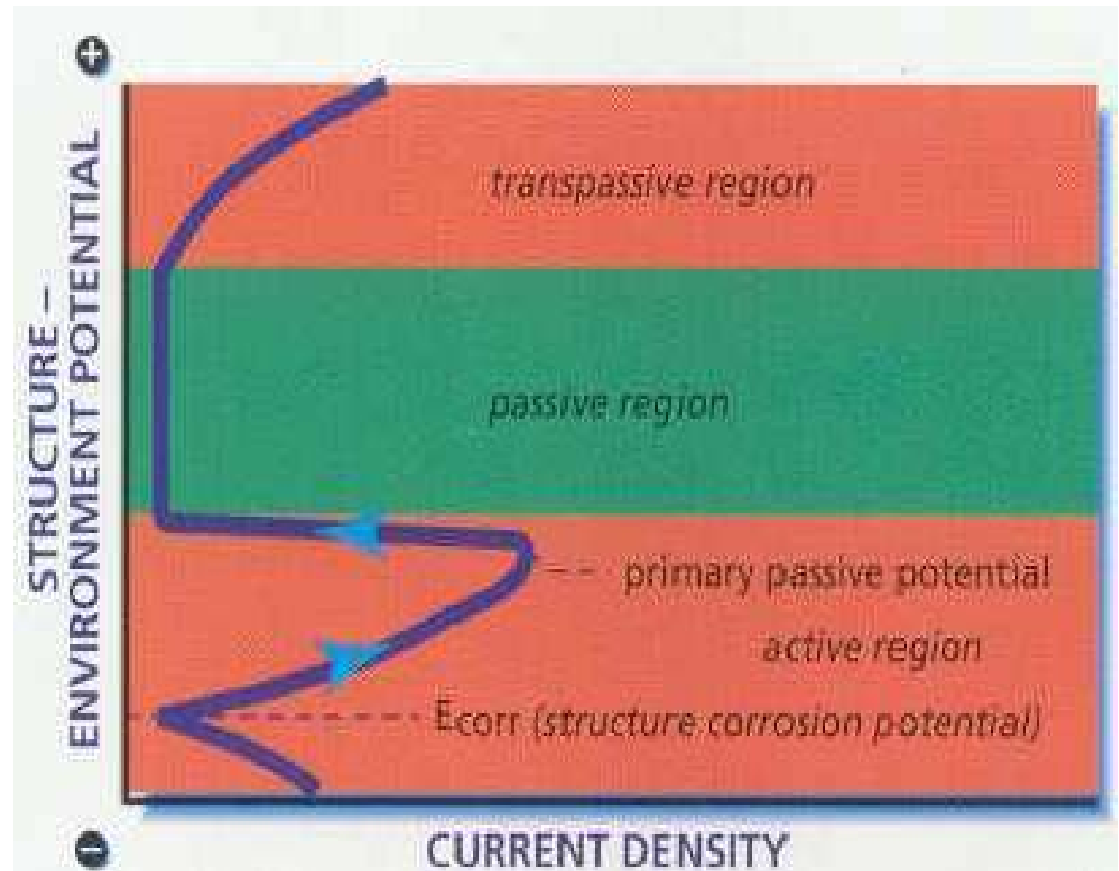
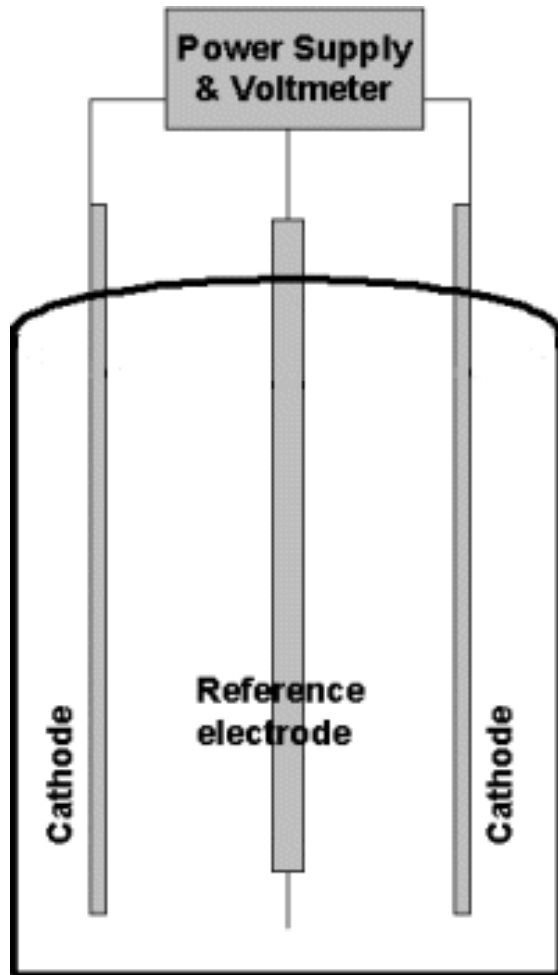


Use of sacrificial anodes

Figure 11.17 Use of sacrificial anodes to mitigate cathodic interference (schematic).

ANODIC PROTECTION

Feasibility of anodic protection is firstly demonstrated and tested by Edeleanu in 1954



Anodic protection can decrease corrosion rate substantially.

Anodic protection of 304SS exposed to an aerated H_2SO_4 at 30°C at 0.500 vs. SCE

Acid concentration, M	NaCl, M	Cor. Rate $\mu\text{m}/\text{y}$ (Unprotected)	Cor. Rate $\mu\text{m}/\text{y}$ (Protected)
0.5	10^{-5}	360	0.64
0.5	10^{-3}	74	1.1
0.5	10^{-1}	81	5.1
5	10^{-5}	49000	0.41
5	10^{-3}	29000	1.0
5	10^{-1}	2000	5.3

ANODIC PROTECTION

Anodic protection has been proposed to protect iron and stainless steels in a number of environments some of which are shown below.

- Stainless steel heat exchangers used for handling concentrated sulfuric acid
- Cast iron in boiling sulfuric acid
- Certain stainless steels in acetic acid
- Mild steel in certain types of phosphate containing fertilizers
- Certain steels and stainless steels in phosphoric acid in plants and tankers

One characteristic of these environments is that they usually do not induce pitting or other types of localized corrosion. Control of potential above the corrosion potential may induce localized corrosion if the environment contains agents (e.g. chloride) that are known to initiate localized corrosion of the alloy being protected.



CATHODES FOR ANODIC PROTECTION

- Should be permanent and can be used as current collector without any significant degradation.
- Having large surface area in order to suppress cathodic overpotential.
- Low cost.

Platinum clad brass can be used for anodic protection cathodes because this cathode has low overpotential and its degradation rate is very low, however it is very expensive.

Cathodes used in recent anodic protection systems

Cathode metal	Environment
Platinum-clad brass	Sulfuric acid of various concentrations
Steel	Kraft pulping liquor
Chromium nickel steel	H ₂ SO ₄ (78–105%)
Silicon cast iron	H ₂ SO ₄ (89–105%)
Copper	Hydroxylamine sulfate
S30400	Liquid fertilizers (nitrate solutions) Sulfuric acid
Nickel-plated steel	Chemical nickel plating solutions
Hastelloy C	Liquid fertilizers (nitrate solutions) Sulfuric acid of various concentrations Kraft digester liquid

- **Anodic protection has been applied to protect storage tanks, reactors, heat exchangers and transportation vessels for corrosive solutions.**
- **Heat exchangers (tubes, spirals and plates types) including their anodic protection systems can be easily to purchase in the market.**
- **i.e. AISI 316 SS HE is used to handle 96-98% sulfuric acid solution at 110⁰C. Anodic protection decreases corrosion rate of the stainless steel, initially from 5mm/year down to 0.025mm/year and therefore less contaminated sulfuric acid can be obtained.**

Current density requirements for anodic protection

H ₂ SO ₄	Temperature, °C	Alloy	Current density	
			To passivate, mA·cm ⁻²	To maintain, μA·cm ⁻²
1 M	24	S31600	2.3	12
15%	24	S30400	0.42	72
30%	24	S30400	0.54	24
45%	65	S30400	180	890
67%	24	S30400	5.1	3.9
67%	24	S31600	0.51	0.10
67%	24	N08020	0.43	0.9
93%	24	Mild steel	0.28	23
99.9% (oleum)	24	Mild steel	4.7	12
H ₃ PO ₄				
75%	24	Mild steel	41	20,000
115%	82	S30400	3.2×10^{-5}	1.5×10^{-4}
NaOH				
20%	24	S30400	4.7	10