High Strength Steel for Steel Constructions

Ronny Willms
AG der Dillinger Hüttenwerke

CONTENT

High strength steel – What´s that?

End of 1920: Introduction of the steel grade St52 (S355) for bridge-building (Prof. Klöppel)

→ **St52 was called a high strength steel for a long period**

Now: S355 is a standard material for bridge-building

→ **Definition of „high strength“ depends on the technical developement**

Today´s Definition: high strength steel

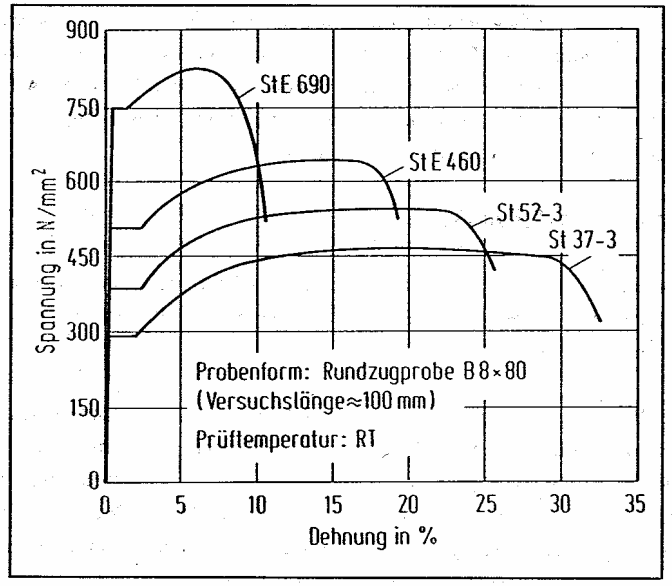
⇔

Steel with R_{eH} > 355 MPa

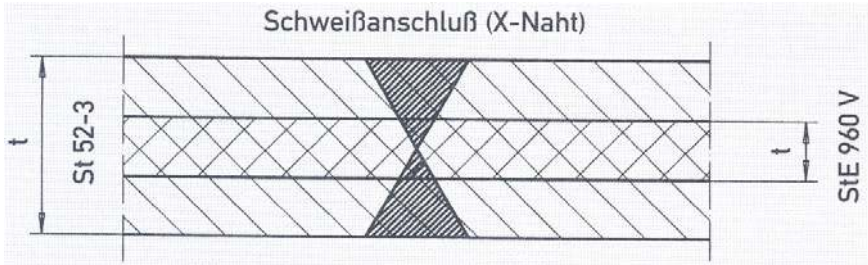
Introduction

High strength steel

Weight reduction

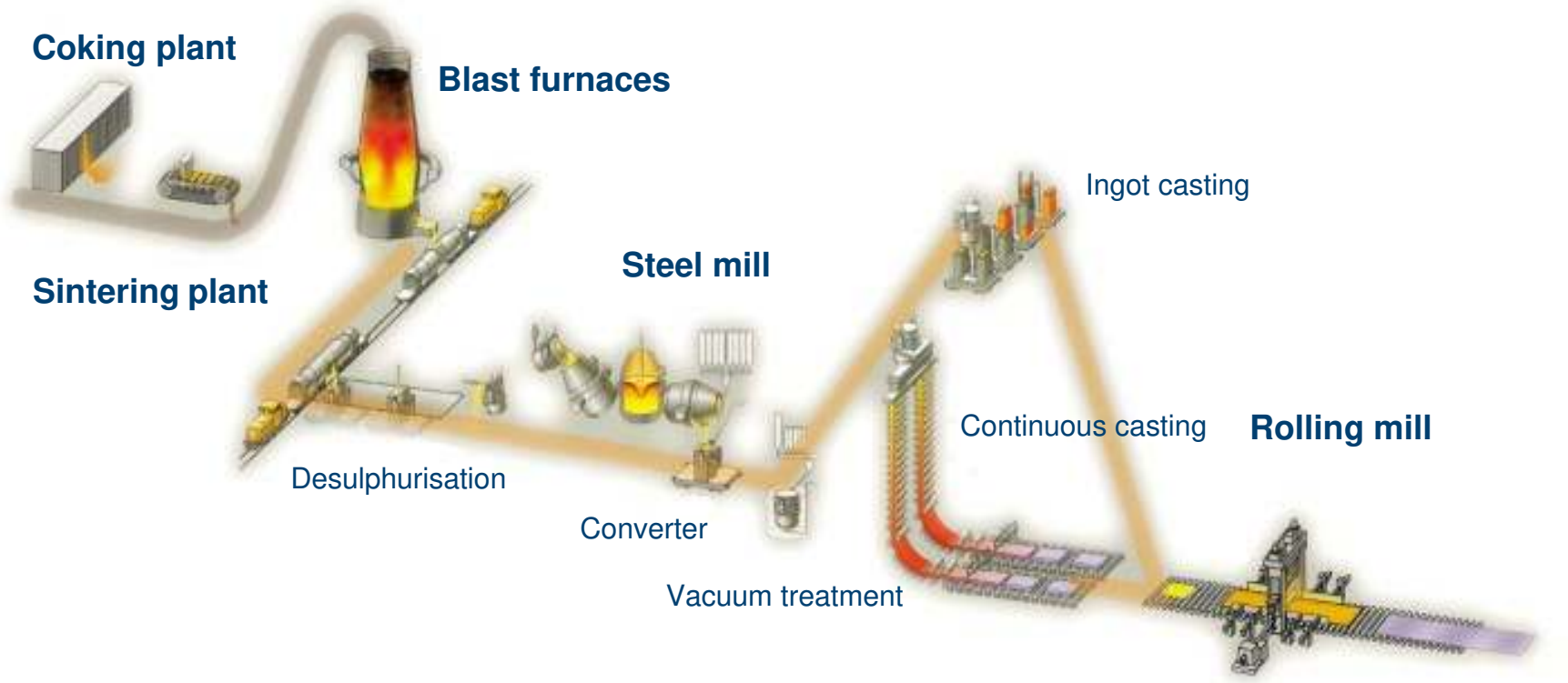


Economical processing

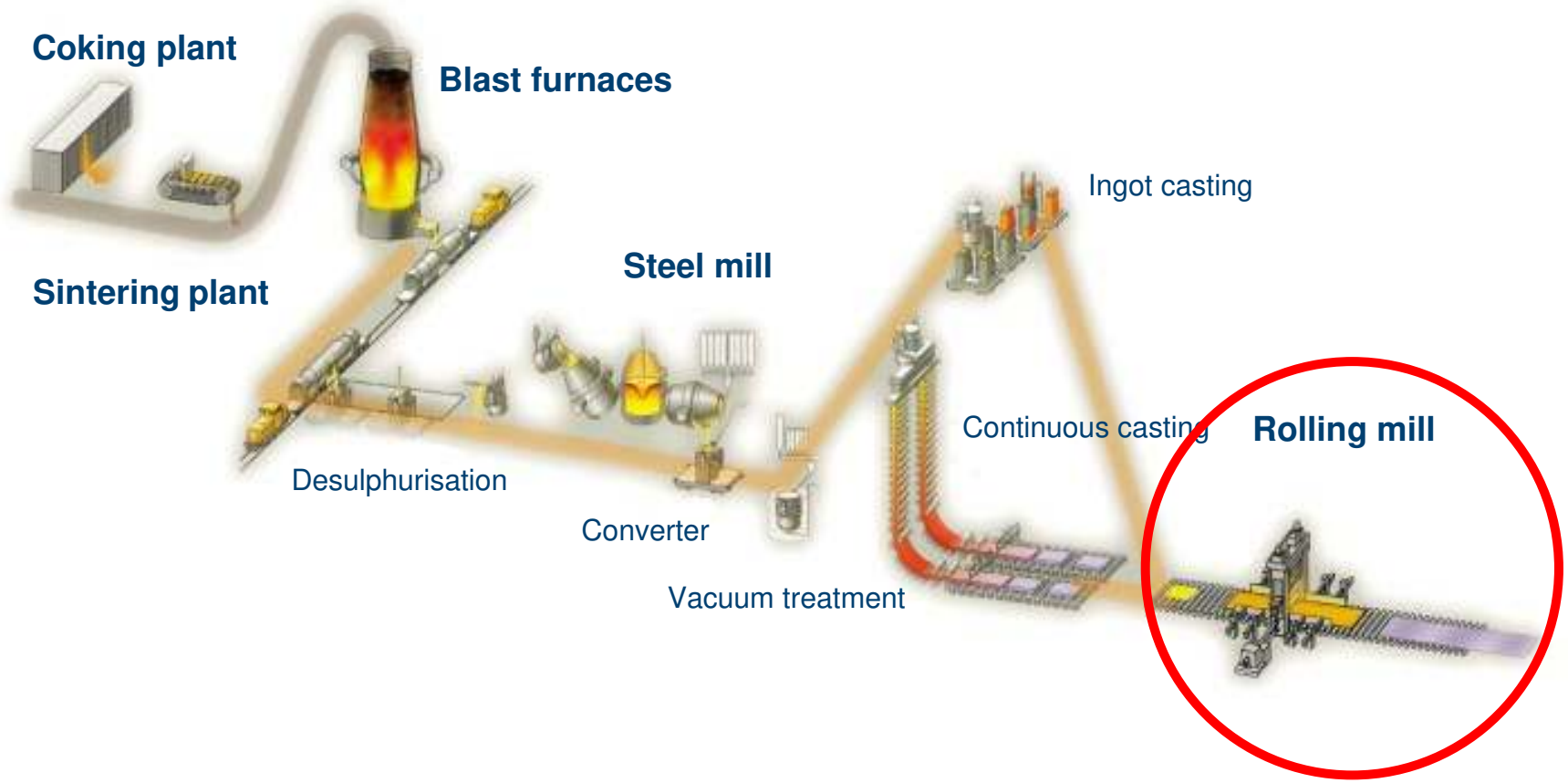


Verhältnis		Verhältnis
1	Streckgrenze	2,8
3	Blechdicke t	1
7, 4	Schweißgutmenge	1
1	Kosten d. Schweißdrahts	3,3
2,3	Kosten Schweißnahtmaterial	1
5,1	Bezogene Kosten der Schweißung	1

Introduction



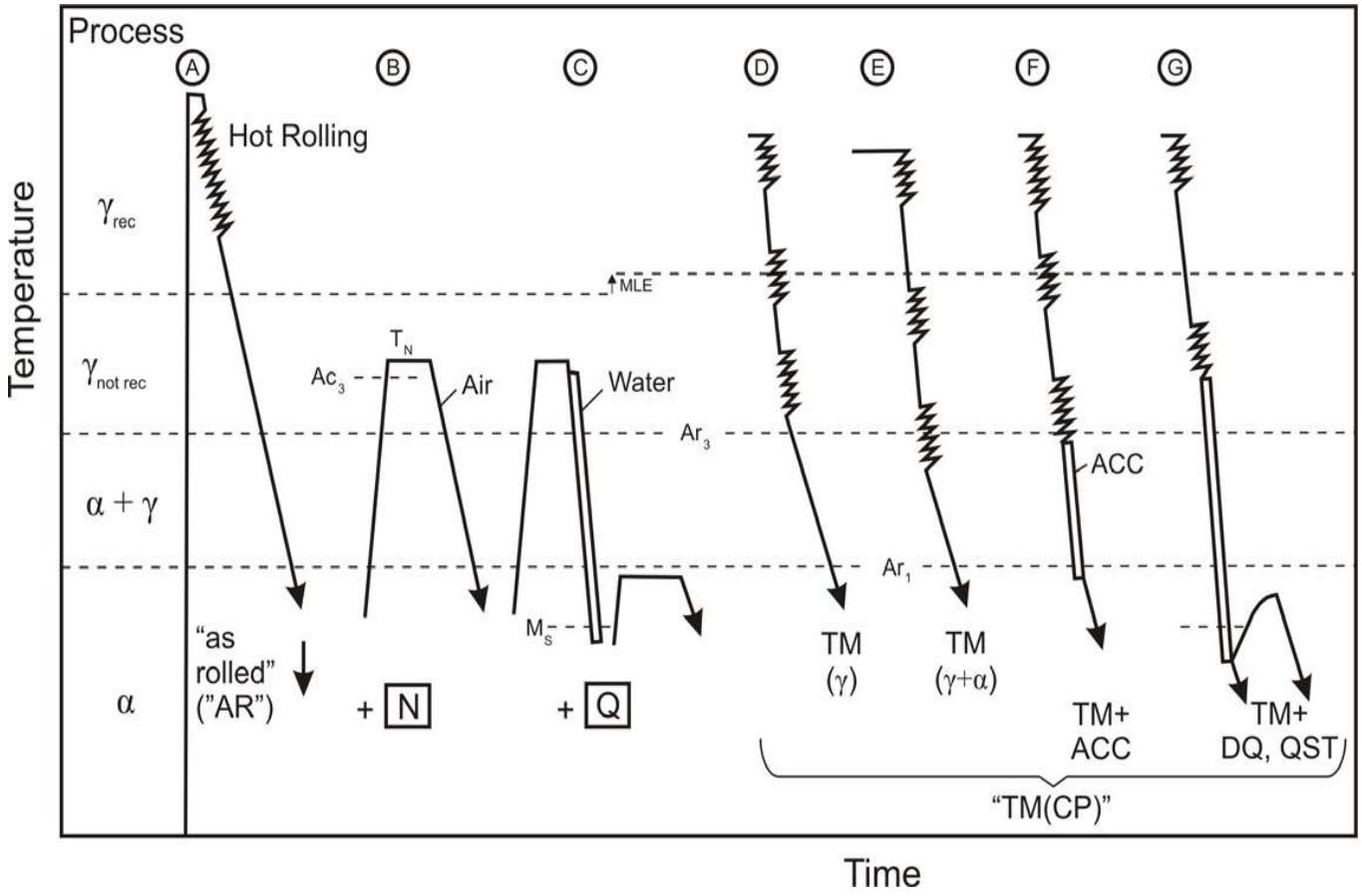
Introduction



DELIVERY CONDITIONS

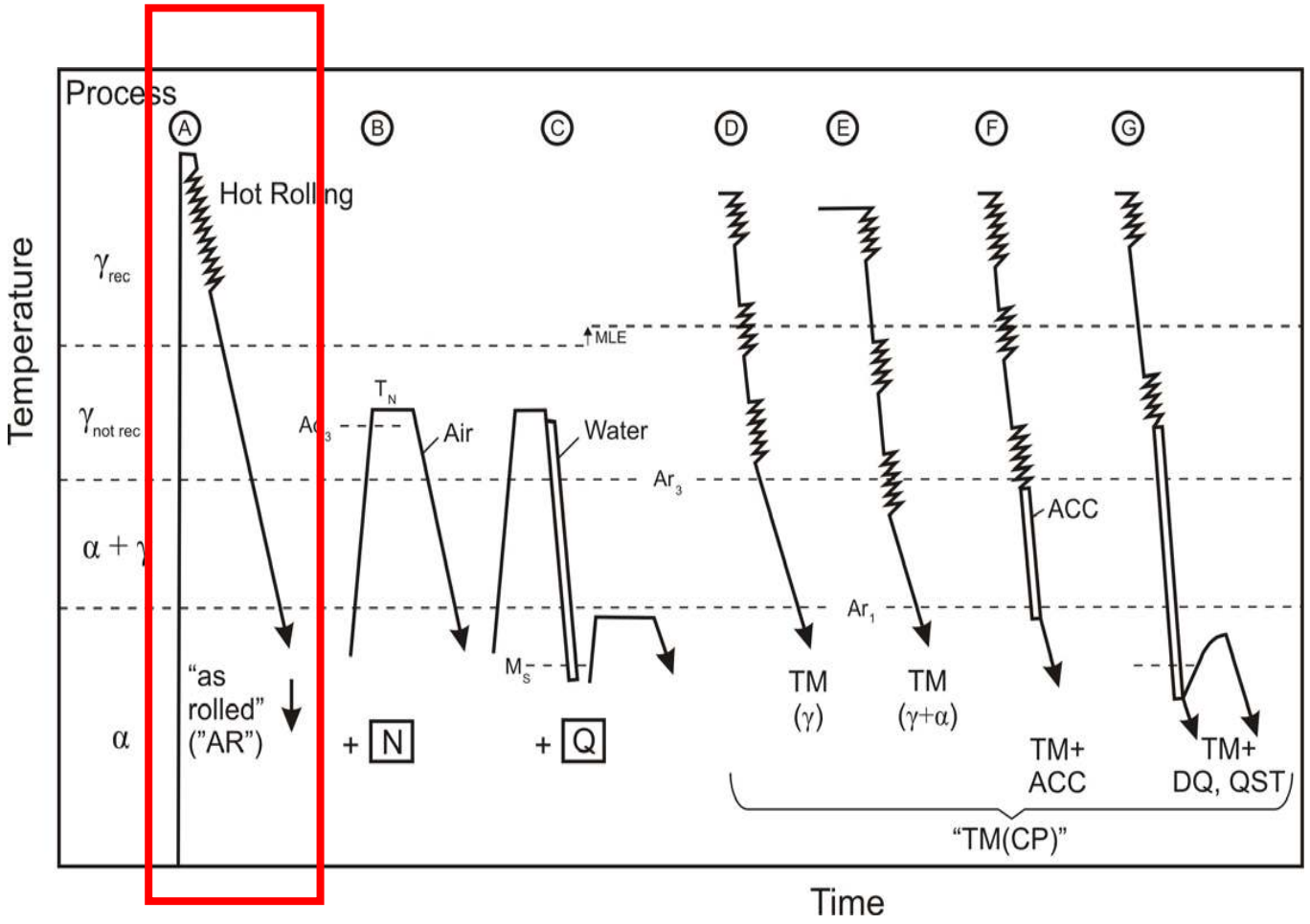
AR TM Q+T N

Delivery Conditions



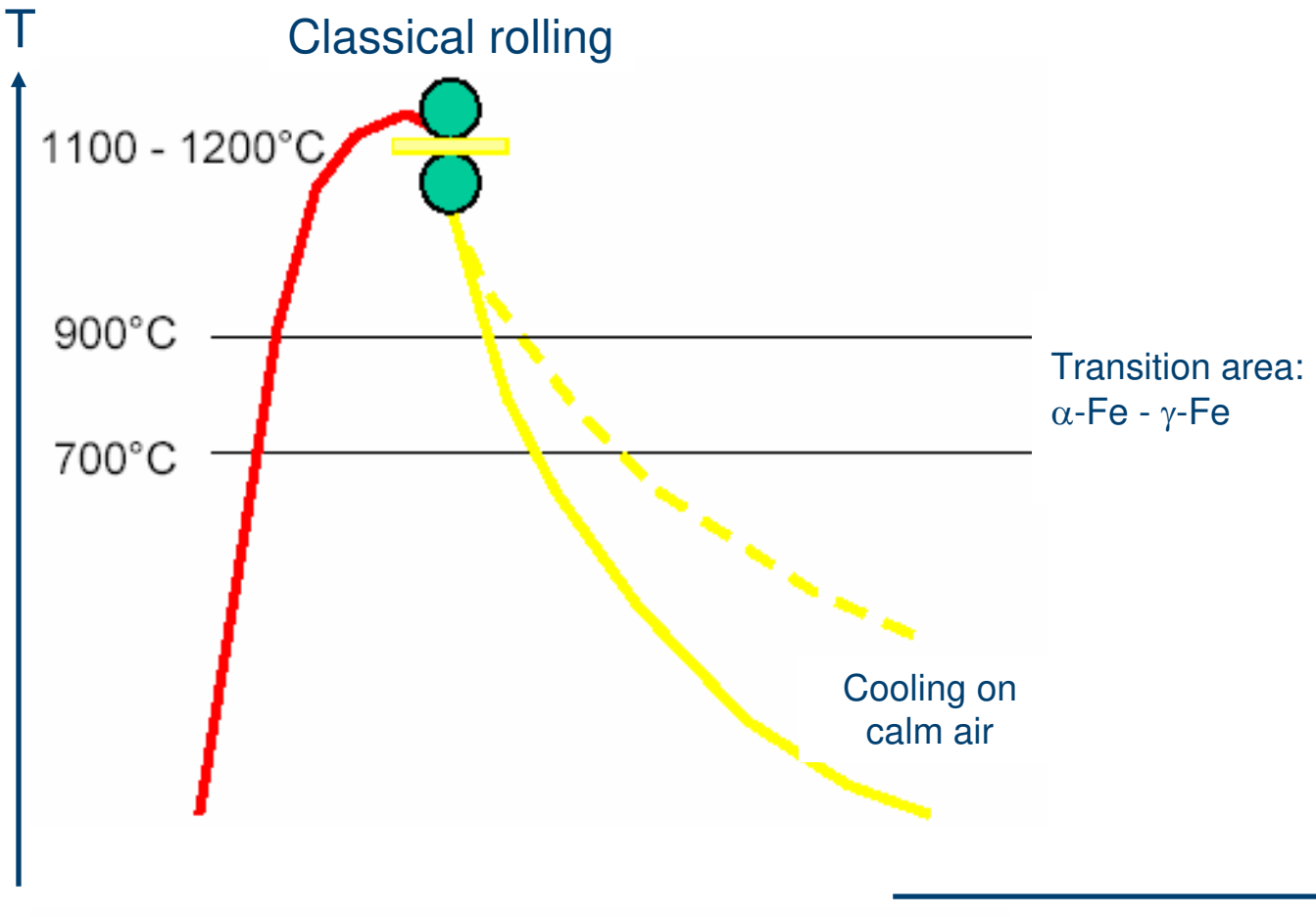
Delivery Conditions

AR



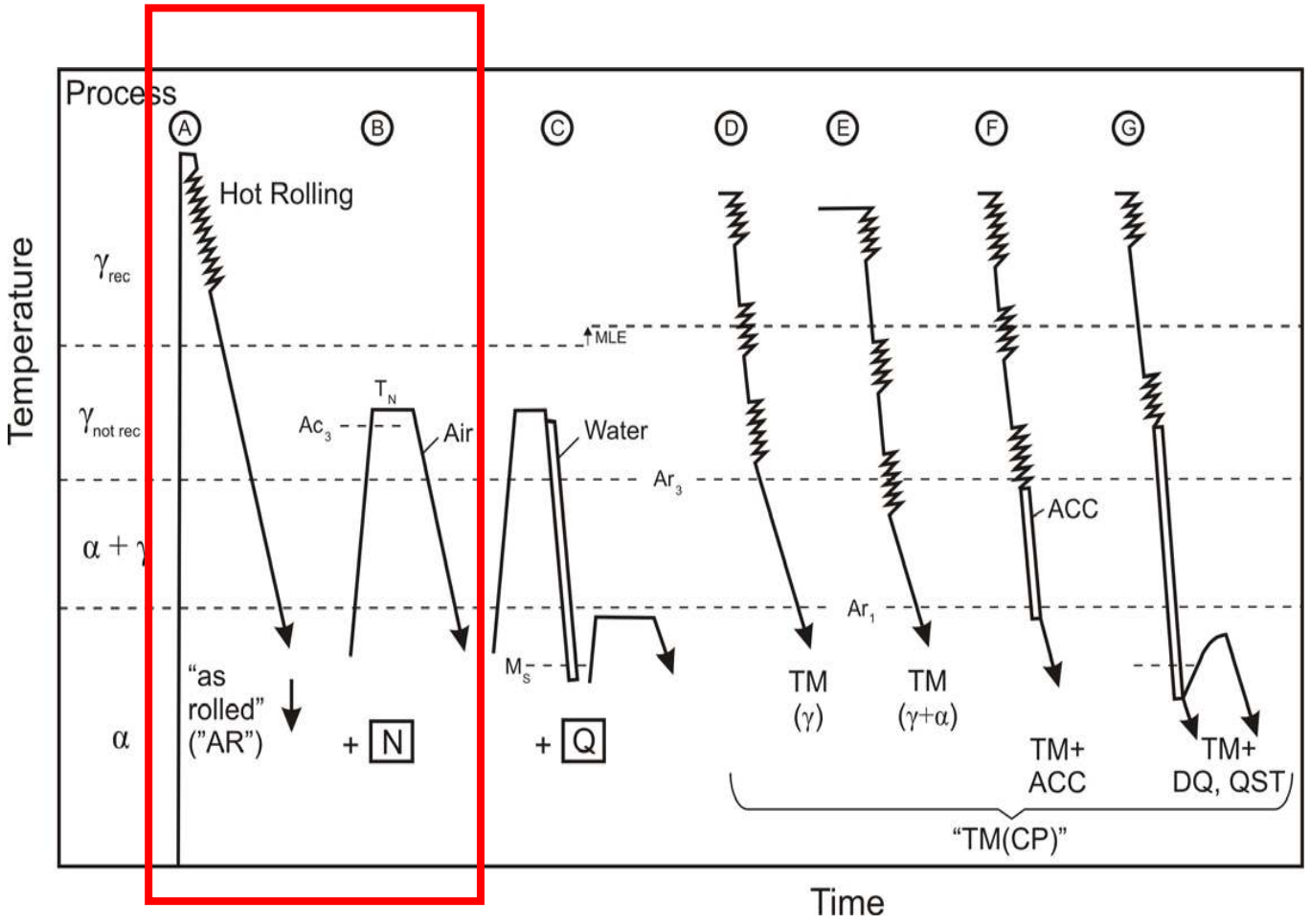
hot rolling

AR ➡ As Rolled


T
Classical rolling
1100 - 1200°C
900°C
700°C
Transition area:
α-Fe - γ-Fe
Cooling on
calm air
t

Delivery Conditions

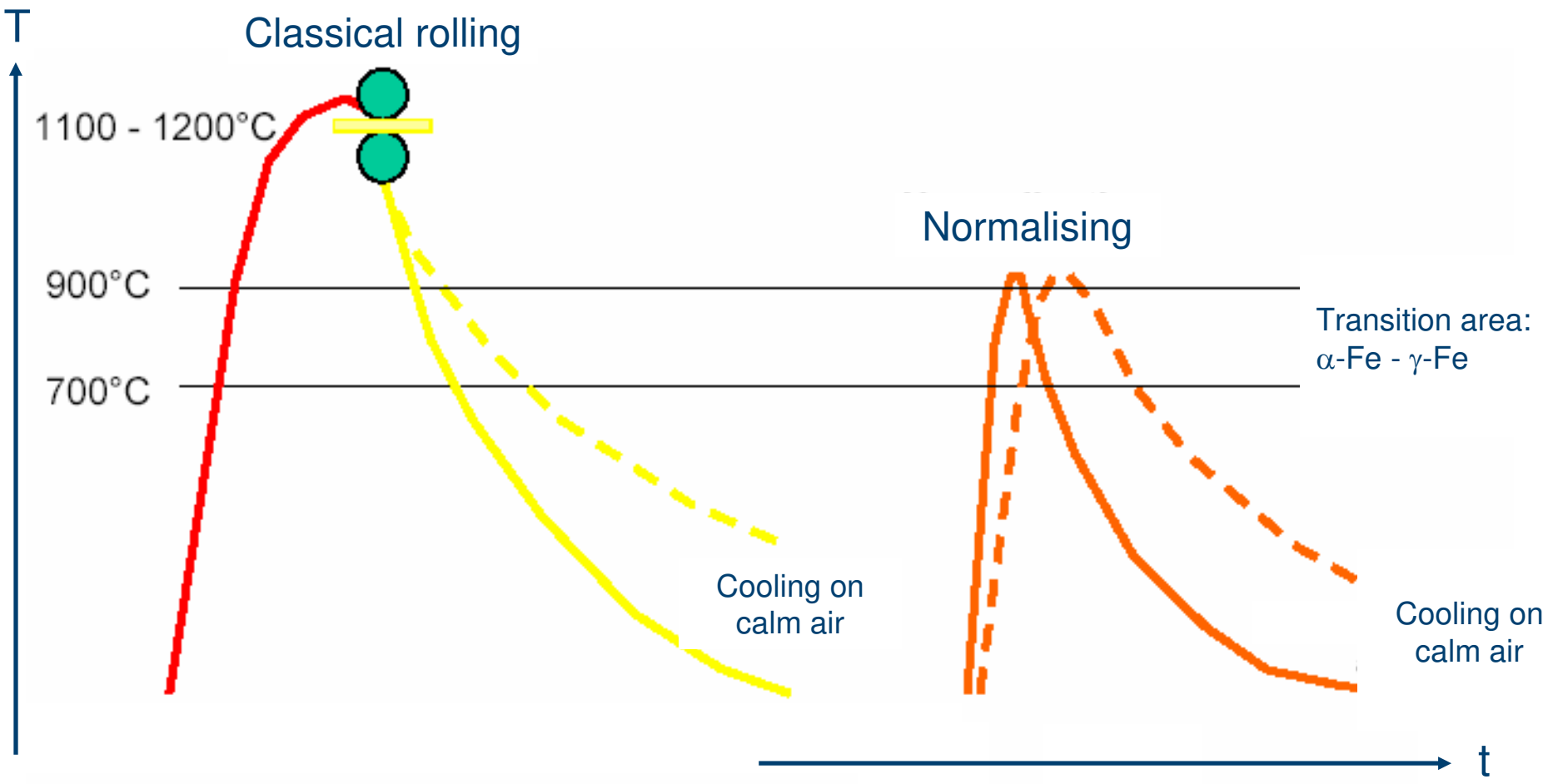
N



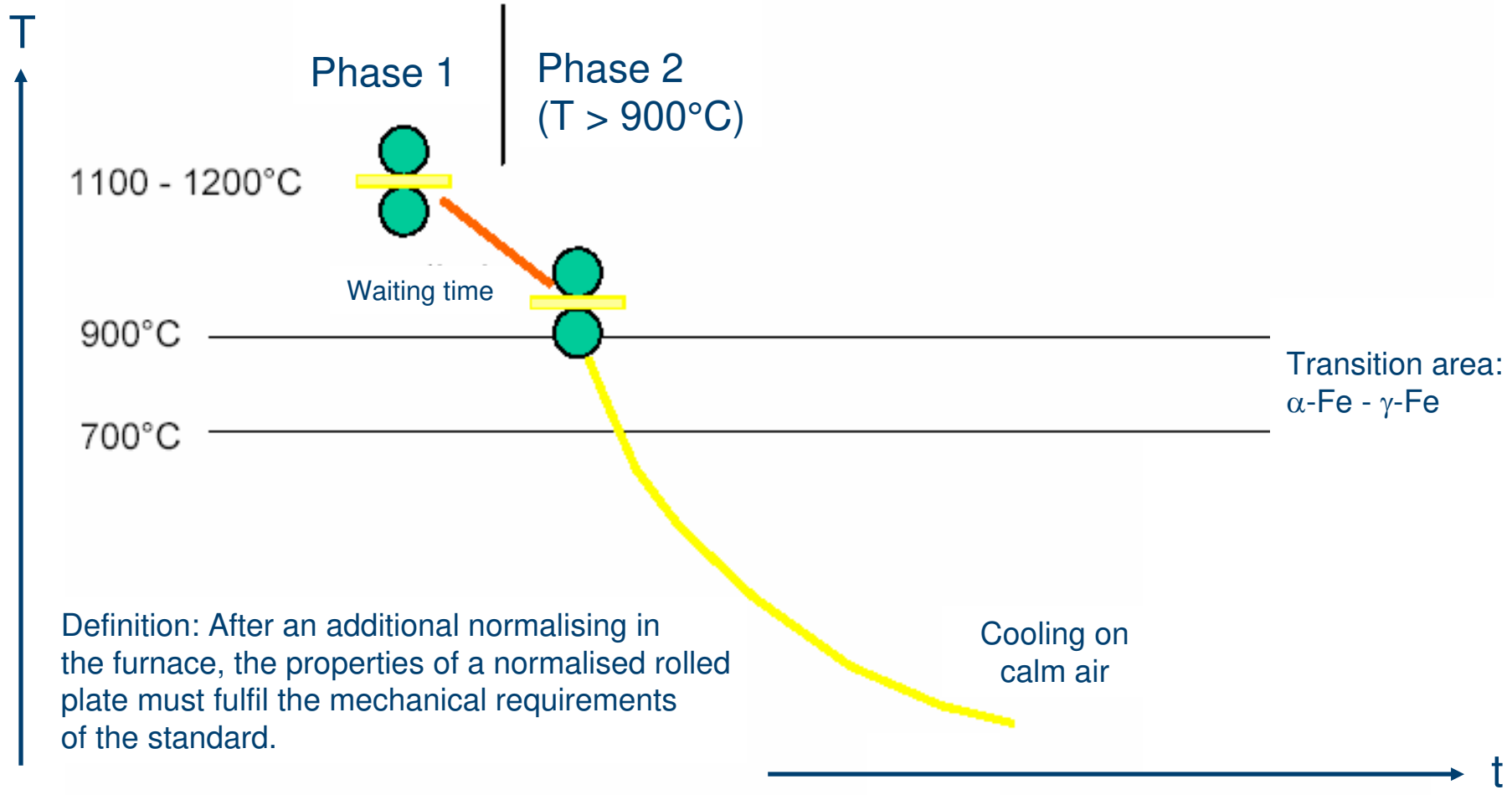
hot-rolling + Normalising

Delivery Conditions

N ➡ Normalising



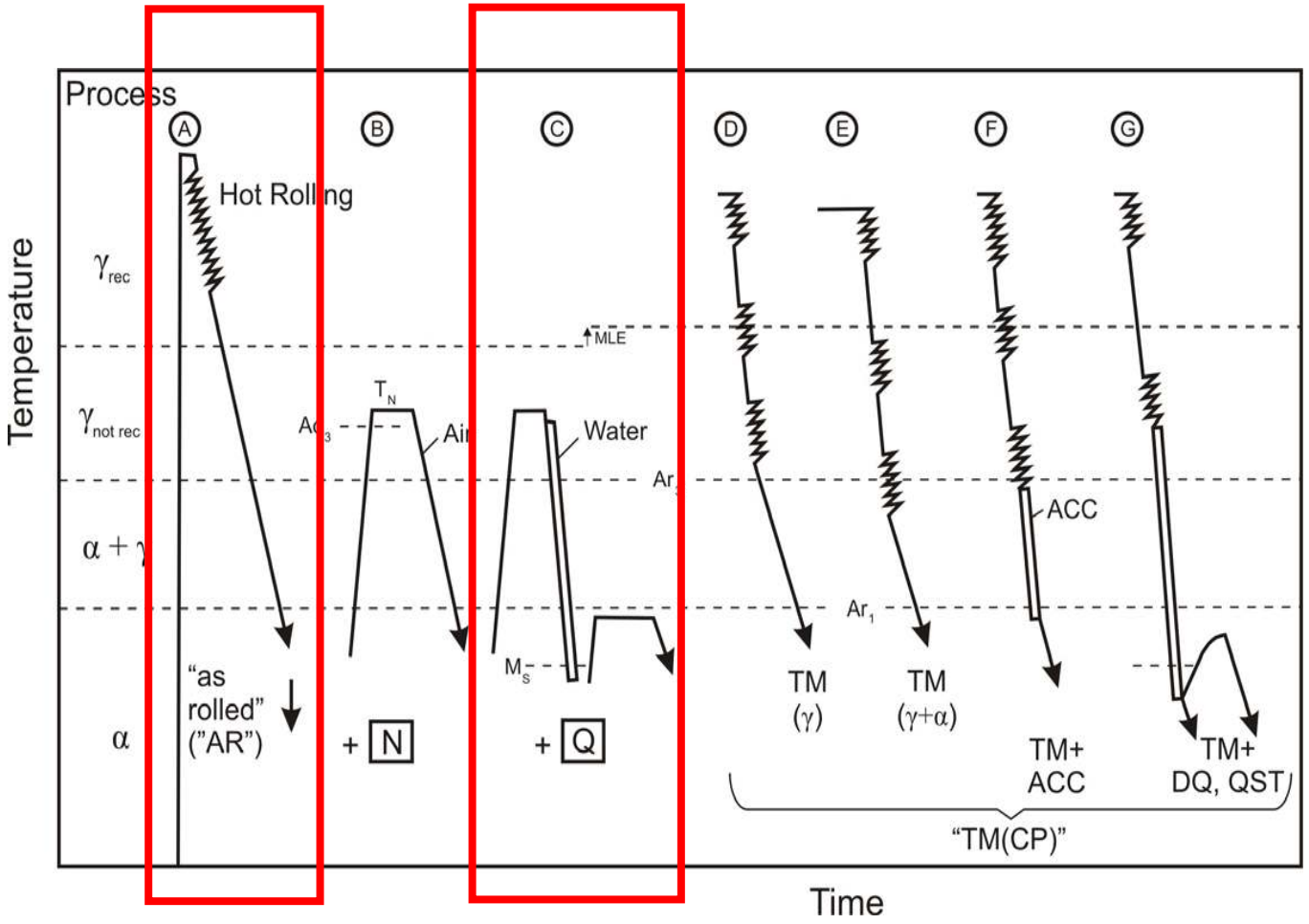
N ➡ Normalising rolling



Definition: After an additional normalising in the furnace, the properties of a normalised rolled plate must fulfil the mechanical requirements of the standard.

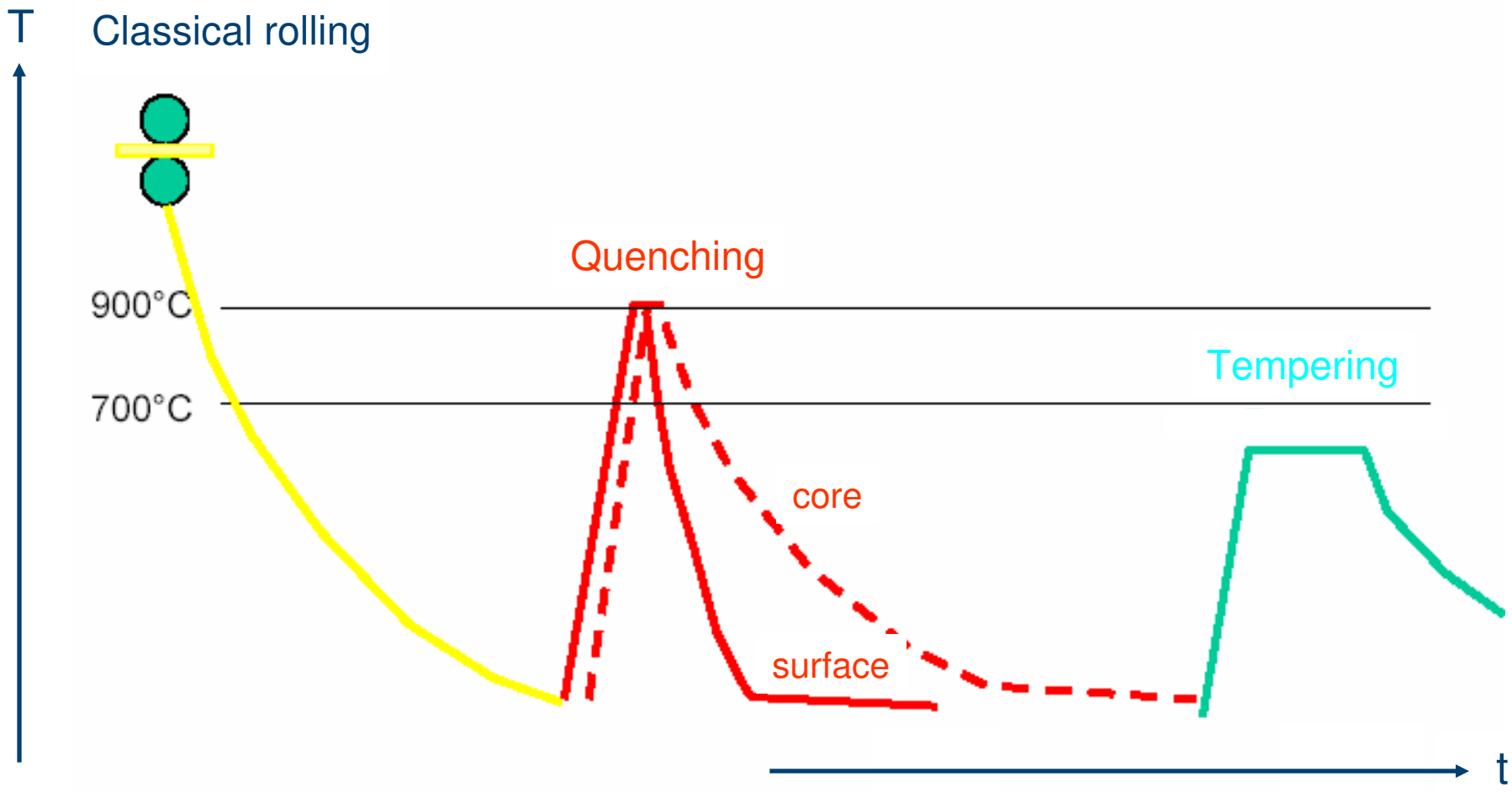
Delivery Conditions

Q+T



hot-rolling Quenching + Tempering

Q+T ⇨ Quenching + Tempering



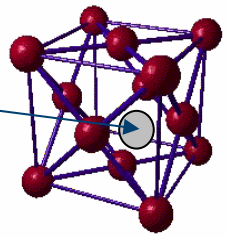
Q+T ⇨ Effect of quenching

[°C]

1390

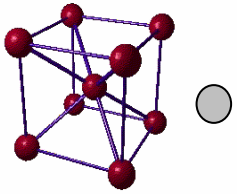
910

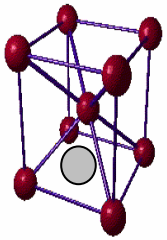
Carbon solved in the lattice



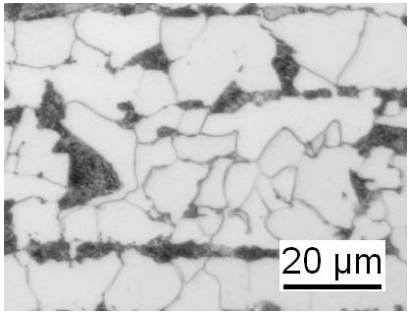
Austenite

Ferrite + Cementite (Carbon can leave the lattice)





Martensite (Carbon stays in the lattice, distorted structure)

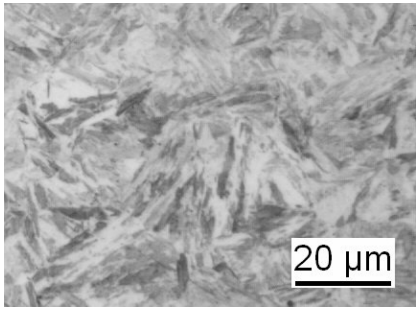


slow cooling:

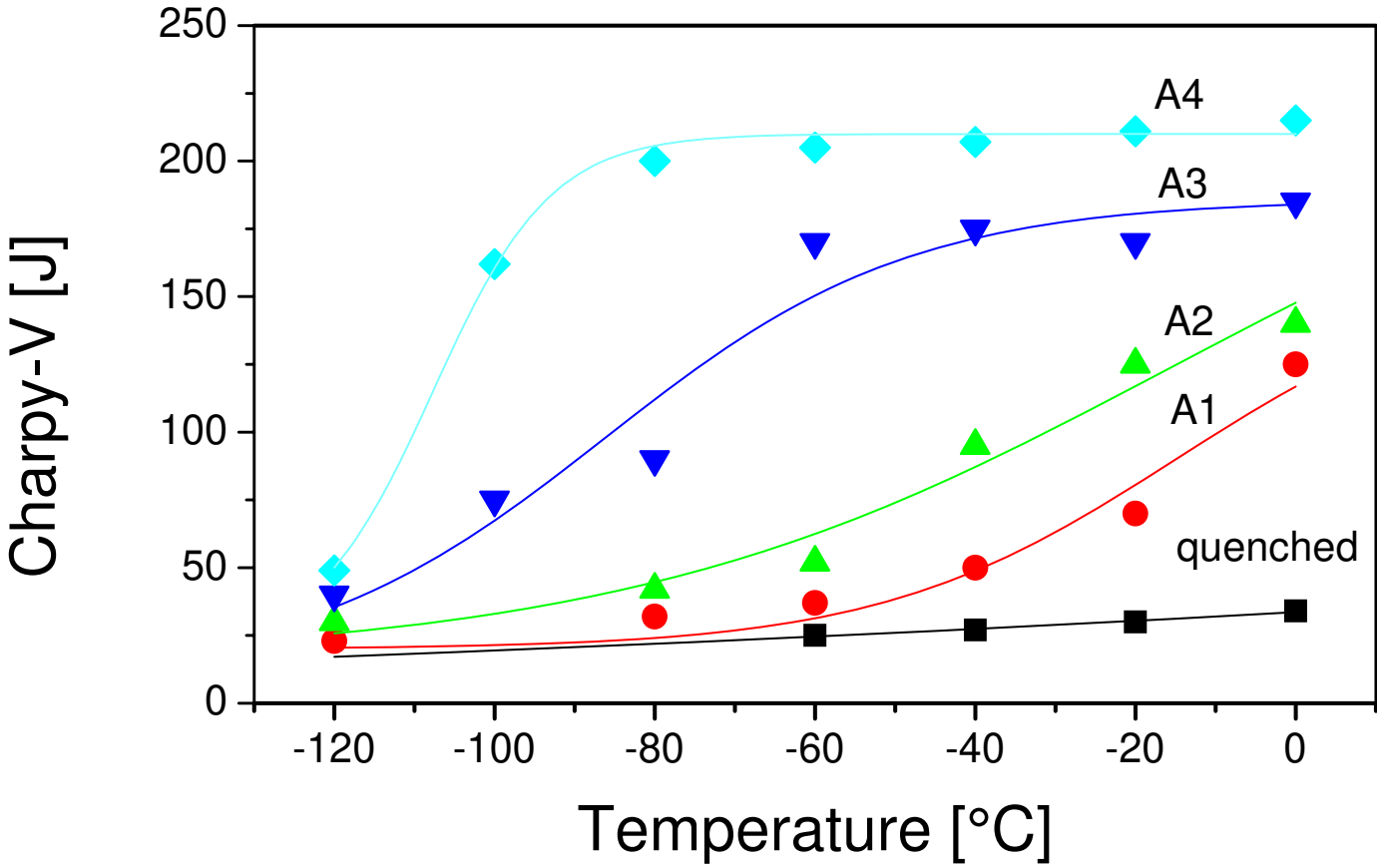
Ferrite + Perlite

fast cooling:

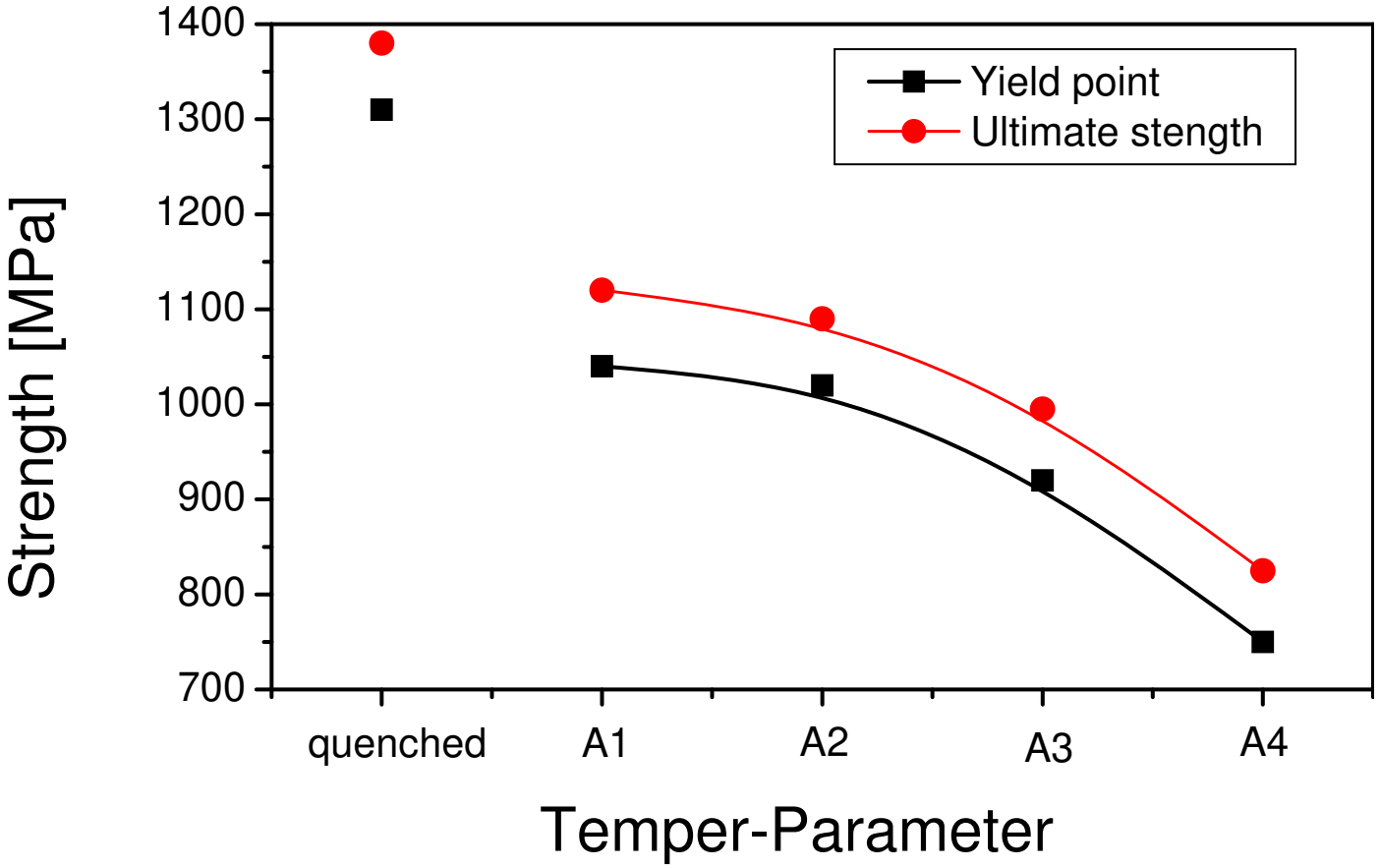
Martensite



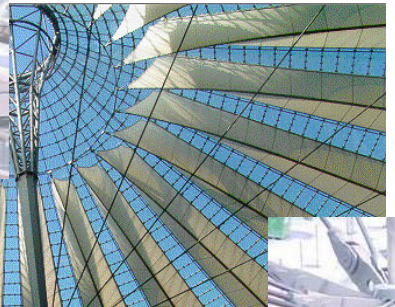
Q+T ⇨ Effect of tempering



Q+T ⇨ Effect of tempering

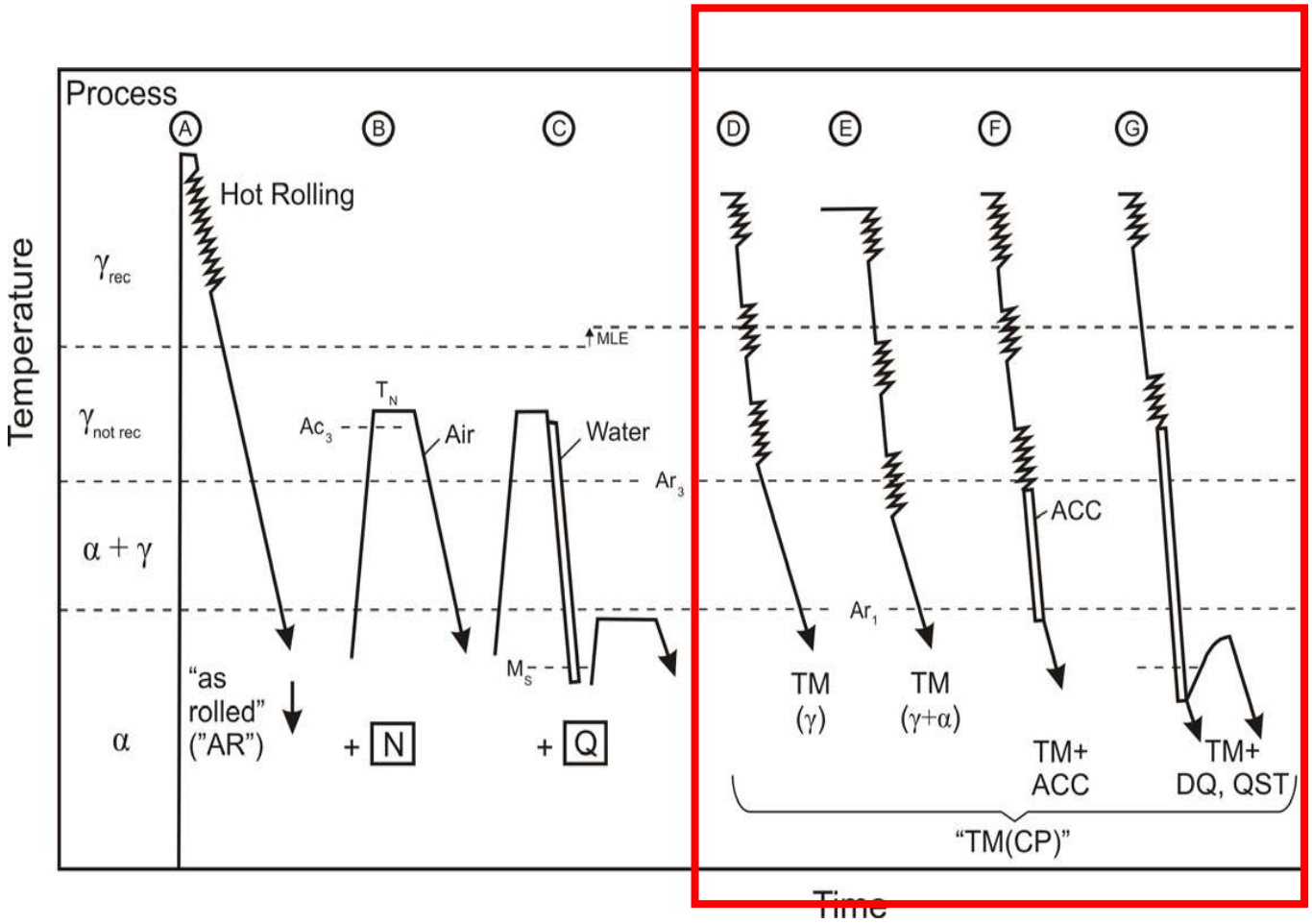


Q+T ⇨ Typical applications



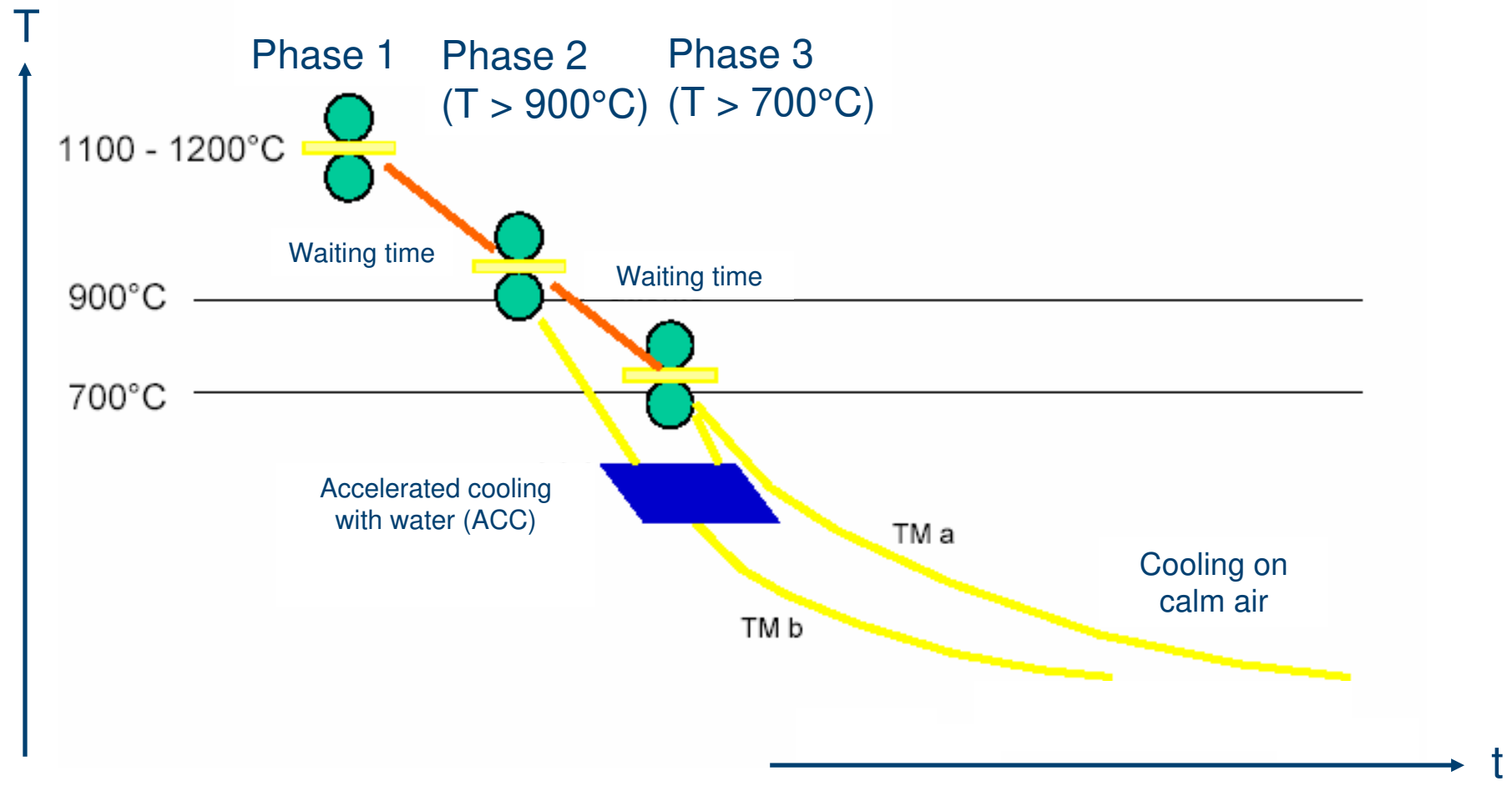
Delivery Conditions

TM

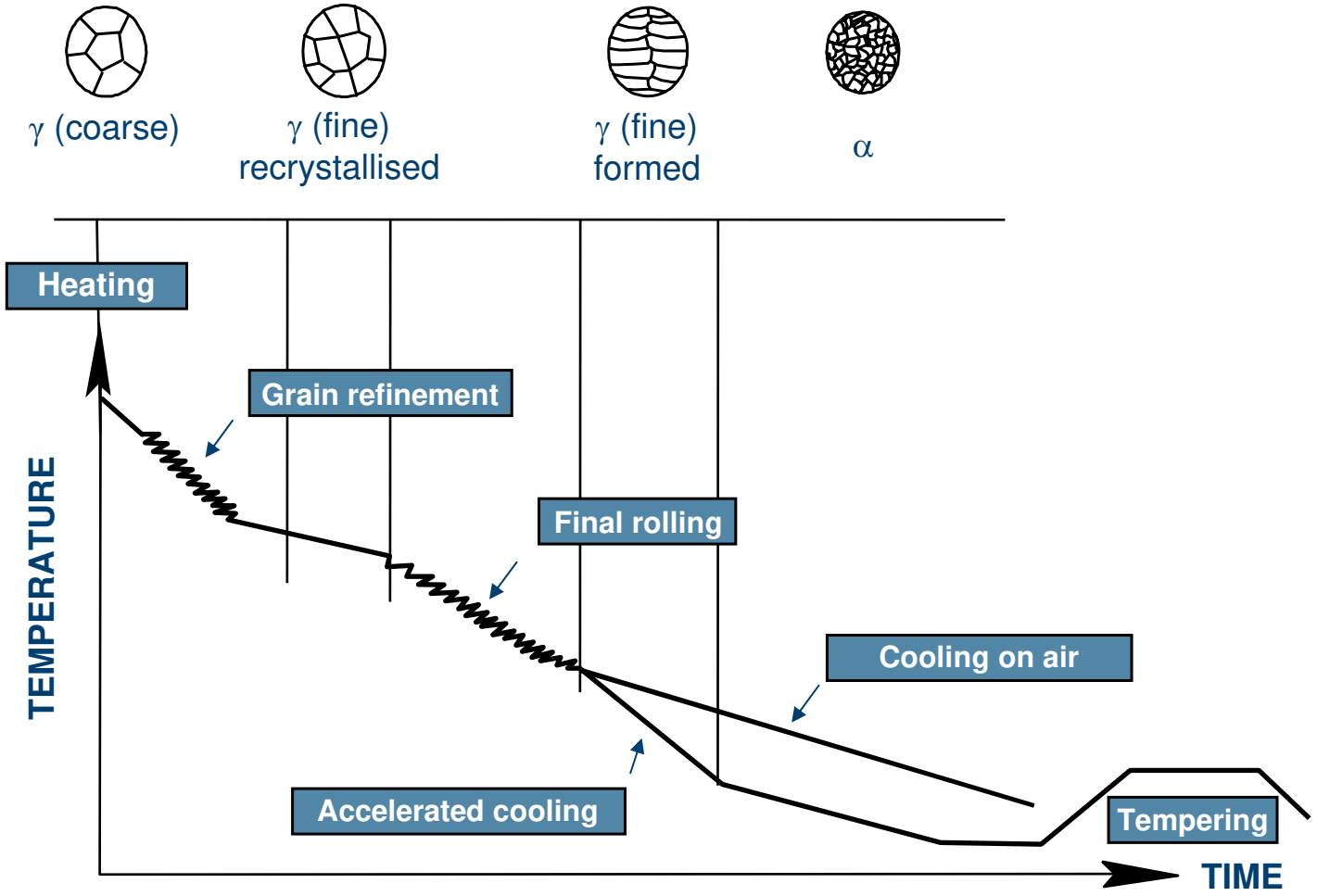


ThermoMechanical rolling

TM ➡ Thermomechanical rolling



TM ⇨ Thermomechanical rolling



PROPERTIES OF TM-steel:

TM ⇨ Fine grain

TM ⇨ High toughness

TM ⇨ Low carbon content

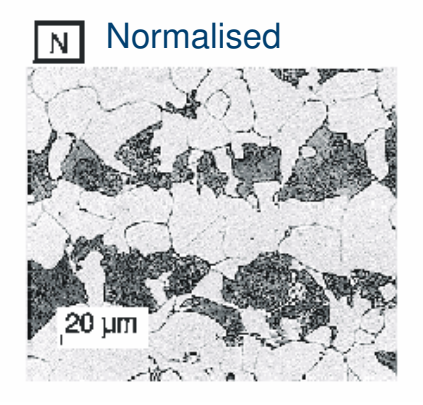
TM ⇨ Low preheating temperatures

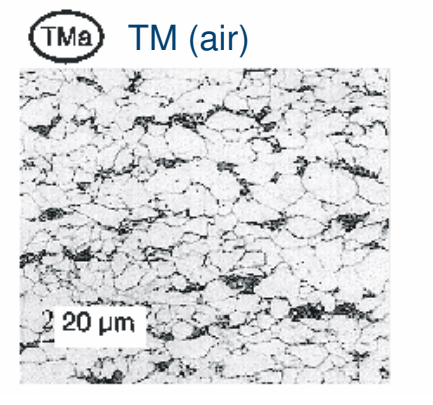
⇩

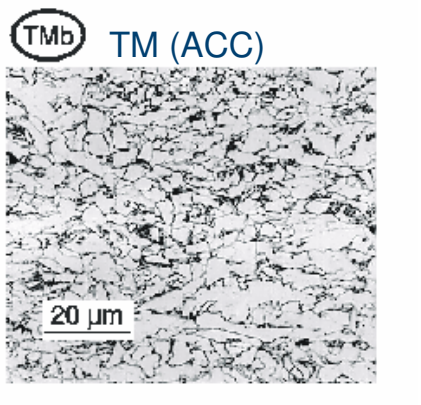
Excellent WELDABILITY

Advantages of TM-steel - Processing

TM ⇨ Fine grain





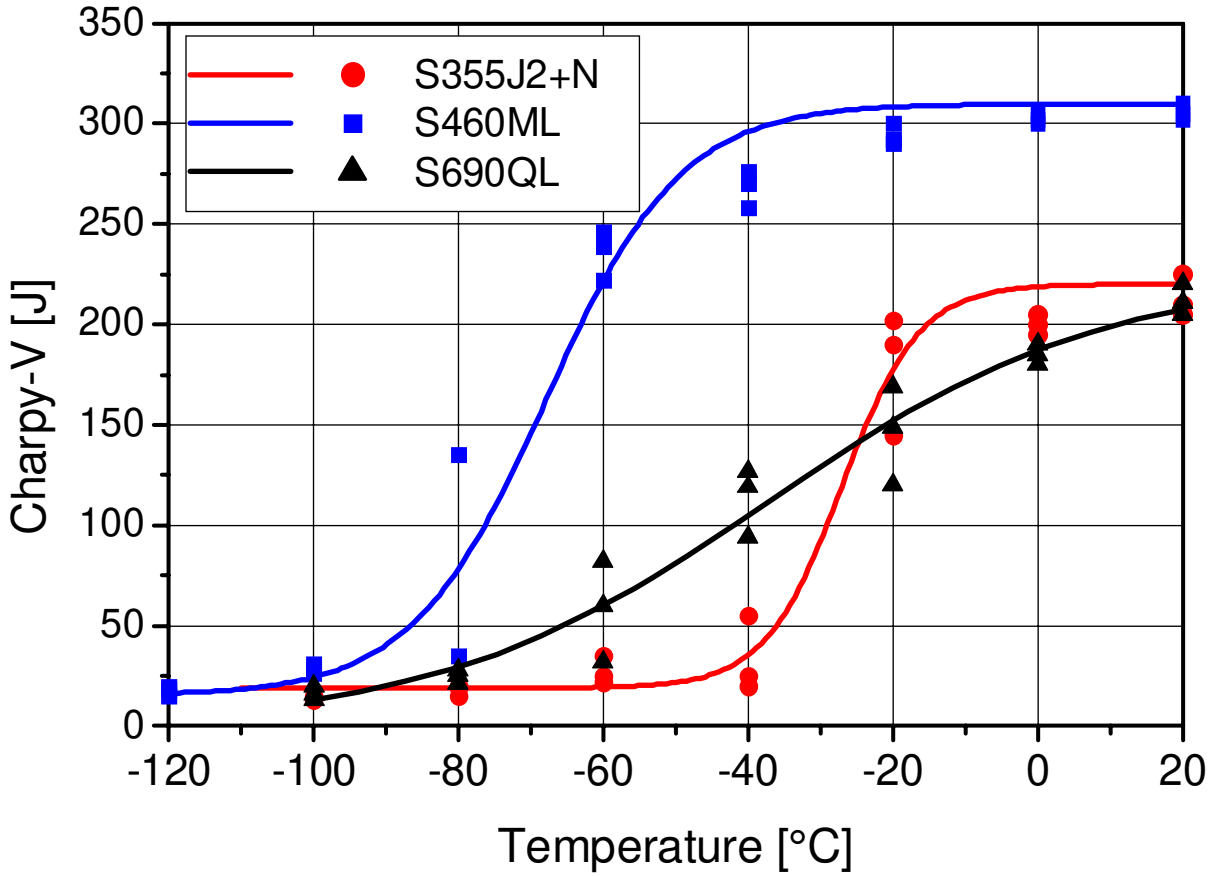


Hall-Petch:

Grain size ↓ → Strength ↑, Toughness ↑ + Excellent weldability

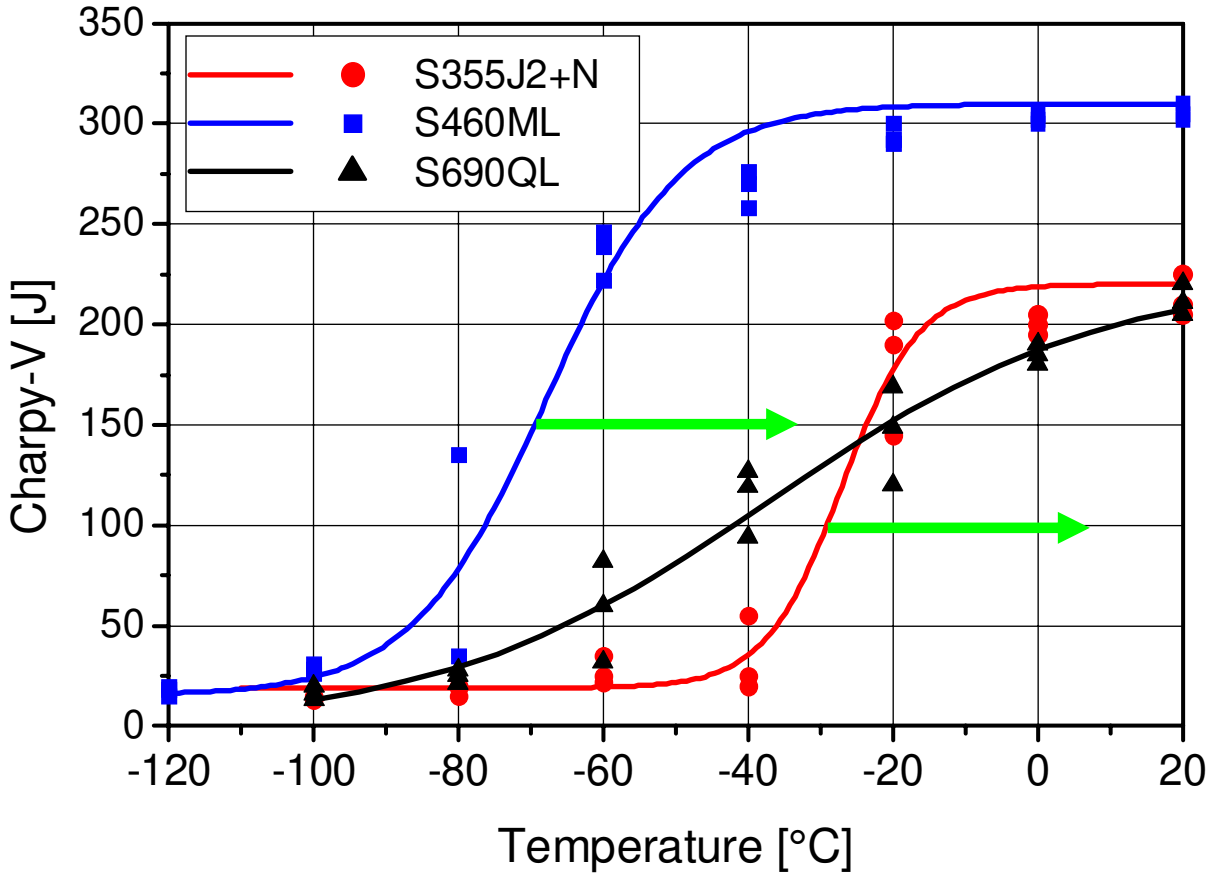
Advantages of TM-steel - Processing

TM ⇨ High toughness / High safety



Advantages of TM-steel - Processing

TM ⇨ High toughness / High safety



Welding leads to

toughness reduction

High toughness in the base material reduces the risk of brittle fracture and gives saftey!

Advantages of TM-steel - Processing

TM ⇨ High toughness / High safety

Example: **Ilverich Rhine Bridge (Germany)**
DI-MC 460 with a thickness up to 100 mm
Charpy tested at - 80°C

Advantages of TM-steel - Processing

TM ⇨ Low carbon content

	S 460 NL		S 460 ML	
	acc. EN 10025-3	Auxiliary Data	acc. EN 10025-4	Auxiliary Data
C	< 0,20	0,17	< 0,16	0,09
Si	< 0,60	0,45	< 0,60	0,30
Mn	1,00 - 1,70	1,65	< 1,70	1,50
P	< 0,030	0,015	< 0,030	0,011
S	< 0,025	0,010	< 0,025	0,005
Nb	< 0,05	-	< 0,05	< 0,04
V	< 0,20	0,17	< 0,12	< 0,05
Mo	< 0,10	-	< 0,20	-
Ni	< 0,80	0,29	< 0,45	0,25
CE		0,50		0,39
Pcm		0,29		0,20
CET		0,34		0,28

Plate thickness 50 mm

Carbon equivalents:

$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni+Cu)/15$

$Pcm = C + Si/30 + (Mn + Cu + Cr)/20 + Ni/60 + Mo/15 + V/10 + 5B$

$CET = C + (Mn + Mo)/10 + (Cr + Cu)/20 + Ni/40$

Advantages of TM-steel - Processing

TM ⇨ **Low preheating temperatures**

EN 1011-2
Recommendations for arc welding of ferritic steels

$$T_p = 697 \times CET + 160 \times \tanh\left(\frac{d}{35}\right) + 62 \times HD^{0.35} + (53 \times CET - 32) \times Q - 328$$

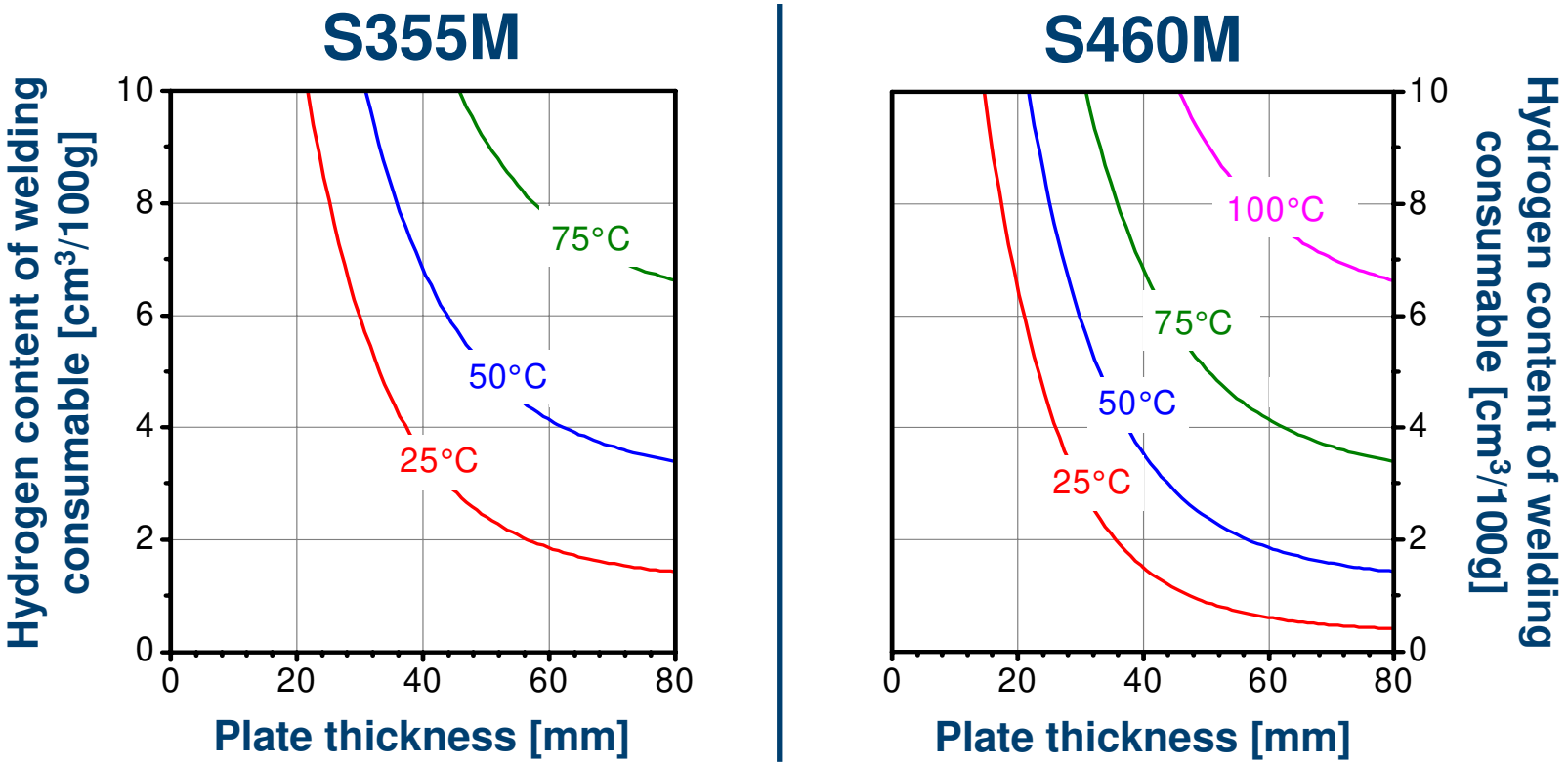
T_p	-	Preheating temperature [°C]
CET	-	Carbon equivalent [%]: CET = C + (Mn + Mo)/10 + (Cr + Cu)/20 + Ni/40
d	-	Plate thickness [mm]
HD	-	Hydrogen content [cm³/100 g]
Q	-	Heat input [kJ/mm]

Preheating is necessary to avoid: ⇨ excessive hardening

⇨ cold cracking

Advantages of TM-steel - Processing

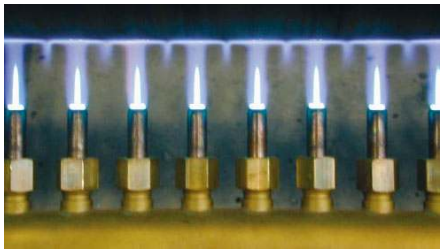
TM ➡ Low preheating temperatures



Calculated with Q = 2.5 kJ/mm (submerged arc welding) and for typical CET´s

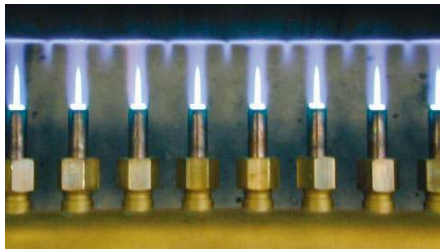
Advantages of TM-steel - Economics

TM ⇨ Cost efficiency – Low preheating

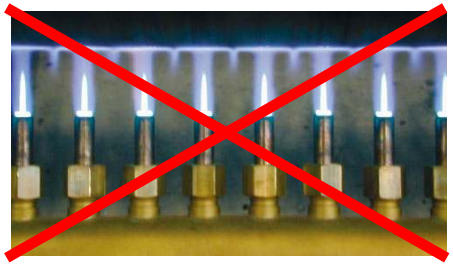
1. 

Reducing preheating temperatures →

Gas consumption ↓
Heating time ↓

2. 

Avoiding preheating →

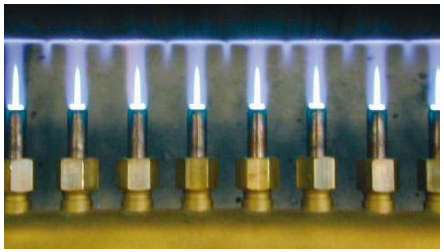


No installations
No setting up time
No gas

Advantages of TM-steel - Economics

TM ⇨ Cost efficiency – Low preheating

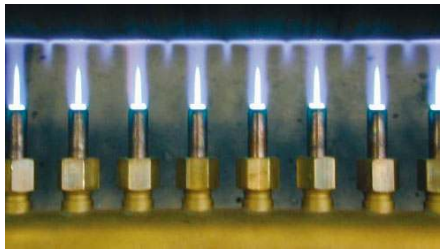
Often underestimated,
but worth to think about

1. 

Reducing preheating

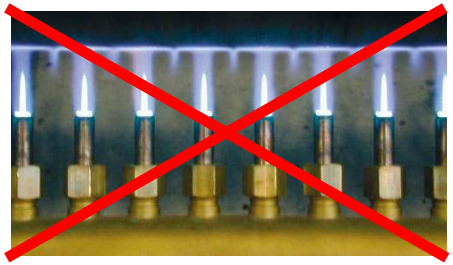
temperatures

Gas consumption ↓
Heating time ↓

2. 

Avoiding

preheating



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Advantages of TM-steel - Economics

TM ⇨ Cost efficiency – Low preheating

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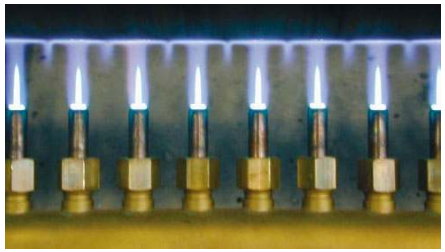
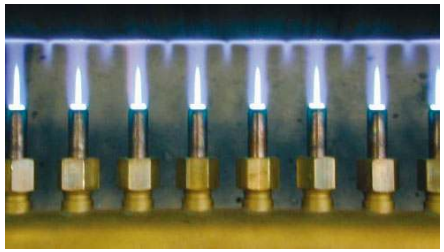
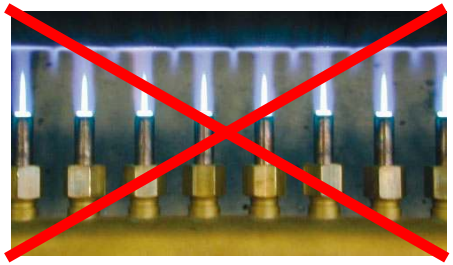
1. 

Reducing preheating temperatures →

Gas consumption ↓
Heating time ↓

2. 

Avoiding preheating →

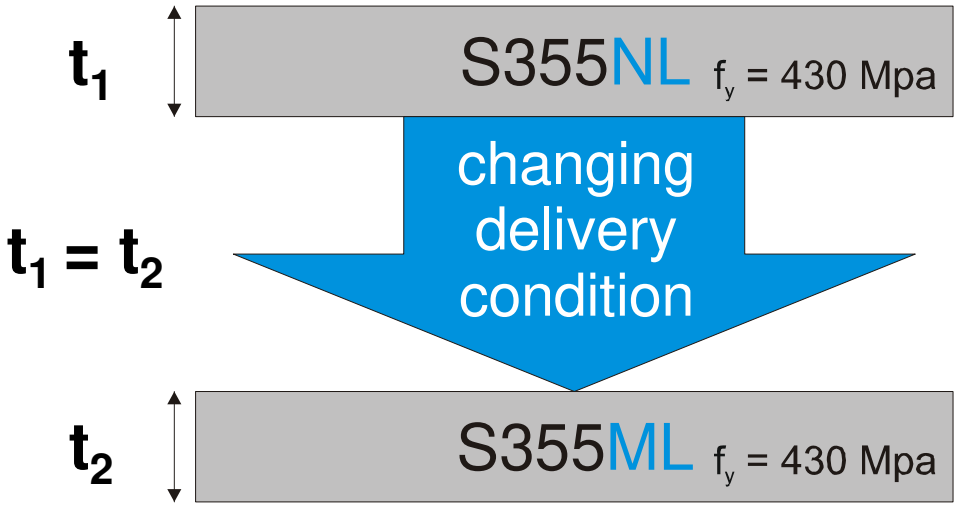


No installations
No setting up time
No gas

Biggest potential
for saving costs

Advantages of TM-steel - Economics

TM ⇨ Cost efficiency – Low preheating

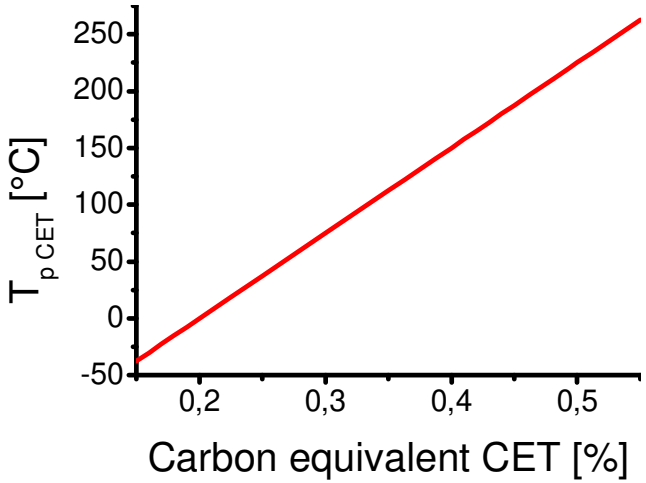


Possibility to avoid preheating!
- no gas consumption
- no set-up times
- higher capacity in the work shop

EN 1011-2:

$T_{pCET} = 750 \times CET - 150$

0.01% CET ⇔ ca. 7.5°C



Advantages of TM-steel - Economics

TM ➡ Cost efficiency – Low preheating

Sauertal Bridge (Germany)

Box-girder-bridge
Length: 1195 m
Width: 27 m
11 Spans: 75 – 150 m
Tonnage: 13,000 t
Grade: S355J2+N

3000 t > 25 mm thickness

TM ⇨ Cost efficiency – Low preheating

Alternative:

S355J2+N > S355M
No preheating

Conditions:

30,000 h welding time
15 % for preheating
50 €/h labour costs

A) Saving preheating times	A = 30,000 h x 15 % x 50 €/h	225,000 €
B) Additional costs S355M (25 €/t)	B = 3,000 x 25 €/t	75,000 €
BENEFIT	C = A - B	150,000 €

Advantages of TM-steel - Economics

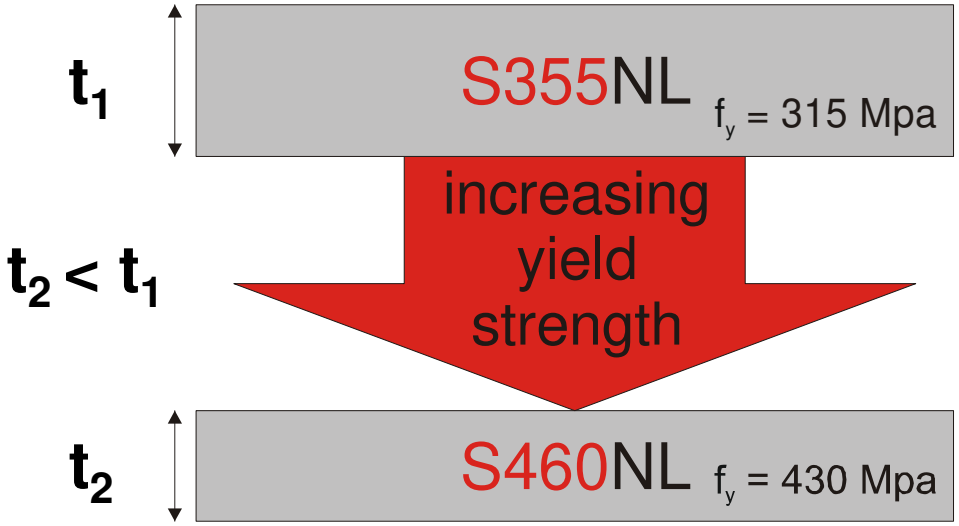
TM ⇨ Cost efficiency – Low preheating

Low preheating temperatures are not only a matter of costs!
Also in terms of job safety, low preheating temperatures are beneficial!

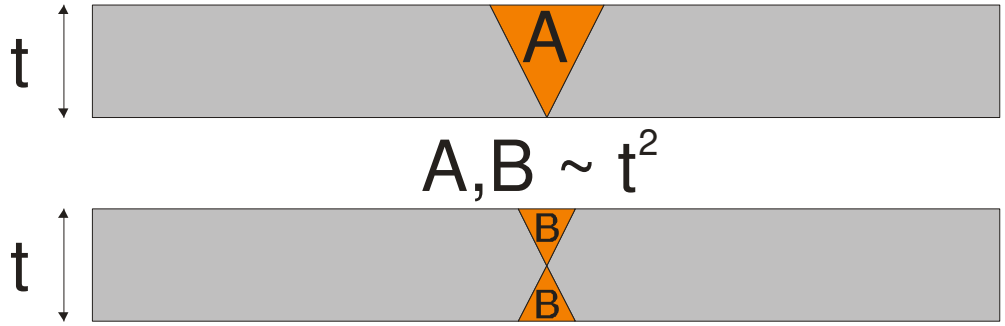
NO HOT SURFACES / NO HANDLING WITH GAS / BETTER WORKING CONDITIONS

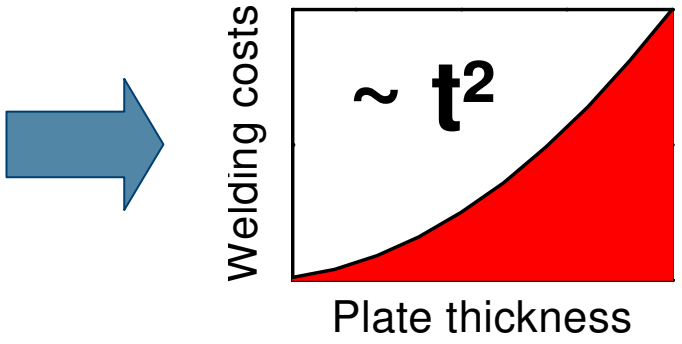
Advantages of TM-steel - Economics

TM ⇨ Cost efficiency – High strength TM



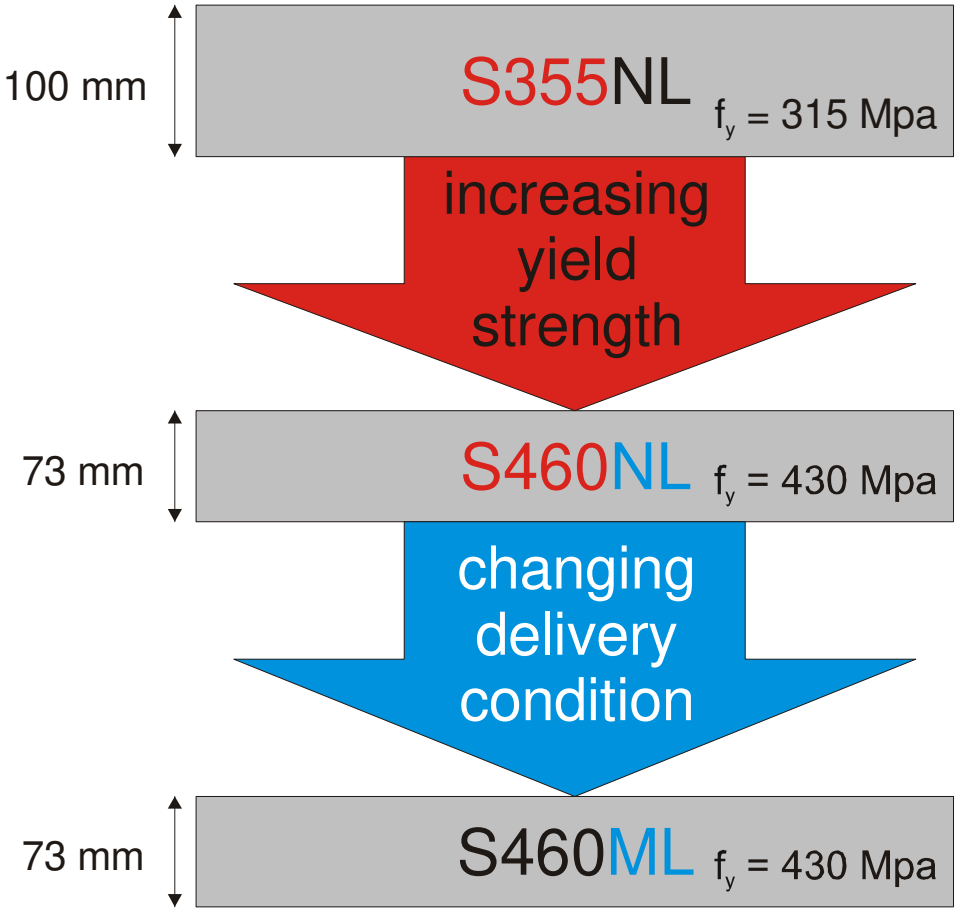
- Weight reduction
- Bigger assembling units possible
- Less holding times in the workshop
- Less welding consumables
- Reduction of welding time
- Reduction of testing time





Advantages of TM-steel - Economics

TM ⇨ Cost efficiency – High strength TM

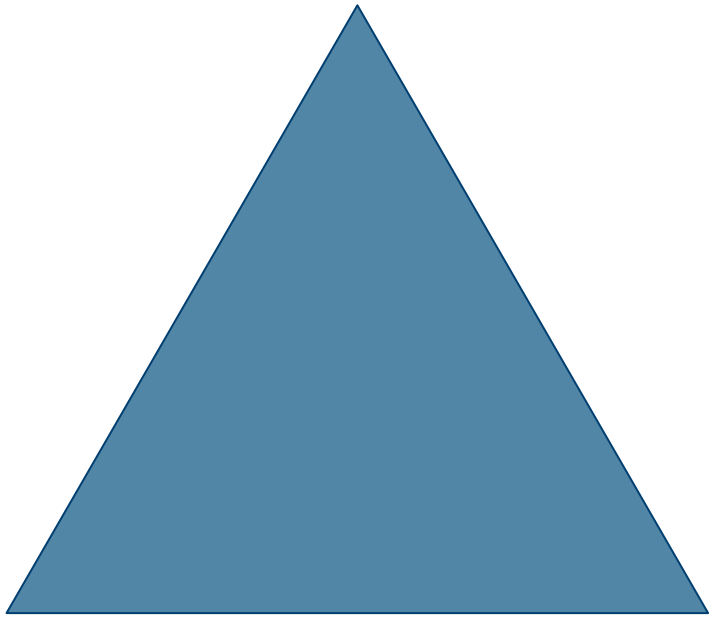


- Weight reduction (ca. 30%)
- Bigger assembling units possible
- Less holding times in the workshop
- Less welding consumables
- Reduction of welding time
- Reduction of testing time

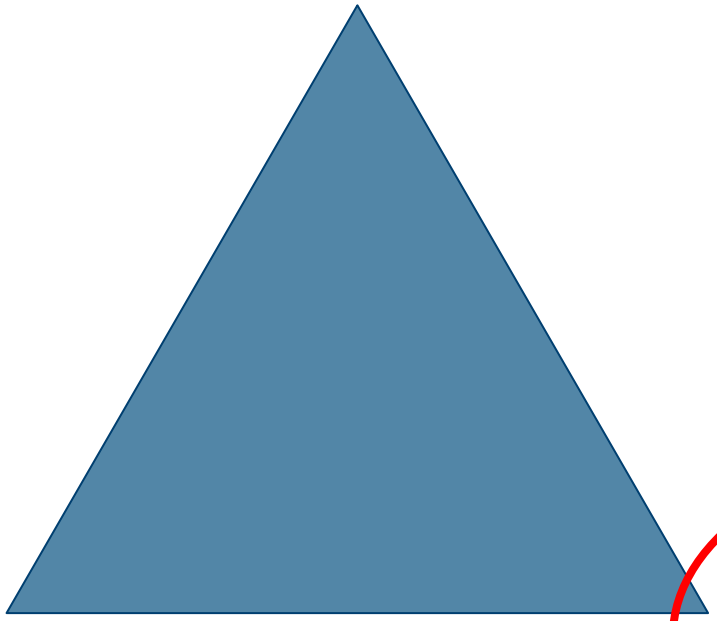
- Avoiding/Reducing preheating
- Better weldability
- High toughness reserves

=> High safety

Choosing the right steel



Choosing the right steel



Airbus-Hangar (Frankfurt / M.)

- TM-Steel S460ML
- constant yield strength up to 120 mm

World Financial Center (Shanghai)

- TM-Steel S460M
- thickness
  up to 100 mm
- constant yield
  strength

Øresund Bridge (Denmark-Sweden)

- TM-Steel
- S460M/ML
  up to 80 mm

Thank you for your attention!