Analysis of CDT Methods and Factors Affecting Cathodic Disbondment :

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Outline

- Introduction
- Selection of Representative Standards
- Experimental:
  - Comparative CD testing
  - Analysis of the most important factors affecting CD Process
- Analysis and Discussion of the results
- Conclusions
- Acknowledgements

Introduction – 1.

Corrosion protection of buried/immersed structures is based on:

- Cathodic Protection (CP) and
- Barrier coating, which is critical for reduction of CP-current and expenditures related to the CP

Introduction – 2.

- An important criterion in selection of a barrier coating is its performance in the CD test.
- Due to specific variations in design of CDT Standard Methods, the same coating may produce very different results.
- This work is an attempt to prepare a basis for comparison of CDT ratings obtained by different Standard Methods.

Selection of representative CDT Standard Test Methods

The selection was based on the following principles:

- All CDT Standard Methods have a common theoretical ground
- They are based on qualitatively identical group of Parameters and Procedures (or Factors)
- Many can be grouped under the same method

Selection Criteria

The selection criteria included:

- Voltage specified
- Temperature
- Duration
- Electrolyte composition
- Anode separation
- Vessel type

Review of Selected CDT Standard Methods

Standard	Voltage	Temperature	Solution	Duration
	[V]	[°C]	[aqueous]	[days]
CSA Z-245	1.5 or 3.5 V	Selection	3 % NaCl	Selection
ASTM G8	1.5	RT	Triple salt	Selection
ASTM G42	1.5	Selection	Triple salt	30
ASTM G80	1.5	RT	Triple salt	60
ASTM G95	3.0	RT	3 % NaCl	90
ISO 15711	1.05	RT	Sea water	182
AS 3862	3 mA	Selection	3 % NaCl	Selection
NF A 49-711	1.5	Selection	3 % NaCl	Selection

Notes: 1. Selection means multiple choices.
2. Triple salt solution is 1/1/1% of $NaCl/Na_2CO_3/Na_2SO_4$.

Experimental Design

CD tests were run with two 2-component liquid epoxy materials:

- Superior coating **α** and
- Inferior coating **β**

- Selecting 800 - 900 µm thick coatings
- Using 65°C & 28 days whenever possible
- Maintaining the Voltage daily
- Controlling the Current draw
- Using an impressed current system, which delivered stable CP-power

Results

Standard	Current	Temp.	Duration	Disbondment [mm]	
	[mA]	[°C]	[days]	Coating α	Coating β
CSA Z-245	5 - 7	65	28	2 - 4	11 - 14
ASTM G8	20 - 25	RT	30	2	6
ASTM G42	40 - 55	65	30	4 - 5	8 - 14
ASTM G80	20 - 25	RT	60	2	6
ASTM G95	25 - 30	RT	90	5	15 - 25
ISO 15711	0.9 – 1.1	RT	182	7.5	13.5
AS 3862	3 mA	65	28	2 - 3	10 – 13.5
NF A 49-711	3 - 5	65	28	2.5 - 3	5 - 6

Notes: 1. The current draw corresponds to one sample being tested.
2. The coatings were 800 to 900 µm

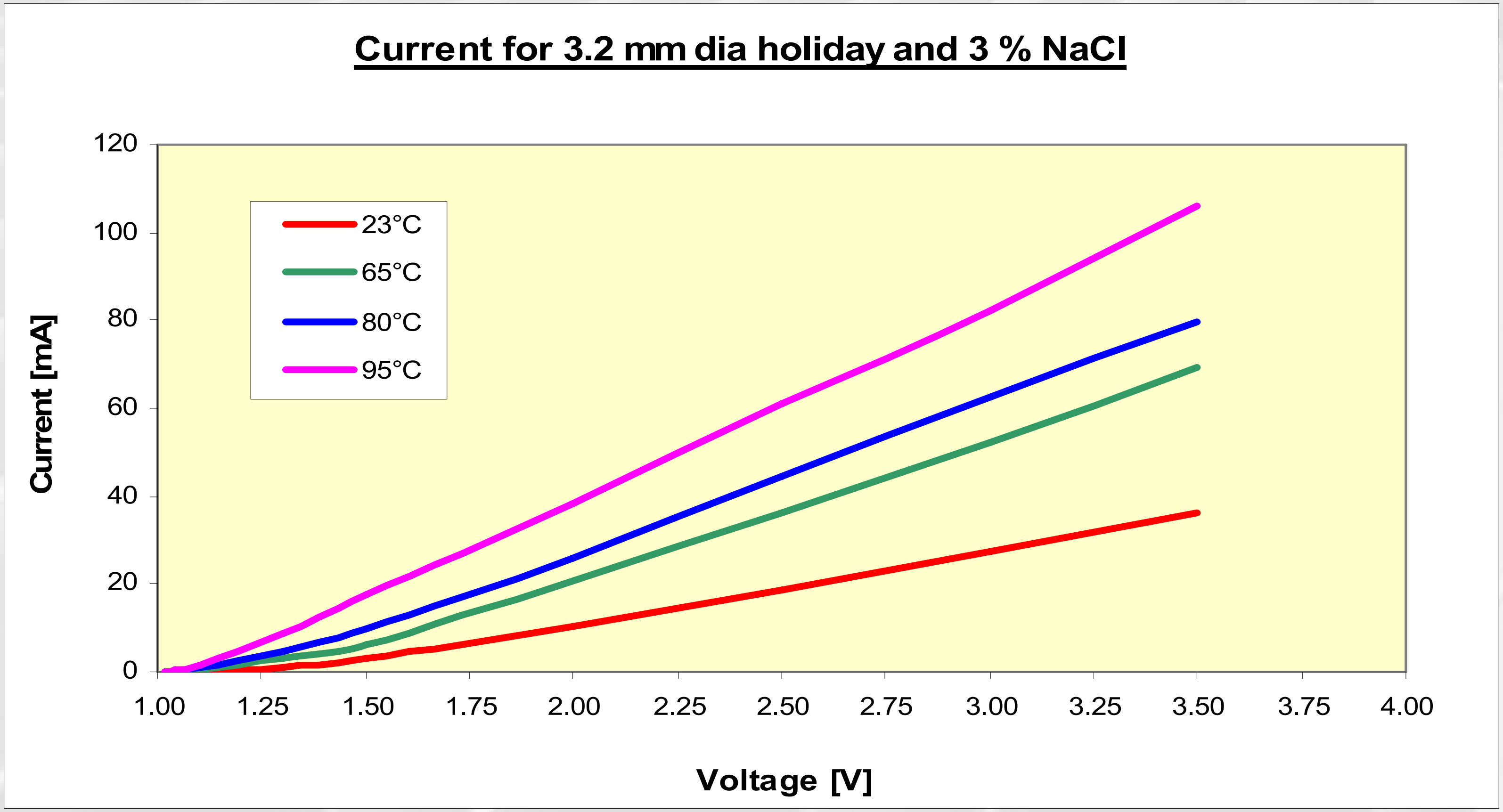
Factor analysis - 1

The work was focused on clarifying the problems encountered with:

- Voltage application in the CD cell
- Measurements with SCE
- Inter-relation of Voltage & Current draw
- Inter-relation of Current draw with Holiday size & Electrolyte type

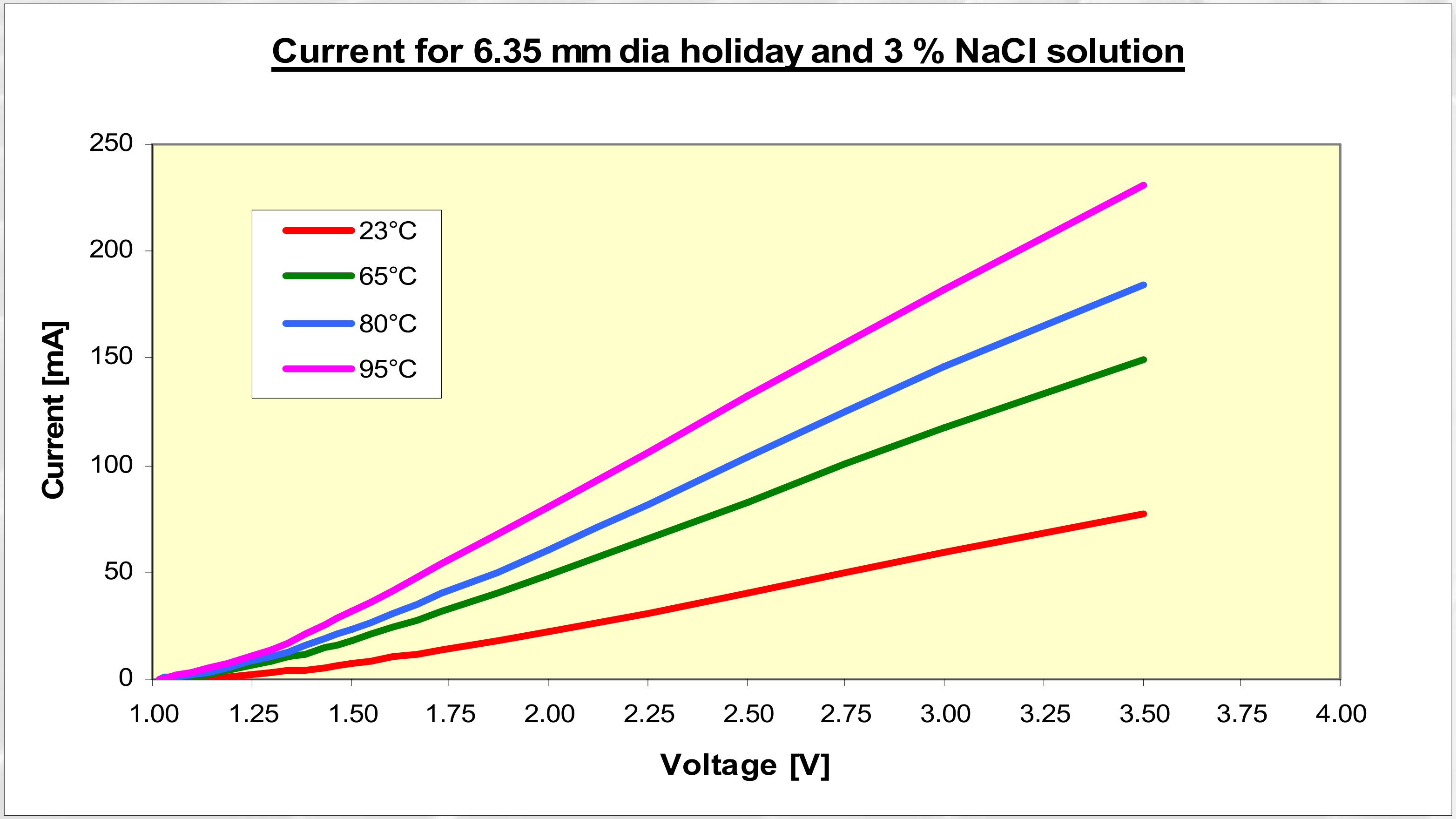
Current Developments

Figure 1: Current drawn by a 3.2 mm holiday in a cell filled by a 3 % NaCl solution:



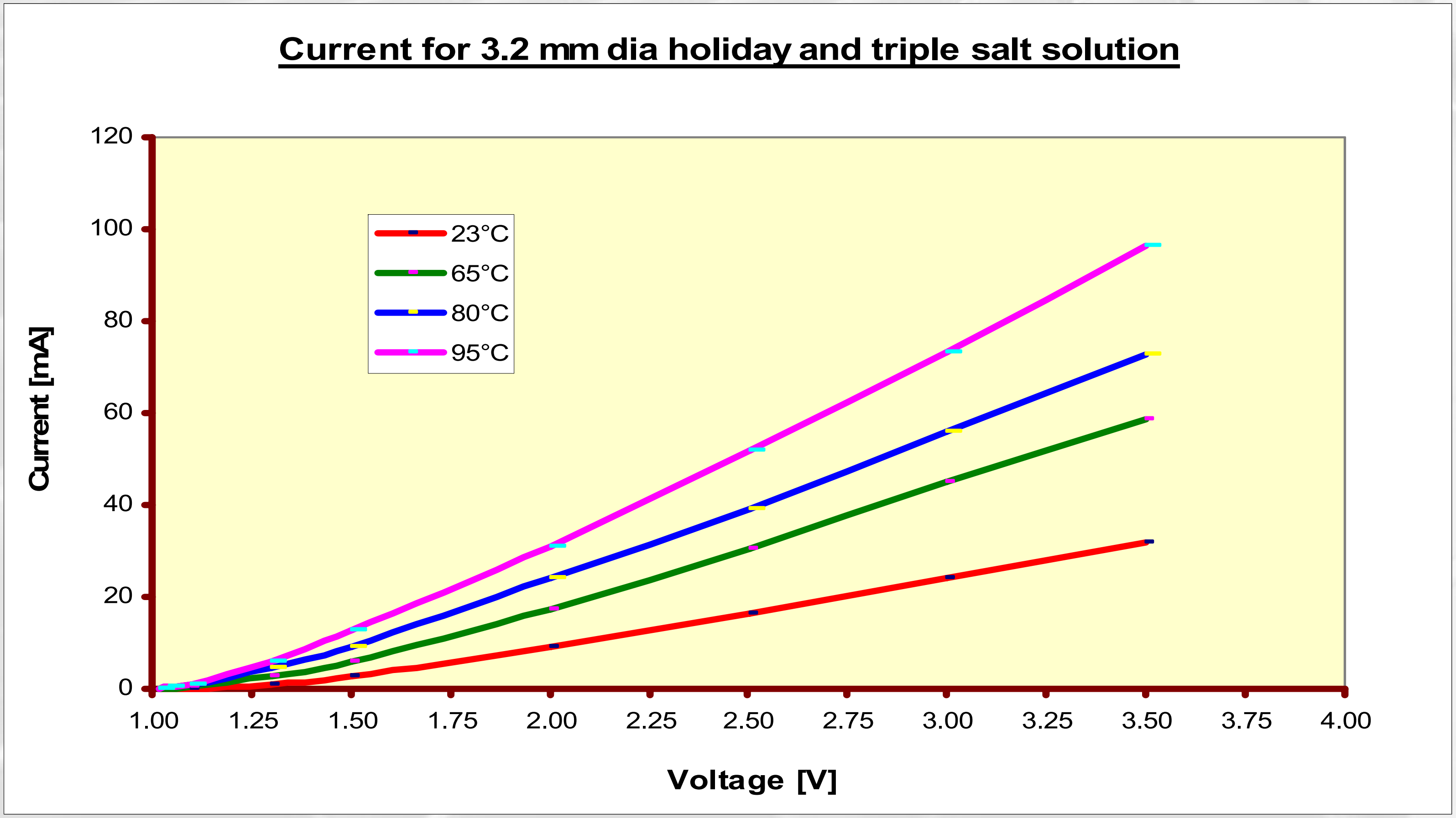
Current Developments

Figure 2: Current drawn by a 6.35 mm holiday in a CD cell filled by a 3 % NaCl solution:



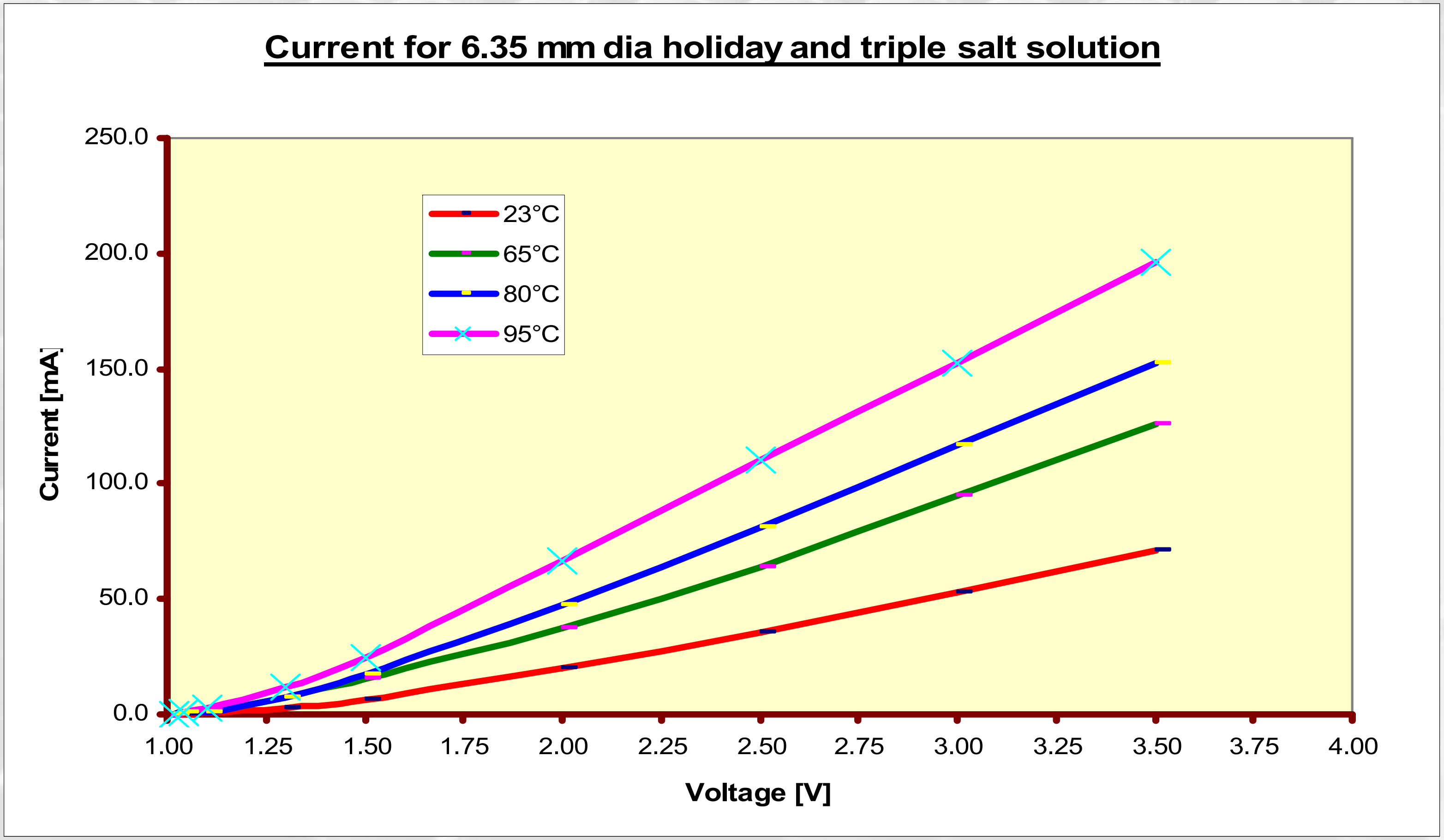
Current Developments

Figure 3: Current drawn by a 3.2 mm holiday in a CD cell filled by triple salt solution:



Current Developments

Figure 4: Current drawn by a 6.35 mm holiday in a CD cell filled by triple salt solution:



Current Effects - A:

Current converts chloride into chlorate [1]

[1] $Cl^- \rightarrow ClO^-$

Chlorate concentration depends on total Current Load passing through unit volume during the test [2]

[2] C.L. [mC/ml] = 96.5 * I * t / v

where **I** [mA], **t** [sec], **v** [cm^3]

Current Effects - B:

The amount of ClO^- generated can be calculated as per equation [3]:

[3] Cl_2 [gr] = 0.02306 * I * t

where - **<u>I</u>** is current intensity in [mA]

and **<u>t</u>** is time in [days]

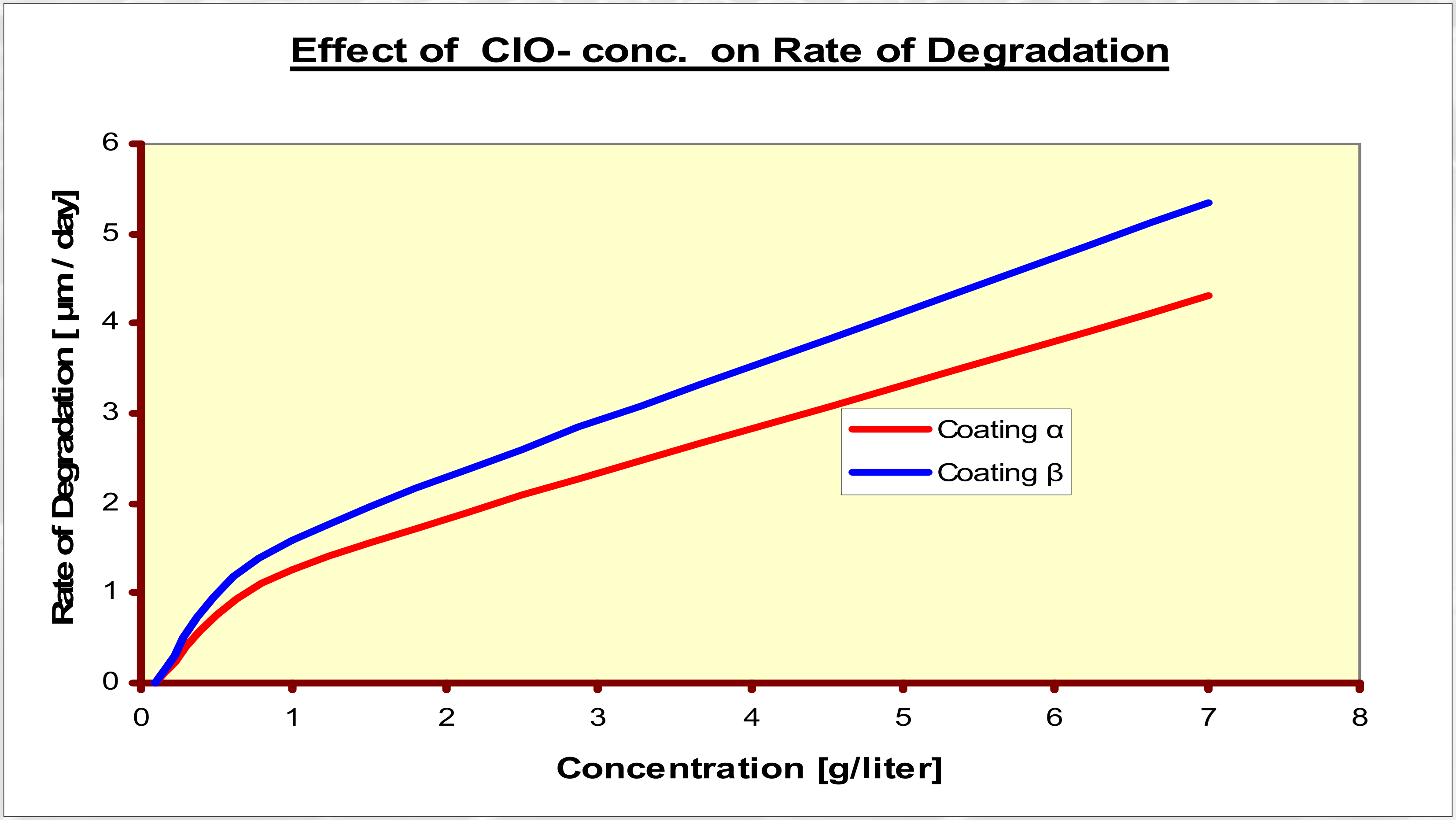
Factor Analysis - 2

Further factors analyzed include:

- Coating thickness effects
- Chlorate effect on coating removal
- Temperature effect on current draw (coating conductivity) and transport phenomena
- Interface oxide removal under very high pH conditions

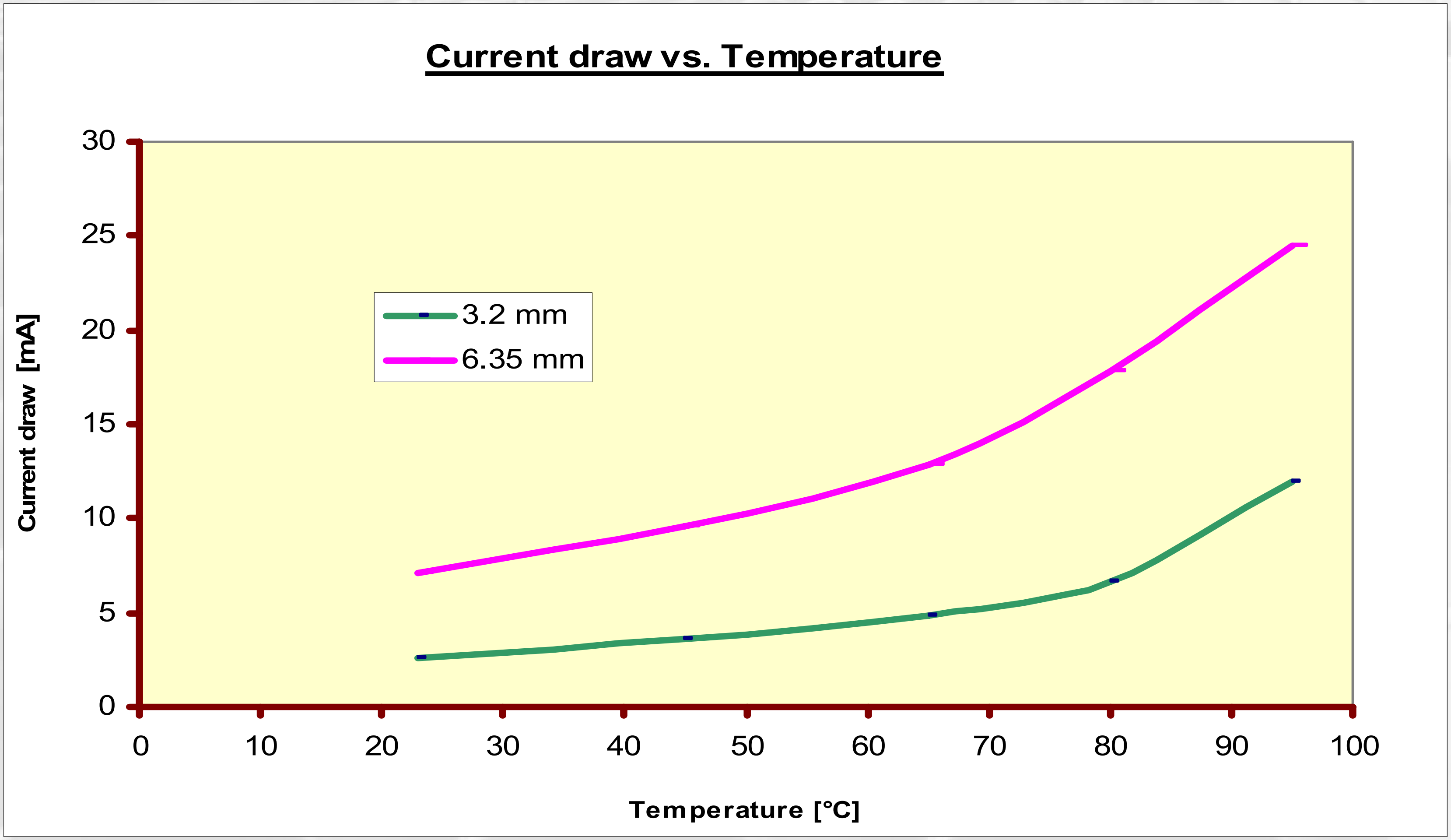
Coating Degradation by ClO-

Figure 5: ClO^- driven degradation of barrier coating:



Temperature Effect on Current

Figure 6: Effect of the temperature on Current Draw:



Factor Analysis - 3

Procedures were performed in an uniform manner:

- The disbondments were measured as Disbonded Distance not Disbondment diameter
- Six equal tests were run and the extreme results disregarded
- The parameters to be analyzed were properly separated in specific tests

Discussion of CDT Results - 1.

CD results obtained with similar Standards fell within experimental error if:

1. The conditions such as Temperature, Voltage and Duration were equal

2. The coating's thickness was equal

3. An extreme accumulation of chlorate in the electrolyte was not present

Discussion of CDT Results - 2.

Varying results were produced by Standards which specified parameters such as:

1. Low voltage & long duration ISO-15711
2. High voltage & long duration ASTM-G95
3. Separate anode AS-3862

These results are not readily comparable with the results of the tests run at 1.5 V vs. SCE

Discussion of CDT results - 3.

Distribution of the disbondments obtained with identical test conditions illustrates the effect of other factors, such as:

1. Local coating inhomogeneities
2. Increased porosity due to degradation of the coating's surface
3. Substrate contamination

Discussion of CDT results - 4.

Variance of CD results caused by local inhomogeneities, porosity and substrate contamination can be minimized by:

1. Running multiple equal tests

2. Daily control of the test parameters

Discussion of Experimental Results - Factor - 1.

1. Current is directly proportional to Voltage, Temperature, size of the holiday (Figures 1,2,3,4,6).

2. Position of the Calomel electrode is not very sensitive to voltage measurement in highly conductive electrolyte (except within 1 cm of the holiday).

Discussion of Experimental Results-Factor-2.

3. Other Factors, such as Electrolyte volume, Frequency of electrolyte change, Duration, Anode separation and Current load affect Chemical stress and resulting degradation of the coating (Figure 5).
4. Coating thickness affects transport of liquid water, water vapor and ionic species through the coating.
5. Temperature accelerates all physical and chemical processes in the CD cell.

Discussion of Experimental Results – Factor - 3.

CD is directly caused by:

- Dissolution of interface oxides as indicated by the silvery portion of the disbonded area
- Transport of water and ionic species through the coating and along the interface
- Osmotic pressure of water

Results - 1.

A series of comparable CD tests showed that:

1. CDT Methods using 1.5 Volts vs. SCE produce similar disbondments when run with identical temperature & duration
2. AS/NZS' methods with separated anode give slightly reduced disbondments due to lower voltage/current being used
3. CDT Methods using less than 1.1 V vs. SCE generate inconsistent results

Conclusion

Further analysis of specific Factor showed, that:

1. Anode separation alone will not result in reduction of the disbondment

2. Coating thickness and Current Load should be specified when comparing CD performance of different coatings

Acknowledgements

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