A review of state of the art in Corrosion under insulation (CUI) testing

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December 2015, Al-Jubail

The absence of test data

Minimal mention of test protocols

No mention of pre-qualification

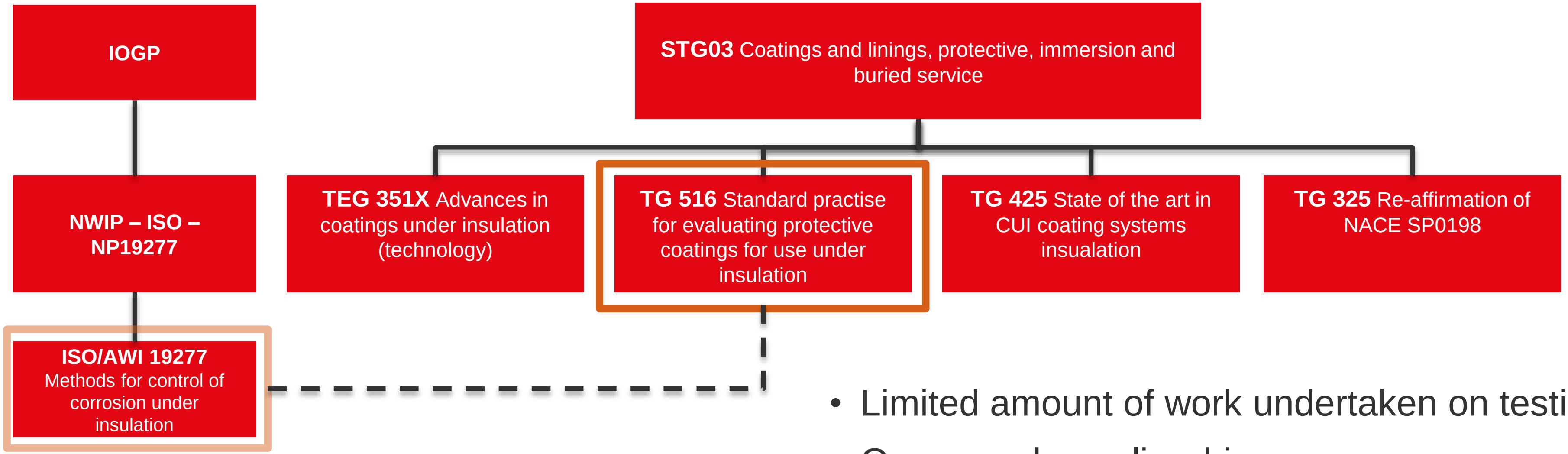
CUI is addressed in a number of test documents

- NACE SP0198 Control of corrosion under thermal insulation and fire proofing – A systems approach
- EFC Corrosion under insulation guideline (WP13 and WP15)
- API 583 Corrosion under insulation and fireproofing
- AGI Q151Corrosion protection under thermal and cold insulations at industrial Installations

- Owner specifications
- Supplier documentation and recommended test practises
- Conference papers and other materials

Testing Development

- NACE and ISO



- Limited amount of work undertaken on testing
- Owner and supplier driven
- Relatively slow to deliver results

CUI Testing and the contract chain

Concept | Feasibility study | Design | EPC phase | Operations

OWNER

ENGINEERING CO

ENGINEERING CO

EPC | FABRICATORS | COMMISIONING

OWNER

Long term performance

CUI performance

Performance under different conditions

Independent testing

Design limitations (min max)

Design simplification

Cost optimization (scheme thickness, no. of coats)

Cost optimization (scheme thickness)

Over-coatibility

Application sequence

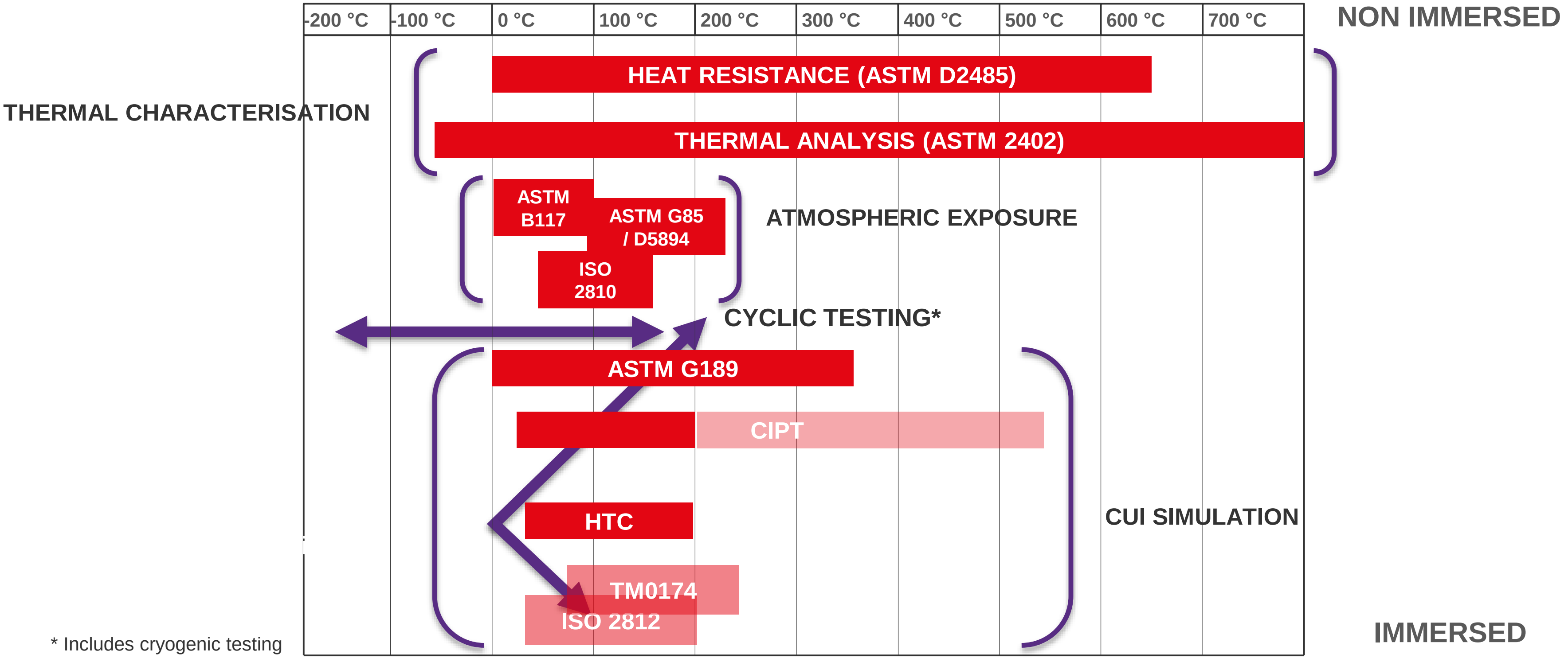
Physical durability

Repairibility

Hot application data (for maintenance paitning)

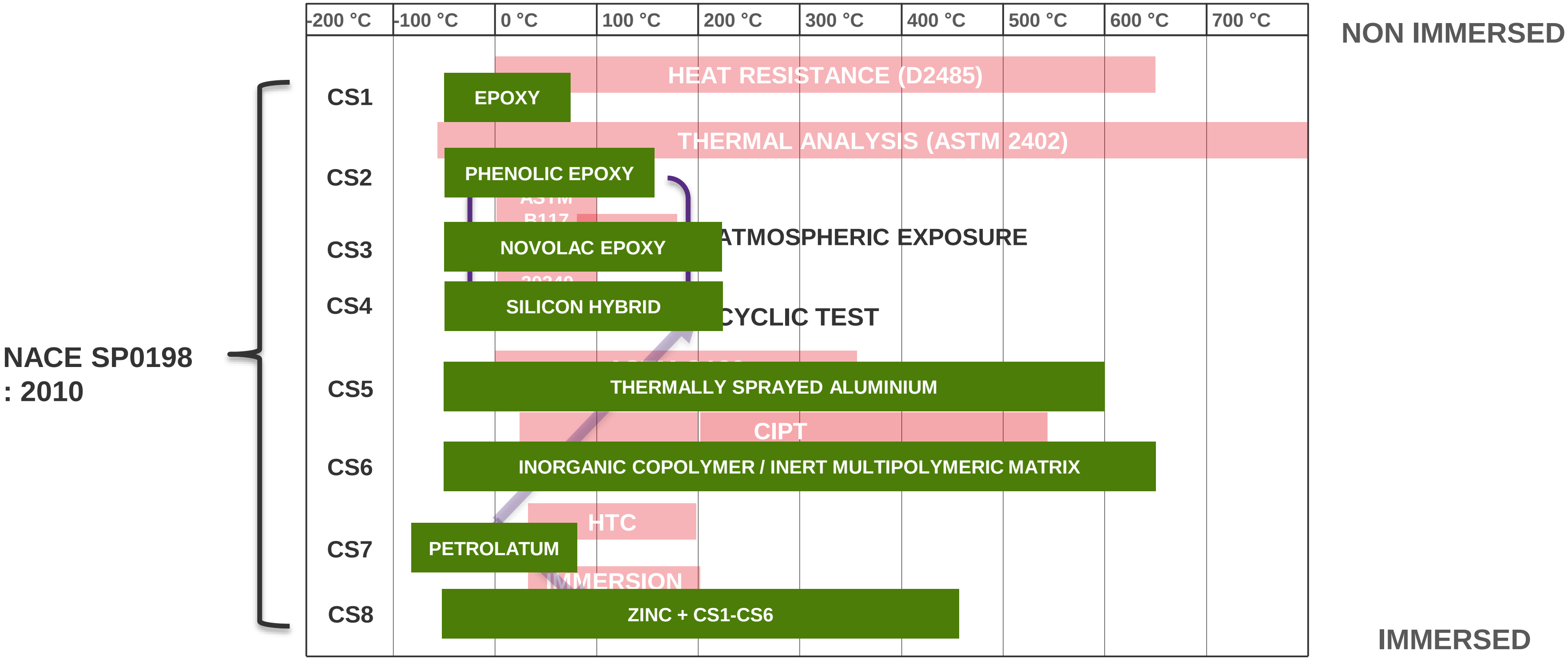
COATING SUPPLIER

Testing relevant to CUI



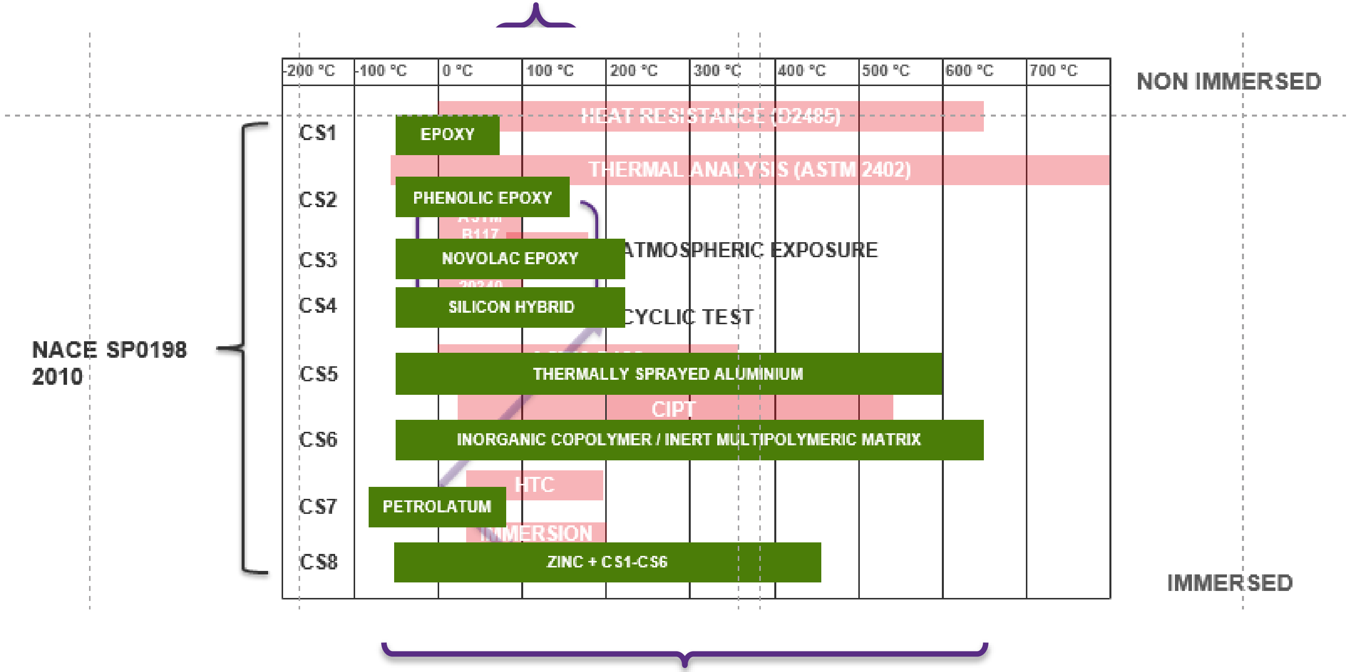
* Includes cryogenic testing

Influence of coating type on test relevance



Test relevance to objective

CUI PERFORMANCE



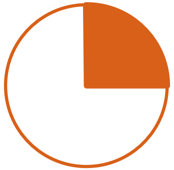
DESIGN LIMITS

What tests are in common use?

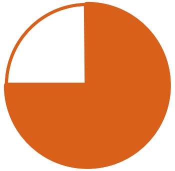
* Denotes a modified version	ASTM D2485	ASTM D2402 (TGA)	ASTM B117	ASTM G85 / D5894	ISO 2810	ASTM G189	CIPT	HTC	Cyclic	ISO 2812 (NACE TM0174)
Manufacturer A	✓*	✓	✓	✓	✓		✓		✓	✓
Manufacturer B	✓			✓	✓		✓		✓	✓
Manufacturer C						✓*				
Manufacturer D	✓	✓	✓					✓	✓	✓
Manufacturer E									✓	✓
Manufacturer F			✓				✓*		✓	✓
Operator 1						✓*				
Operator 2						✓*				
Operator 3	✓*		✓						✓*	✓*

Source: Review of web available test data November 2015.

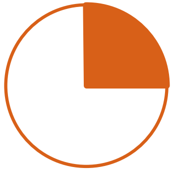
ASTM D2485



Cost

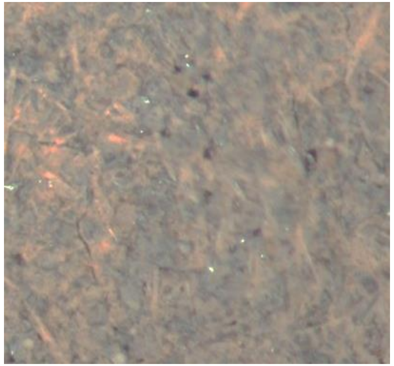


Ease of use



CUI relevance

- Test panels heated T°C
- Up to T_{max}
- Cooling i) air ii) water
- Visual inspection / mandrel test
- Corrosion test supplement
  - Usually ASTM B117 (salt spray)



Microscopic examination after ASTM D2485

Useful for

- Determining coating T_{max}
- Ensuring film condition < T_{max}

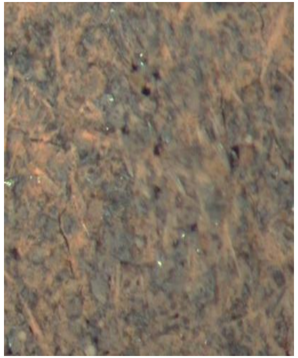
Watch out for

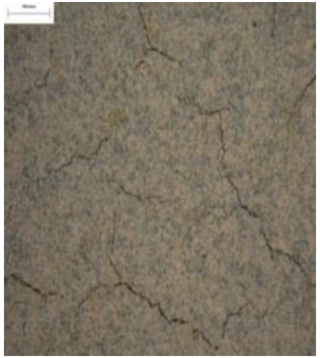
- Visual inspection insufficient
  - Corrosion screen also required
  - Microscopic inspection Temperature increase rate may affect results

ASTM D2485 (continued)

CS3 | **CS6**

- **Novolac Epoxy (2x 100 µm)**
- **High build silicone #1 (MIO) 1 x 150 µ**
- **High build silicone # 2 (MIO) 1 x 150 µ**
- **High build silicone # 3 (ALU) 1 x 150 µ**





- 250° C
- 650° C
- 400° C
- 300° C

Heating as per ASTM D2485 from 200°C to 650°C (250°C for Novolac epoxy, 450°C for #3 Alu) in 50°C increments every 24 hours. Visual and microscopic inspections between each interval.

ASTM D2485
- Supplementary corrosion screen

- **Thin film silicone**

- 650° C

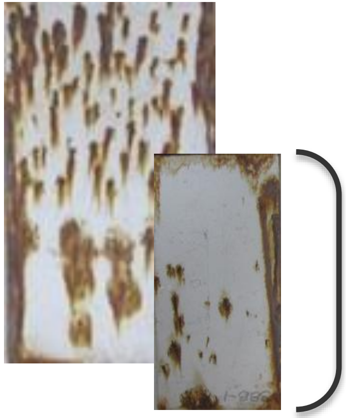
- **High build silicone #1 (MIO) 2 x 150 µ**

- 650° C

- **High build silicone # 2 (MIO) 2 x 150 µ**

- 650° C

- **High build silicone # 3 (ALU) 2 x 150 µ**

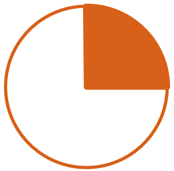


3 x 150 µ

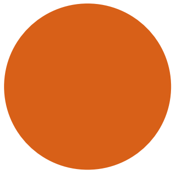
- 450° C

Samples exposed to 1440 hours salt spray following heating to 650°C (450°C for #3 Alu) as per standard ASTM B117.

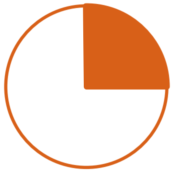
ASTM D2402 Thermogravimetric analysis



Cost

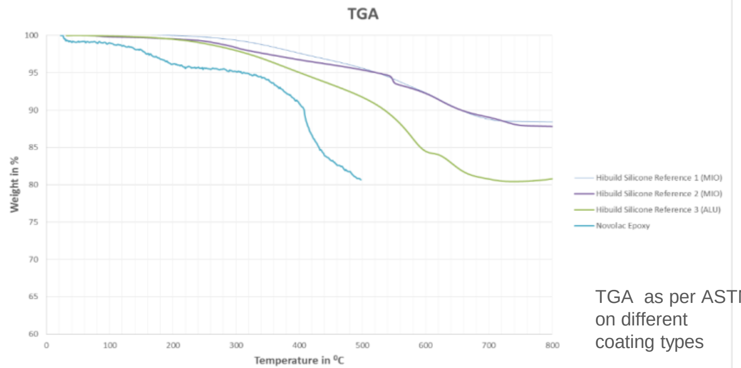


Ease of use



CUI relevance

- Weight loss over heating period
- Sample weight is measured accurately
- Temperature increased
- Volatile = mass loss
  - Carrier solvent (low temperatures)
  - Organic binder (decomposition)



TGA as per ASTM on different coating types

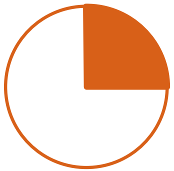
Useful for

- Determines binder resistance to heat
- Mass loss correlation with film porosity
- Candidate screening

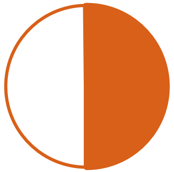
Watch out for

- High mass loss over narrow temperature range
- Some pigment types (ALU) may contain high levels of carrier solvent

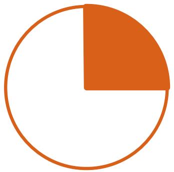
Atmospheric exposure



Cost



Ease of use



CUI relevance

- Accelerated or natural corrosion
  - Hot salt spray (ASTM B117 / ISO 7253)
  - Prohesion (ASTM G85 or ISO D5894)
  - Atmospheric exposure (ISO 2812 C5M)
- Evaluation to recognised standards
  - Rusting, blistering, flaking, etc

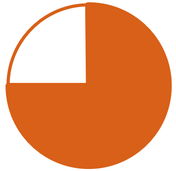
Useful for

- Determining corrosion protection after heating
- Highlighting porosity / lack of X-linking
  - Generally gives poor results

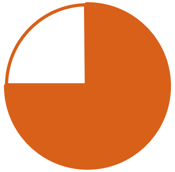
Watch out for

- Some barrier pigments may provide very good performance
- Scheme thickness (significant effect)
- Effect of “Thermal history”

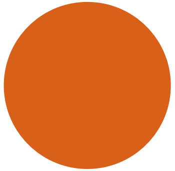
ASTM G189 (including modified variants*)



Cost



Ease of use



CUI relevance

- Heated pipe (constant temp.)
- *Coating applied as coupons or pipe
- Tests specific CUI conditions can be replicated
  - Temperature / Insulation type / Presence of annular space
- More sophisticated modifications
  - Inclusion of EIS

Mounted insulation pieces in water immersion area

Photograph attributable to Statoil ASA

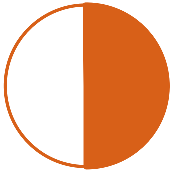
Useful for

- Accurately reproducing specific CUI issues
- Detailed information about coating performance
- Analysing multiple samples

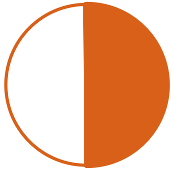
Watch out for

- Test program variation between operators
- Limited manufacturer information to this standard
- Limited maxim temperature

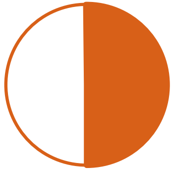
Cyclic insulated pipe test (CIPT)



Cost



Ease of use



CUI relevance

- Heated pipe (temperature gradient)
- *Coating applied to pipe
- Insulated then heating cycle applied
- Salt water solution introduced regularly
  - Saturates insulation

CIPT test underway

Photograph attributable to Hempel A/S

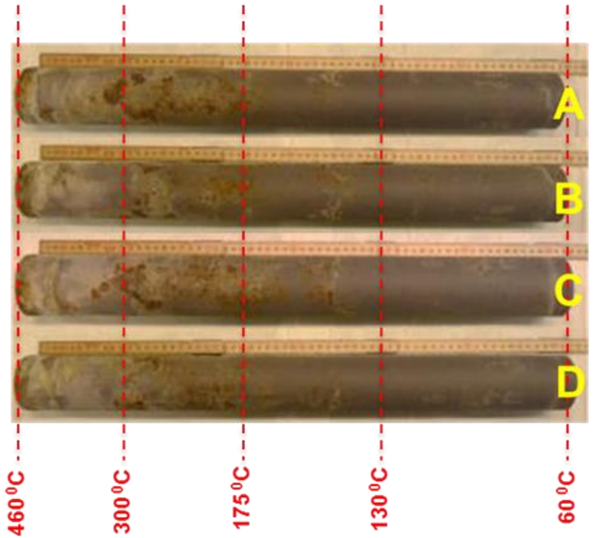
Useful for

- Screening performance at multiple temperatures
- Identifying areas of performance concern
- Easy low cost means to produce an insulated test

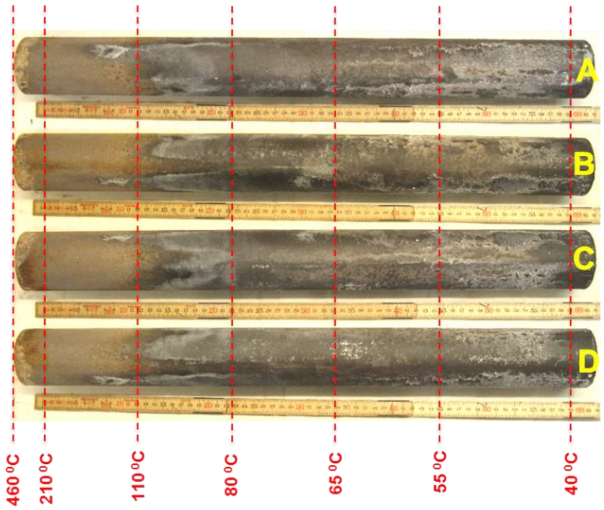
Watch out for

- Effect of insulation saturation on test temperature
- Type of insulation
- Limited sample area

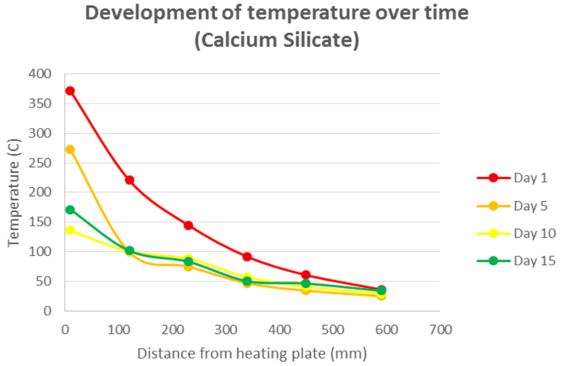
Cyclic insulated pipe test (CIPT)

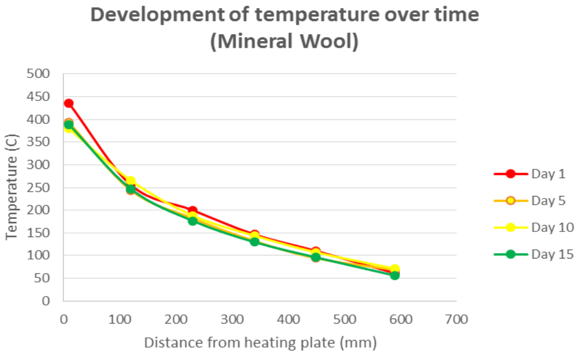


Mineral Wool insulation

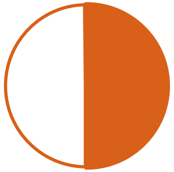


Calcium silicate

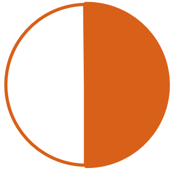




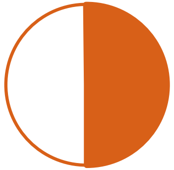
Environmental cell (HTC)



Cost



Ease of use



CUI relevance

- Heated “pipe” (single temperature)
- *Coating applied to test piece
- Square samples used + scribe
- Alternates wet and dry cycles
- 5% Electrolyte heated and evaporated / condenses (250 cycles)

HTC test cell

Photograph attributable to PPG

Useful for

- Evaluating multiple samples
- Evaluation at lower temperatures
- Indicating products performance under constant immersion
- Provides alternate views for epoxy based performance limits

Watch out for

- Different cycles can have an effect
- Absence of insulation - correlation effect with real life performance

Effect of thermal "history"

"The thermal conditions a coating has been exposed to" can have a significant effect on material performance.

- CUI is not a zero time event
- Most materials will have some thermal history before encountering CUI conditions
- Needs to be considered
- Built into test program

Consider

- Time
- Temperature
- Rate

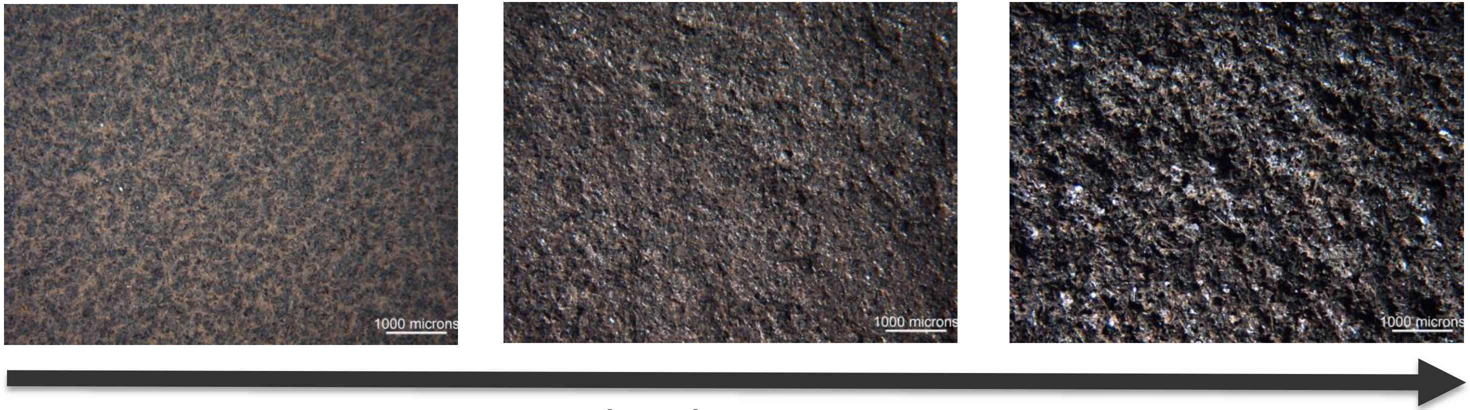
Gradual heating to T_{max}

Rapid heating to T_{max}

Supplementary testing

- Other factors to consider
  - Physical damage during fabrication / installation
  - Changes to film forming ability (e.g. application to hot surfaces)

20° C



200° C

Increasing substrate temperature

Current status

- Limited work to standardise CUI testing
- Industry heavily dependent upon supplier data (wide ranging)
- Different stakeholder requirements
  - - Strong operator focus on CUI test itself
- CUI specific testing
- A variety of tests is required to accurately gauge material performance

So what is required?

In the authors view

- Better definition of temperature supported by evidence (i.e. min, max, range)
- Minimum suite of tests to pre-qualify a material
- Pre-qualification scheme allows consideration of
  - Insulated and uninsulated use
  - Thermal history of the products which reflects likely service
  - Application restraints. i.e hot surfaces
- Test standard development / elimination of improvised tests
- Must be driven to recognised standard status (e.g. ISO, NACE)