




A new concept for cathodic protection of offshore pipelines to reduce Hydrogen Induced Stress Cracking in high strength steel materials

Materialdagen 2003

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STATOIL




Why start the development?

-  Failure on existing 13CR pipelines (hydrogen induced stress cracking)
-  Testing and verification of materials properties
-  Decision time! – Level of cathodic polarization

Traditional CP design

-  Restricted by Norsok M-503 and DnV RPB 401

New CP design - opportunity, challenge and result

-  **Opportunity** - The new ISO standard for submarine pipelines
-  **Challenge** – adapting the most radical parameters
-  **Result** - Description of the new concept

Special features connected to the CP design

Concluding remarks

Can we use 13% Cr SMSS materials with CP?

How resistant is girth welds to HISC?



What modifications to CP should and can be done?




Conclusions from Testing and Verification of girth welds


Reduced polarization with a negative limit of -0.800 V (Ag/AgCl)

-  No susceptibility to HISC (based on crack growth testing)
-  Difficult to implement practical solutions

Standard polarization with a negative limit of -1.050 V (Ag/AgCl)






-  Acceptable results on crack initiation
-  No cracking observed in service
-  Qualifications to materials, design and fabrication necessary

-  **CP design utilizing standards such as Norsok M-503 and DnV RPB 401:**
 -  Are generally considered to be conservative
 -  Gives an excessive number and amount of anodes and anode connections





-  **The costs of anodes are small and the costs for retrofitting are very high**

Cathodic Protection of Carbon Steel

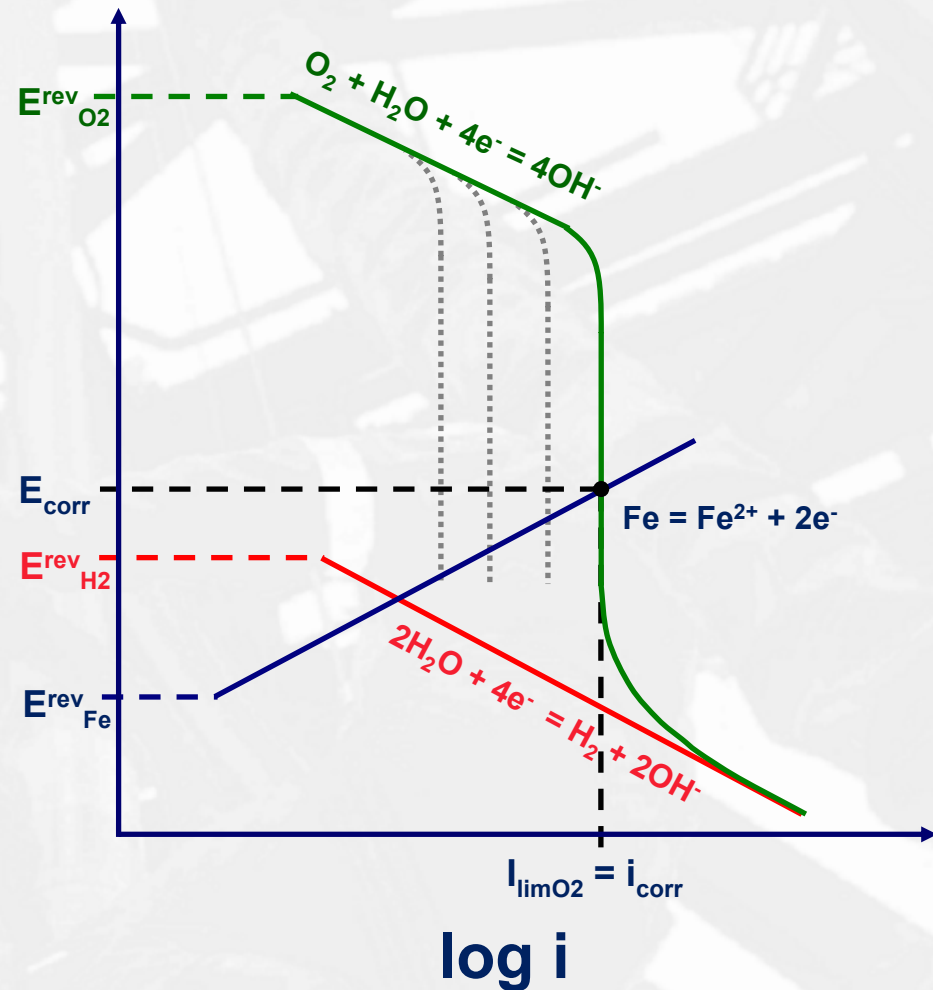
Oxygen reduction dependant on

-  O₂ concentration
-  Flow rates
-  Temperature
-  pH
-  Calcareous deposits

Hydrogen dependant on

-  Temperature
-  Hydrostatic pressure
-  pH
-  Calcareous deposits?

W



Cathodic Protection of Stainless Steel

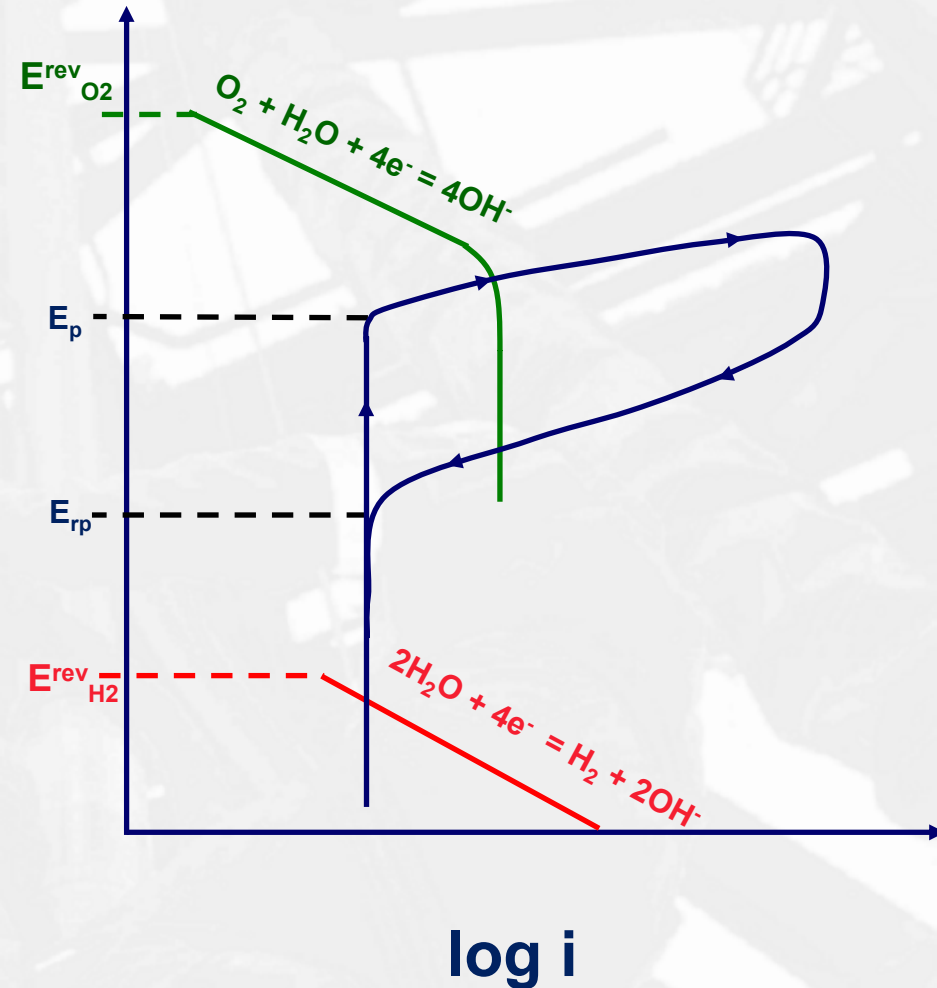
Pitting/repass. dependent on

- Material type
- Welding
- Temperature
- pH
- Chlorides

Hydrogen dependant on

- Temperature
- Hydrostatic pressure
- pH
- Calcareous deposits?

Ψ



The New ISO standard for CP ISO – 15889 - 2

-  **The work group was established in 1998**
-  **Final voting will take place during 2003**
-  **The basis was the various existing RP's and standards such as DnV, Nace, CEN, ..**
-  **The document cover:**
 -  Design
 -  Fabrication
 -  Installation
 -  Operation
-  **Publication spring 2004**



Differences Between Norsok and the New ISO Standard for a Given Example

NORSOK Data

- 📄 Max. 200 m between anodes
- 📄 Coating breakdown: 0.048
- 📄 Current density: 110 mA/m²
- 📄 Protection potential: -800 mV

ISO Data





- 📄 Distance between anodes not limited
- 📄 Coating breakdown: 0.003
- 📄 Current density: 104 mA/m²
- 📄 Protection potential: -500 mV

Calculated area of bare steel:

7 Km pipeline 6" diameter

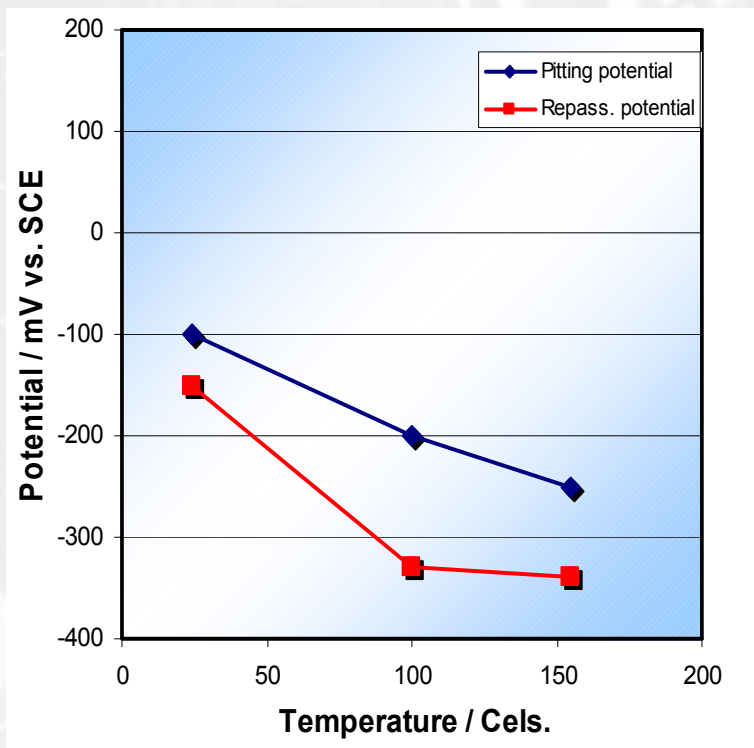
Norsok: **158 m²**

ISO: **10 m²**

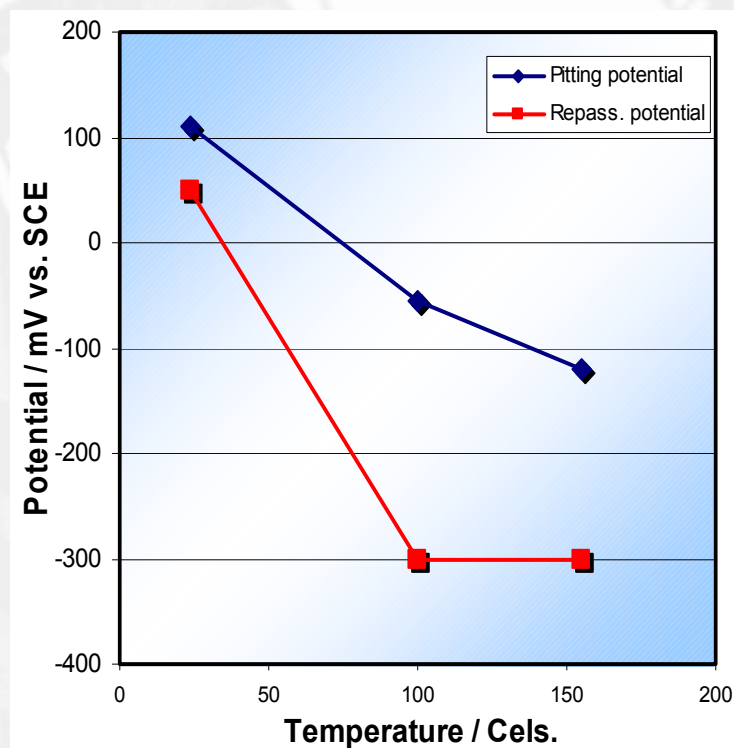
-  **Selection of protection potential for SMSS 13% Cr steel**
-  **Current densities, including temperature dependence**
-  **Coating breakdown parameters**
-  **Current capacity of anodes**

Positive protection potential Limit – pitting potential

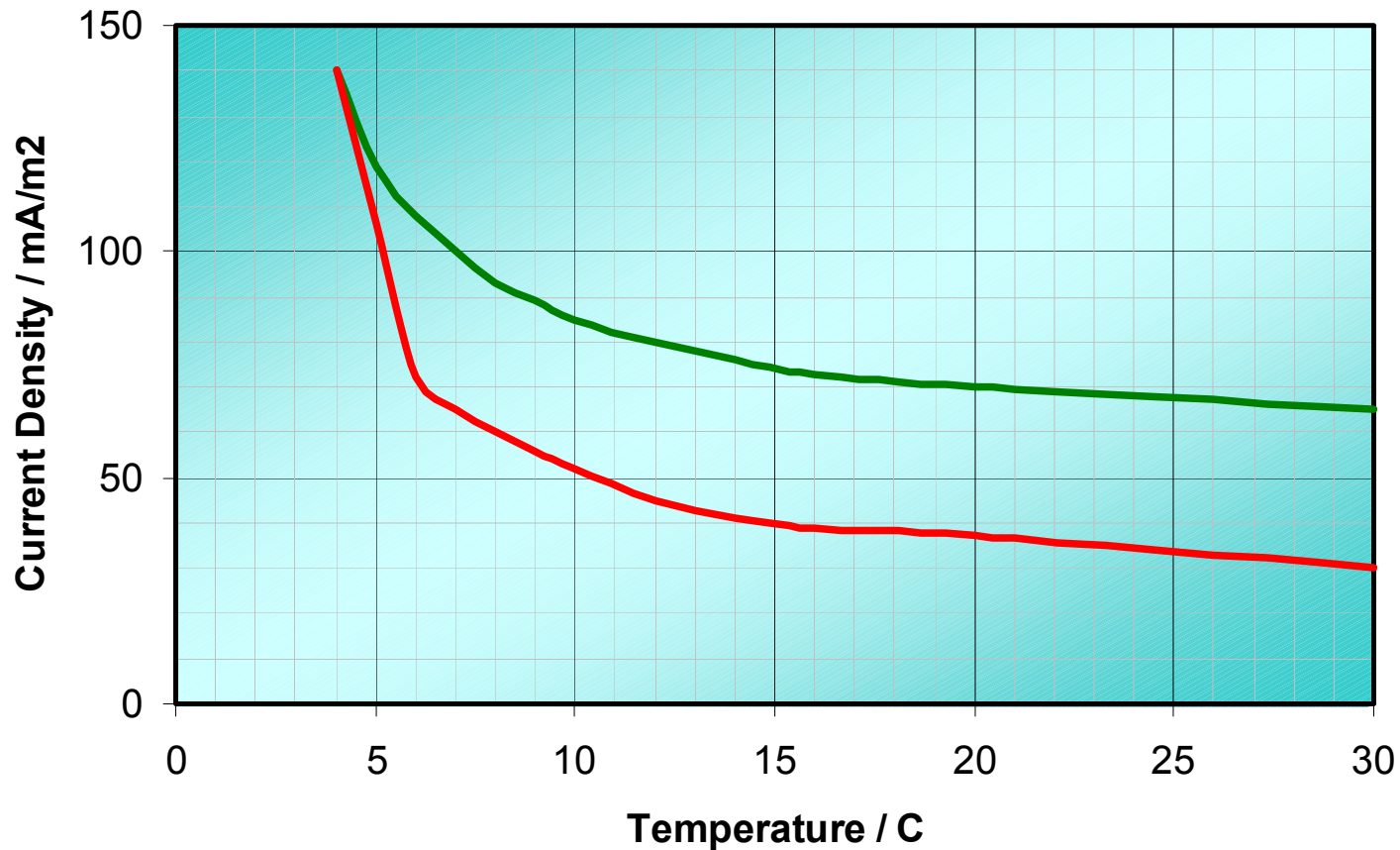
WELDED







BASE MATERIAL





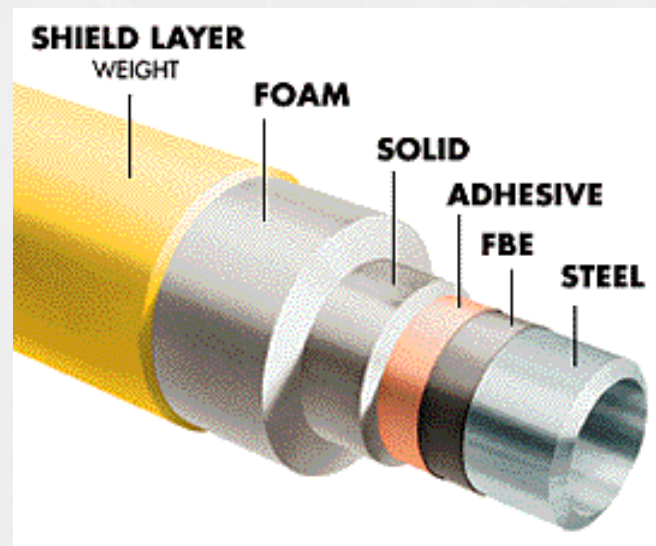
Current Density Given by the Draft ISO Standard.






-  **The design criteria not relevant for coating systems for insulated pipelines**
-  **Anode attachment detrimental to HISC for SMSS pipelines**
-  **Present coating breakdown factors (Norsok M-501) not in accordance to insulation requirements for flow assurance**
-  **The ISO values are based on operational experiences**

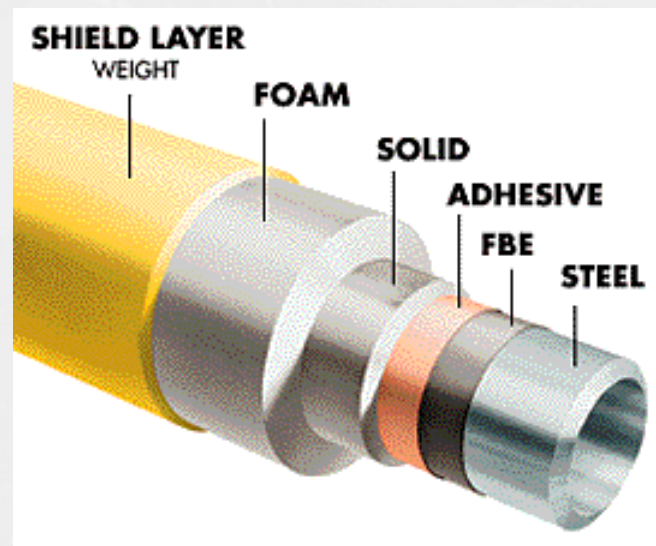
 For some later projects concerns have been expressed regarding the coating performance at high temperatures

-  Higher temperatures may increase the coating degradation
-  A higher coating breakdown was recommended to compensate for this effect



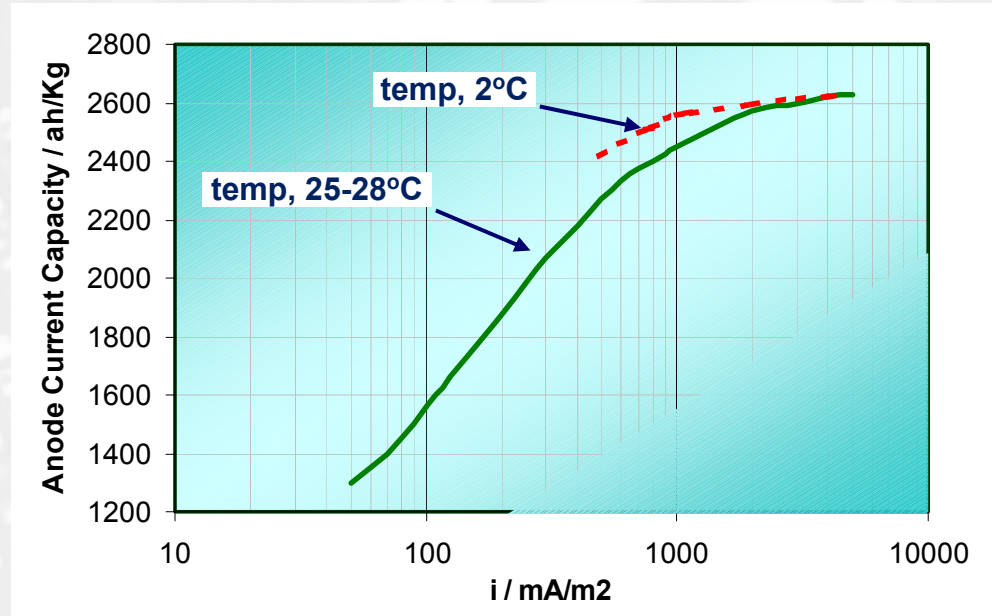
 **The coating qualification indicates that it is adequate for the intended service**

-  The main suspected coating failure is disbonding and degradation of the FBE layer due to the high temperature
-  Of special concern will be if the disbonding results in any circulation of seawater beneath the intact coating. This can result in severe corrosion of the SMSS material if the high IR drop will not give adequate CP
-  An increase in the coating breakdown factor will however not compensate for the IR drop and this type of coating degradation



Current capacity and Design Calculations

$$M = \frac{A_c \times 8760}{u} \int_t i_c \times f_c \times (1/\varepsilon) dt$$

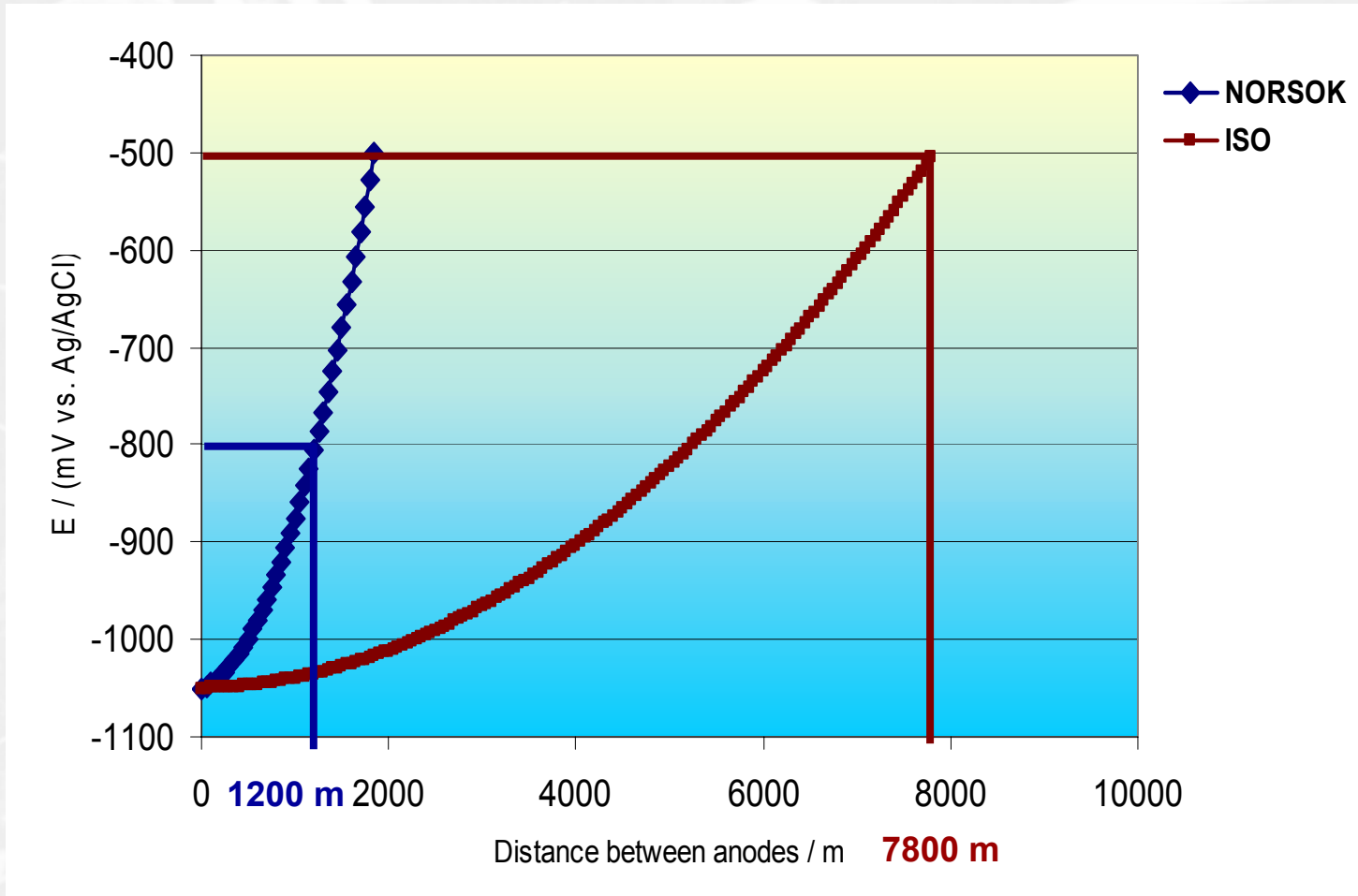


$$\Delta E = \frac{L^2 \cdot \rho \cdot i \cdot f_c \cdot D}{4 \cdot d \cdot (D - d)} + \frac{R_{Anode} \cdot i \cdot \pi \cdot D \cdot f_c \cdot L}{2}$$

Pipe wall

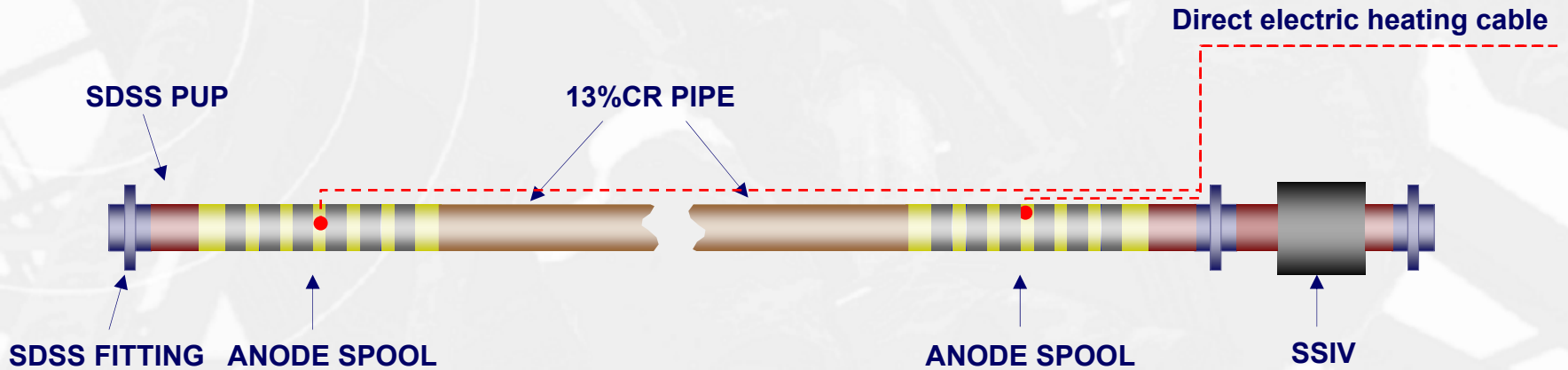
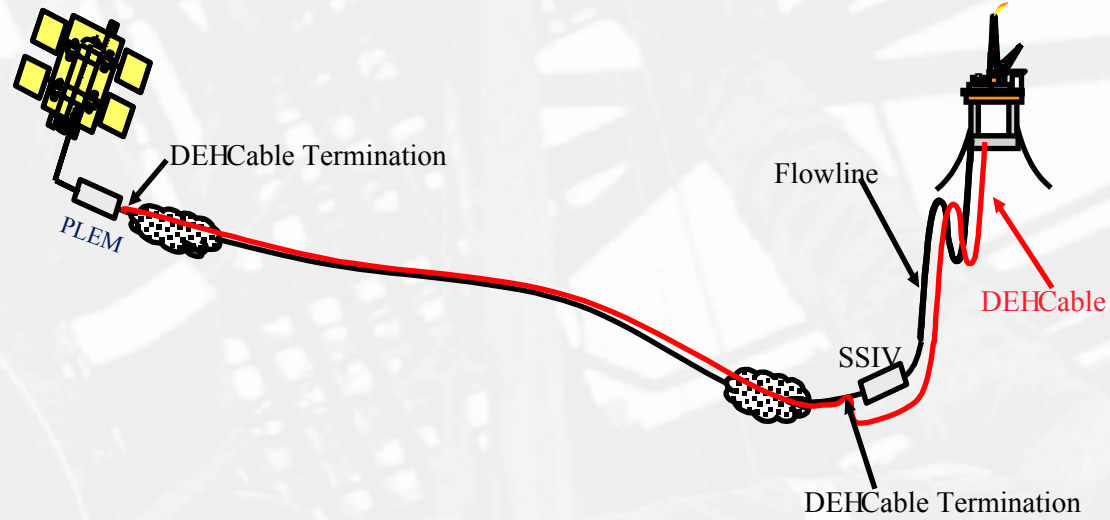
Close to the anode

Example of Protection Distance

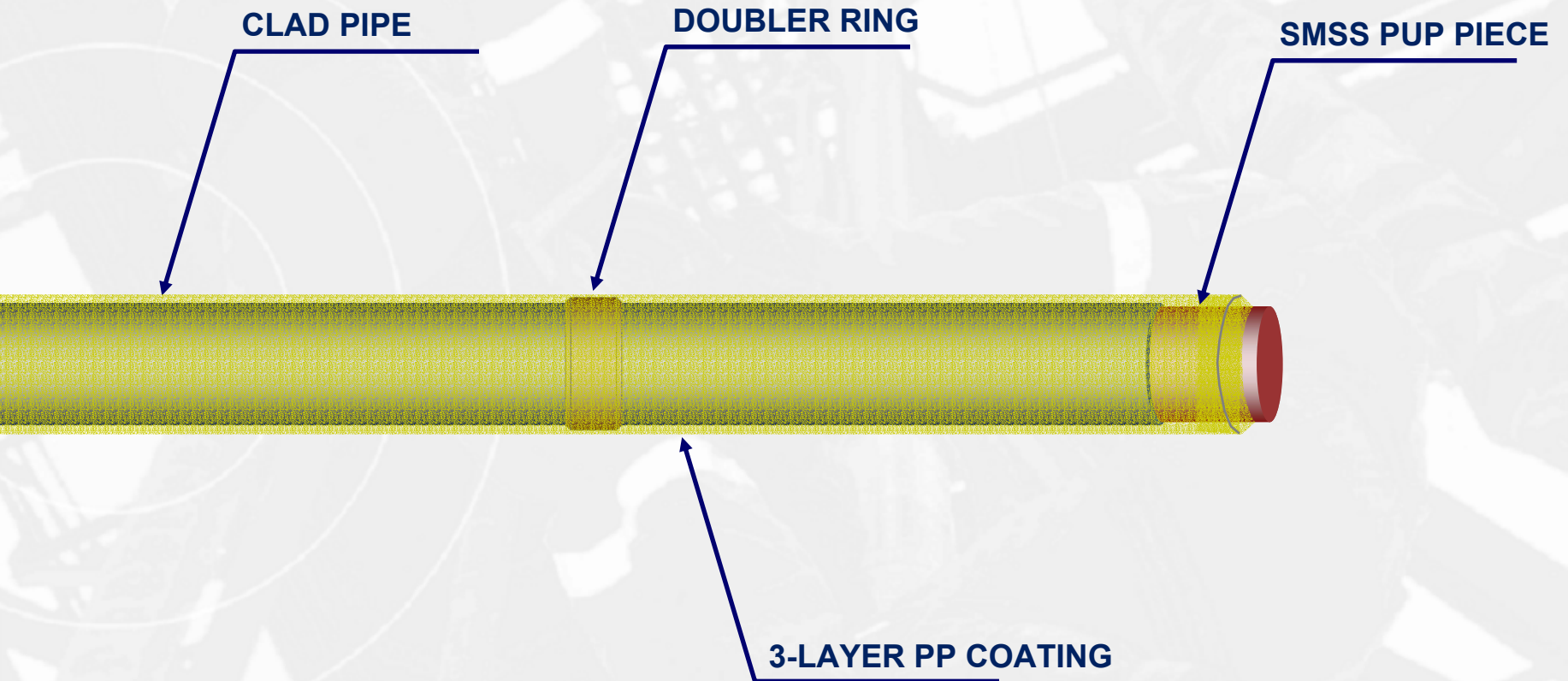


High alloy steel

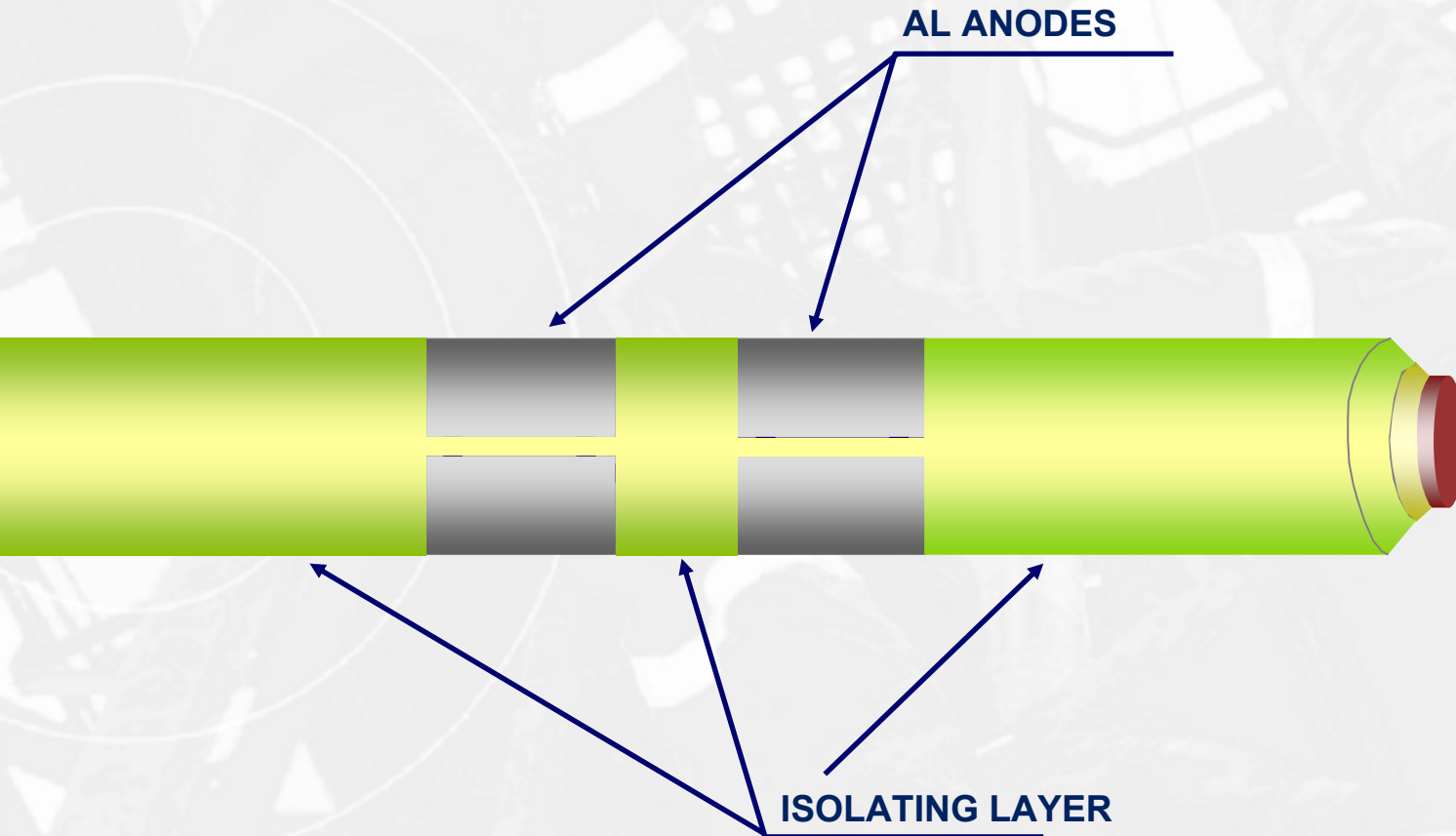
Overview of System



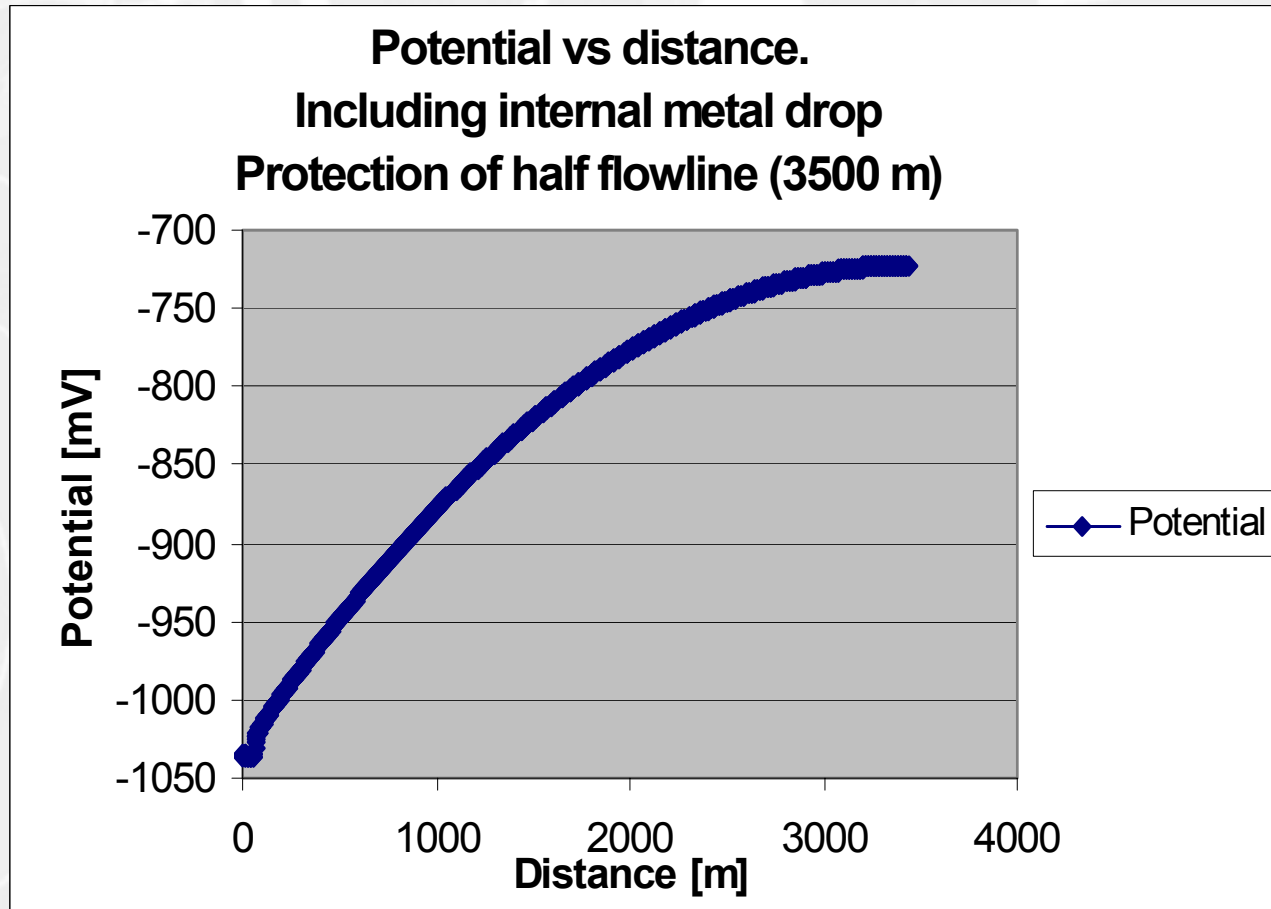
Anode Spools



Anode Spools

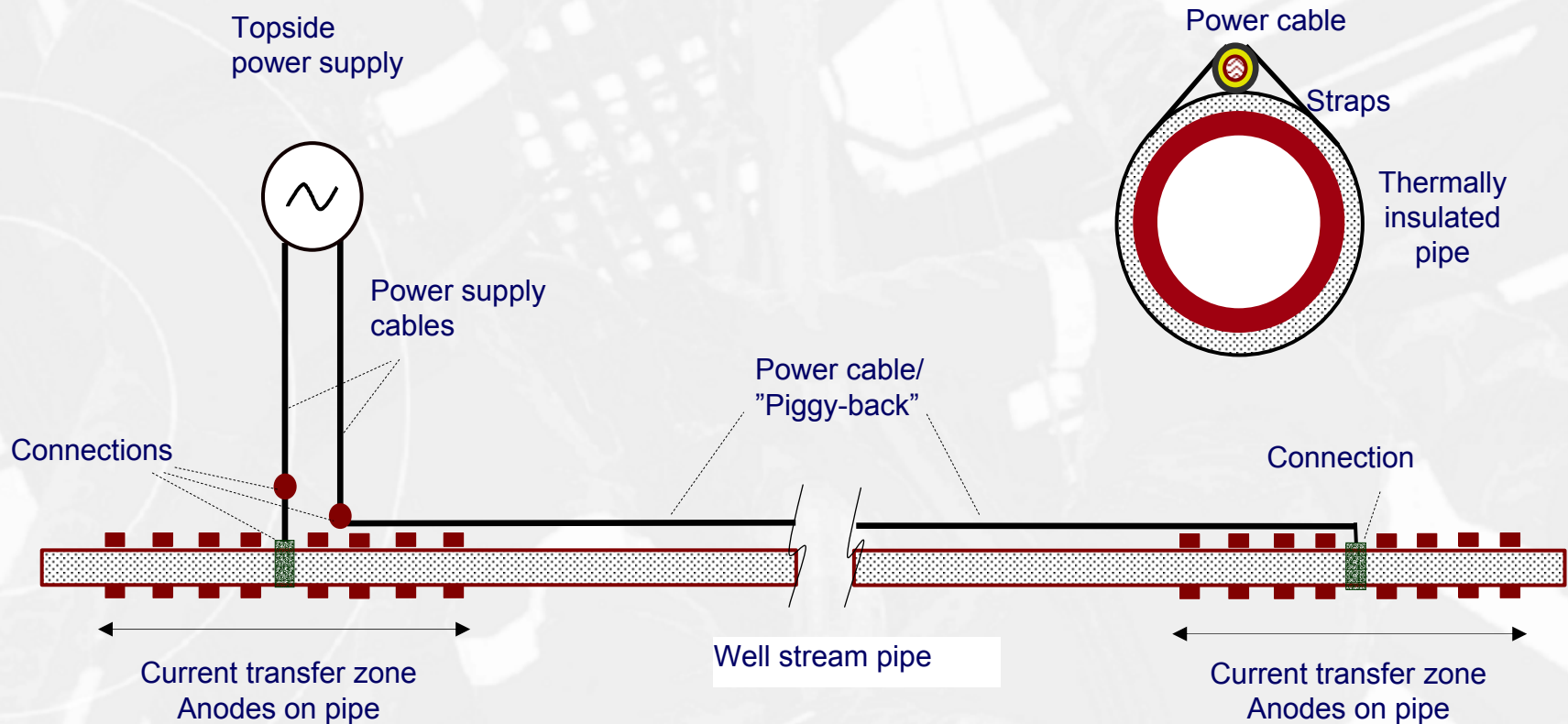


Verified Potential Profile







General Design Outline




- ✓ Steel wall of pipeline is an electrical conductor
- ✓ Heat generated by resistive current losses
- ✓ Typical heat generation 70 – 150 W/m



HISC for thermally insulated pipelines with SMSS materials can be controlled by:

-  Selection adequate materials and welding procedures
-  Reduce global strain to maximum 0.4 %
-  Qualified fabrication procedures
-  Apply the new CP concept

The new CP concept

-  Implement the new ISO criteria
-  Using the anode spool arrangement
-  Continue to qualify the concept with reduced polarisation

For installation in 2004 the new CP concept will be used for 4 projects