Introduction to Workshop

Tools and guides to facilitate welding of duplex stainless steel

A workshop to summarize and discuss the findings in the Vinnova projects:

DUWELTOOL - Prediction of ferrite fraction and precipitation of sigma phase in duplex stainless steel welds

SuperAVON – Avoidance of nitride precipitation during duplex stainless steel welding

at Jernkontoret 2020-02-20

Staffan Hertzman

Microstructure control in welding and processing of duplex stainless steels

Two problems to address:

- N-super-saturation in ferrite during **fast cooling** between ~1380 and 900°C → limited austenite reformation → quenched-in nitrides

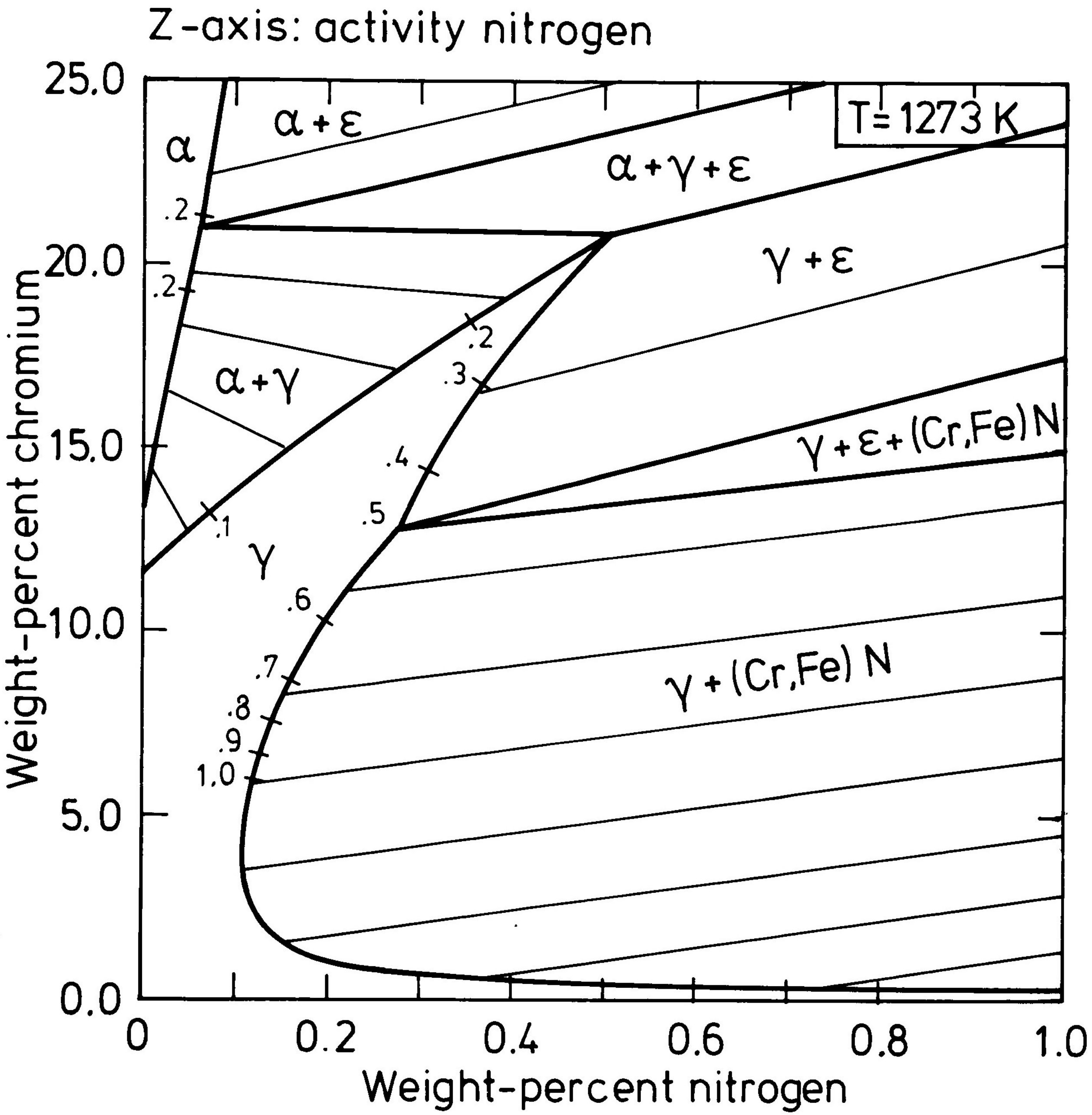
- **Slow cooling** through the intermetallic phase regime (below 1000°C approx) → Sigma phase Chi phase etc

NITRIDES
equilibrium vs quenched-in

- Primarily a HAZ problem in welding
- In thick gages

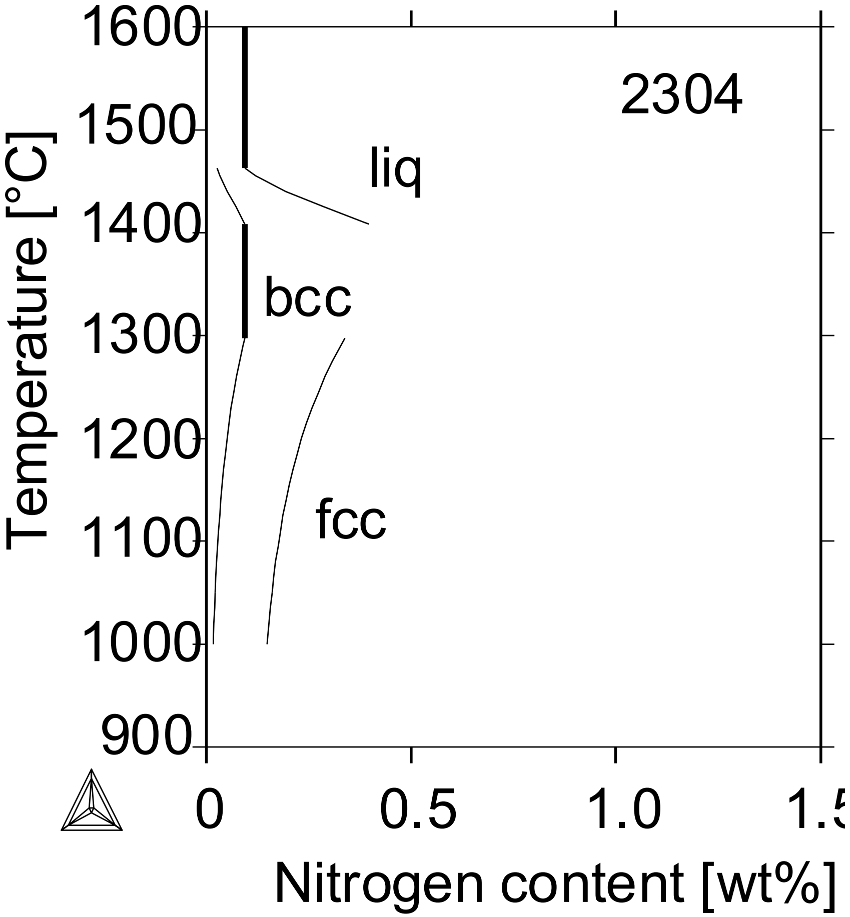
- Occurs when the austenite reformation is limited
  -large ferrite grains

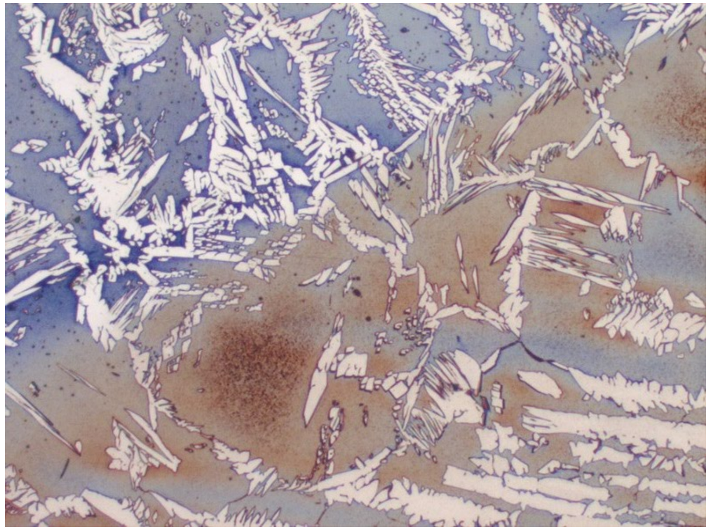
- Problem less if high N composition – The N paradox – since austenite reformation is favoured



The Fe Cr N Phase diagram (equilibrium)

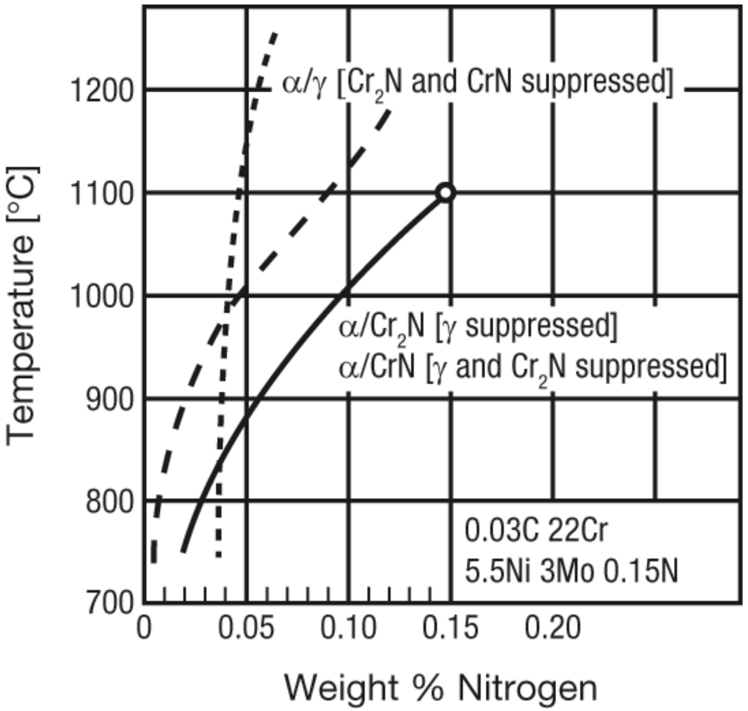
Calculated phase diagram for a DSS

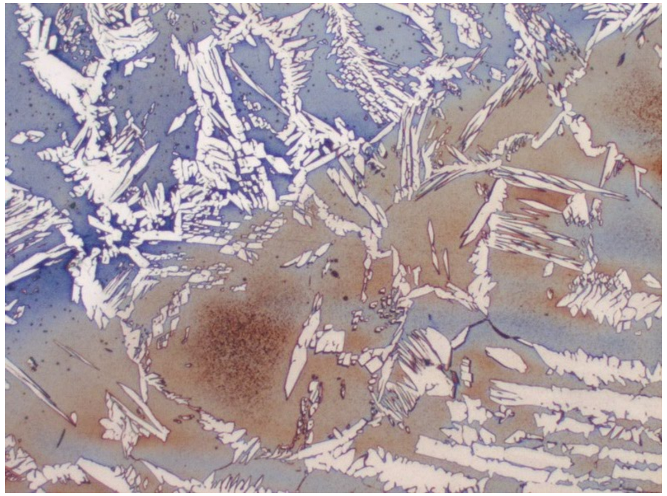




2205 phase diagram

stable and metastable equilibria



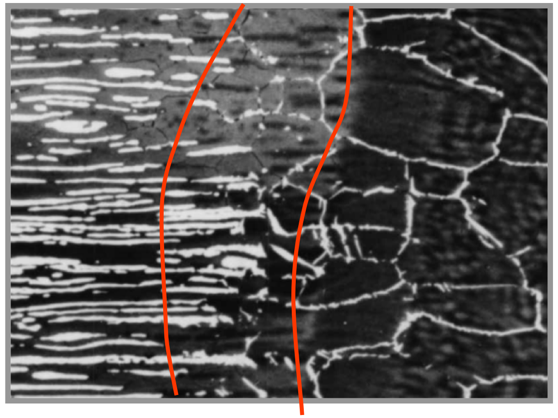


Cr_2N - stable nitride
CrN - may form at large undercoolings due to favourable nucleation (low lattice misfit in ferrite)

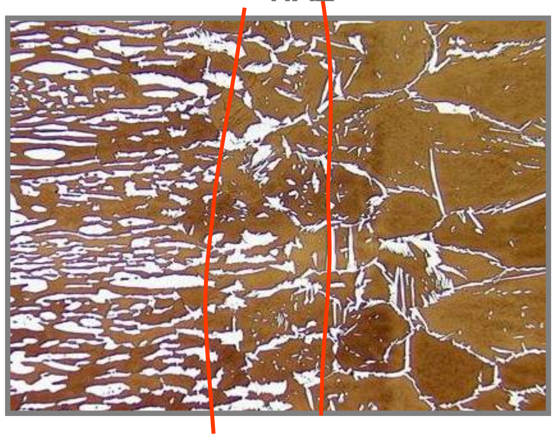
Increased Nitrogen content

0,13% → *0,21%*

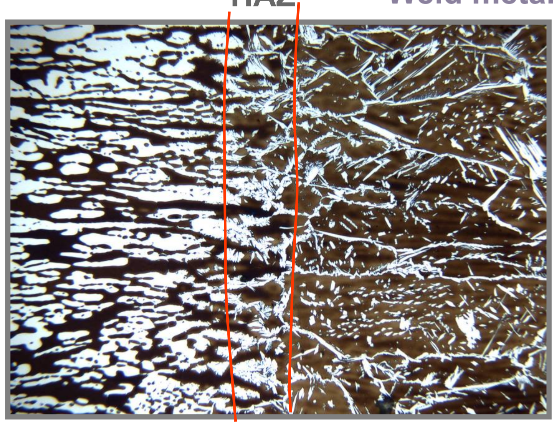
HAZ Weld metal



HAZ Weld metal



HAZ Weld metal



100 µm

HAZ	83% ferrite 0,20 mm width	76% ferrite 0,18 mm width	69% of ferrite 0,07 mm width
Weld metal	95% ferrite	89% ferrite	68% ferrite

Tests performed on UNS S 31803 / S 32205 - Electron Beam welding – As welded HAZ
Welding conditions not recommended; performed for experimental trials, N2 effects.

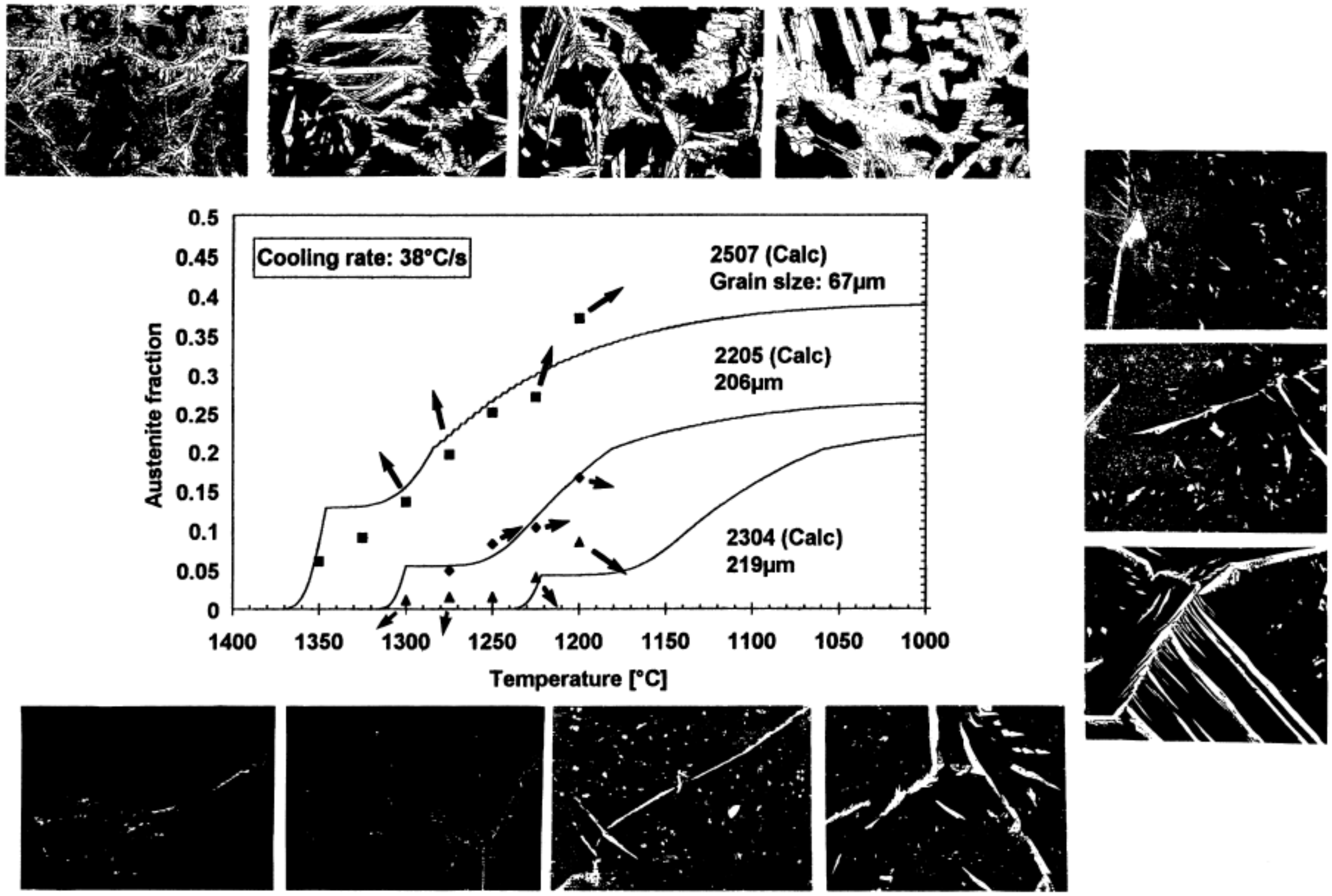


Fig. 12—Austenite fraction *vs* quenching temperature for the three alloys investigated; the same data as in Fig. 11, but with micrographs representing a selection of conditions.

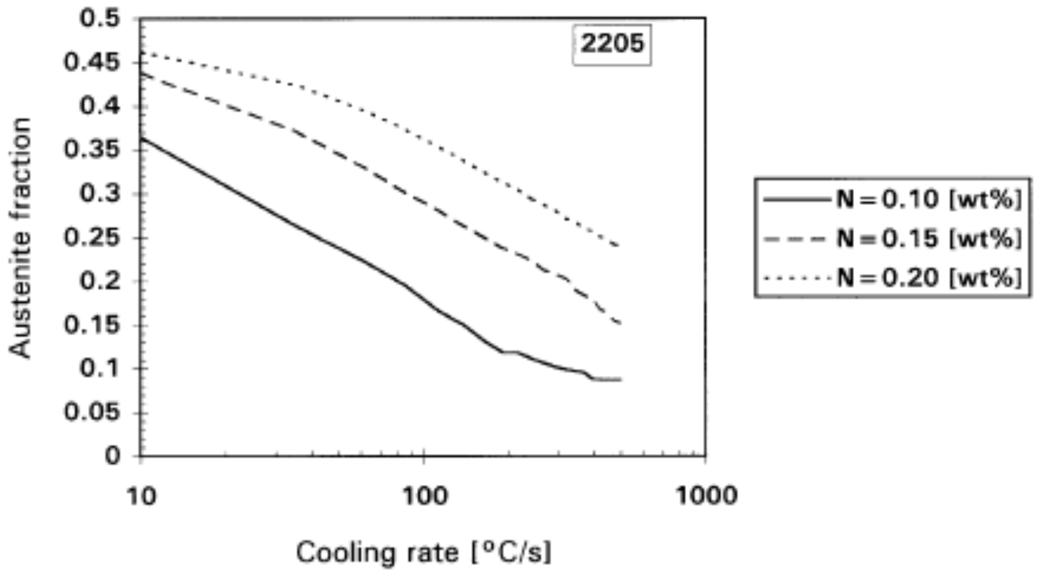
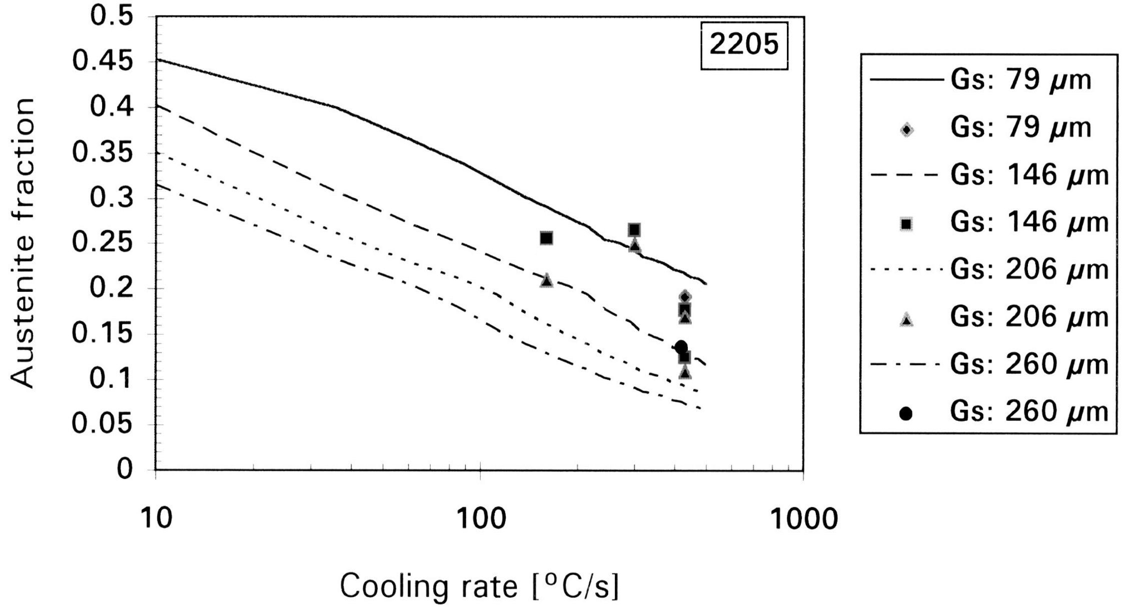


Fig. 14—Prediction of the effect of nominal alloy nitrogen content on the austenite reformation rate for alloy 2205.



2205
Austenite fraction
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
10
100
1000
Cooling rate [°C/s]
Gs: 79 μm
Gs: 79 μm
Gs: 146 μm
Gs: 146 μm
Gs: 206 μm
Gs: 206 μm
Gs: 260 μm
Gs: 260 μm

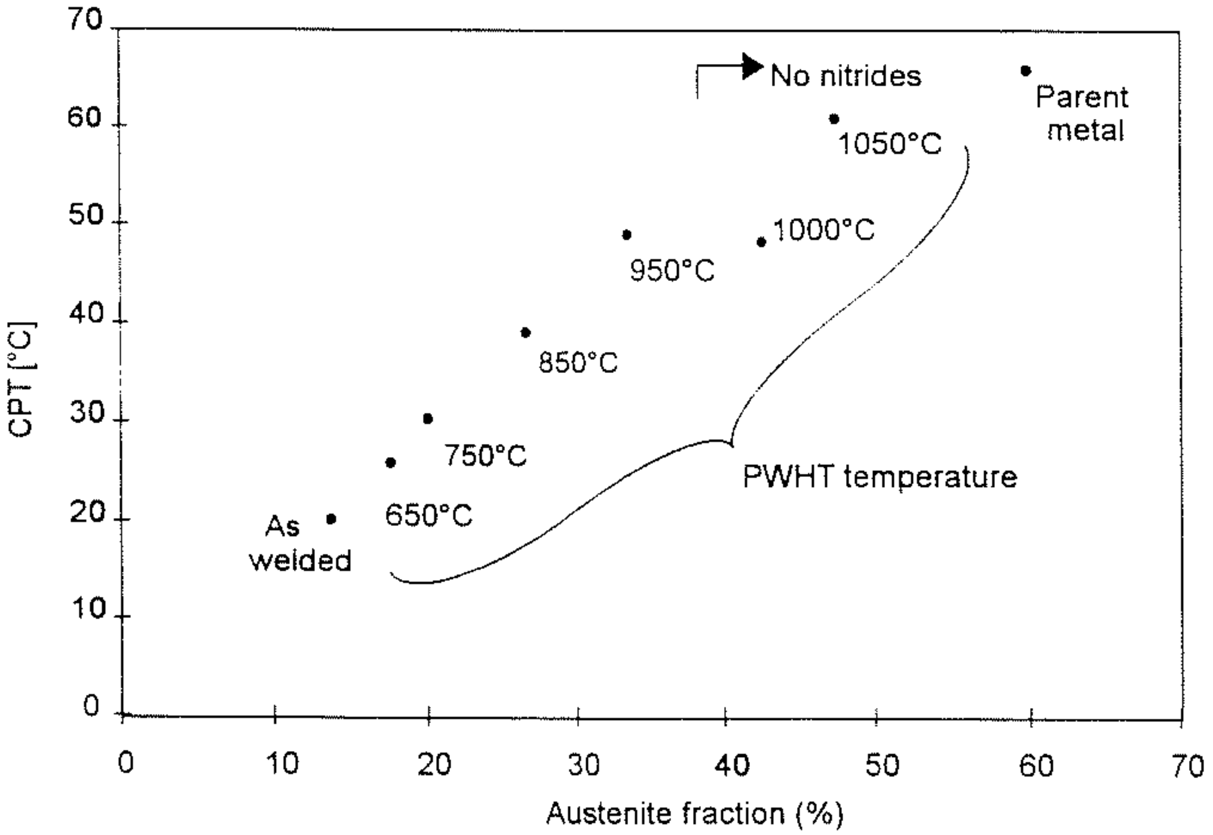
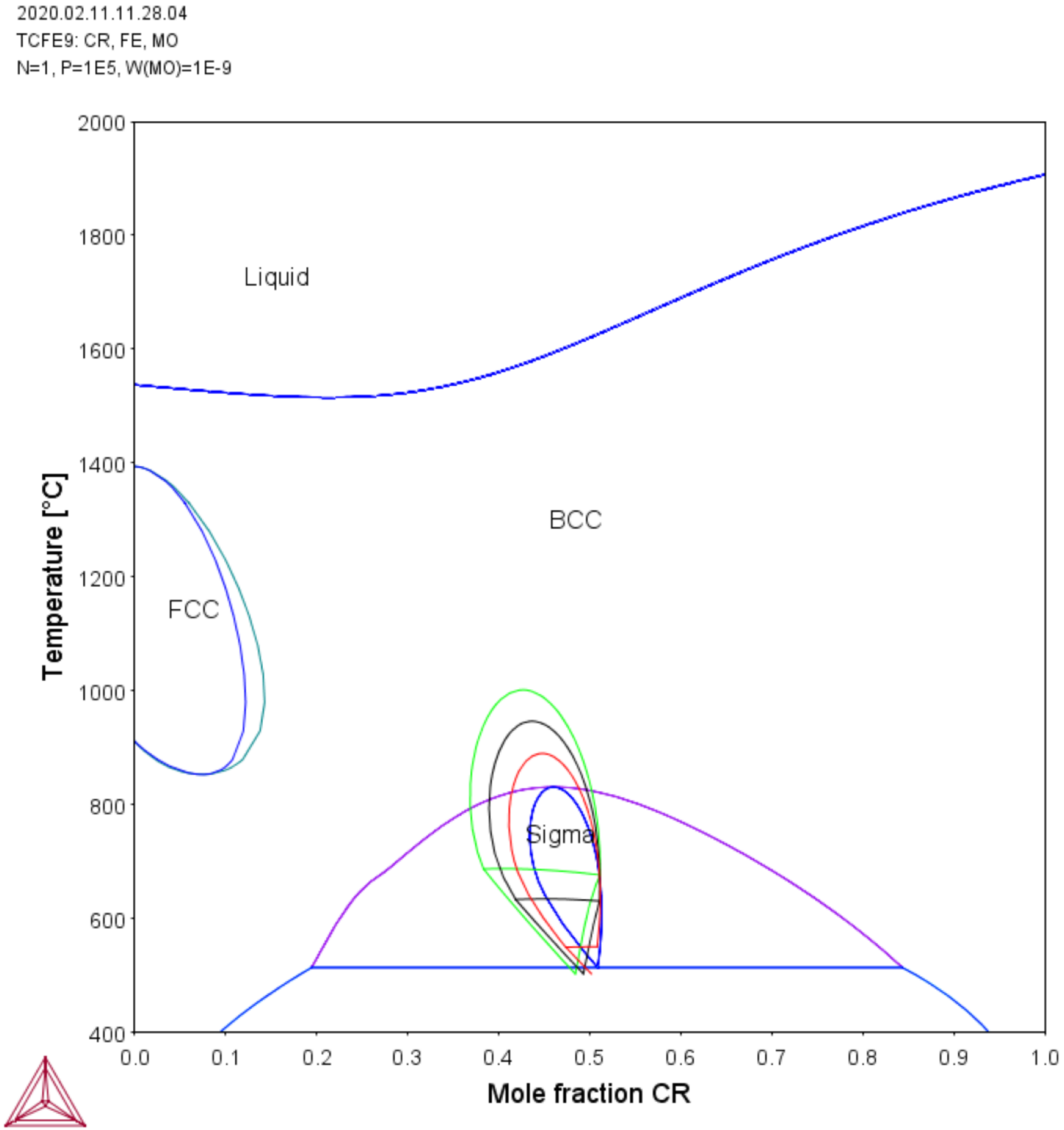


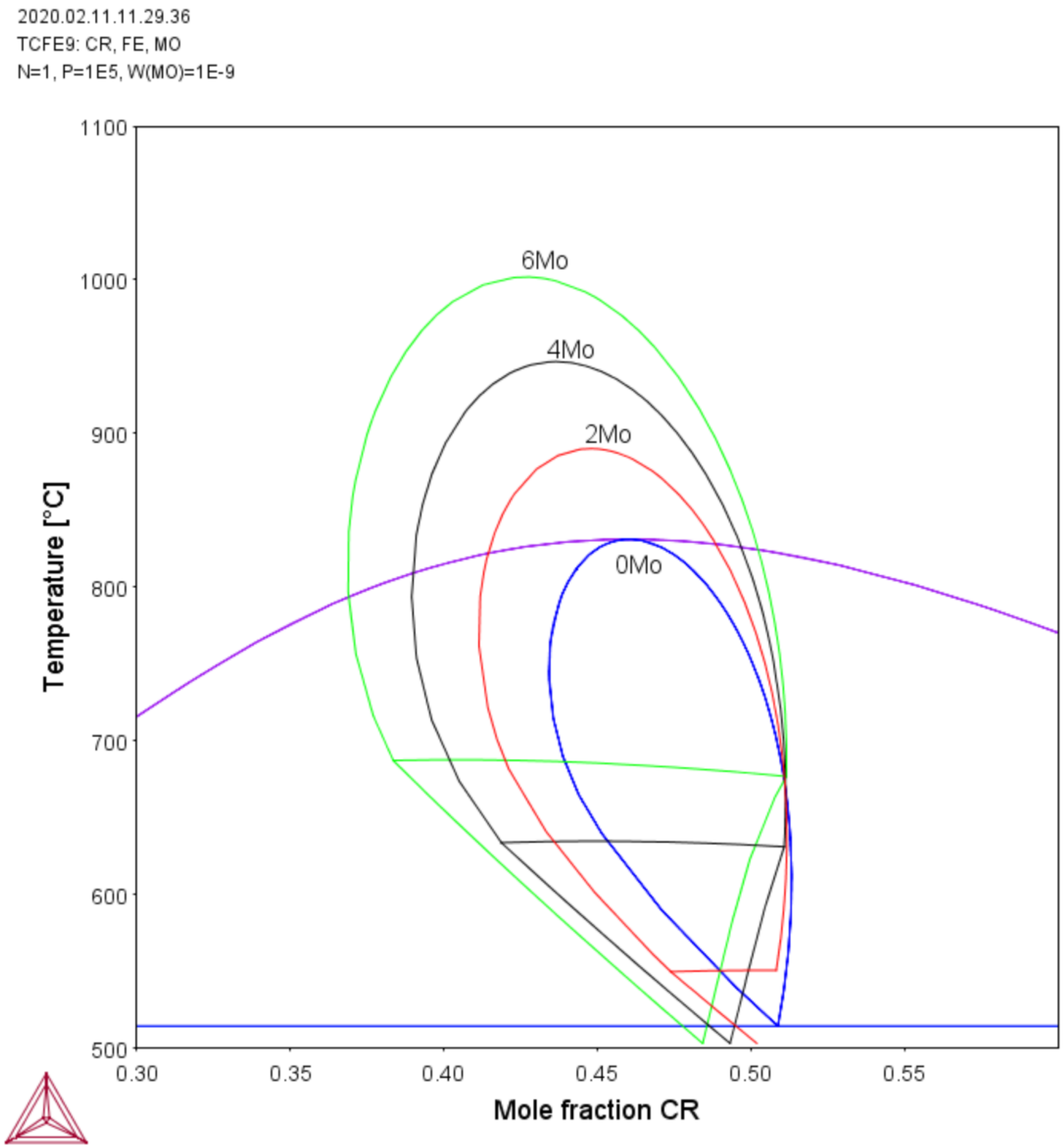
Fig. 4. Effect of PWHT to various peak temperatures on microstructure and critical pitting temperature of weld B (0.45 kJ/mm)

Sigma Phase

austenitics – kinetics slowed down by N
duplex – smaller effect by N and
 - faster kinetics since ferrite has high mo high Cr



Fe Cr phase diagram



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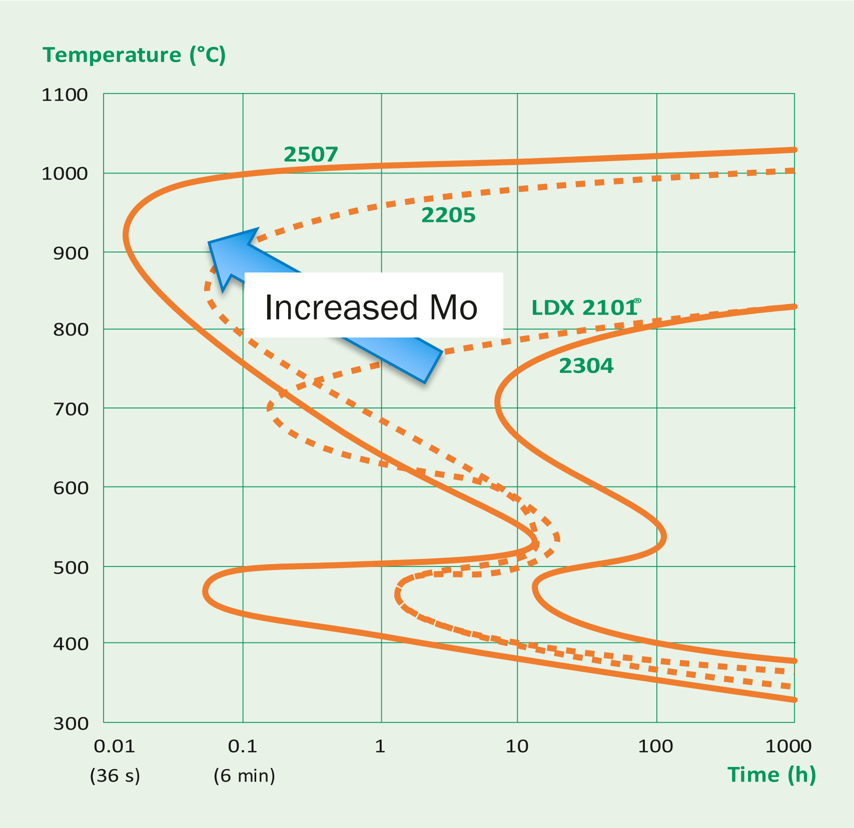
TCFE9: CR, FE, MO
N=1, P=1E5, W(MO)=1E-9
6Mo
4Mo
2Mo
0Mo
Temperature [°C]
Mole fraction CR
1100
1000
900
800
700
600
500
0.30
0.35
0.40
0.45
0.50
0.55

Curves for reduction of impact toughness to 50% compared to solution annealed condition



(Outokumpu broschure on duplex grades)

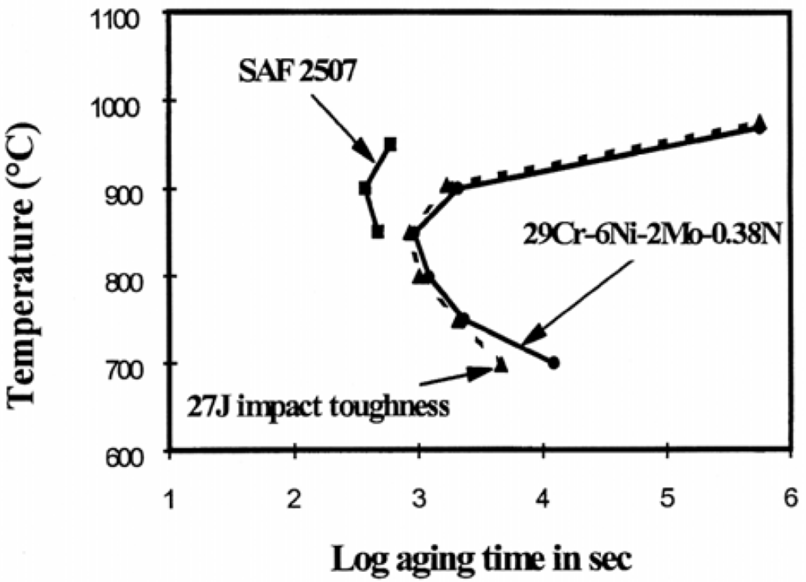
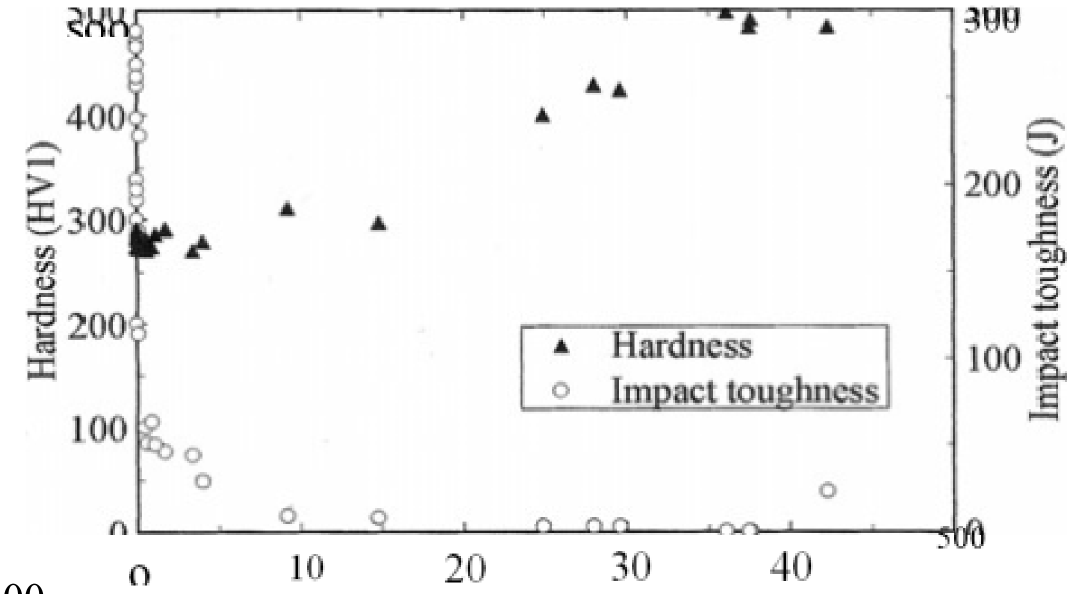


Fig. 11—TTT diagram showing the C curve representing 5 pct σ phase for the present alloy and, for comparison, the coresponding curve for the super DSS SAF 2507. As shown in the diagram, the curve corresponding to an impact toughness of 27 J shows a very good agreement with 5 pct σ phase.

Influence of sigma phase on mechanical properties in SAF 2906 superduplex



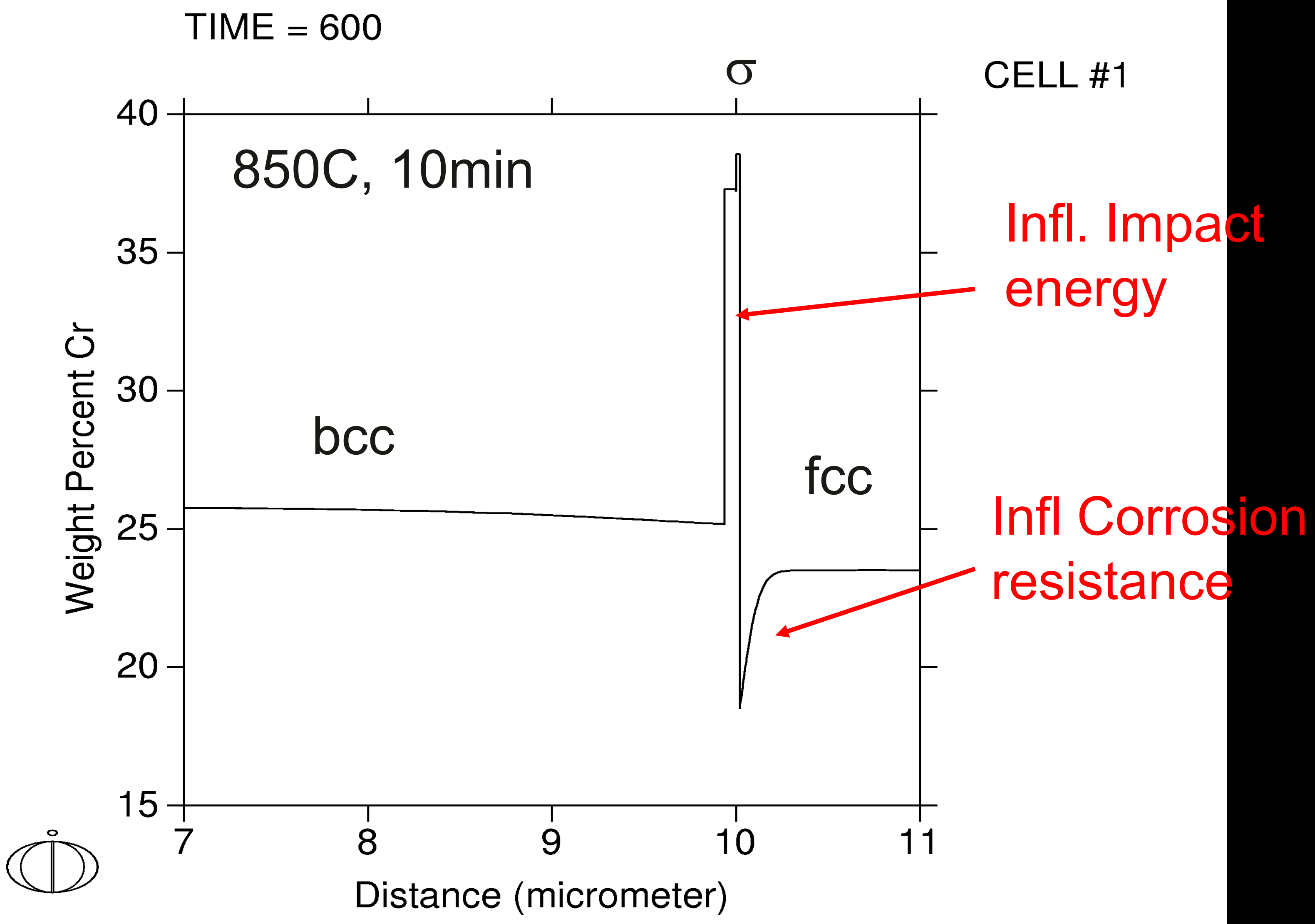
100

Volume pct of intermetallic phase

Fig. I—Hardness and impact toughness plotted as a function Of volume percent of T phase showing a rapid decrease in toughness already for small amounts Of phase but a slow increase in hardness starting beyond as much as 5 pct of phase.

J.-O. NILSSON, P. KANGAS, T. KARLSSON, and A. WILSON Met Trans jan 2000

Intermetallic phase effect on properties



Thank you for the attention!

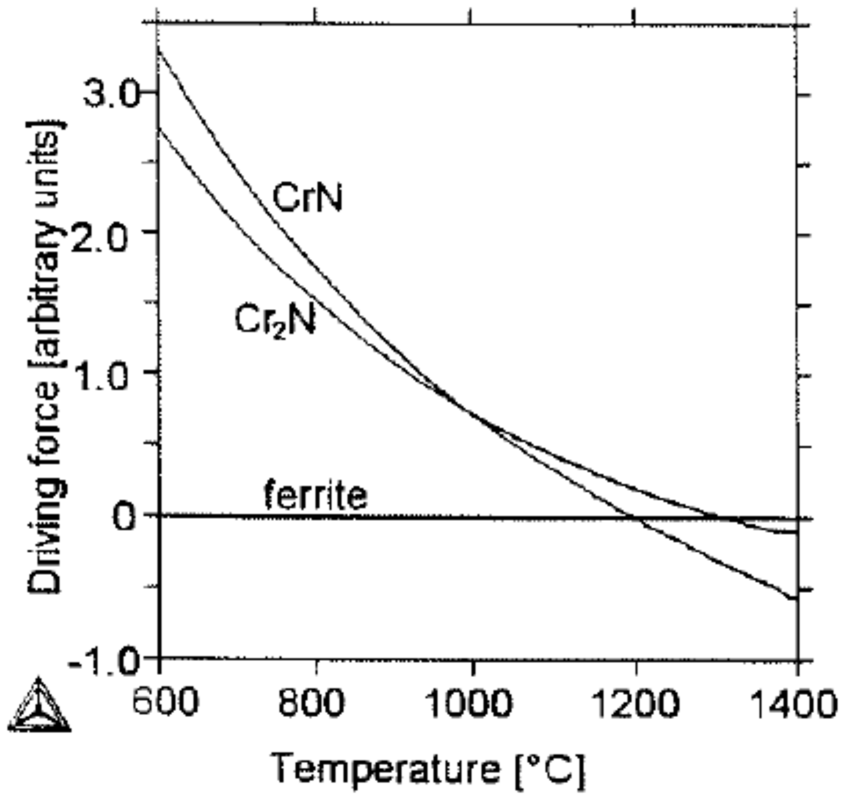


Fig.9 Driving force for precipitation of nitrides in a supersaturated ferritic matrix of a typical UNS 31803 duplex stainless steel composition. At lower temperatures the CrN nitride has a larger driving force for precipitation which, in addition to the probably more critical fact that the lattice misfit is favourable, leads to the precipitation of CrN under rapid cooling conditions.