# Electrochemical corrosion measurements in concrete structures

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- Causes of corrosion damages in concrete structures
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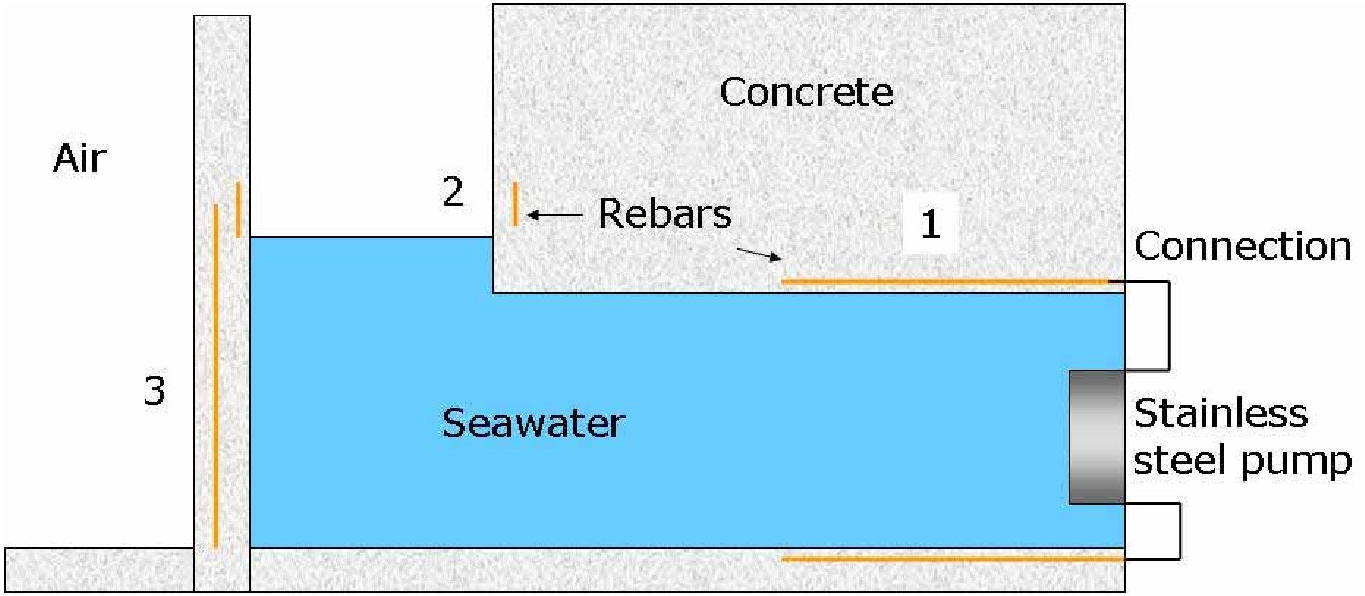
# Causes of corrosion damages in concrete structures



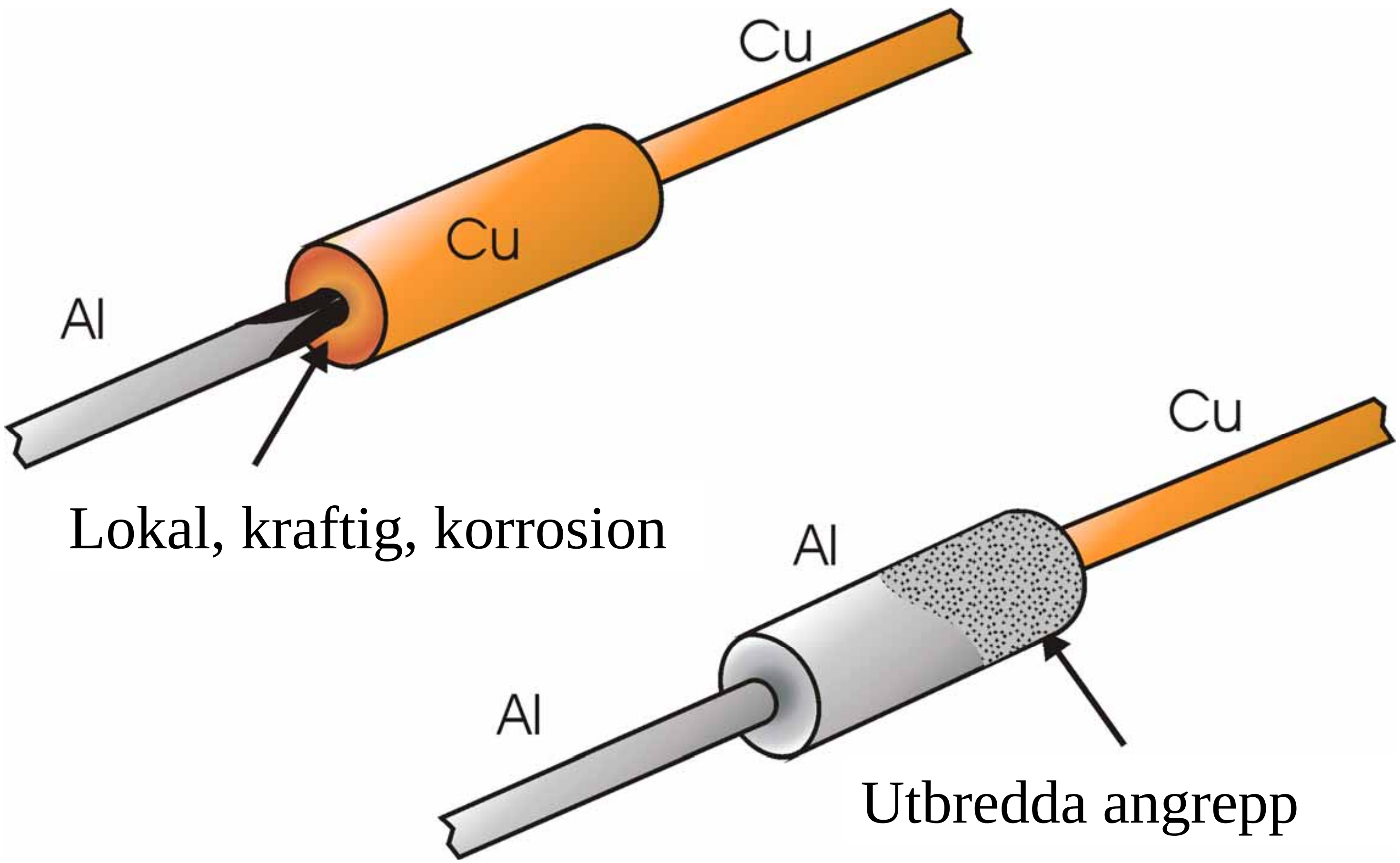

| | |
|---|---|
| 1: | Rebar connected with a more noble material<br>→ Galvanic corrosion |
| 2-3: | Optimum moisture condition for corrosion |
| 4: | Stray current corrosion |

# Galvanic corrosion

- Differences in corrosion potential of the metals which are connected
- The ratio of anodic and cathodic areas (unnoble and noble areas).
- The electric conductivity of the electrolyte
- The oxygen concentration of the electrolyte
- The anodic and cathodic polarization behavior of the metals.

# *Galvanisk spänningsserie (havsvatten, vid 20°C)*

| | | Elektrodpotential $E_H$, volt |
|---|---|---|
| alltmer ädla metaller ↑<br>alltmer oädla metaller ↓ | Guld | + 0,42 |
| | Silver | + 0,19 |
| | Rostfritt stål (18/8) i passivt tillstånd*) | + 0,09 |
| | Koppar | + 0,02 |
| | Tenn | — 0,26 |
| | Rostfritt stål (18/8) i aktivt tillstånd*) | — 0,29 |
| | Bly | — 0,31 |
| | Stål | — 0,46 |
| | Kadmium | — 0,49 |
| | Aluminium | — 0,51 |
| | Förzinkat stål | — 0,81 |
| | Zink | — 0,86 |
| | Magnesium | — 1,36 |


Cu
Cu
Al
Lokal, kraftig, korrosion
Cu
Al
Al
Utbredda angrepp

# Stray current corrosion

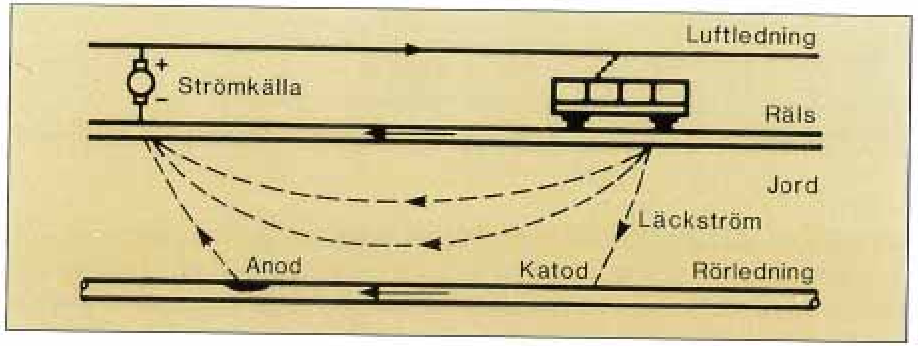



*Fig 52. Läckströmskorrosion vid likströmsbana.*

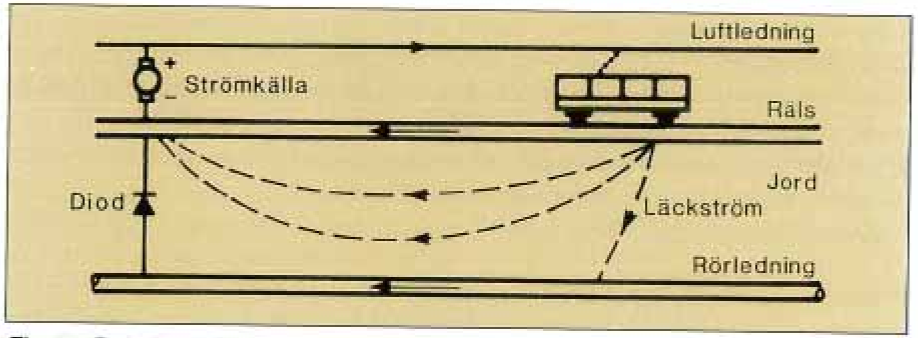



*Fig 53. Polariserad elektrisk dränering.*

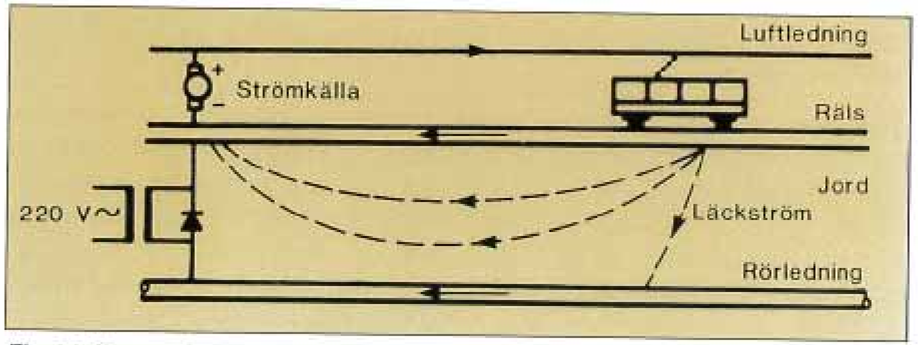



*Fig 54. Forcerad elektrisk dränering.*

# Stray current korrosion from HVDC transfer

- Long constructions in contact with water can suffer from stray current corrosion by HVDC transfer
- The risk of stray current corrosion increases with shorter distance to the HVDC station
- Highest risk when the HVDC transfer is monopolar or unbalanced bipolar transfer

# Olika typer av HVDC-ledningar

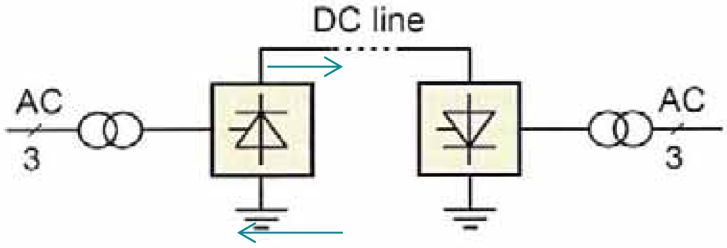



*Figure 3-1. Monopolar HVDC system.*

”Monopolär”

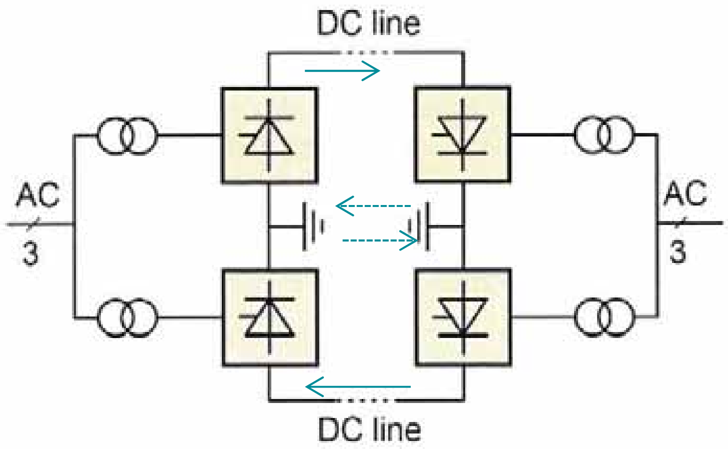



*Figure 3-2. "Bipolar" HVDC system consisting of two combined monopolar systems.*

”Bipolär”

# Stray current measurement, Forsmark (SKB Rapport TR-14-15, Elforsk rapport 10:84) Bertil Sandberg/Claes Taxén och B Sandberg et al.

About 4 volt difference.

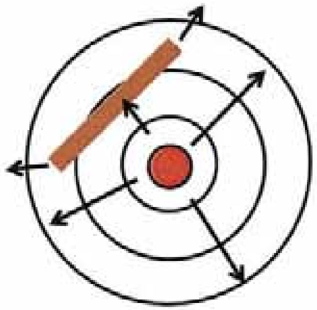
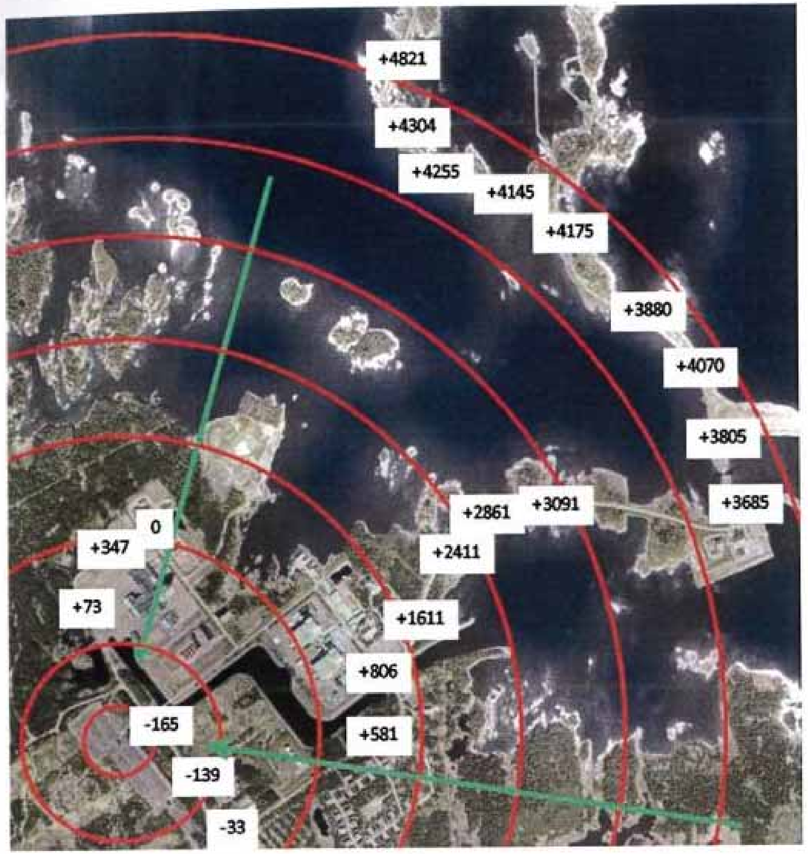


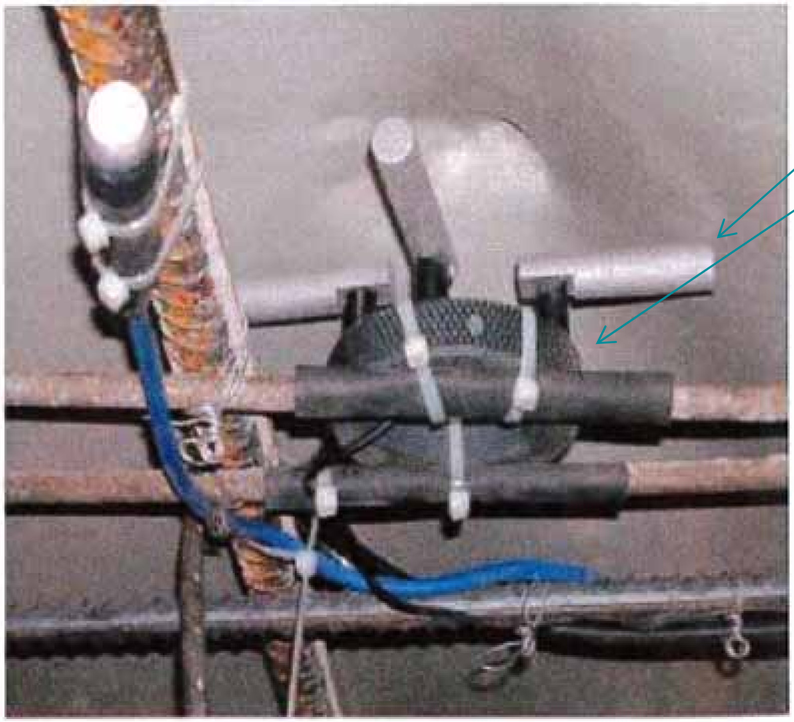
*Figure 3-3. Stray current corrosion caused by an electrical field in the gro*



# Monitoring methods

- Measure corrosion potential
- Measure corrosion current
  - LPR (linear polarisation resistance method)
  - Zero resistance ampere meter

# Corrowatch (force): For new constructions



CorroWatch and ERE 20 fixed to reinforcement in tunnel

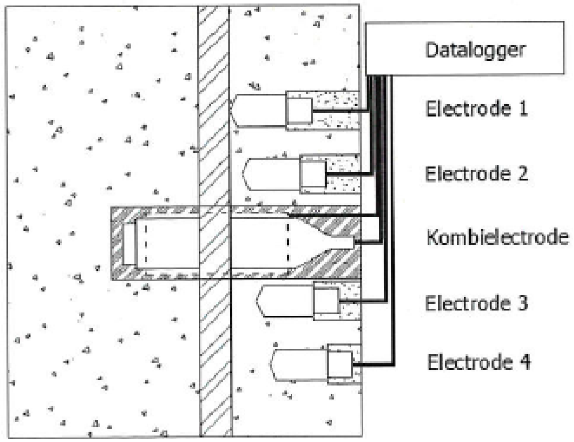
Anode: ”rebar”
cathode: titanium net

- Measure corrosion current with a zero resistance ampere meter
- Linear polarisation resistance method

# CorroRisk (Force): For existing constructions

Photo of CorroRisk installation on marine bridge pillar

Photo of anodes of CorroRisk sensor




- Measure corrosion current with a zero resistance ampere meter

- Linear polarisation resistance method

# Corrosion potential

# Previous measurements: Ringhals, cooling water tunnels

- Background

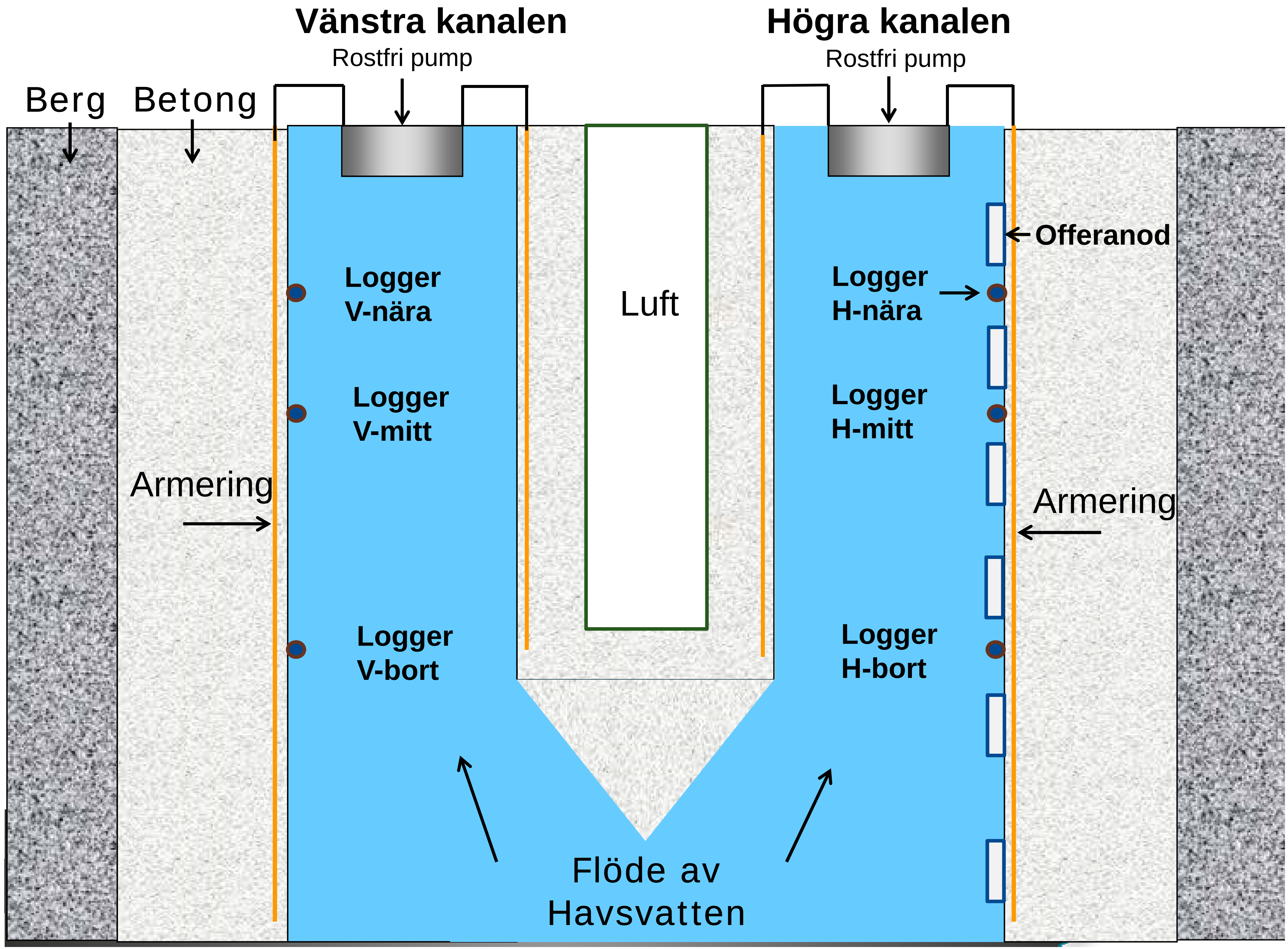
  The consumption rate of sacrificial anodes was high. Why?

  Is there a risk of galvanic korrosion?

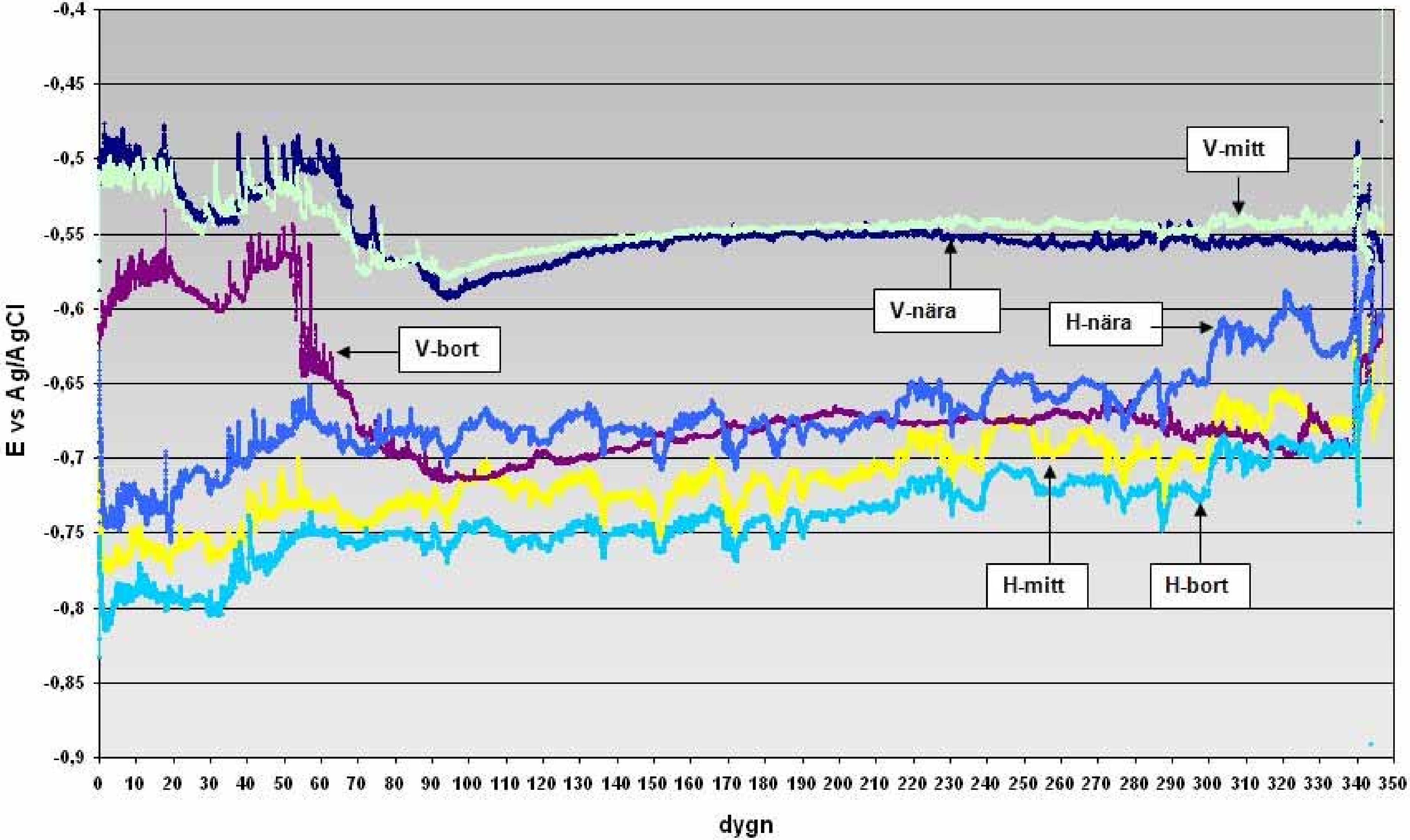
- Measurements: Corrosion rate and temperature over time.

- Corrosion potential

| | |
|---|---|
| Stainless steel in seawater: | -100 mV |
| Rebar in water saturated concrete: | -650 mV |
| Aluminium in seawater: | -1000 mV |



Vänstra kanalen
Rostfri pump
Högra kanalen
Rostfri pump
Berg
Betong
Luft
Offeranod
Logger
V-nära
Logger
V-mitt
Logger
V-bort
Logger
H-nära
Logger
H-mitt
Logger
H-bort
Armering
Armering
Flöde av
Havsvatten



-0,4
-0,45
-0,5
-0,55
-0,6
-0,65
-0,7
-0,75
-0,8
-0,85
-0,9
E vs Ag/AgCl
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320 330 340 350
dygn
V-mitt
V-nära
H-nära
V-bort
H-mitt
H-bort

# Conclusion

- Galvanic corrosion risk:

  -100/200 mV in concrete with 1 weight-% Cl by weight of cement. -300/400 mV with 2% Cl.

- The high consumption rate of sacrificial anodes was explained by a high potential difference between the anodes and rebar+stainless steel pump.

- The corrosion potential logger could detect potential differences with distance from the pump and difference between the left and the right side.

- The measured potentials did not indicate galvanic corrosion

# New project

- Installation of corrosion potential loggers in cooling water tunnels.
- Determine the risk of galvanic corrosion and stray current korrosion.
  - condense pipes made of titanium, galvanic corrosion?
  - Is there a potential difference when HVDC transportation is changed?
- Measurements in ringhals, oskarshamn and possibly forsmark.

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