

Anodic Protection

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Feasibility of anodic protection is first demonstrated and tested by C. Edeleanu of Tube Investments Research Laboratories, Cambridge in 1954



Corrosion control of metal structure by impressed anodic current.

Interface potential of the structure is increased into passive corrosion domain.

Protective film is formed on the surface of metal structure which decrease the corrosion rate down to its passive current.

Can be applied for active-passive metals/alloys only.



- **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.**



Anodic protection can decrease corrosion rate substantially.

Anodic protection of 304SS exposed to an aerated H₂SO₄ 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



Examples of Metals/Electrolyte that can be anodically protected

Carbon Steel

Sulfuric Acid

Ammonia

Ammonium nitrate

Urea

sodium hydroxide + sodium sulfide.

Stainless Steel

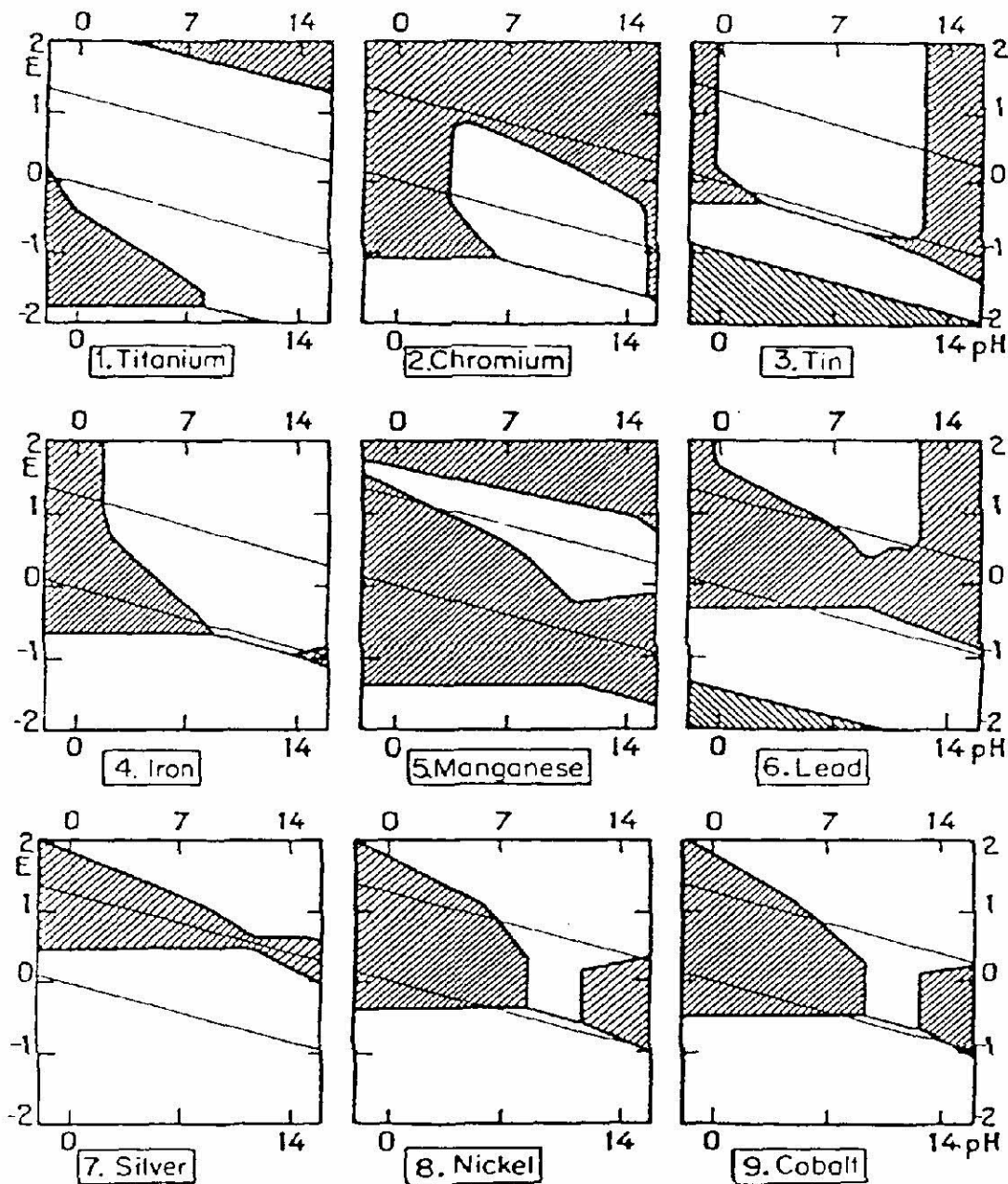
Chrome

Titanium

Nickle

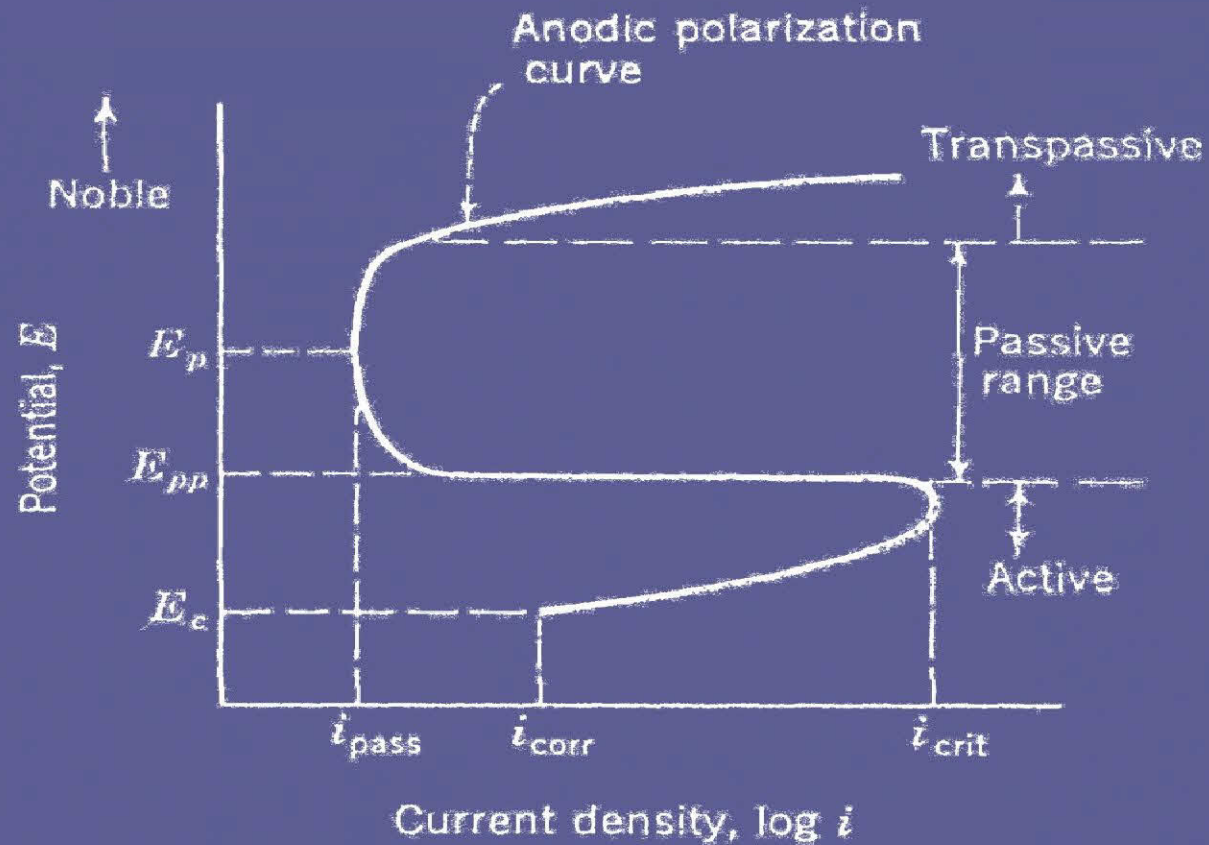
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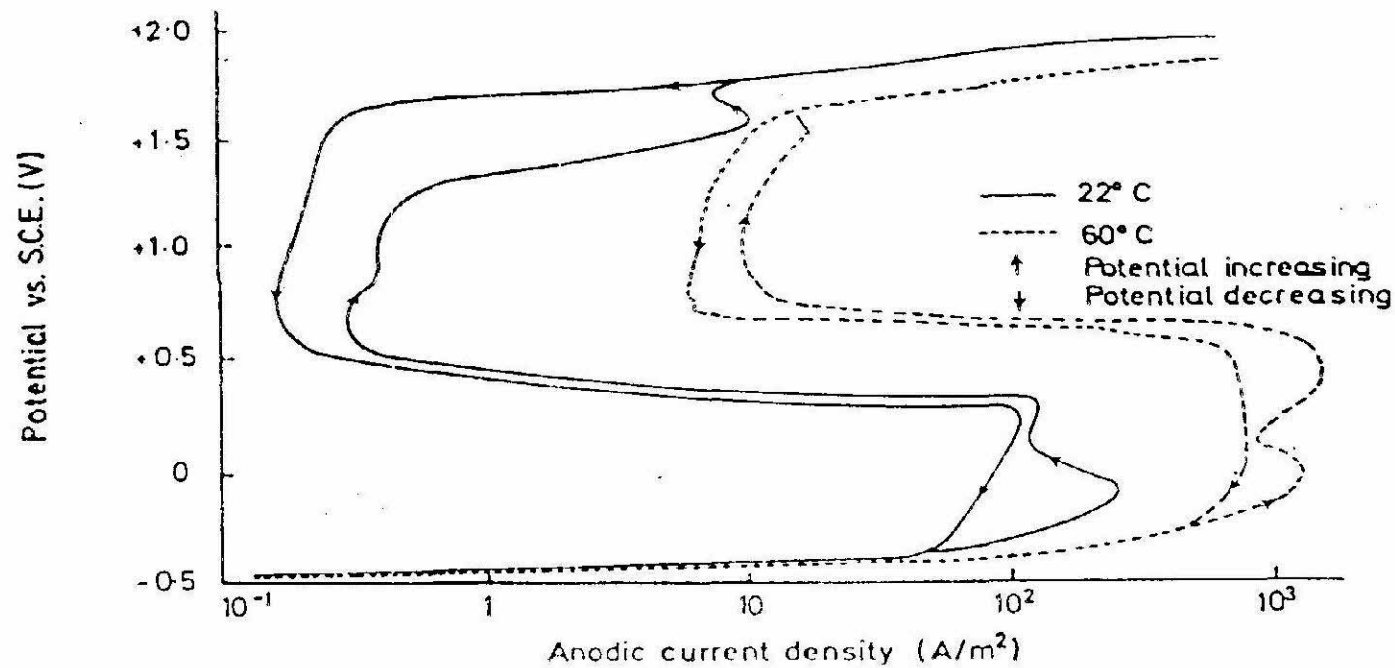
Titanium and chromium can be passivated very easily and their passivation process will occur more often than not, spontaneously, even in the absence of oxidizing agent.





Parameters that should be considered for anodic protection design (Flade potential is not included in the figure)





Anodic polarization curves of a mild steel in 10% sulfuric acid at 22 and 60°C



Anodic protection parameters :

(can be obtained from anodic polarization measurement)

Range of potential in which metal is in passivation state (protection range)

Critical current density

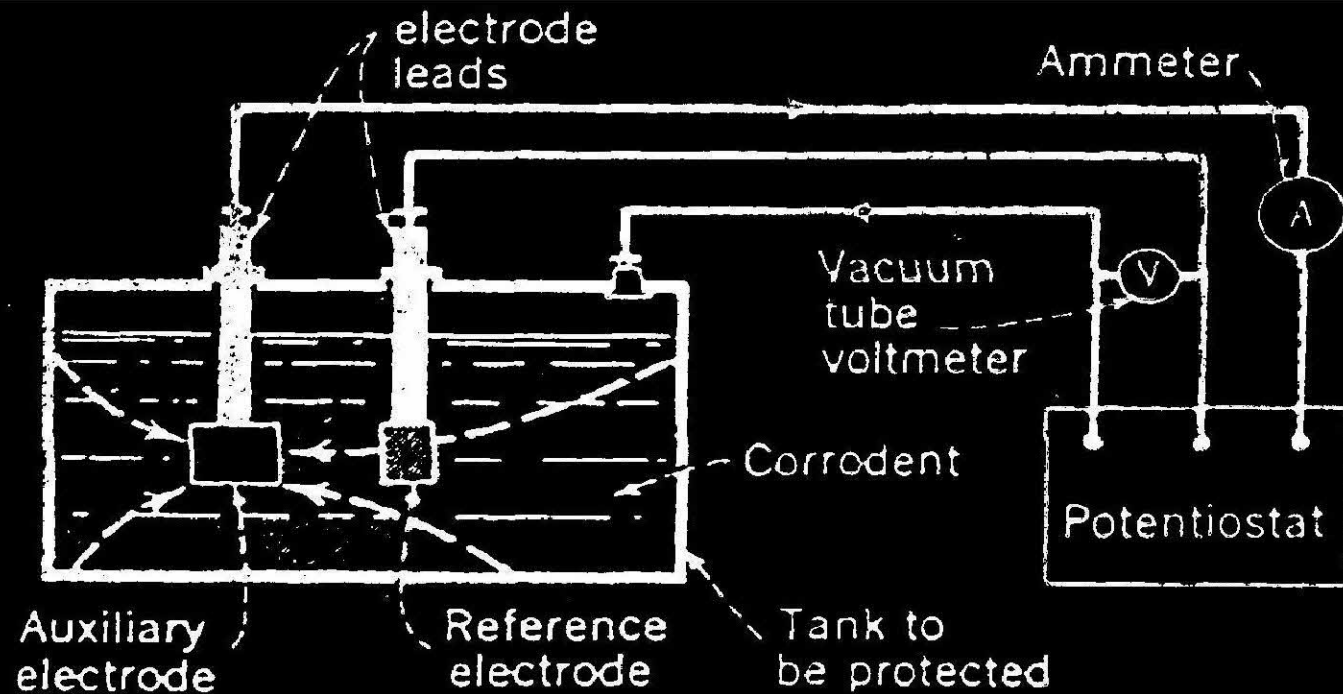
Flade potential

Optimum potential for anodic protection is midway in the passive region



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



Schematic figure of anodic protection system for protecting inner surface of storage tank



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.



TABLE 2. Cathode materials used in 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



Comparison of anodic and cathodic protection :

	Anodic protection	Cathodic protection
Applicability	Active-passive metals only	All metals
Corrosives	Weak to aggressive	Weak to moderate
Relative investment cost	High	Low
Relative operation cost	Very low	Mediums to high
Equipment	Potentiostat + cathode/s	Sacrificial anodes or DC power supply + ICCP anode/s



Throwing power	Very high	Low to high
Significant of applied current	Often a direct measure of protected corrosion rate	Complex Does not indicate corrosion rate
Operating conditions	Can be accurately and rapidly determined by electrochemical measurement	Must usually be determined by empirical testing





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Appendix V

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References

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