Standardisation in High Temperature Corrosion Testing

Review of Task 4 of the UK-US Collaboration

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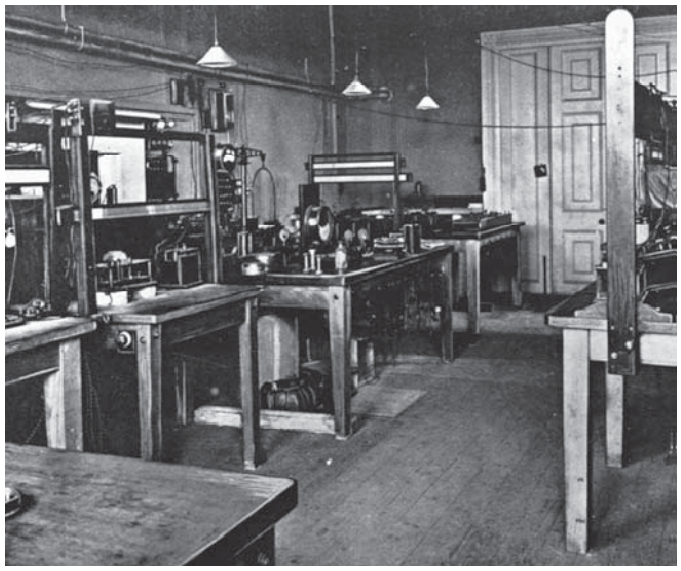
Overview

- Introduction to Task 4
- Data collection and storage
- Standardisation
- Inter-comparison

What was task 4 concerned with?

- To identify critical differences between standards for measurement of high temperature materials properties
- To identify where further standardisation for measurement of high temperature materials properties is required
- To develop a common format for data exchange
- To investigate the use of commercial database software for collecting and maintaining materials properties data and micrographs

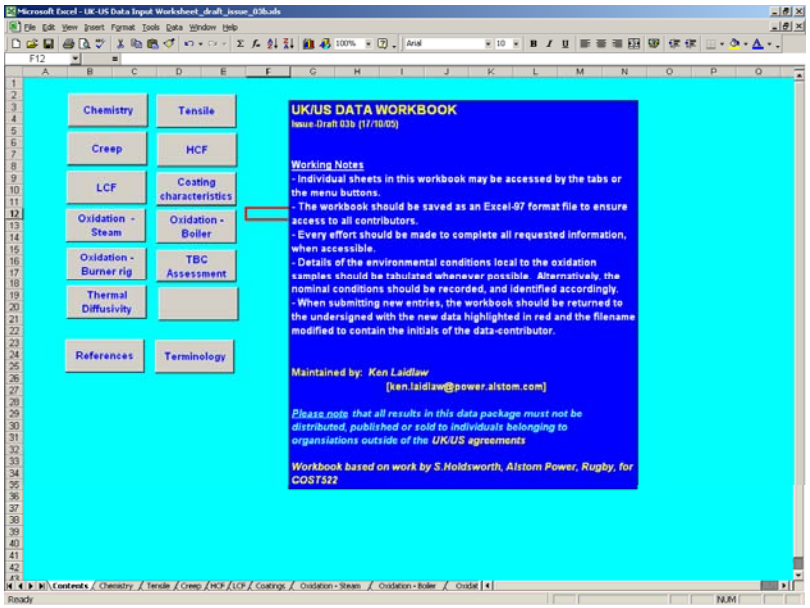
1902
NPL Opens



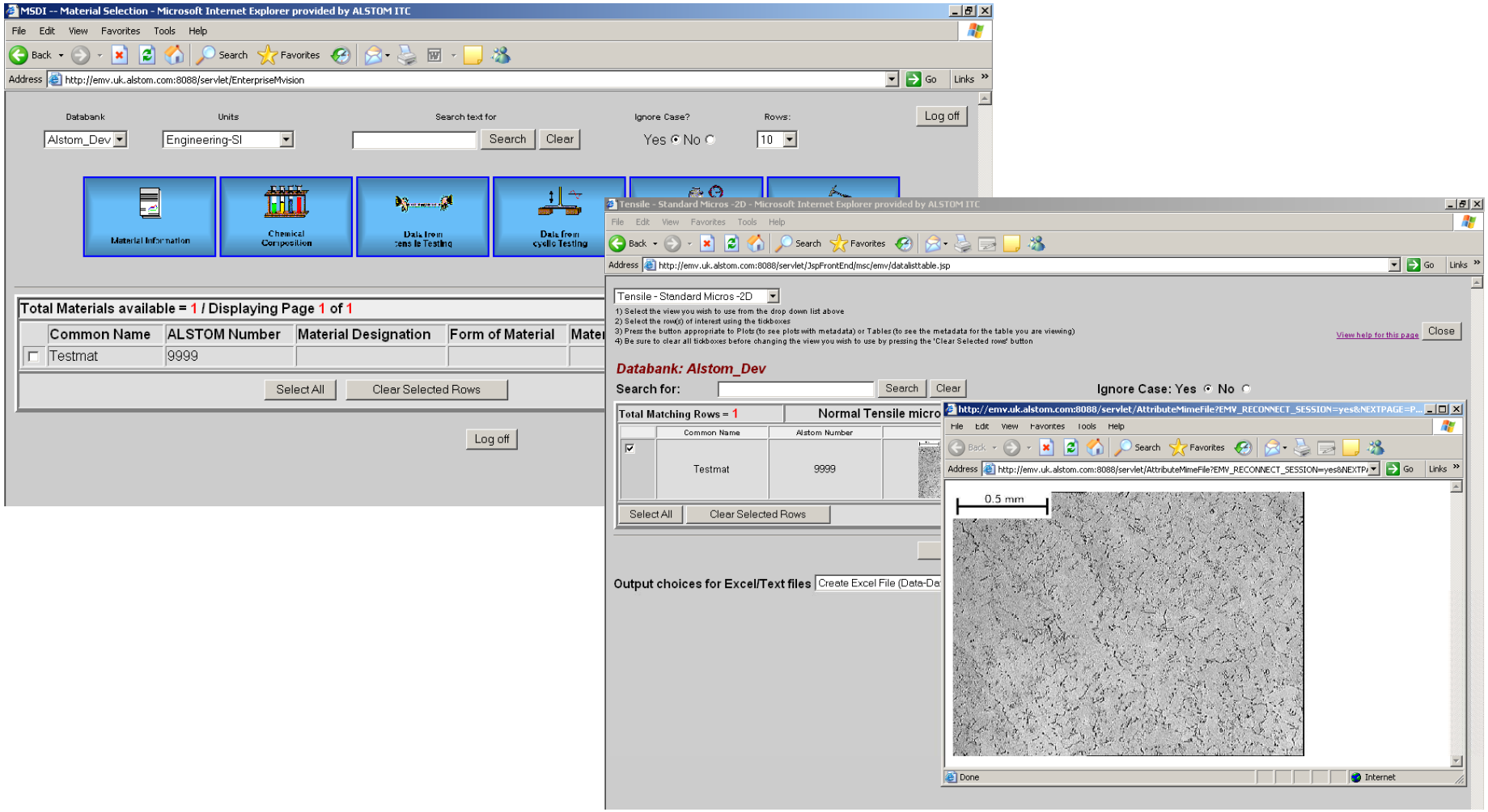
1906
Metallurgical laboratory

The collaboration will generate a lot of data – how do we manage and collect it?

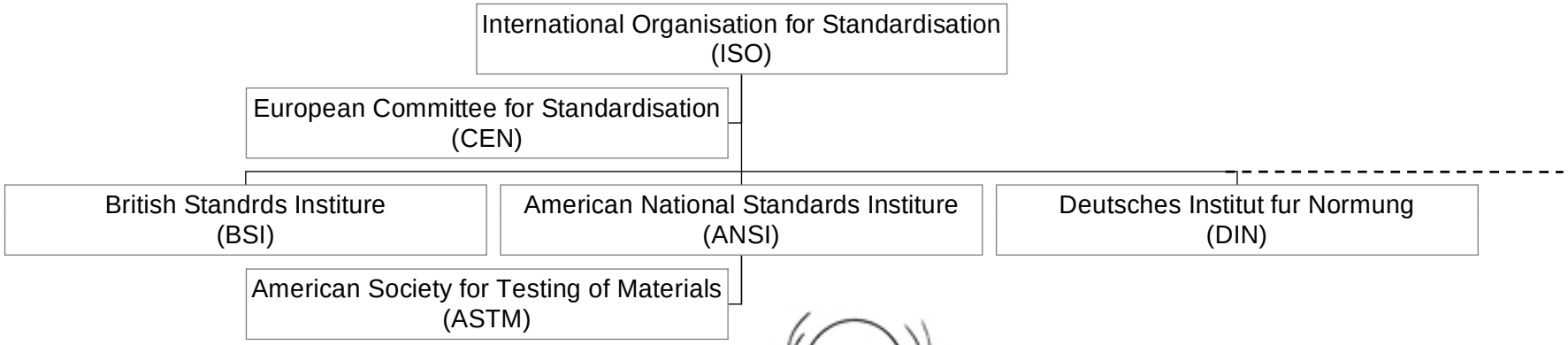
- What data is being recorded?
- Can we agree on what should be reported?
- What is the best method of capturing this data?
- Can everyone use the selected method?

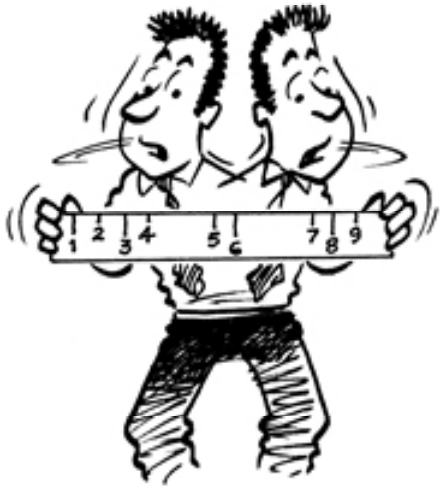


Data collation in a database, which includes metadata



How can we be sure the data is comparable?





How do the UK and US standards compare?

Mechanical Tests

- Hardness
- Tensile
- Creep
- Low Cycle Fatigue (LCF)
- High Cycle Fatigue (HCF)

Physical Testing

- Thermal Diffusivity
- Dilatometry
- Surface Area Measurement

Corrosion Testing

- Laboratory exposures in steam and mixed gases (including deposits)
- Post-exposure evaluation of environmental attack
- Steam Loop exposures
- Coating Thickness
- Burner rig testing
- Thermal Cycling/Cyclic Oxidation

Findings of the review – mechanical testing

Test	Addressed by	Standards	Further work needed
Hardness	ISO - TC164	Knoop, Brinell, Vickers, Rockwell	No
Tensile	ISO - TC164	Ambient Temp. High Temp.	No
Creep	ISO	Uniaxial	No
LCF	ASTM, CEN, BSI	Standards exist for strain controlled, TMF.	Not at this point
HCF	Yes	Ambient Temp.	Yes, HT HCF

Findings of the review – physical testing

Test	Addressed by	Standards	Further work needed
Thermal Diffusivity	ASTM	Laser flash	No
Dilatometry			Yes
Surface Area Measurement	ISO	Gas adsorption or permeability	No

Findings of the review – corrosion testing

Corrosion Testing

- Laboratory exposures in steam and mixed gases (including deposits)
- Post-exposure evaluation of environmental attack
- Steam Loop exposures
- Coating Thickness
- Burner rig testing
- Thermal Cycling/Cyclic Oxidation

At the time of the review there were no international, US or European standards existing for high temperature corrosion of metallic materials.

But…

this area is being actively pursued by ISO TC156 WG13 and standards for:

- Test Method for Isothermal Exposure Testing under High Temperature Corrosion Conditions
- Method for Metallographic Examination of Samples after Exposure to High Temperature Corrosive Environments
- Thermal Cycling Exposure Testing Under High Temperature Corrosion Conditions

are in preparation.

No standards, so what… Inter-comparison

Seam Oxidation

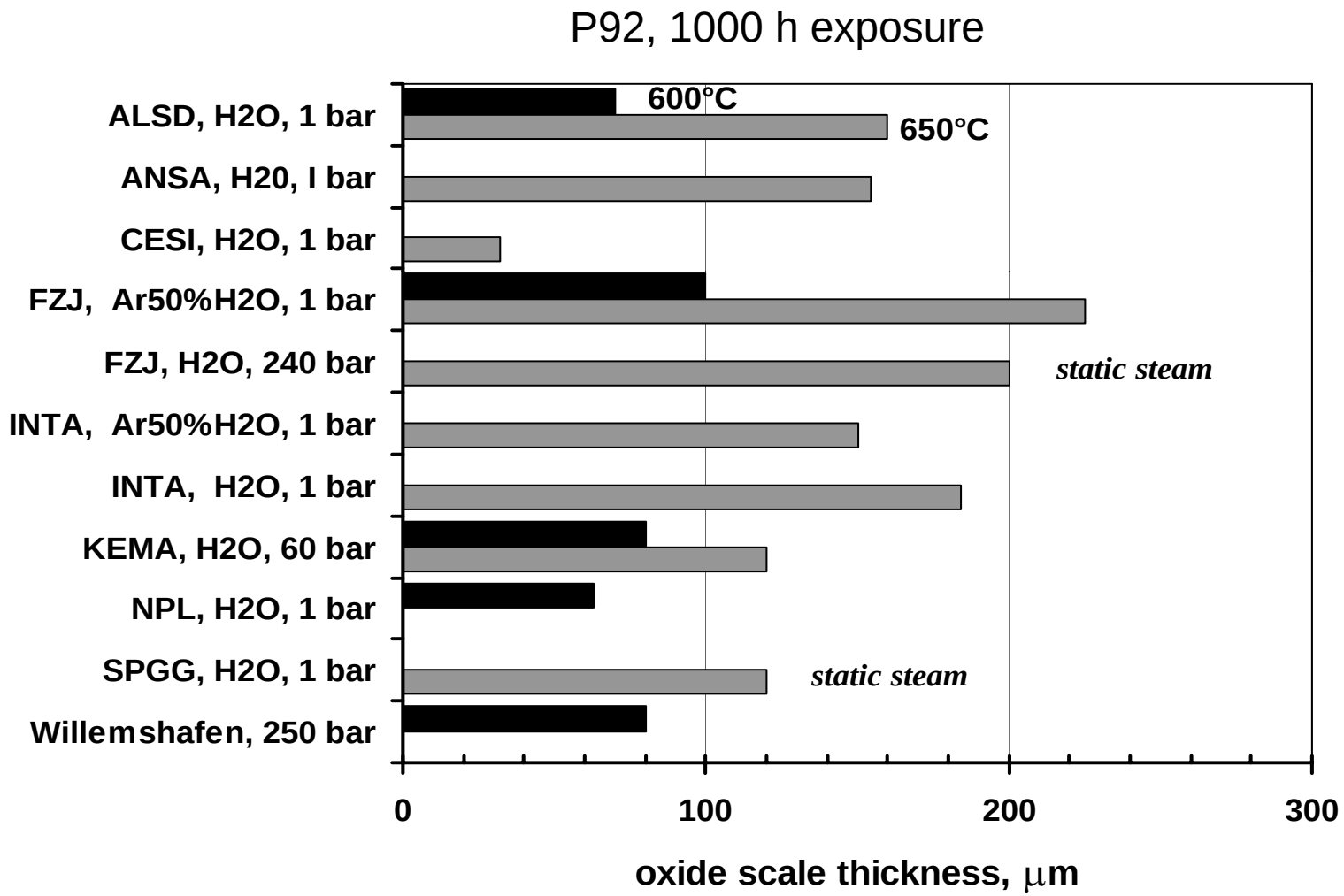
- 3 materials (T92, 347HFG, IN740)
- Same material stock
- Same temperatures

- Lab could prepare samples in their standard manner
- Tests conducted using their own preferred method
- Data analysed in their own preferred technique

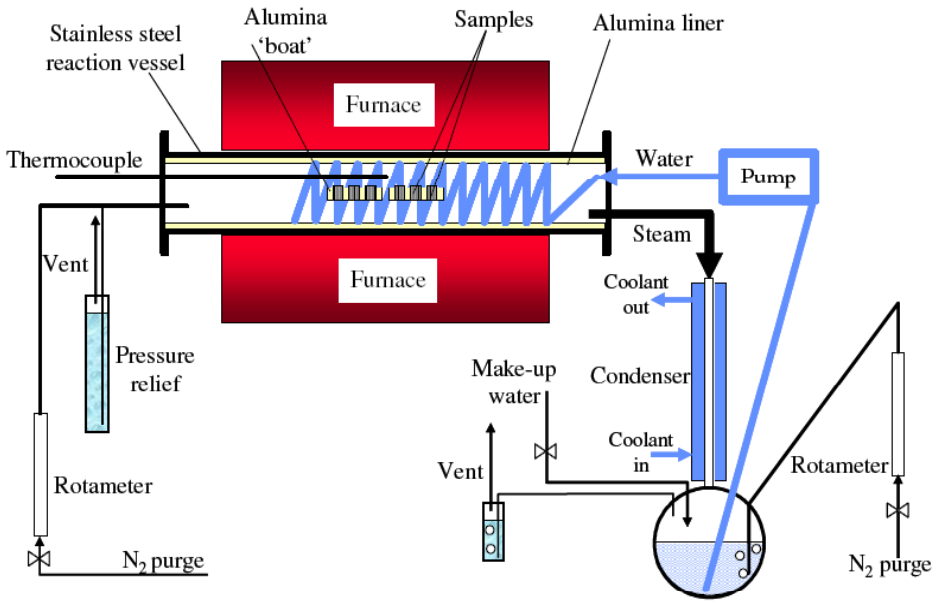
Boiler Corrosion

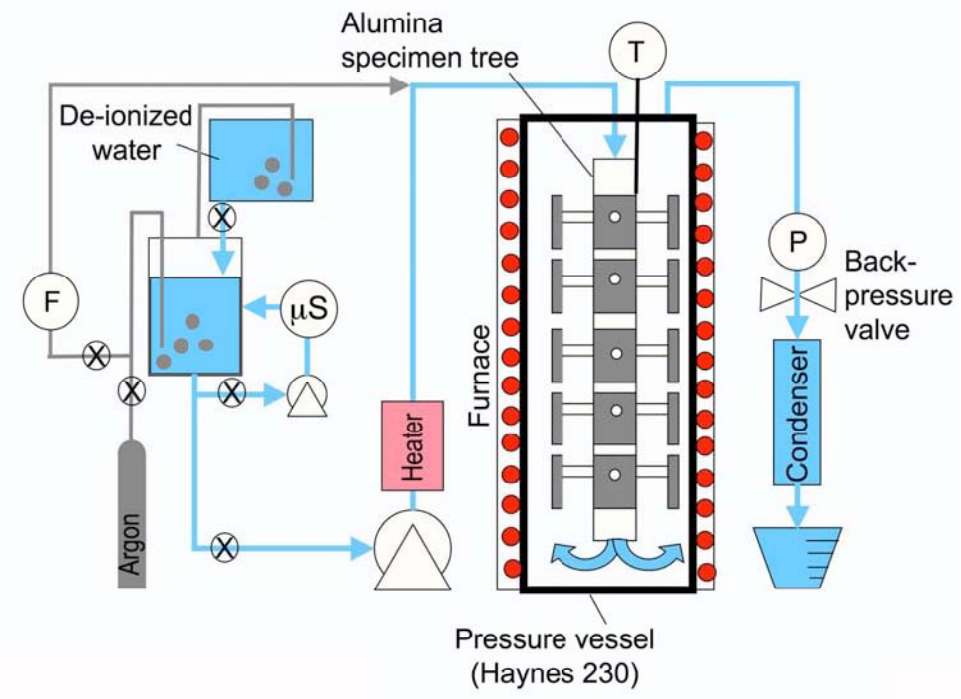
- 2 materials (T22 and P92)
- Same material stock
- Gas composition set
  - 0.3% SO_2 , 6.0% O_2 , 14.6% CO_2 , 74.2% H_2
- Ash composition set
  - $Na_2SO_4/K_2SO_4/Fe_2O_3$ (1.5/1.5/1 on a molar basis)
- Temperatures set

- Lab left to prepare samples and expose using their preferred method


P92, 1000 h exposure
ALSD, H2O, 1 bar
ANSA, H20, I bar
CESI, H2O, 1 bar
FZJ, Ar50%H2O, 1 bar
FZJ, H2O, 240 bar
INTA, Ar50%H2O, 1 bar
INTA, H2O, 1 bar
KEMA, H2O, 60 bar
NPL, H2O, 1 bar
SPGG, H2O, 1 bar
Willemshafen, 250 bar
600°C
650°C
static steam
static steam
0
100
200
300
oxide scale thickness, μm

Steam Oxidation experimental setup

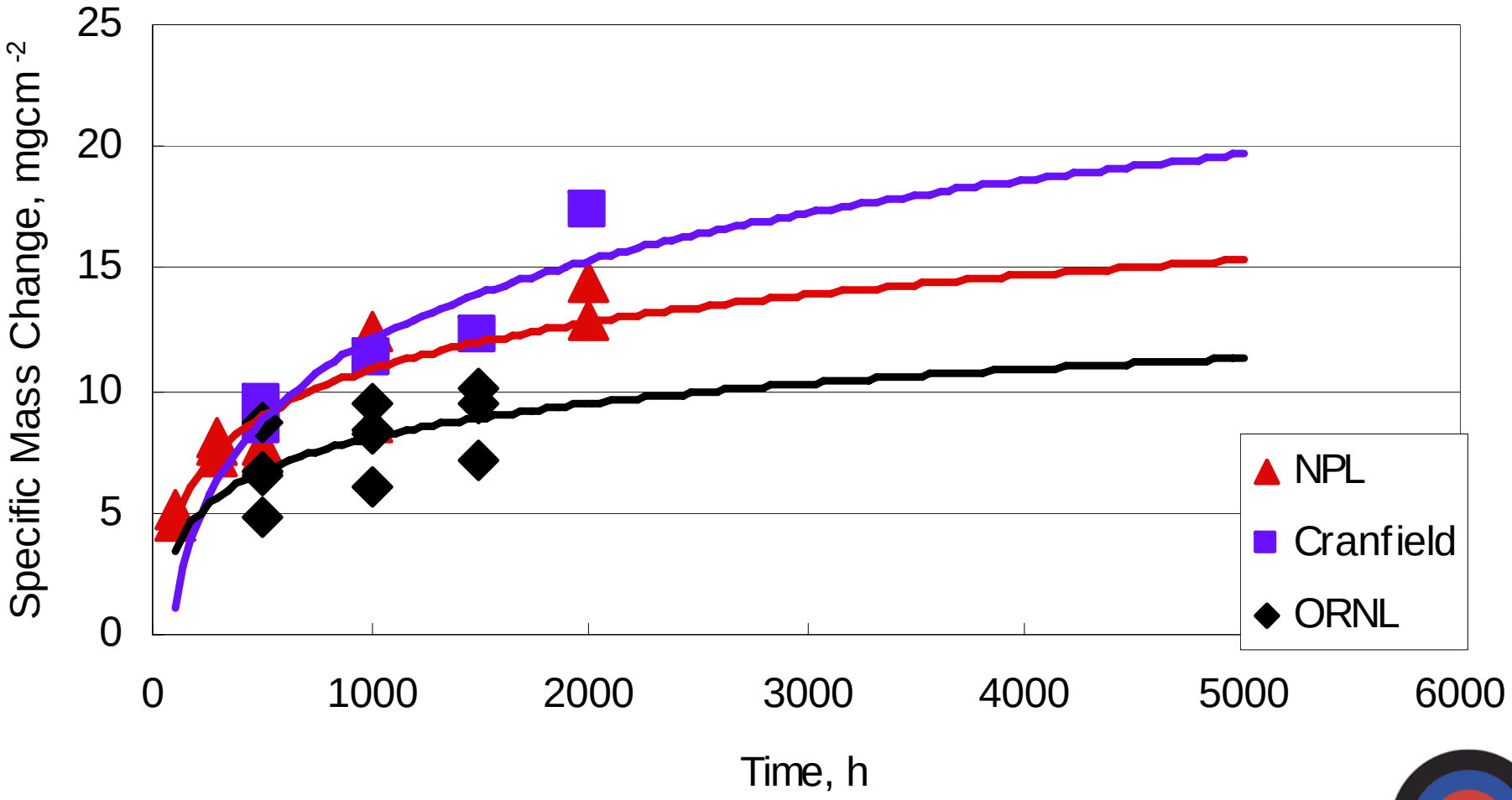




Steam oxidation experimental

- Sample geometry
  - 10 x 10 x 3mm
  - 20 x 10 x 2mm
  - Semicircular section
- Surface Preparation
  - Samples from bulk
  - Samples retained original surface
  - Surfaces prepared 600-grit SiC
- Exposure procedure
  - Duplicate samples exposed for a set time duration (no cycling)
  - Sample all exposed at the same time, thermal cycles introduced to remove samples
  - Ambient pressure & 17 bar

Steam oxidation resultsT92 at 600 ºC



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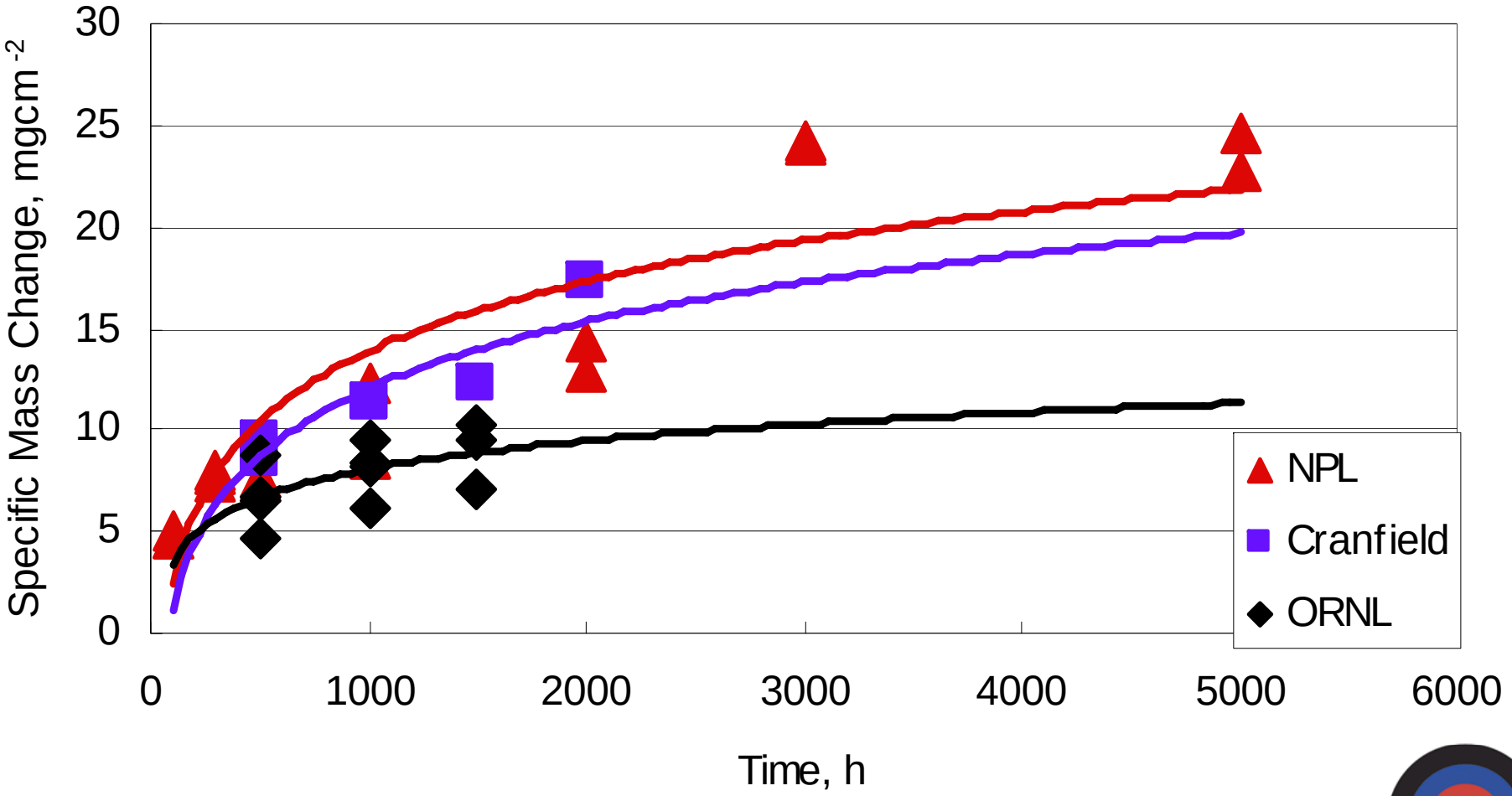
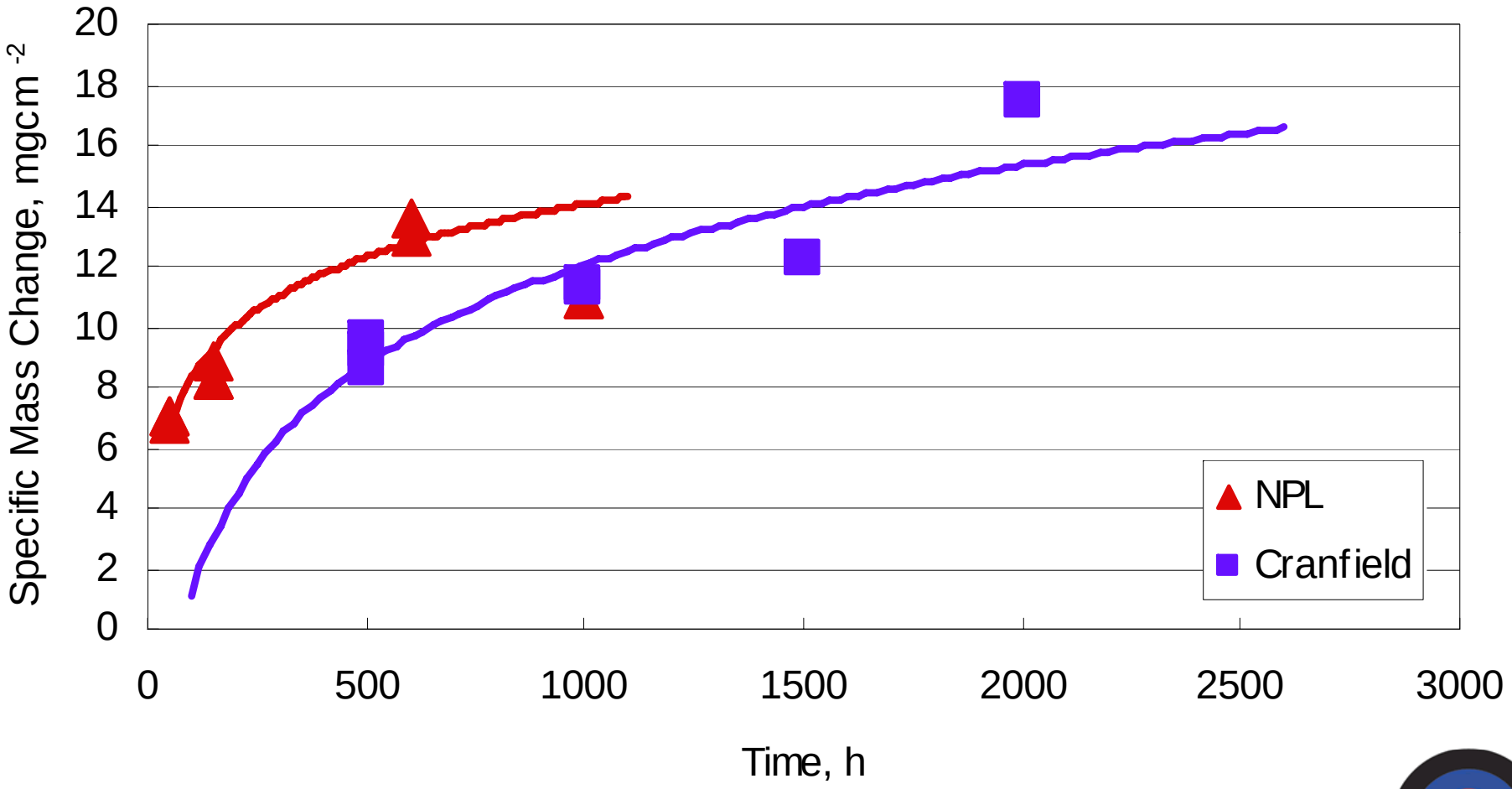
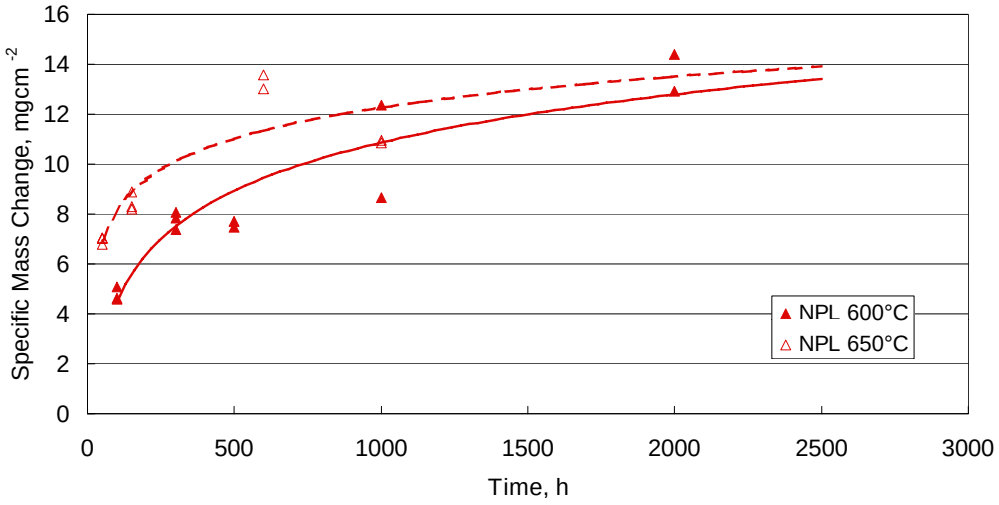
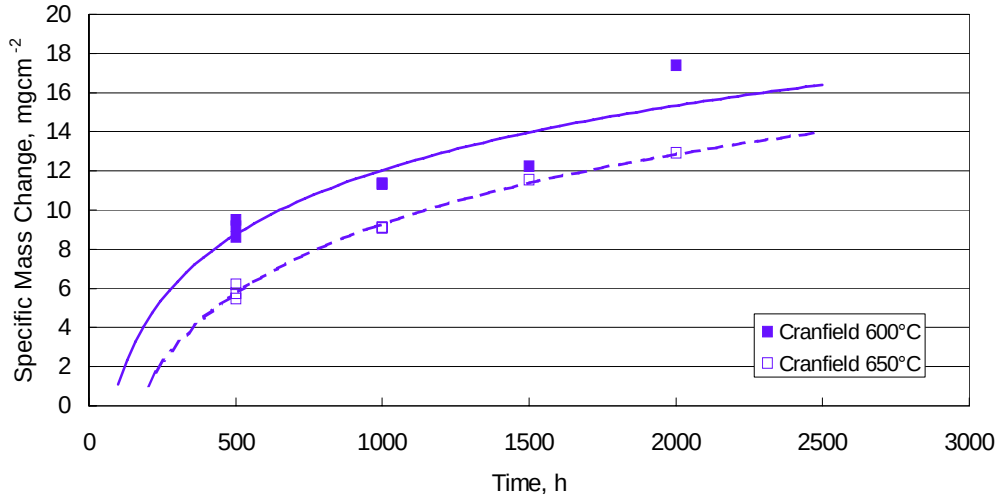


Steam oxidation results T92 at 650 ºC

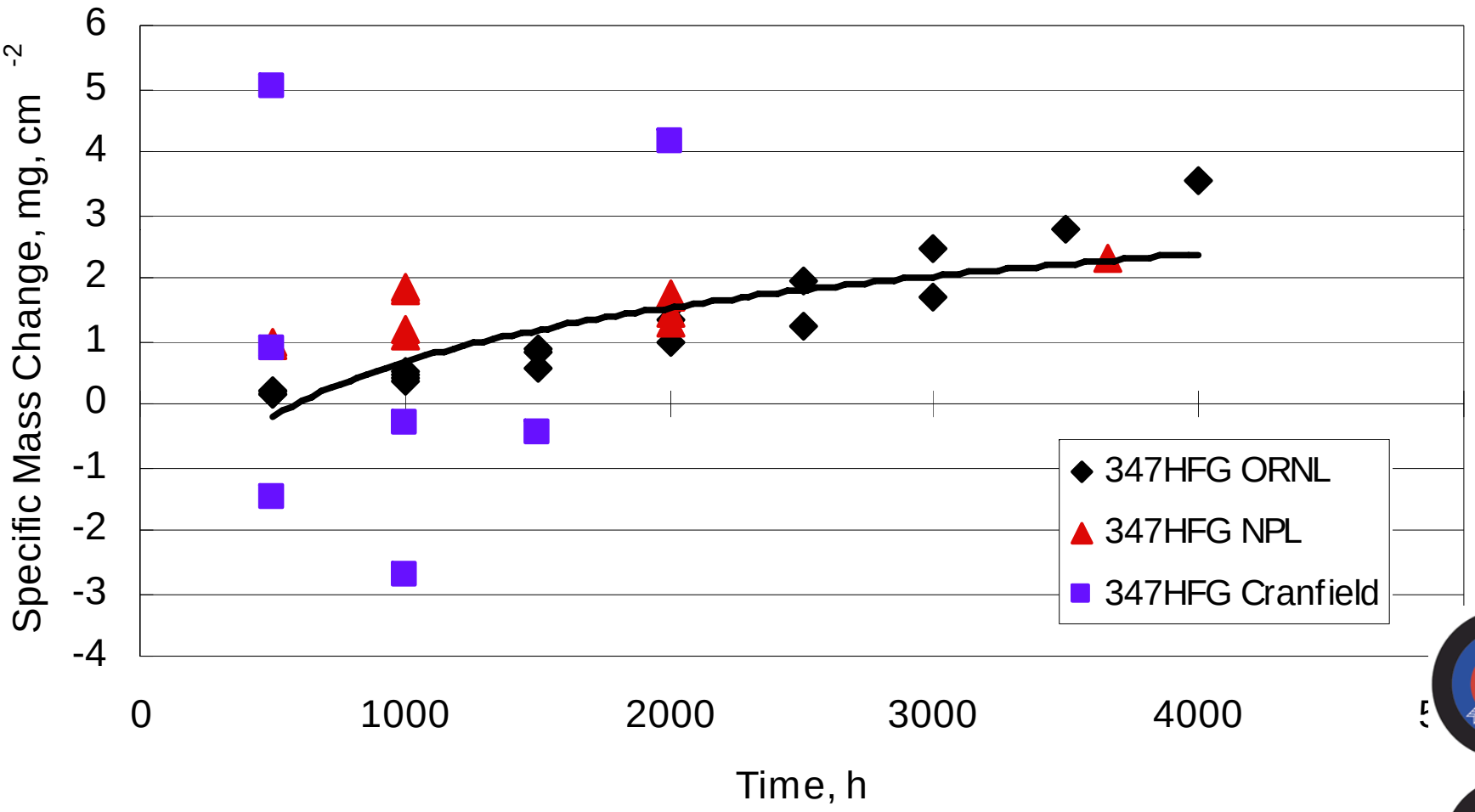


Steam oxidation
T92 temperature dependency

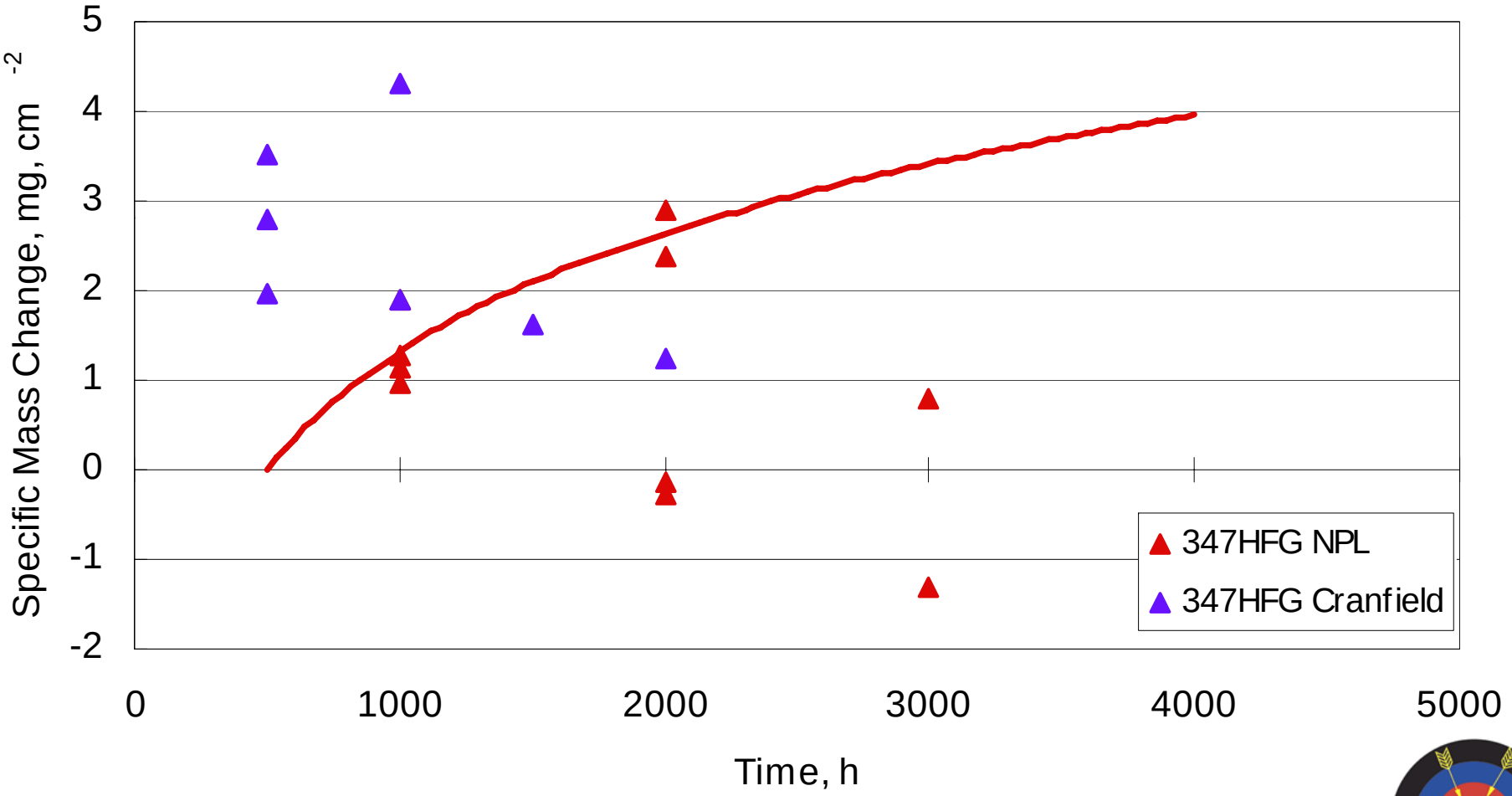




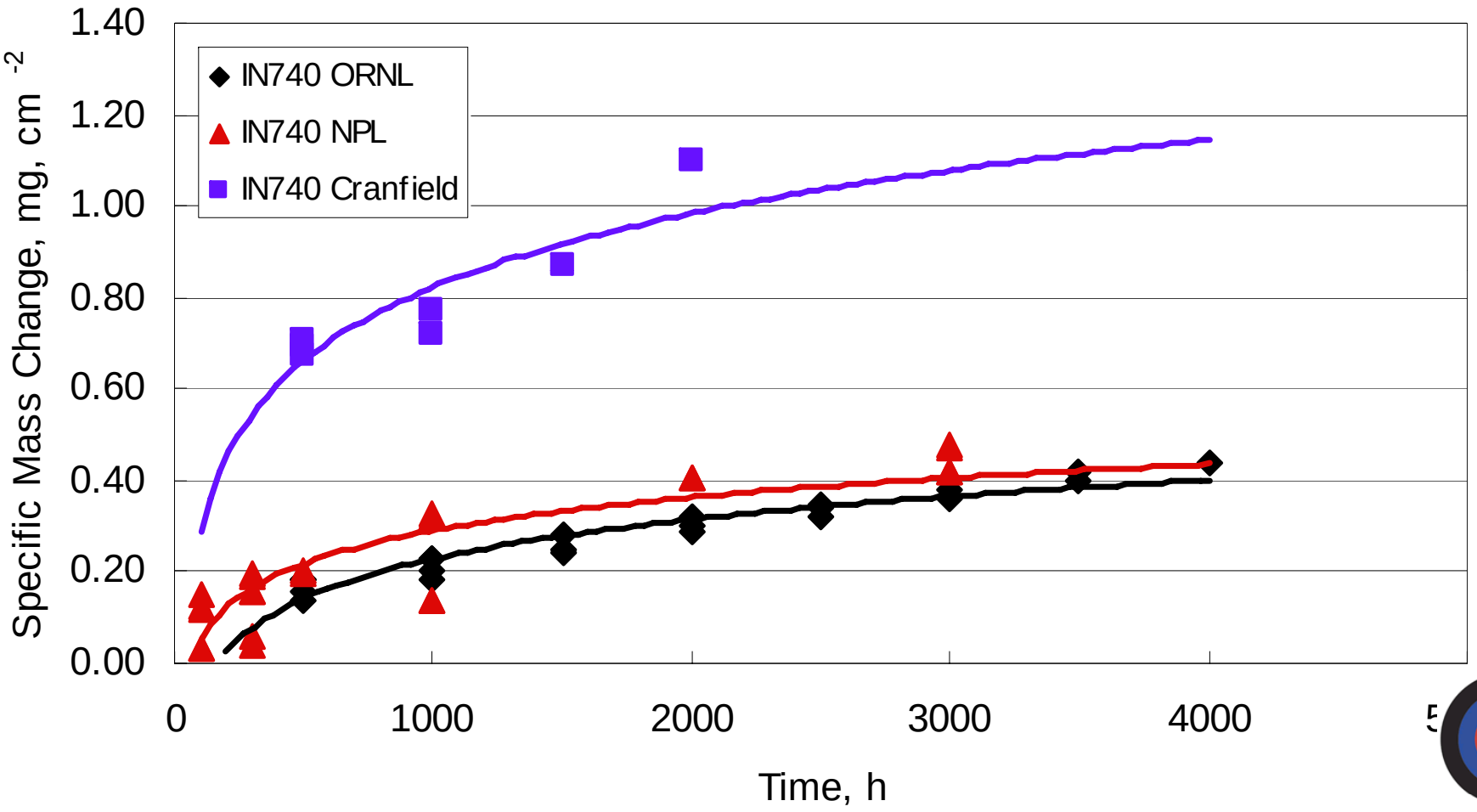
Steam oxidation results 347HFG at 650 ºC



Steam oxidation results 347HFG at 700 ºC

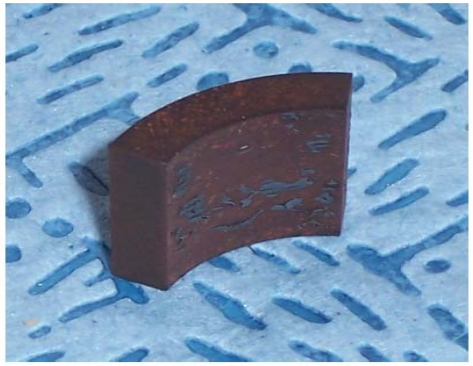


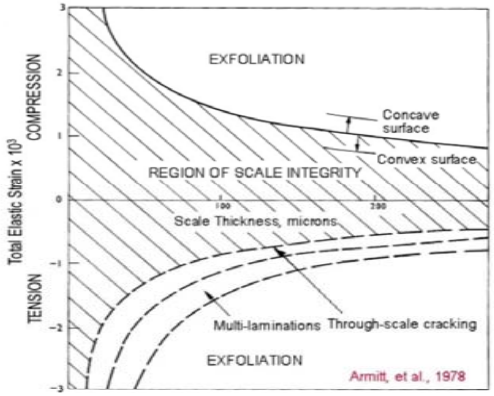
Steam oxidation results IN740 at 750 ºC



What could be causing the differences?

- Specimen Geometry
- Thermal Cycling
- Orientation of grains
- Spallation





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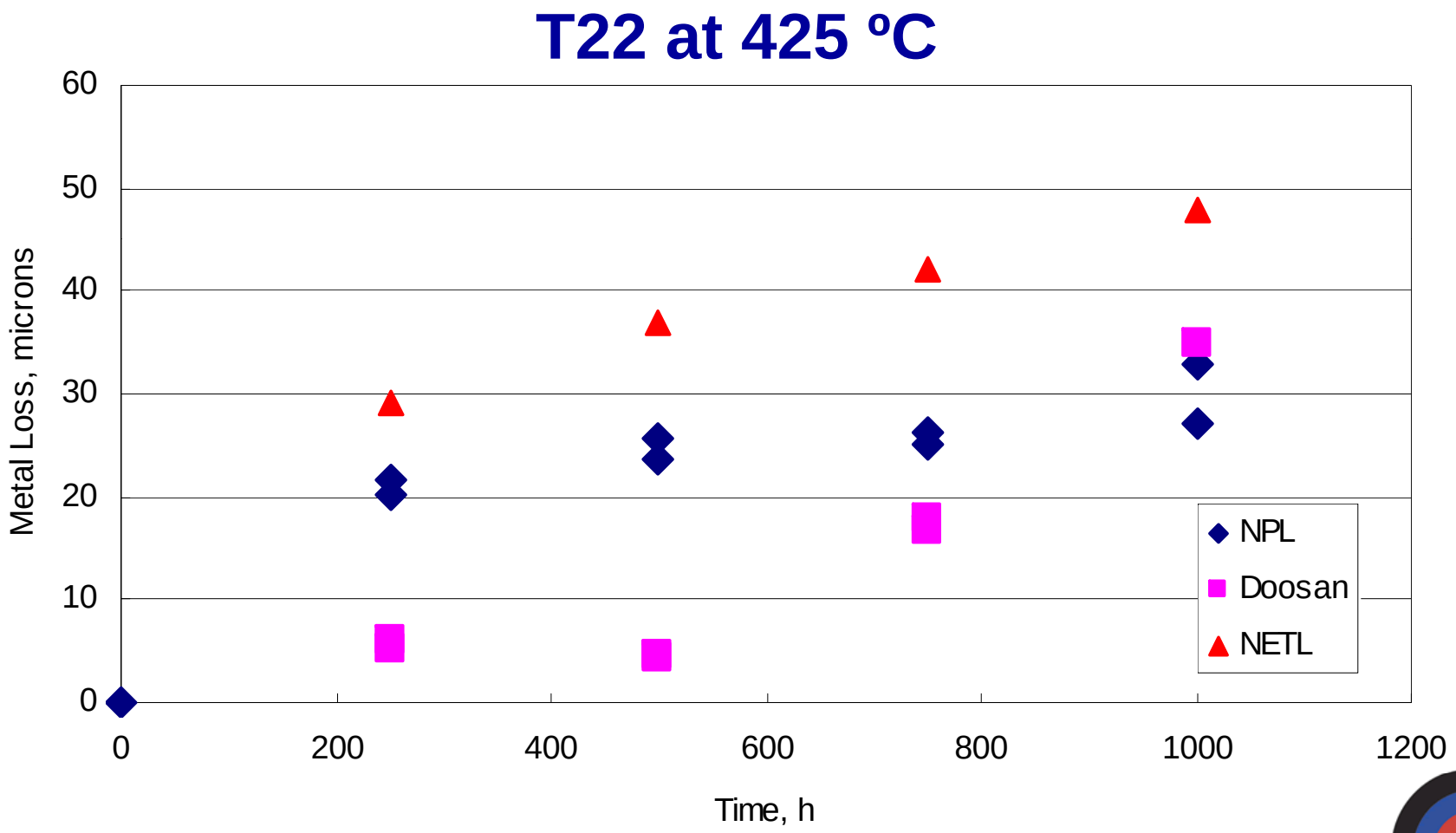
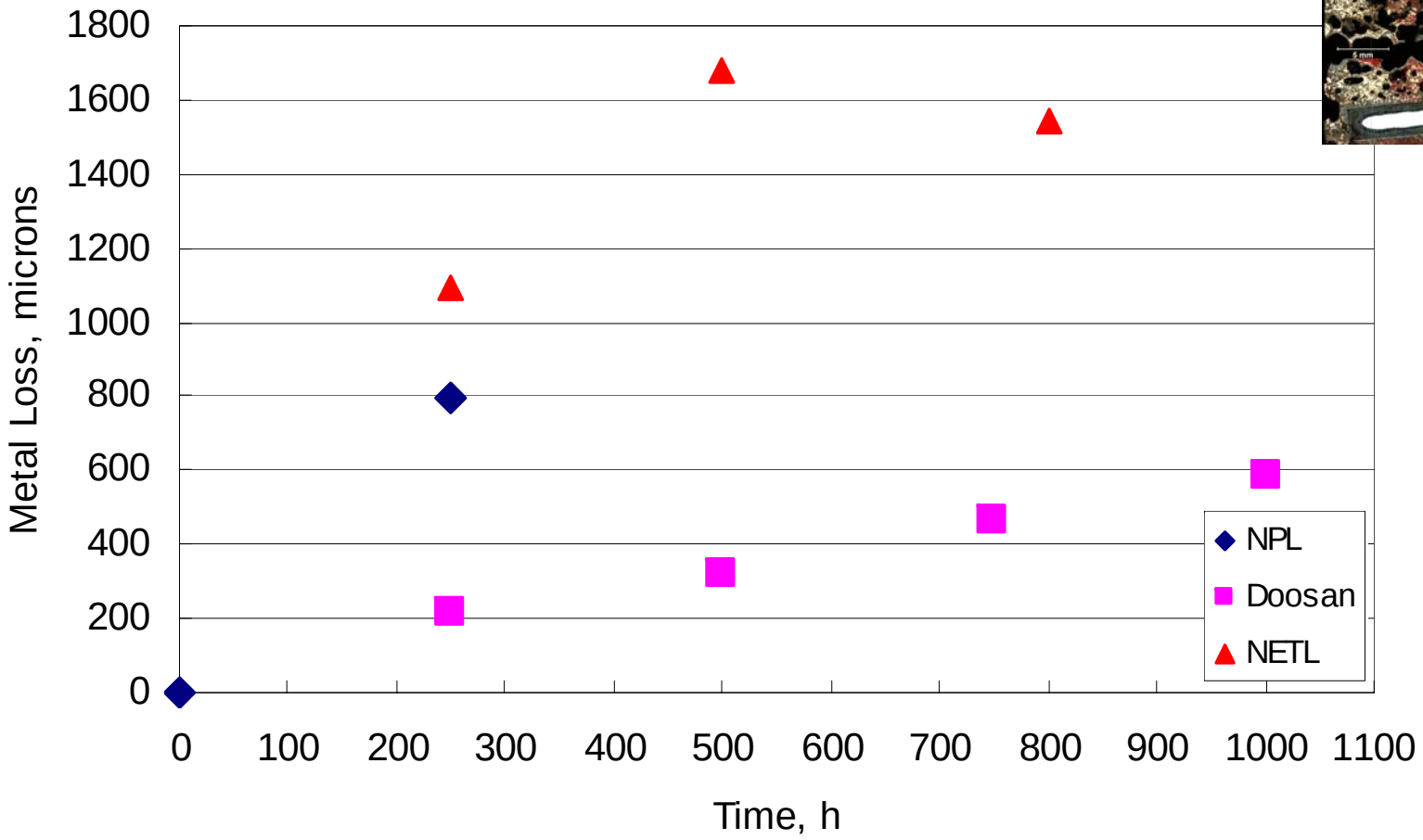
What about boiler corrosion, that's OK…isn't?



P92 at 675 ºC


Metal Loss, microns
1800
1600
1400
1200
1000
800
600
400
200
0
0
100
200
300
400
500
600
700
800
900
1000
1100
Time, h
NPL
Doosan
NETL

Why the differences?

- Specimen manufacture
- Measurement accuracy
- Fundamental differences in the apparatus
- ?

What does all this mean?

No one is wrong, the results are just different

- Results are self consistent with a laboratory
- Measurements are precise but there is scatter due to material effects (i.e. spalling)
- Ideally we would like high precision and good repeatability

Where do we go from here?

- Standard test methods for corrosion testing which address specimen manufacture and preparation as well as the actual test procedure and analysis.

- Need to address
  - Specimen geometry
  - Surface preparation
  - Testing procedures
  - Measurement accuracy & uncertainty

Phase 2 will be addressing some of these issues

Thank you for your attention

Any questions?