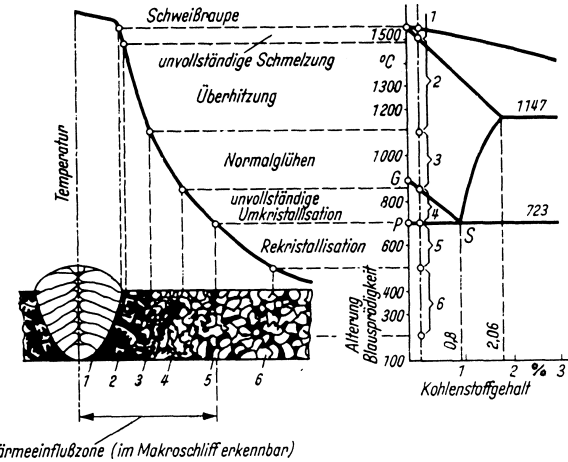
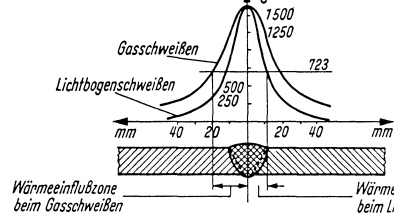
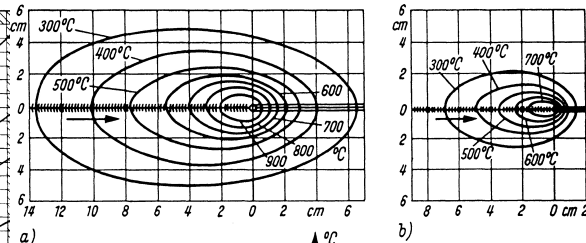
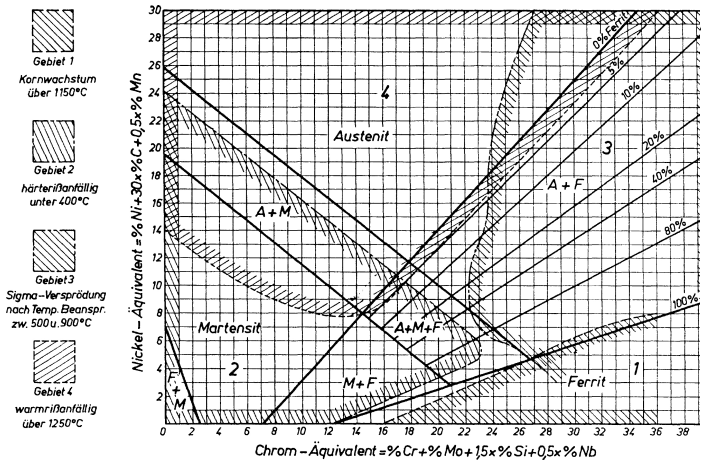


Welding of High-alloyed Steels

Weldability and Problems



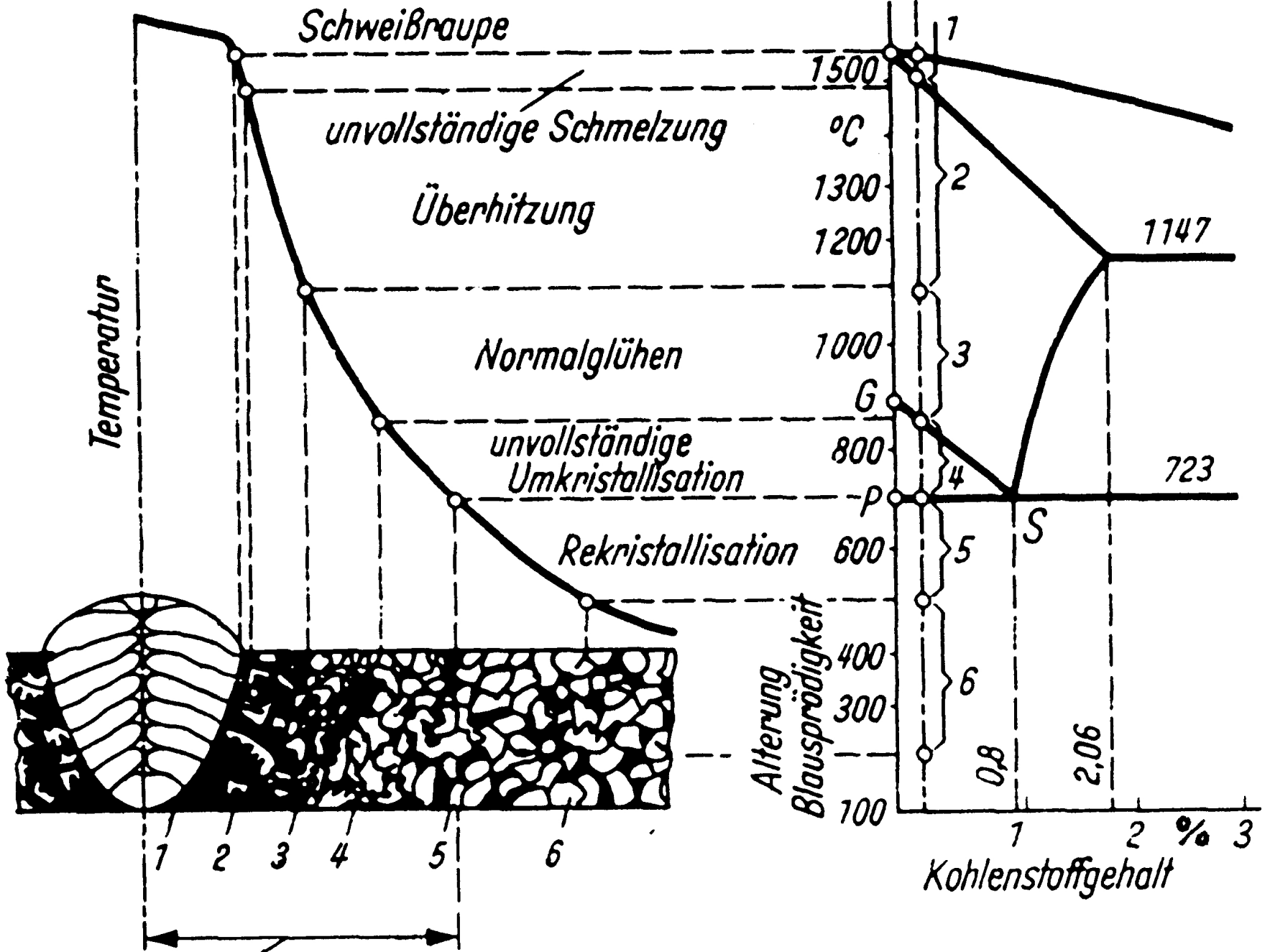
Short report about a literature paper – <http://sandig-fg.de>

Structure

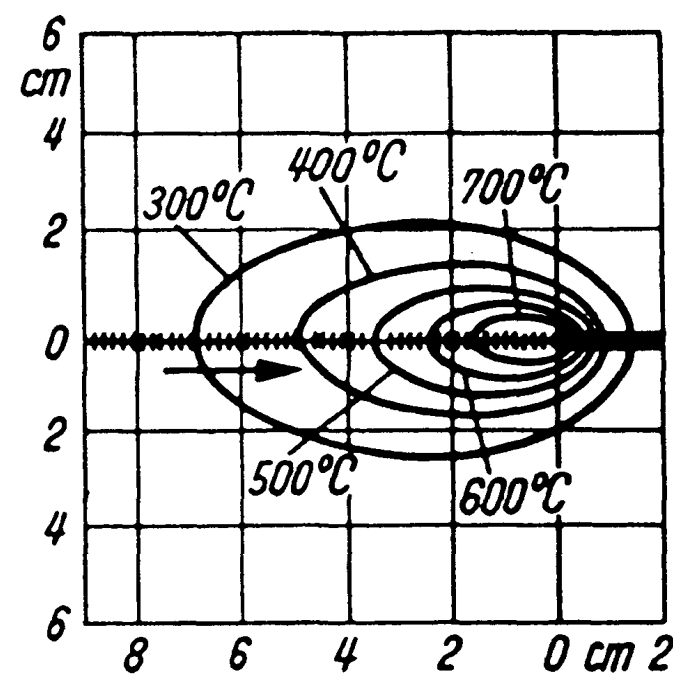
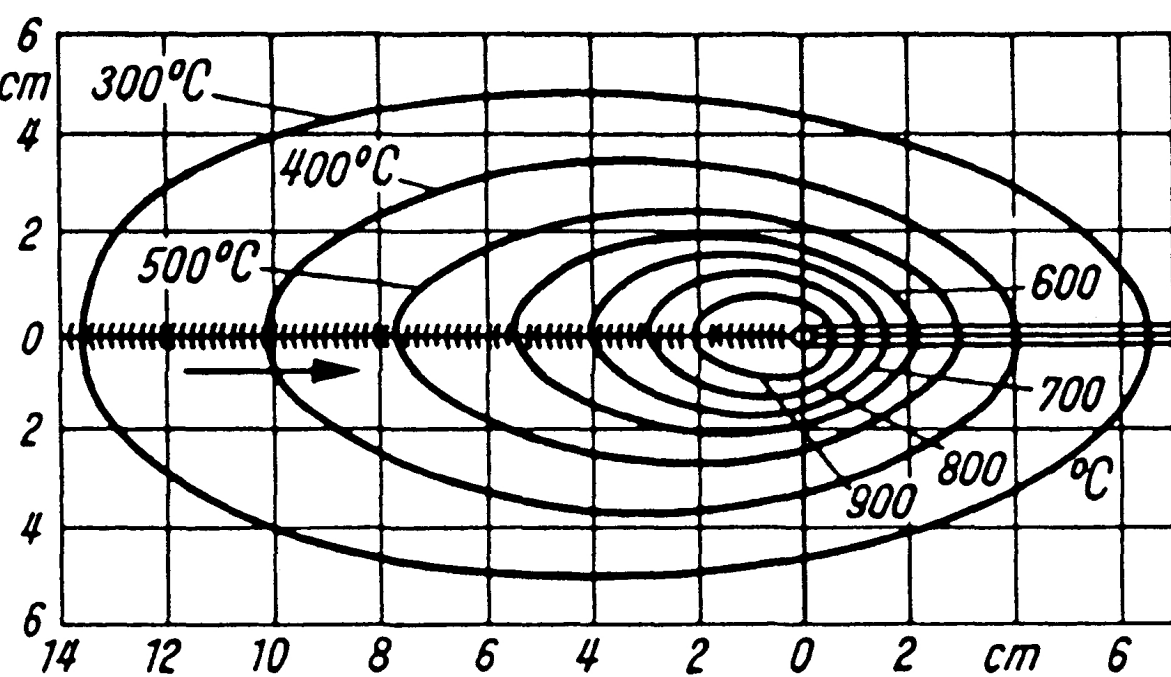
- 1. Material Affection**
- 2. Welding Defects**
- 3. Three Types of Steels**
- 4. High-Mn Austenites**
- 5. Conclusion**
- 6. Sources**

1. Material Affection

- **heat input → changes in microstructure**
- **Fusion zone (FZ)**
- **Heat affected zone (HAZ)**
- **Unaffected material**
- **HAZ similar to heat treatment, uncontrolled**
- **ΔT very high, overheating, small pool, fast cooling and solidification → hardly comparable to casting processes**

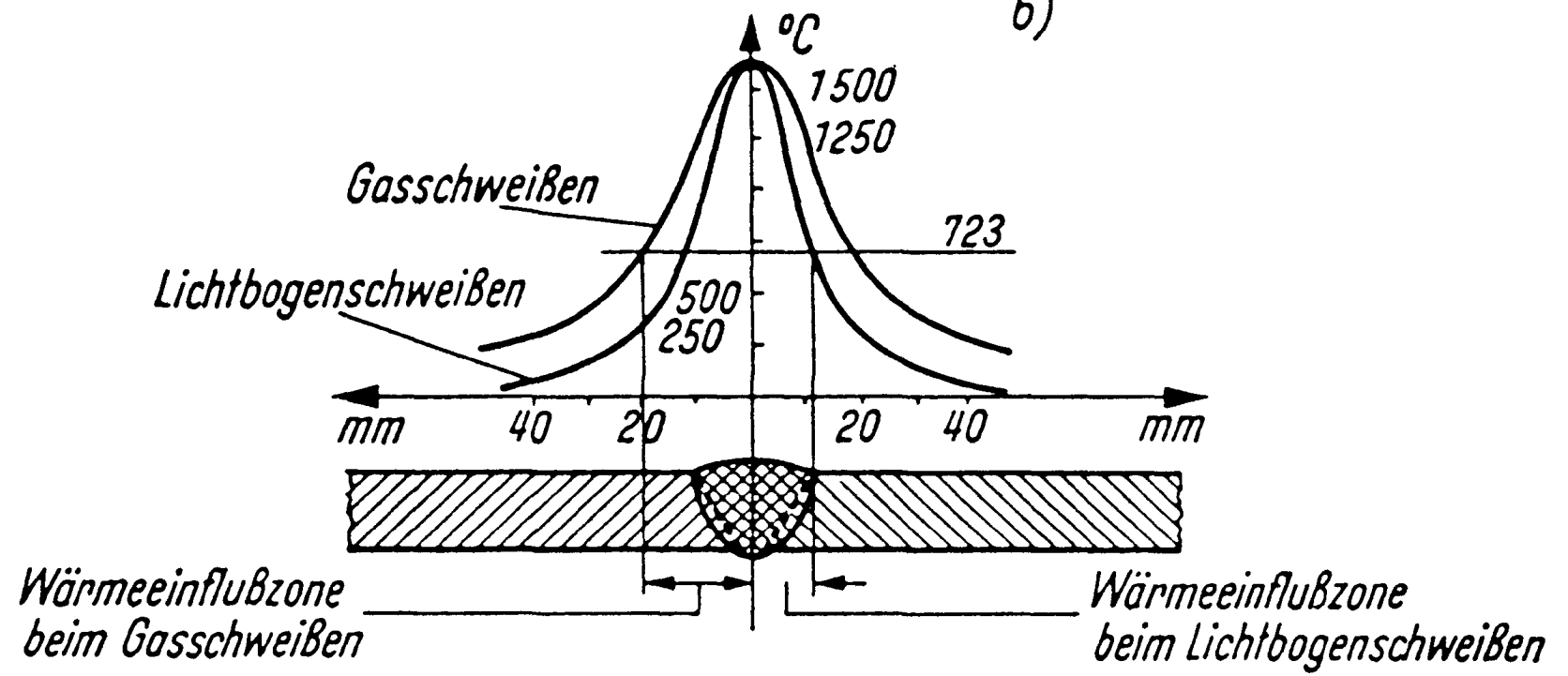


Wärmeeinflußzone (im Makroschliff erkennbar)



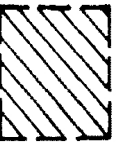

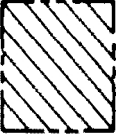
a)

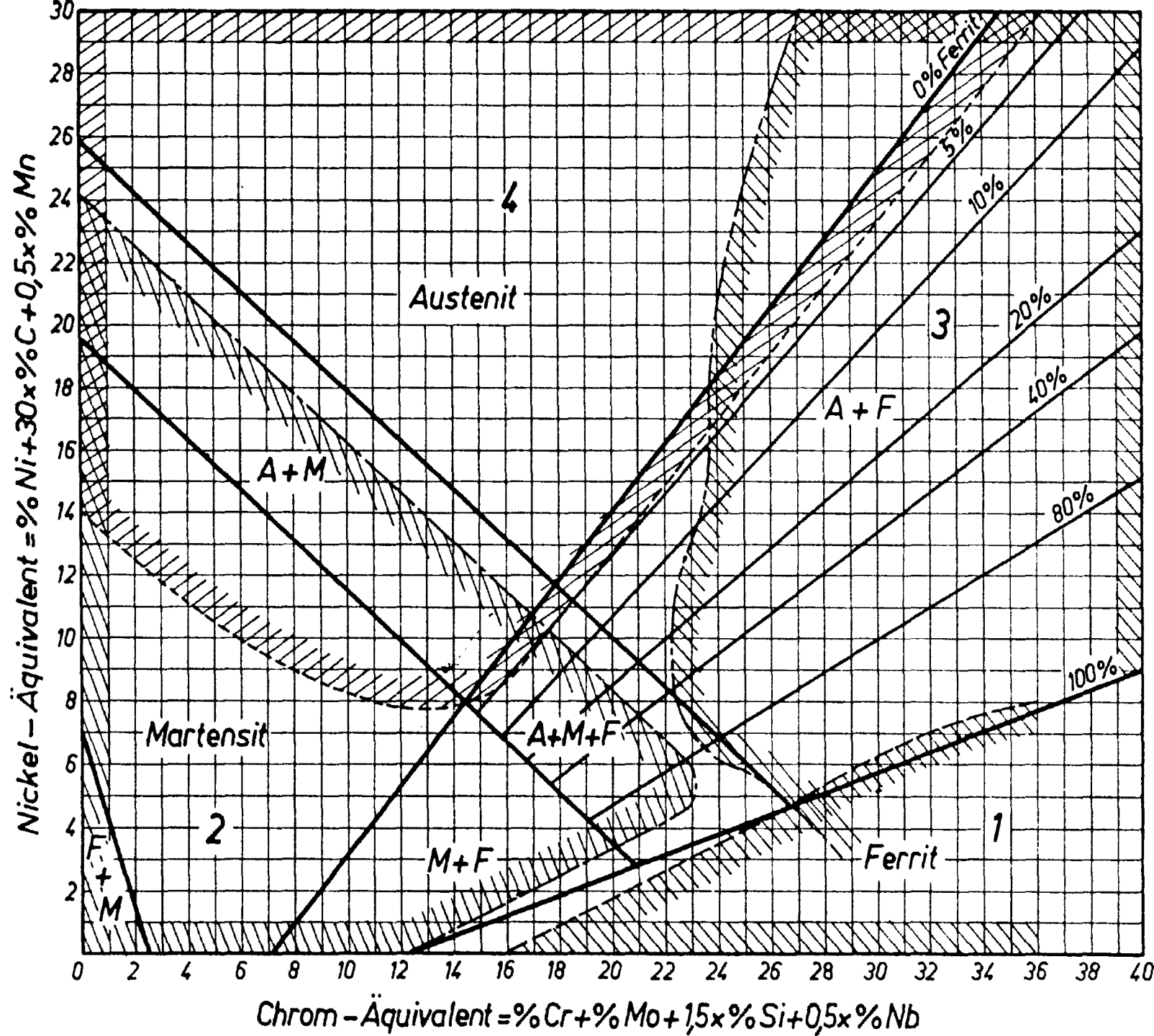
b)



2. Welding Defects

- **Hardening cracks: $T < 200 \text{ }^\circ\text{C}$, Martensite**
- **Coarse grain formation: Ferrite**
- **Hot cracking: $T_l > T > T_s$; S, P, C segregation**
- **Ductility Dip Cracking (below T_s)**
- **Precipitations of $M_{23}C_6$ (sensitisation)**
- **Precipitations of σ -phase**
- **Copper contaminations cracking**

-  Gebiet 1
Kornwachstum
über 1150°C
-  Gebiet 2
härterißanfällig
unter 400°C
-  Gebiet 3
Sigma-Versprödung
nach Temp. Beanspr.
zw. 500 u. 900°C
-  Gebiet 4
warmrißanfällig
über 1250°C



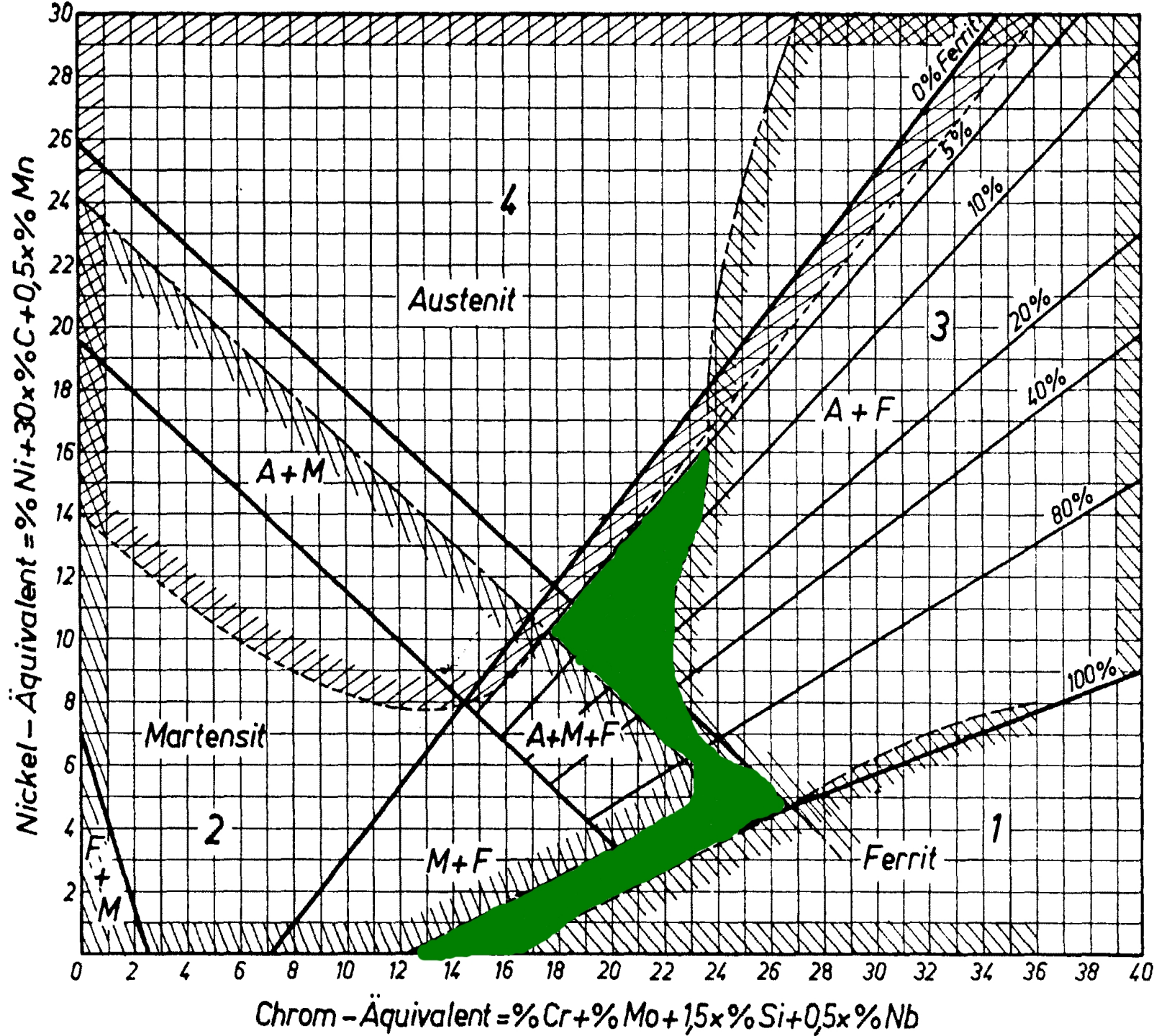
Chrom - Äquivalent = $\%Cr + \%Mo + 1,5x\%Si + 0,5x\%Nb$

Gebiet 1
Kornwachstum
über 1150°C

Gebiet 2
härteriðanfälligkeit
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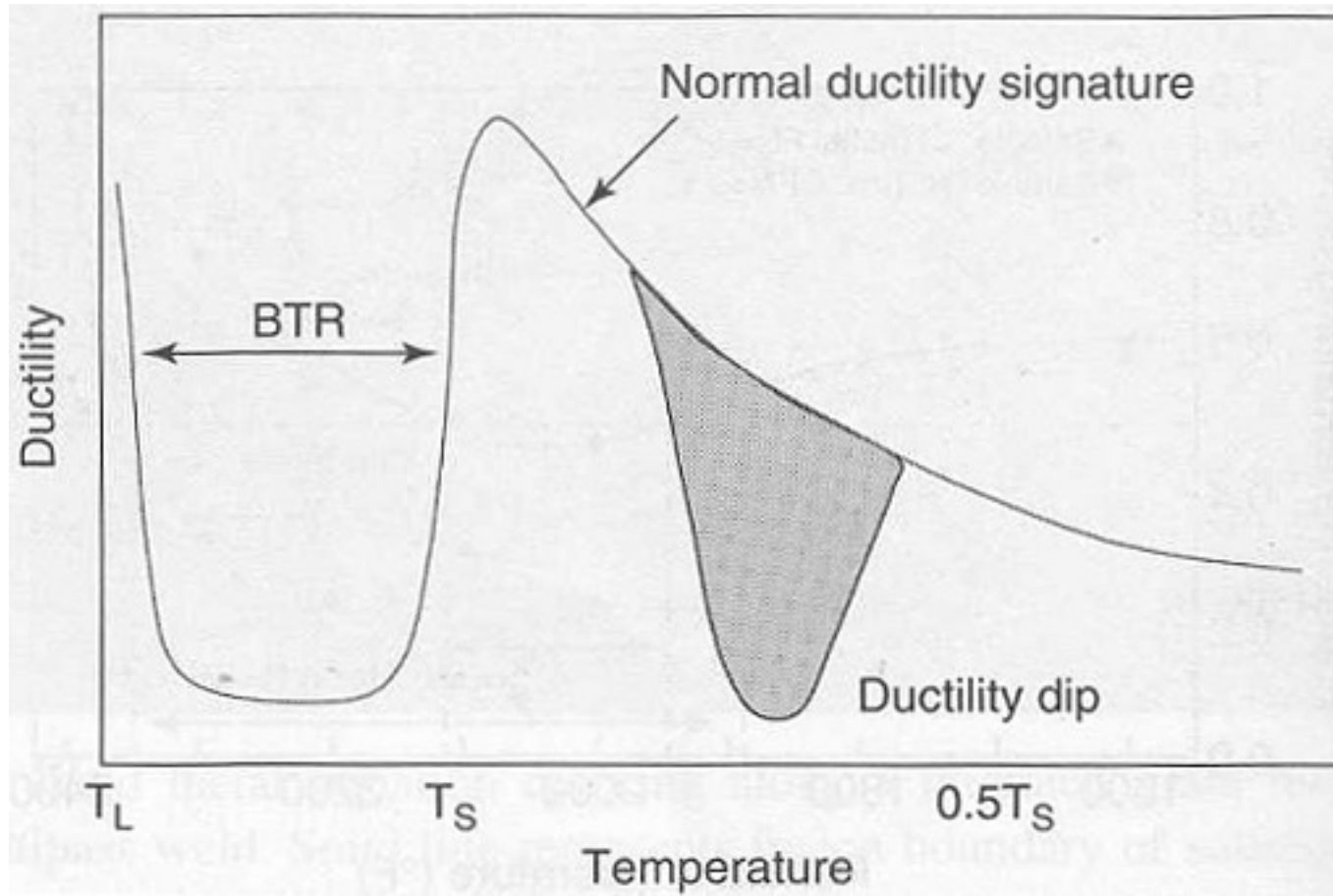
Gebiet 3
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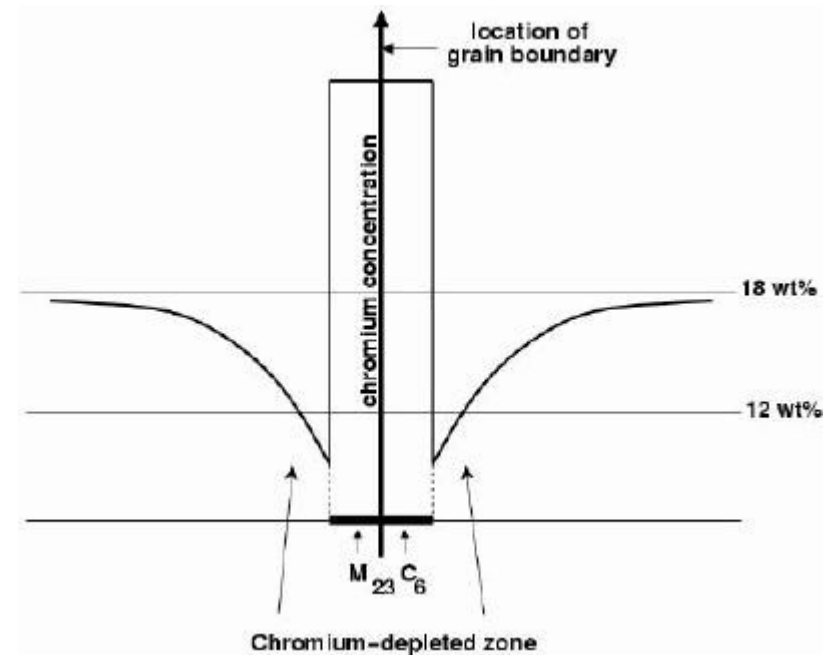
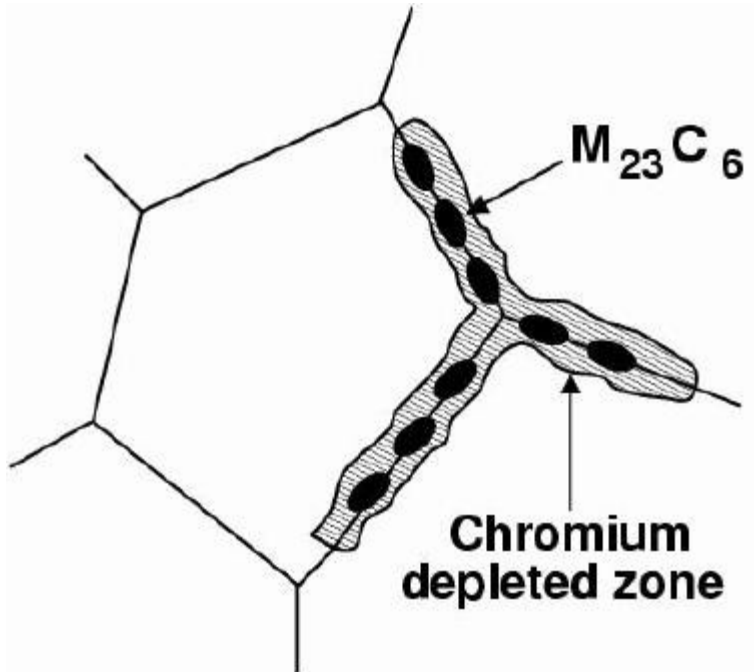


Chrom - Äquivalent = % Cr + % Mo + 1,5x% Si + 0,5x% Nb

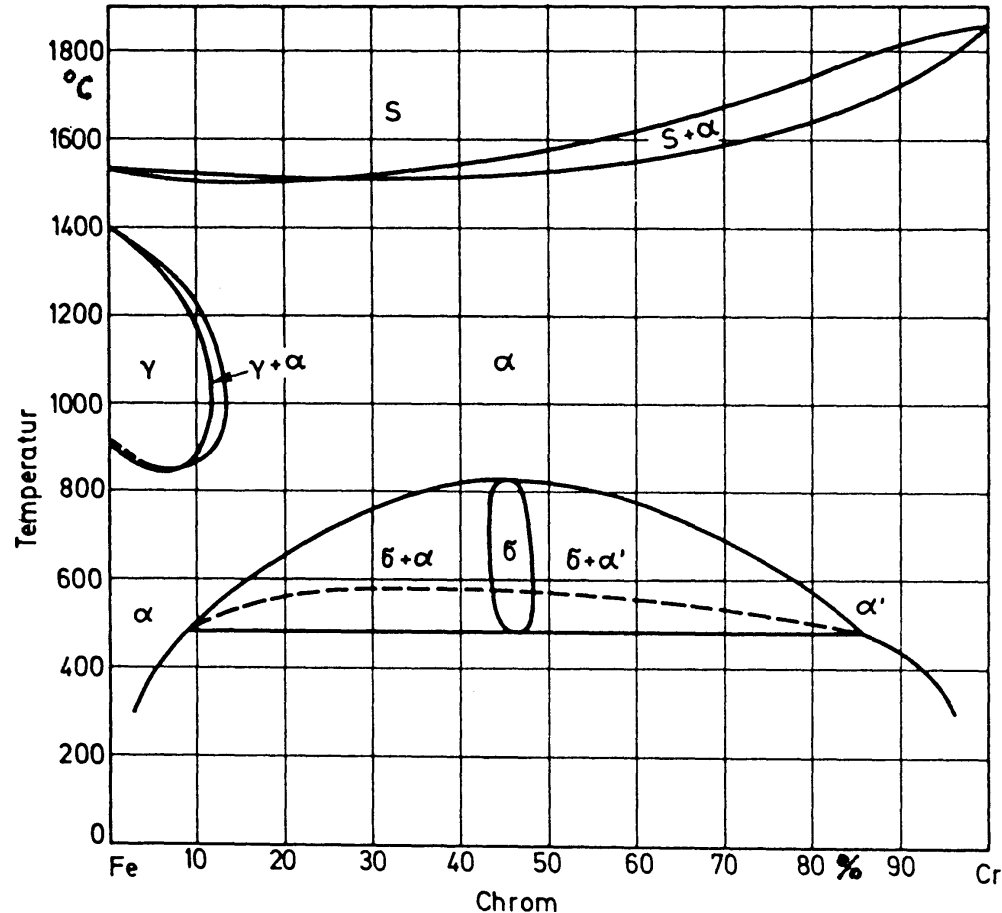
1. Welding Defects



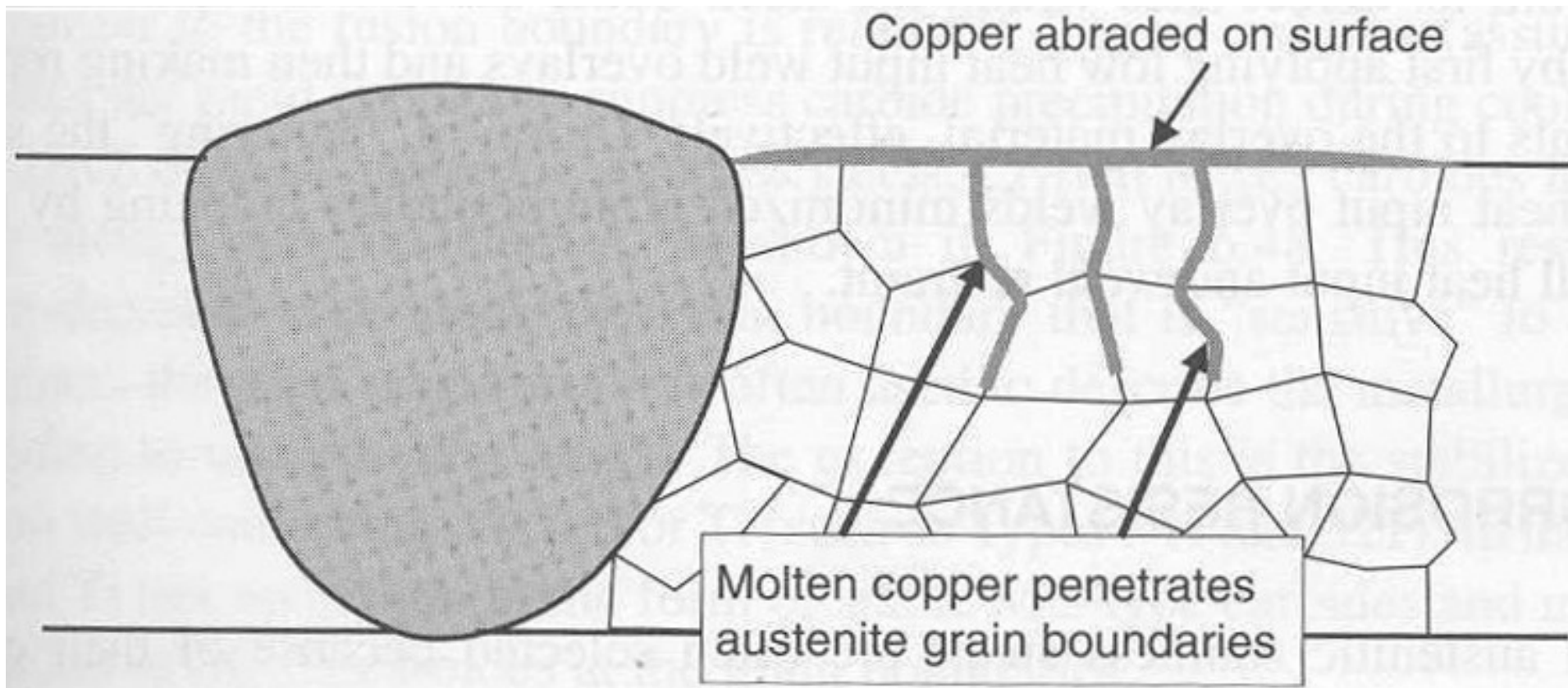
1. Welding Defects



1. Welding Defects



1. Welding Defects



3. Three Types of Steels

Ferritic Stainless Steels

- **13% to 30% Cr, < 0.1% C**
 - **Up to 2% Mo**
 - **Martensite possible, but < 20%**
 - **Average weldability, better than Martensites, worse than Austenites**
 - **Carbide precipitations (C-diffusion in fcc-iron)**
 - **Coarse grain formation**
- **reduce C, add Ti or Nb, TIG welding, low heat input, heat treatment**

3. Three Types of Steels

Martensitic Stainless Steels

- 12% to 18% Cr, < 2.5% Ni, > 0.1% C
- > 0.4% C → 100% Martensite possible
- Some steels: air hardening (X20Cr13)
- Martensite → hardening → cracking

→ good weldability: C < 0.15%, preheating 200 °C to 350 °C, slow cooling, cache layers auf austenitic steel

3. Three Types of Steels

Austenitic Stainless Steels (1)

- **> 18% Cr, > 8% Ni**
- **No transformation → no hardening**
- **Good ductility**
- **Good weldability, best of high-alloyed steels**
- **4% to 10% Ferrite: solves S, P → less hot cracking**
- **Arc welding (shielding gas), beam welding**
- **+30% thermal expansion, -50% heat conductivity than unalloyed steels → shape distortion**
- **DDC, Cu-contamination cracking, Carbides**

3. Three Types of Steels

Austenitic Stainless Steels (2)

- **No copper contact**
- **Nb stabilization (welding wire)**
- **Many tacking points, rather more smaller than less larger welding beads (distortion)**
- **Short arc**
- **Clean working area, cleaning after welding (oxides)**
- **No heat treatment after welding**
- **Best results: beam welding**

4. High-Mn Austenites (1)

- **Good weldability, see austenites ($> 12\%$ Mn)**
- **Mn binds S \rightarrow less hot cracking**
- **Good low-T ductility, higher HAZ ductility**
- **Low Mn prices \rightarrow Ni substitute (Austenite prom.)**
- **Work hardening**
- **Low thermal expansion; $f(\%Mn) \rightarrow$ lower distortion**
- **High solubility for N**
- **N: stabilizes Austenite, may cause problems
> 300ppm**

4. High-Mn Austenites (2)

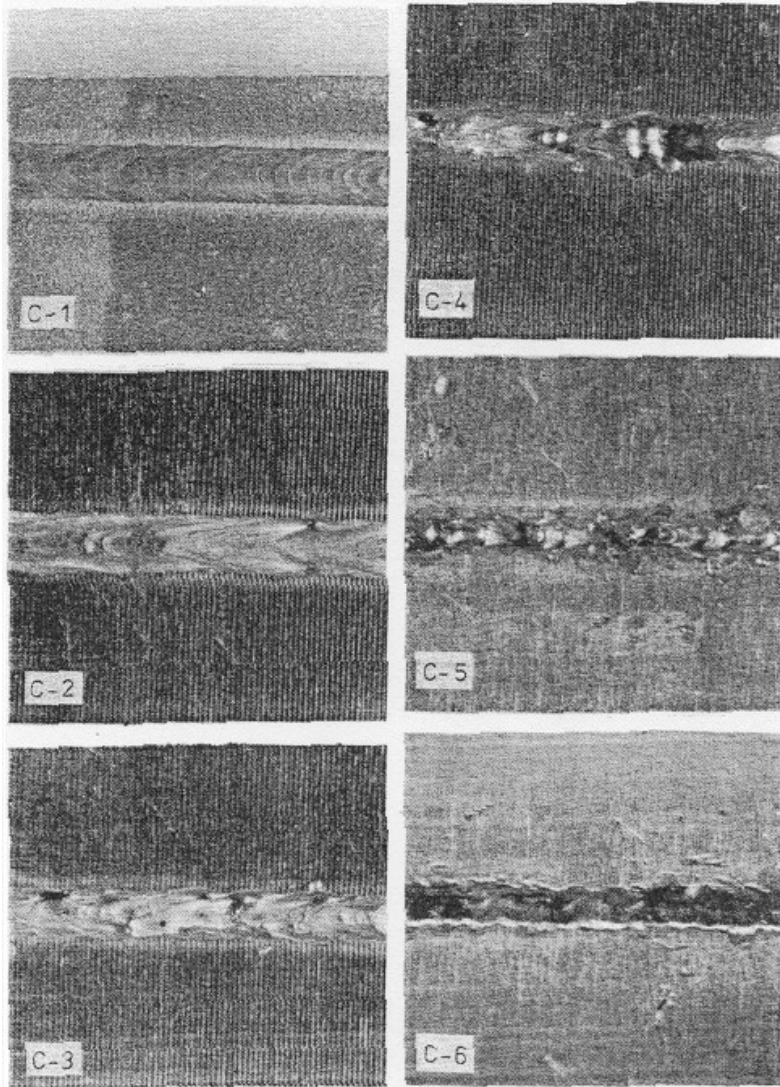
- **Mn: no negative effect on weldability, as Ni**
- **N: weldability decreases, gas eruptions > 2000ppm depending on solubility $f(\%Mn, \%Cr, \%Ni, \dots)$**
- **Laser beam welding**
- **Electron beam welding**
- **Both: less cracking, better surface, good control**
- **Best for welding of high-N steels: electron beam**

E-beam welding of high-Mn austenite with high N content:

El.	Mass%
Cr	20,06
Ni	6,65
Mn	8,96
C	0,033
S	0,011
P	0,019
Si	0,22
N	0,31
O	0,008

variation: I, v, focus

Casey 1976



*Categorisation of weld quality with reference to top bead appearance.
× 2.25.*

5. Conclusion

- **Welding of high-alloyed steels is always possible, but never easy**
- **Special precautions**
- **No air, work fast, low heat input, fast cooling (except for Martensites)**
- **Martensite < Ferrite < Austenite**
- **M: cracking; F: coarse grain, carbides**
A: sensitization, distortion; high-Mn with N: gasing & porosity, but often better than A (S binding)
- **Best results: beam welding**

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[A2]: Askeland, D. R.: Materialwissenschaften - Grundlagen, Übungen, Lösungen; Spektrum Akademischer Verlag GmbH Heidelberg, ISBN 3-86025-357-3

[A3]: Autorenkollektiv: Stahlschlüssel-Taschenbuch, 21. Auflage, Verlag Stahlschlüssel Wegst, GmbH, Marbach / N. 2007, ISBN 3-922 599-22-2

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Reading Recommendation

- **Kotecki, D. J.; Lippold, J. C.: Welding Metallurgy and Weldability of Stainless Steels; WILEY-INTERSCIENCE 2005; ISBN 0-471-47379-0**



Welding of High-alloyed Steels - Weldability and Problems

Thank You!

Any Questions?

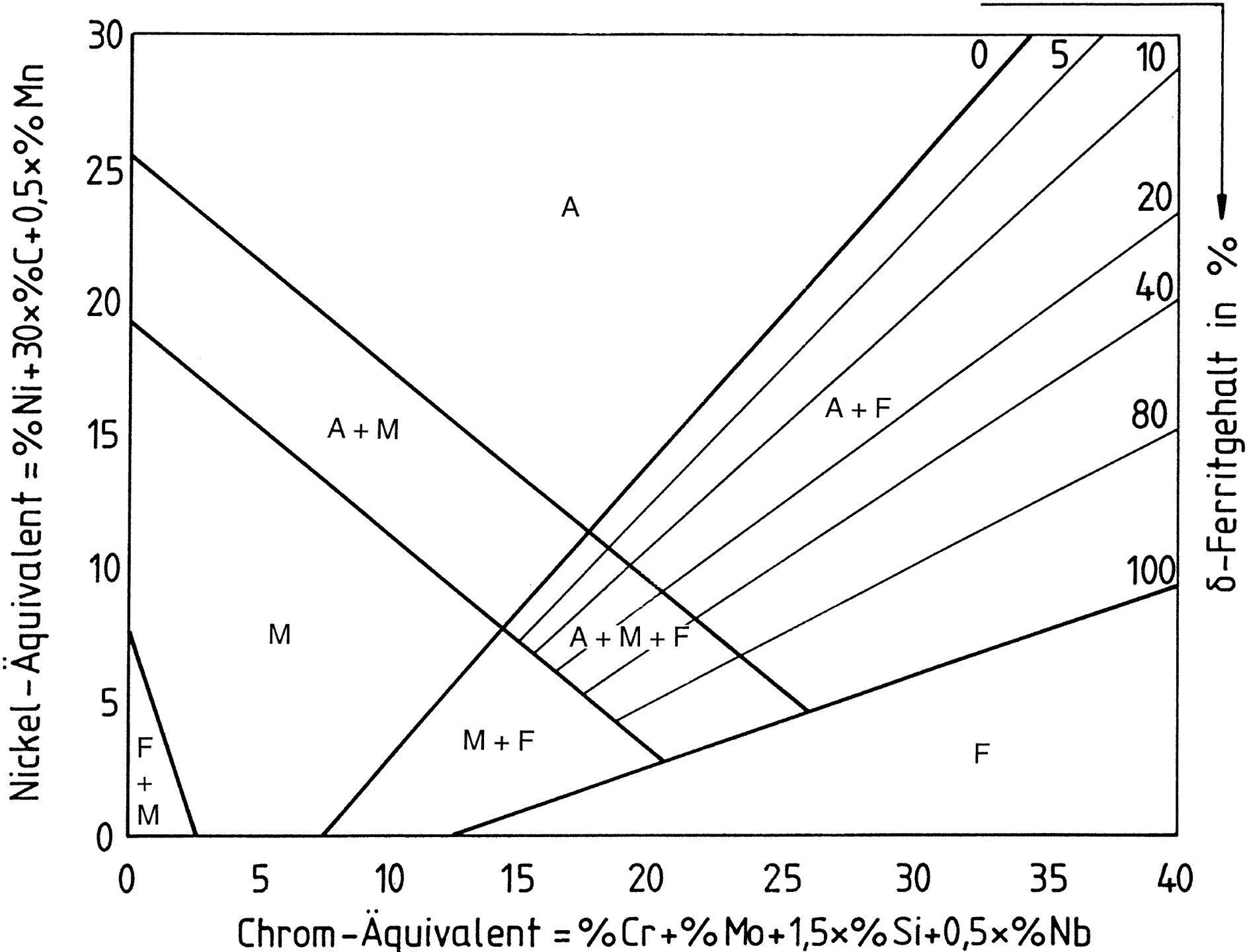
Frank Sandig

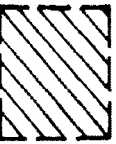

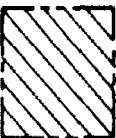
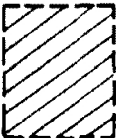
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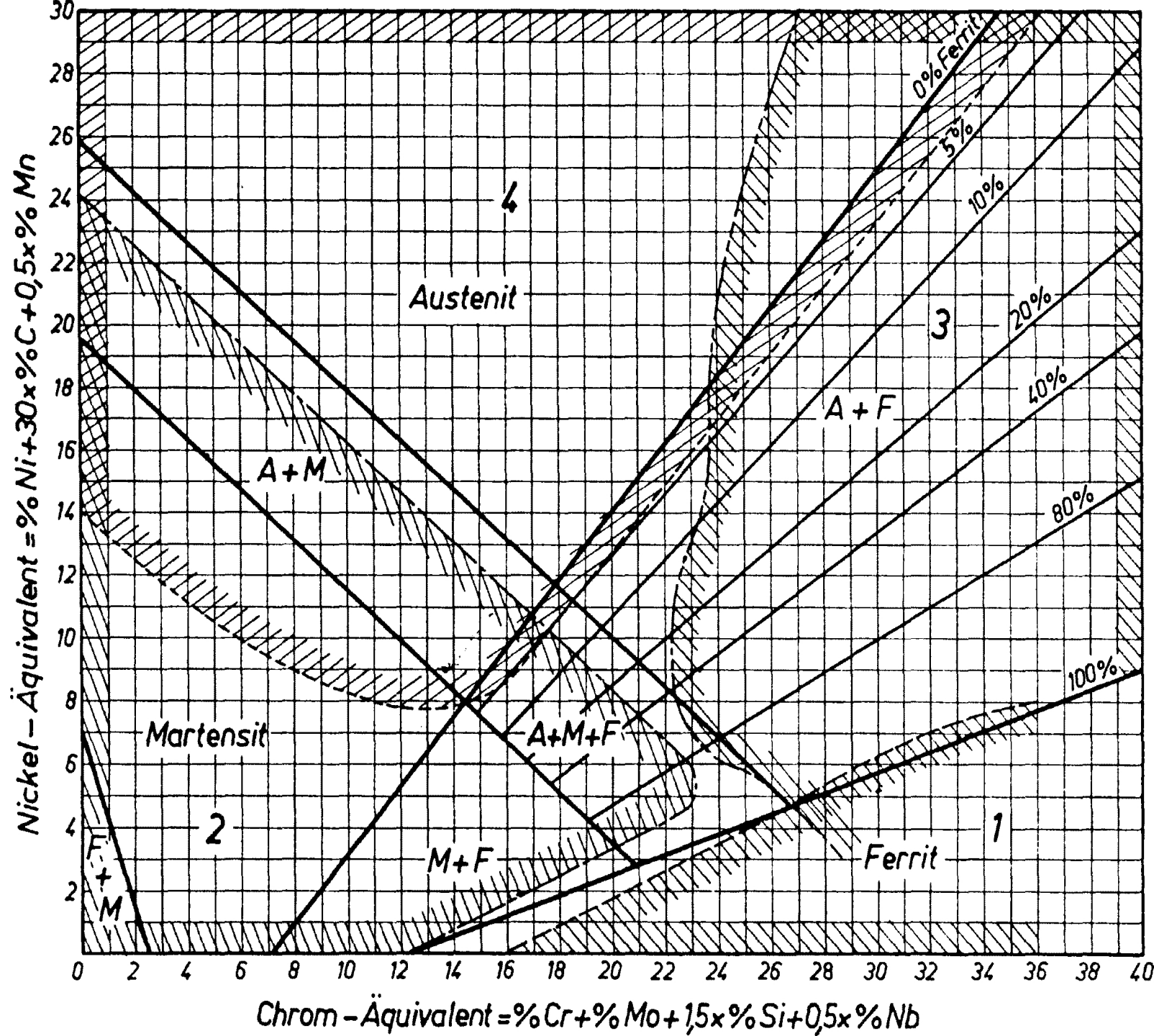
<http://sandig-fg.de>

Welding diagrams

- **Solidified structure after welding**
- **Non-equilibrium diagrams**
- **Many experiments → time**
- **Limited use: chemical composition**
- **Precision vs. extension of range**
- **Schaeffler**
- **Bystram-Schaeffler**
- **WRC-1992**



-  Gebiet 1
Kornwachstum
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härterißanfällig
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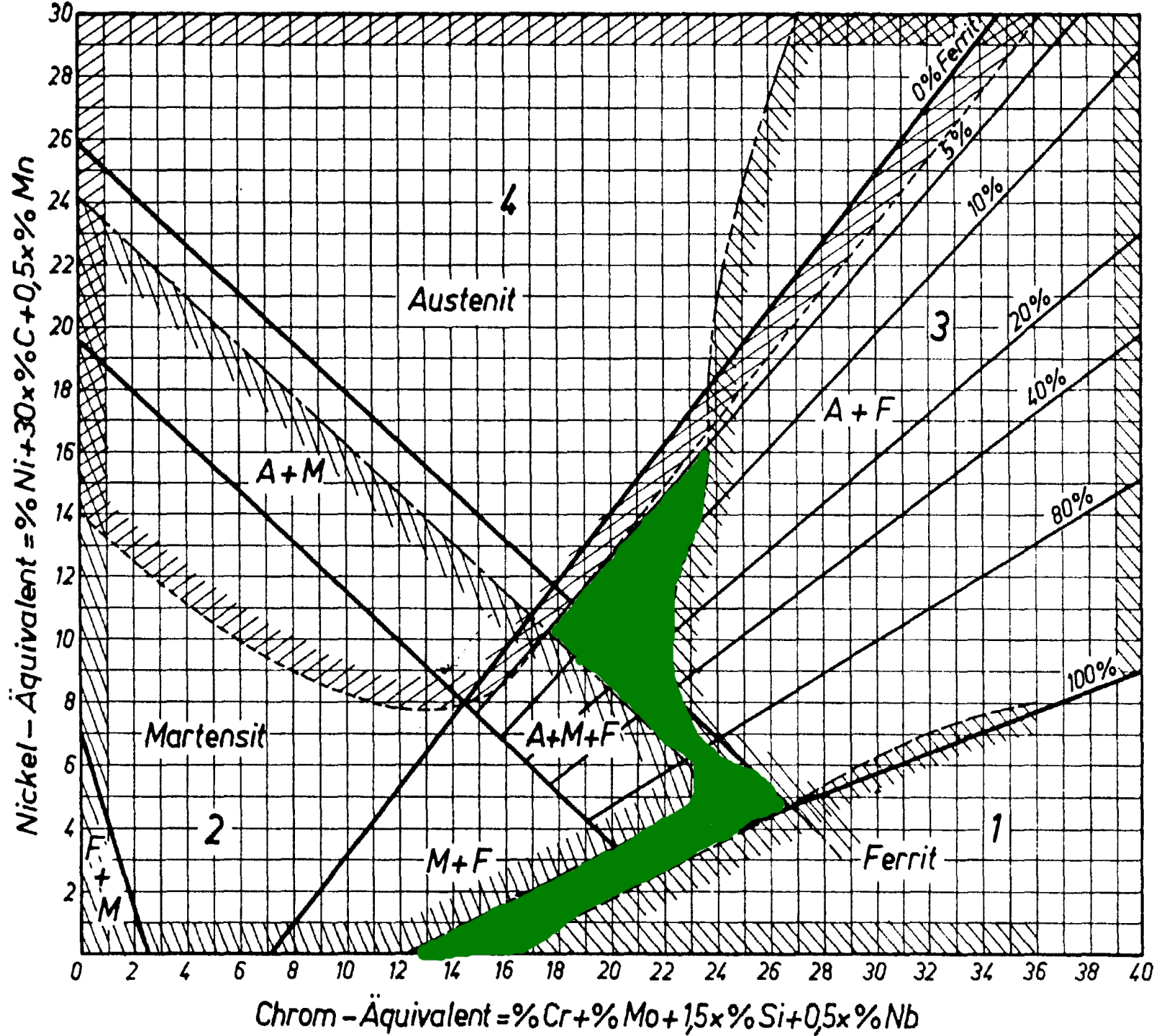


Gebiet 1
Kornwachstum
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härteriðanfälligkeit
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