AECL EACL

WASTE PACKAGE DEGRADATION EXPERT ELICITATION REVIEW

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1. Define the most likely evolution in the repository environment

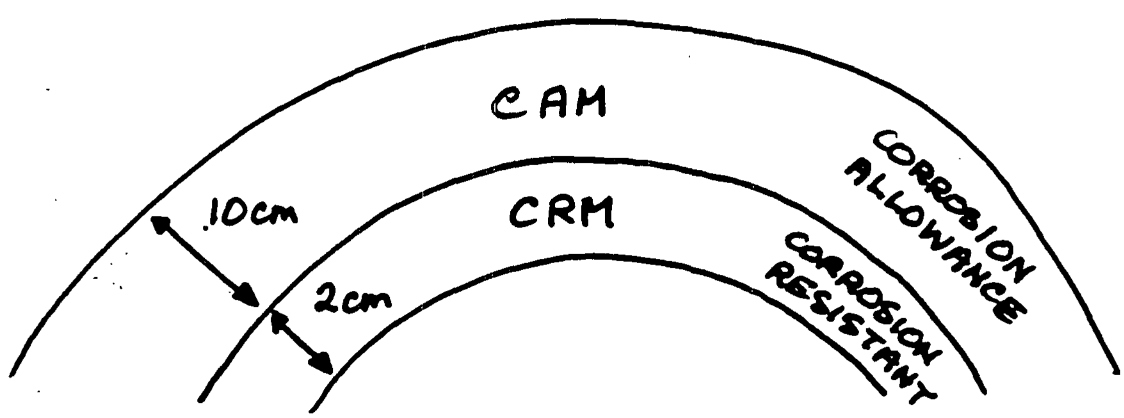
2. Outline the most likely corrosion scenario

3. Specify the procedure for modelling each corrosion process

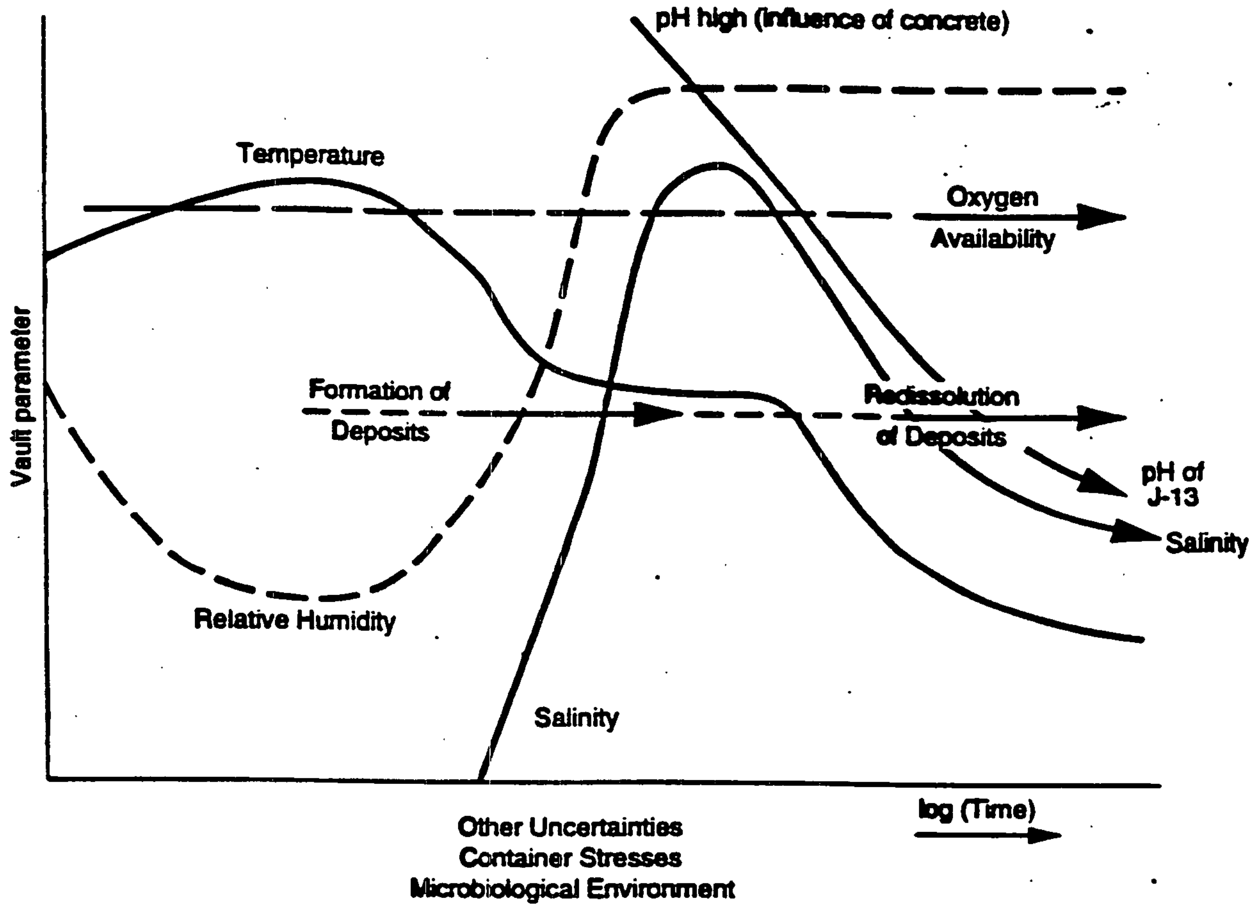
4. Establish criteria for model assumptions and decisions

5. Procedures to address dangerous scenarios

6. Options for avoiding dangerous scenarios



Evolution in Repository Environment



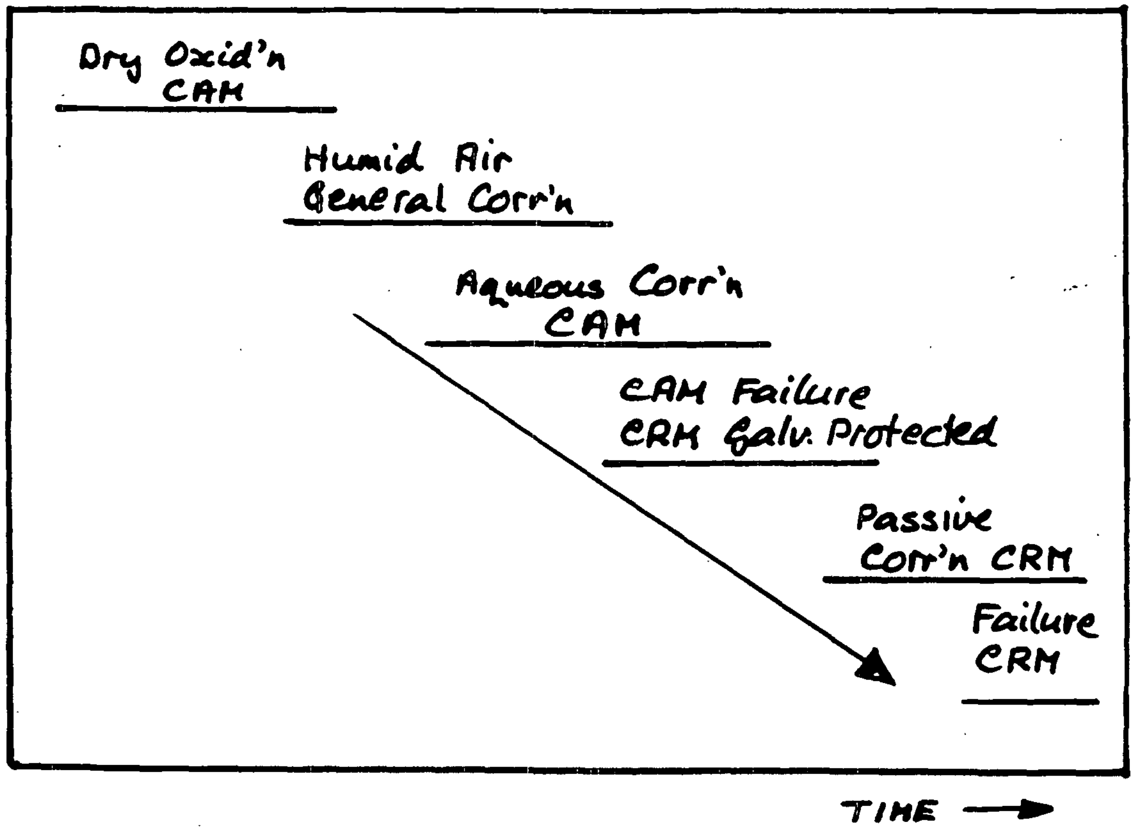
The "No Drip" Scenario

- neutral pH
- no deposits
- low to negligible salinity

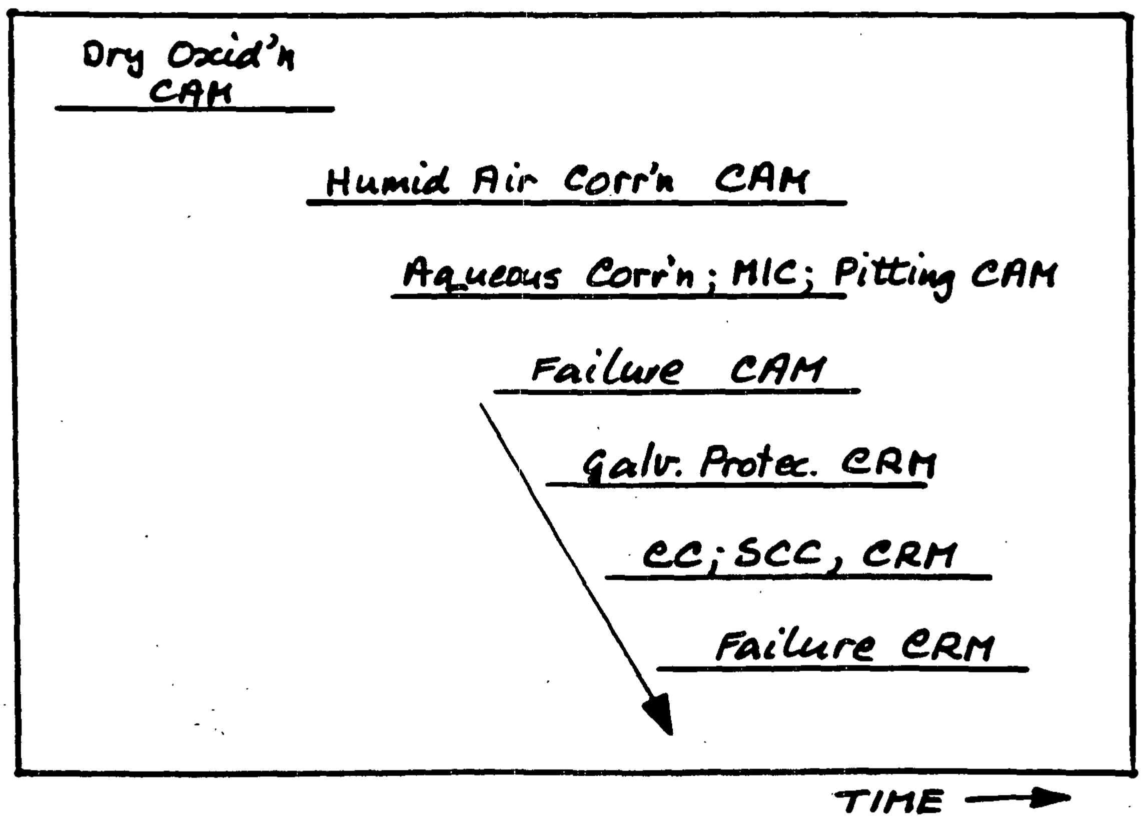
The "Drip" Scenario

- elevated pH
- enhanced salinity
- deposits

"NO DRIP" CORROSION SCENARIO



"DRIP" CORROSION SCENARIO

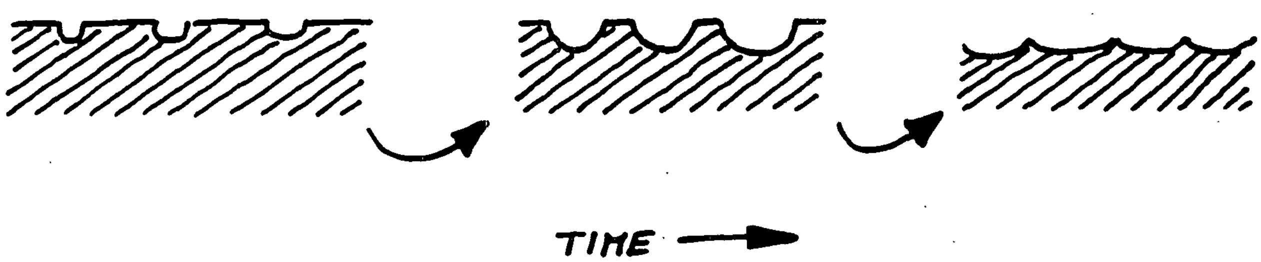


CAM Corrosion in the Absence of Drips

Negligible dry oxidation for relative humidities (RH) < 60%

T_{THRES}	Humid Air/Aqueous Corrosion	110±10°C
RH_{THRES}	Humid Air Corrosion	65-75%
RH_{THRES}	Aqueous Corrosion	85-95%

Even if pitting is initially involved, the hemispherical growth of a large density of pits will lead to their coalescence into a rough general corrosion front

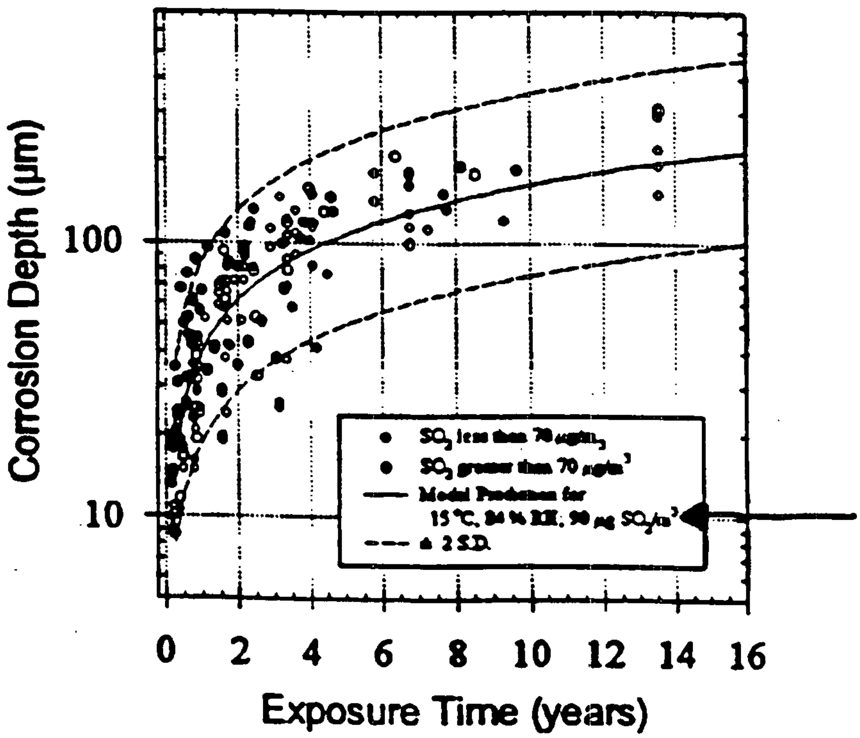


No need to include a pitting factor.

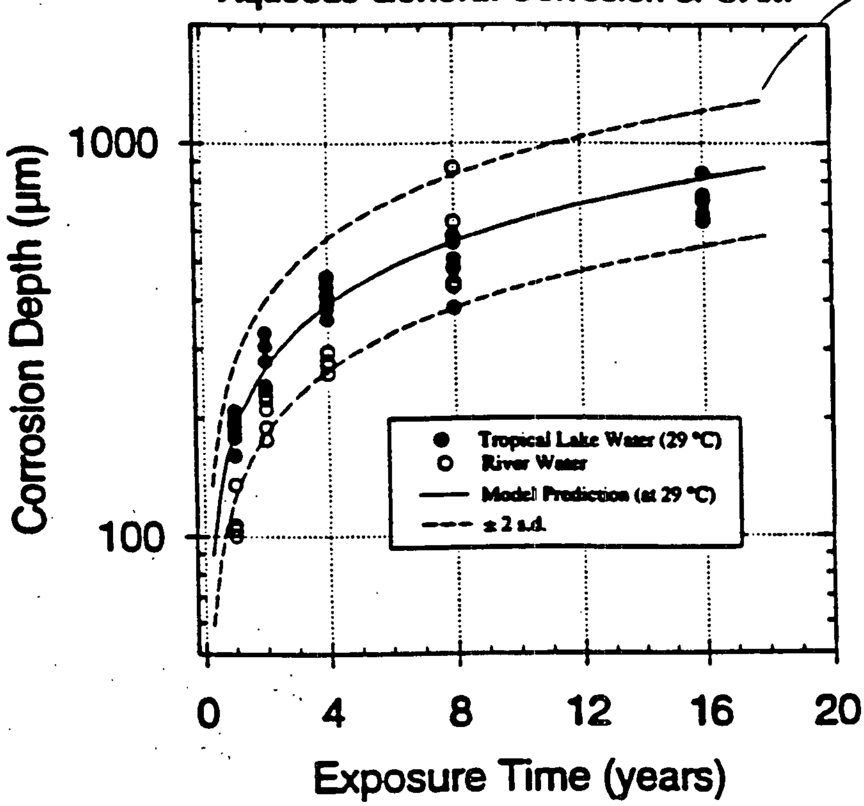
Use TSPA-95 approach but replace the pitting factor with a roughness factor as specified by McCright

THE TSPA-95 DATABASE FOR THE CORROSION OF CARBON STEEL IS EXTENSIVE.

General Corrosion of CAM in Humid Air



Aqueous General Corrosion of CAM

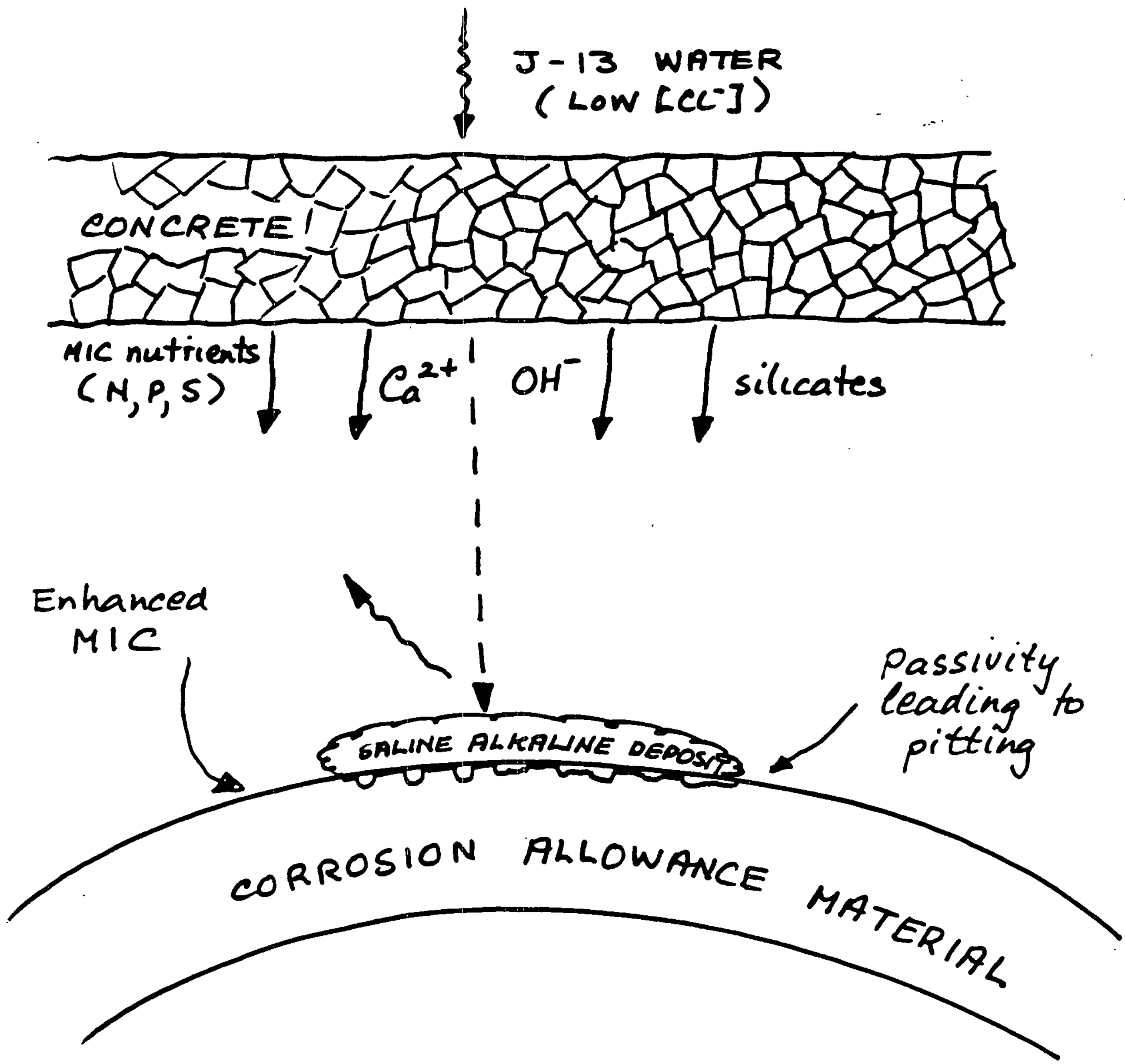


Possibility of Corrosion Enhancement by spallation of protective corrosion product

Judicious to include MIC factor

In the absence of drips, the influence of MIC should decrease with time.

THE PROBLEM WITH DRIPS



SOME KNOWLEDGE OF DRIP VOLUME / FREQUENCY / DISTRIBUTION REQUIRED

ENGINEERING SOLUTIONS ?

DRIP SHIELD ; BACKFILL ; TITANIUM

For the Alkaline Conditions Established by Drips

Passivation of carbon steel could occur leading to the probability of pitting

Use a growth law not a pitting factor

$$p = kt^n \qquad p\text{ - depth} \qquad t\text{ - time}$$

to describe pitting.

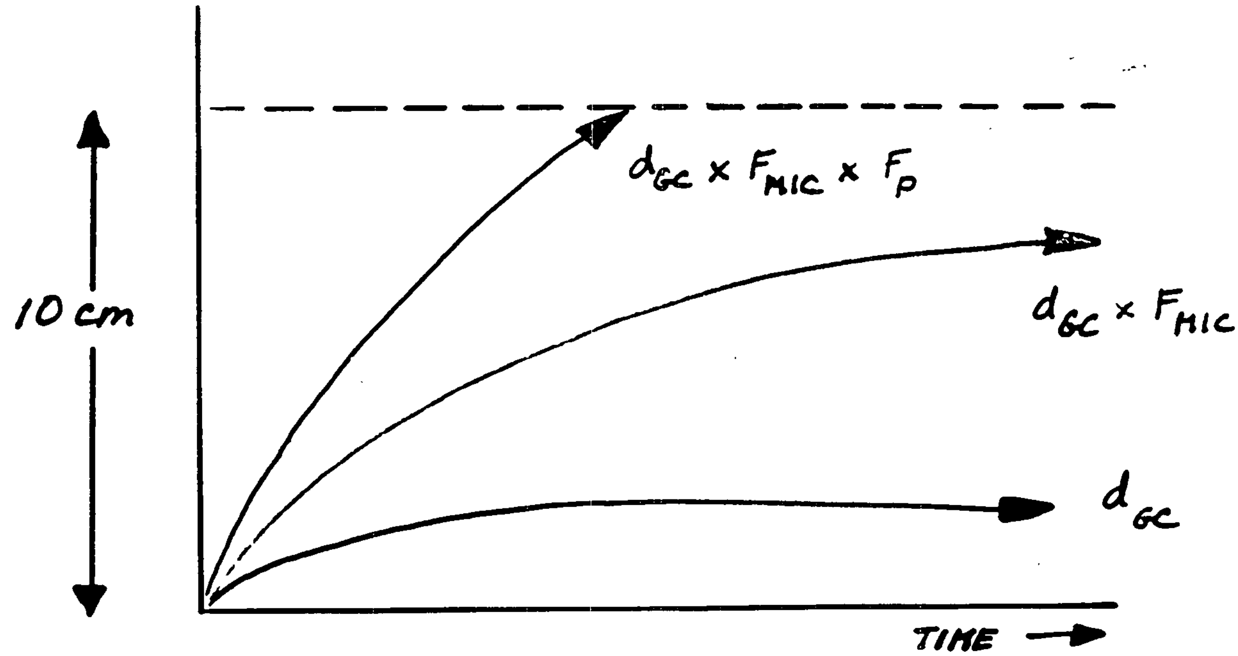
Other influences can be expressed in k (T, $[SO_4^{2-}]/[Cl^-]$)

Pitting will eventually stop as the concrete becomes "washed out" and the pH returns to neutral

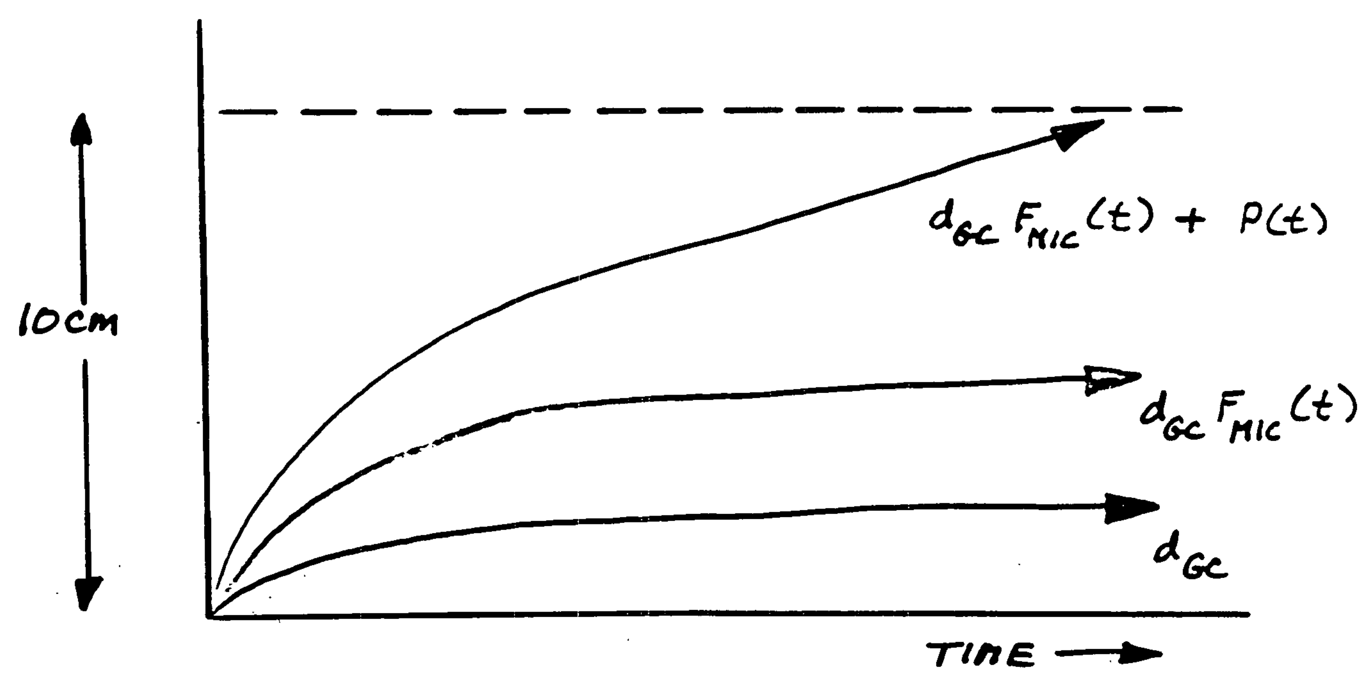
Since nutrients supplied by drips, MIC persists for the lifetime of the CAM

General corrosion rate should be multiplied by the MIC Factor (~4) for the lifetime of the CAM

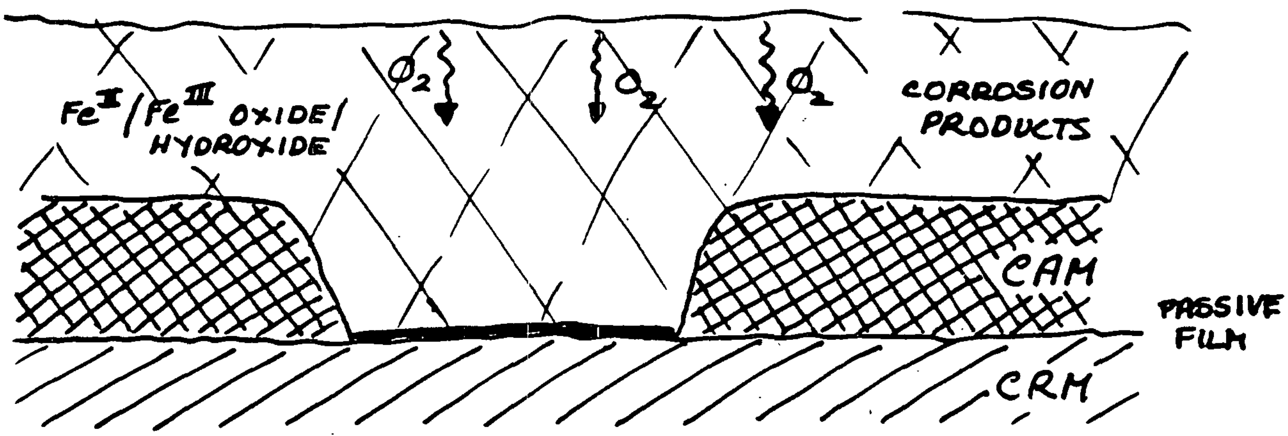
TSPA - 95 SCENARIO FOR CAM CORROSION



WPDEE - 97 SCENARIO FOR CAM CORROSION



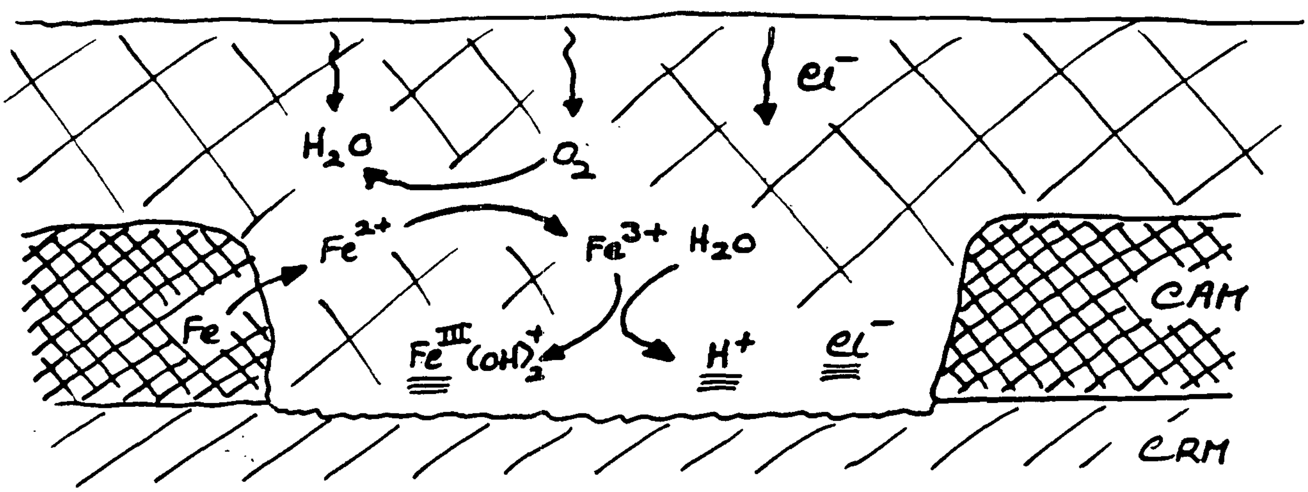
Failure of the CAM Will Expose the CRM



In the absence of water provided by drips, the CRM will undergo slow passive corrosion

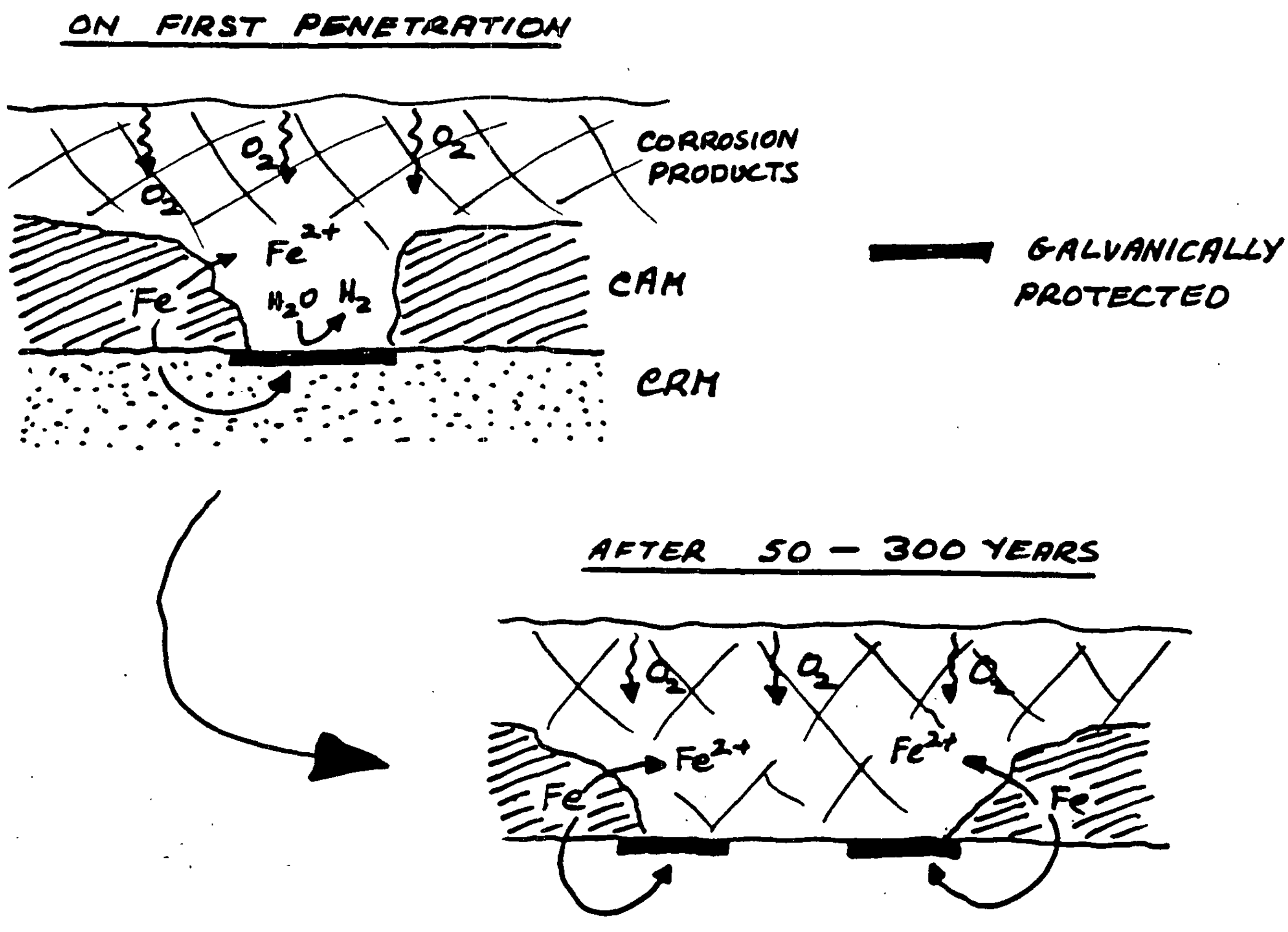
Passive corrosion rate ~0.1μm/year (50 - 100°C)

In the presence of water an aggressive acidic Fe^{III} chloride solution could be formed at the surface of the CAM



The establishment of such conditions could render the CRM susceptible to localized corrosion but could also provide a degree of galvanic protection.

What galvanic protection is gained may soon be lost.



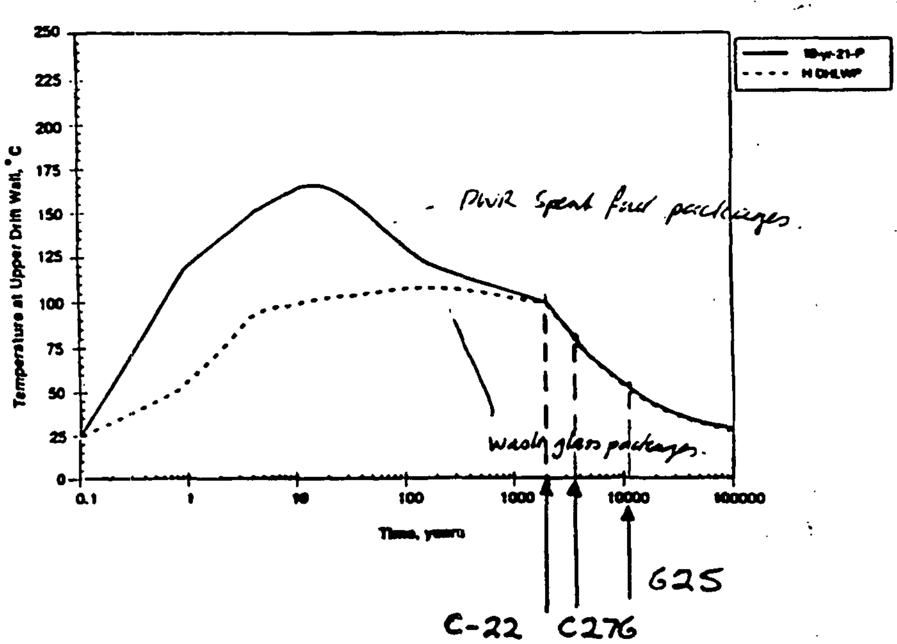
Crevice Corrosion Is the Most Likely Degradation Mechanism for the CRM

In the absence of good databases for the crevice corrosion of candidate CRM, conservative criteria should be established to assess the likelihood of crevice corrosion

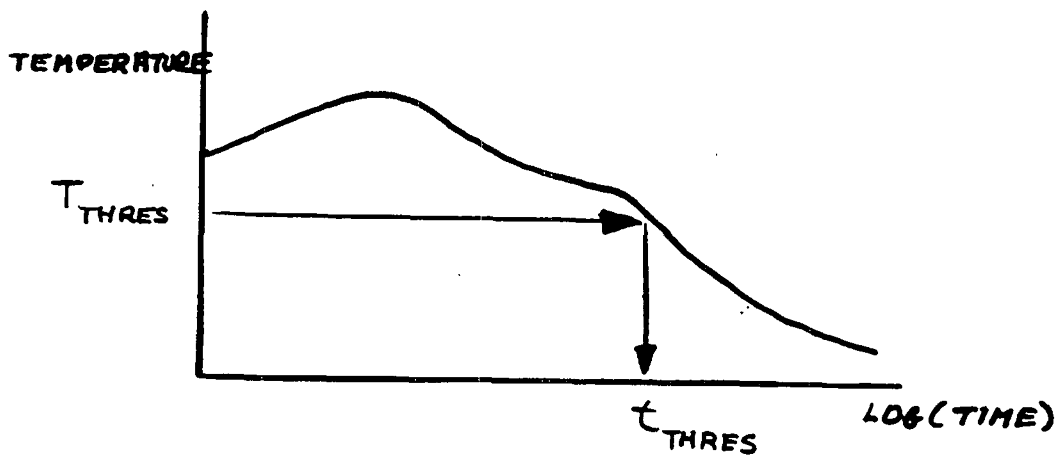
Alloy	Critical pitting temp (°C)	Critical crevice-corrosion temp (°C)
C-22	>150	102
C-276	150	80
625	90	50
825	25	≤-5
Type 316 stainless steel	20	≤-5

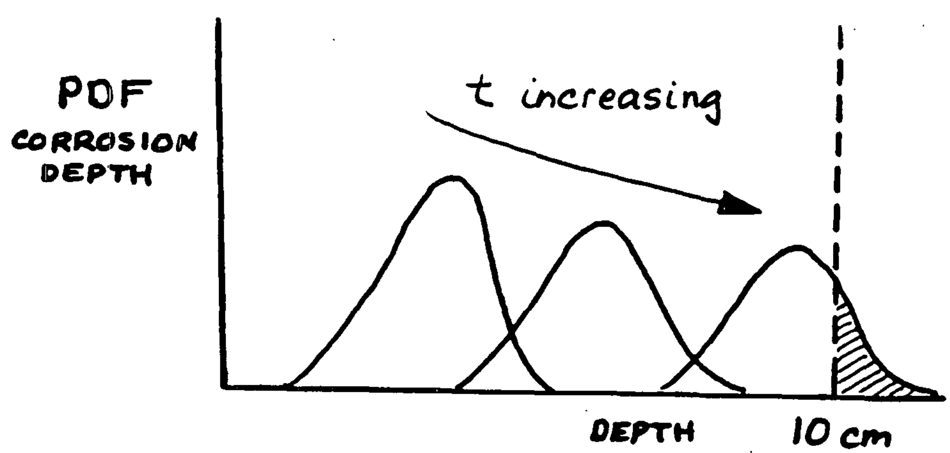
Solution: 4% NaCl + 0.1% $Fe_2(SO_4)_3$ + 0.01*M* HCl; 24,300 ppm chlorides; pH = 2.

These critical values can be used to determine the CAM lifetimes required if localized corrosion of the CRM is to be avoided



These temperature/time thresholds can be used with the distribution in penetration depths calculated for the CAM to predict whether each individual failure site in the CAM will, or will not, initiate a crevice



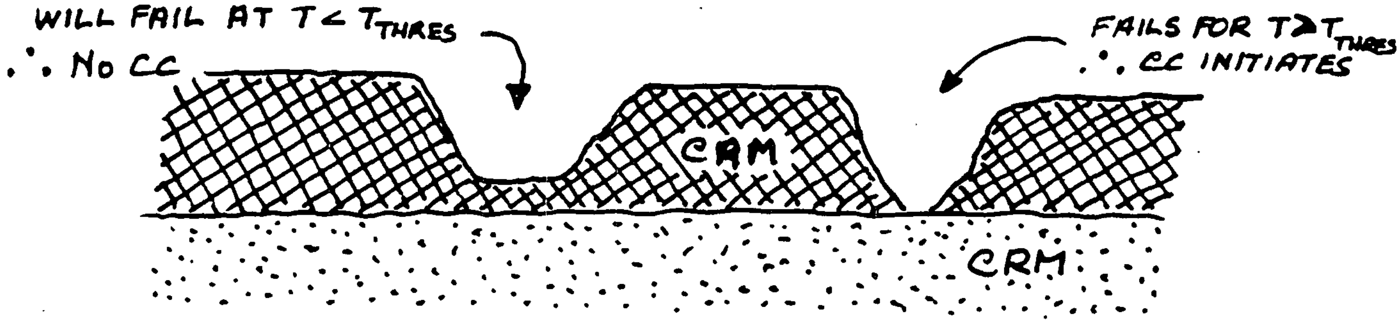


FOR EACH INDIVIDUAL FAILURE SITE IN THE CAM.

At $t = t_F$ $T_F < T_{THRES}$ CC DOES NOT INITIATE

$T_F > T_{THRES}$ CC DOES INITIATE

This Procedure Will Provide A Distribution of Crevice Initiation Times



For $T_F < T_{THRES}$ at $t = t_F$ for the CAM

CRM will corrode passively and long lifetimes will ensue

For $T_F > T_{THRES}$ at $t = t_F$ for the CAM

Crevice corrosion will initiate and proceed with a growth law similar to that used for the pitting of the CAM

$$p = kt^n$$

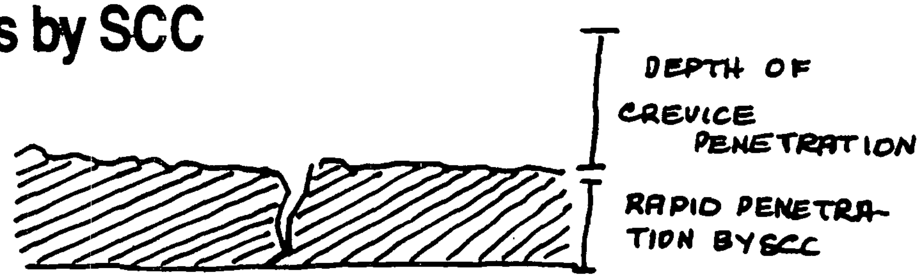
Such laws are generally not available for the candidate materials

(A conservative penetration law is available for Ti-2 studies)

Crevice Corrosion Scenarios

Worst Case

Crevice corrosion propagates to a certain depth and then rapid failure occurs by SCC

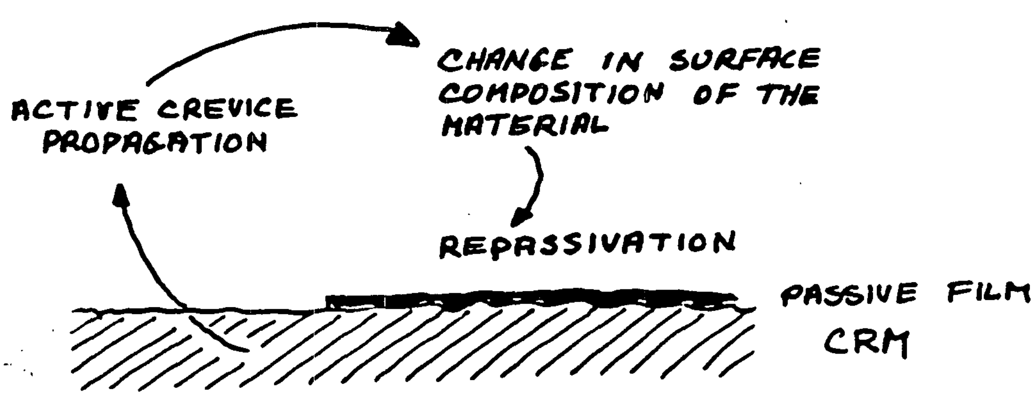


Conservative Case

Crevice corrosion propagates to failure

Realistic Case

Crevice corrosion propagates for a limited period since the compositional and metallurgical properties of the chosen material eventually enforce repassivation



Alternative Corrosion Allowance Material

Generally, not a good idea to switch to Monel 400

- expensive
- poor database (cf to carbon steel)

Not recommended unless the carbon steel outer barrier cannot be shown to last long enough to protect the CRM from localized corrosion

Why not contemplate the use of a titanium outer barrier?

- unaffected by drips
- does not suffer MIC
- thick wall not required

Microbially Influenced Corrosion

In the absence of drips the influence of MIC should be limited by the supply of nutrients

- multiply the CAM general corrosion rate by an MIC factor which decreases with time

In the presence of drips the supply of nutrients could be enhanced

- multiply CAM general corrosion rate by MIC factor until failure
- note corrosion may be intermittent if wet/dry cycles prevail

The candidate CRM materials are generally not susceptible to MIC

- even if they were, MIC would lead to the initiation of localized corrosion but no enhancement of its propagation (Little)
- the influence of MIC can, therefore, be ignored in an already conservative corrosion scenario

Summary and Requirements

1. A much better understanding of the movement of wate in the repository is required.

2. The database for carbon steel is good and prediction c its behaviour is possible.

3. The absence of a good database for the candidate corrosion-resistant materials means a conservative modelling approach is required. These conservatisms can be lifted as more data becomes available.

4. Care should be taken not to over-emphasize the effect: of MIC.