Basics of Rail Metallurgy and Rail Production

Richard Stock – Technical Customer Service
voestalpine Schienen GmbH - Austria

Content

- voestalpine - Austria
- Inside Rail
- From Rock to Rail

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In the heart of Austria

City of Leoben

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Production Plant

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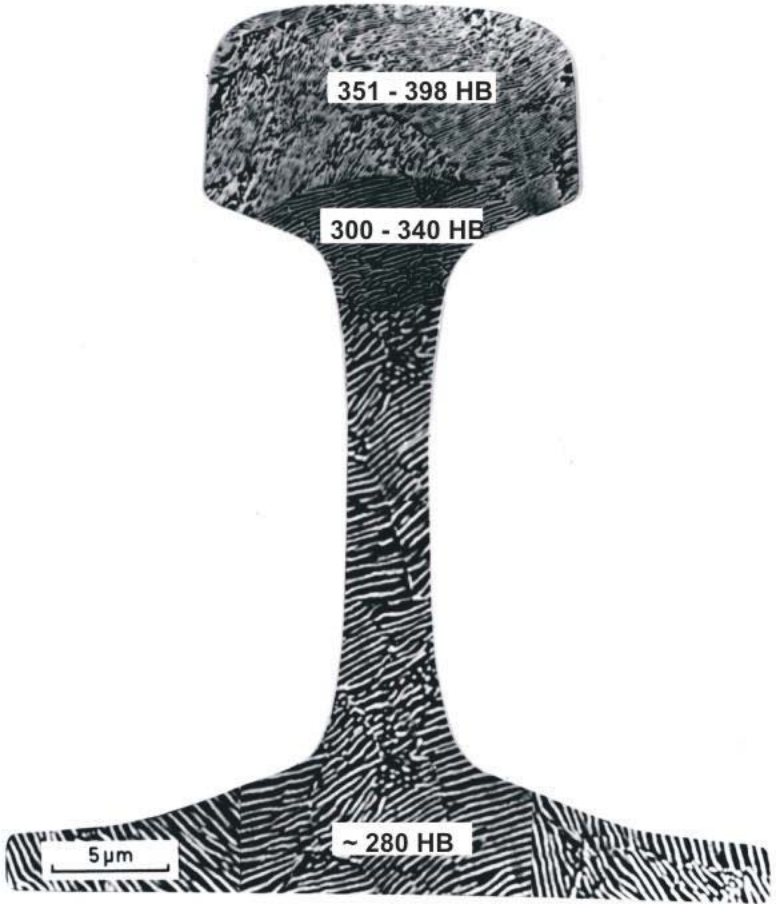
voestalpine Schienen GmbH in Leoben/Austria

voestalpine
ONE STEP AHEAD.

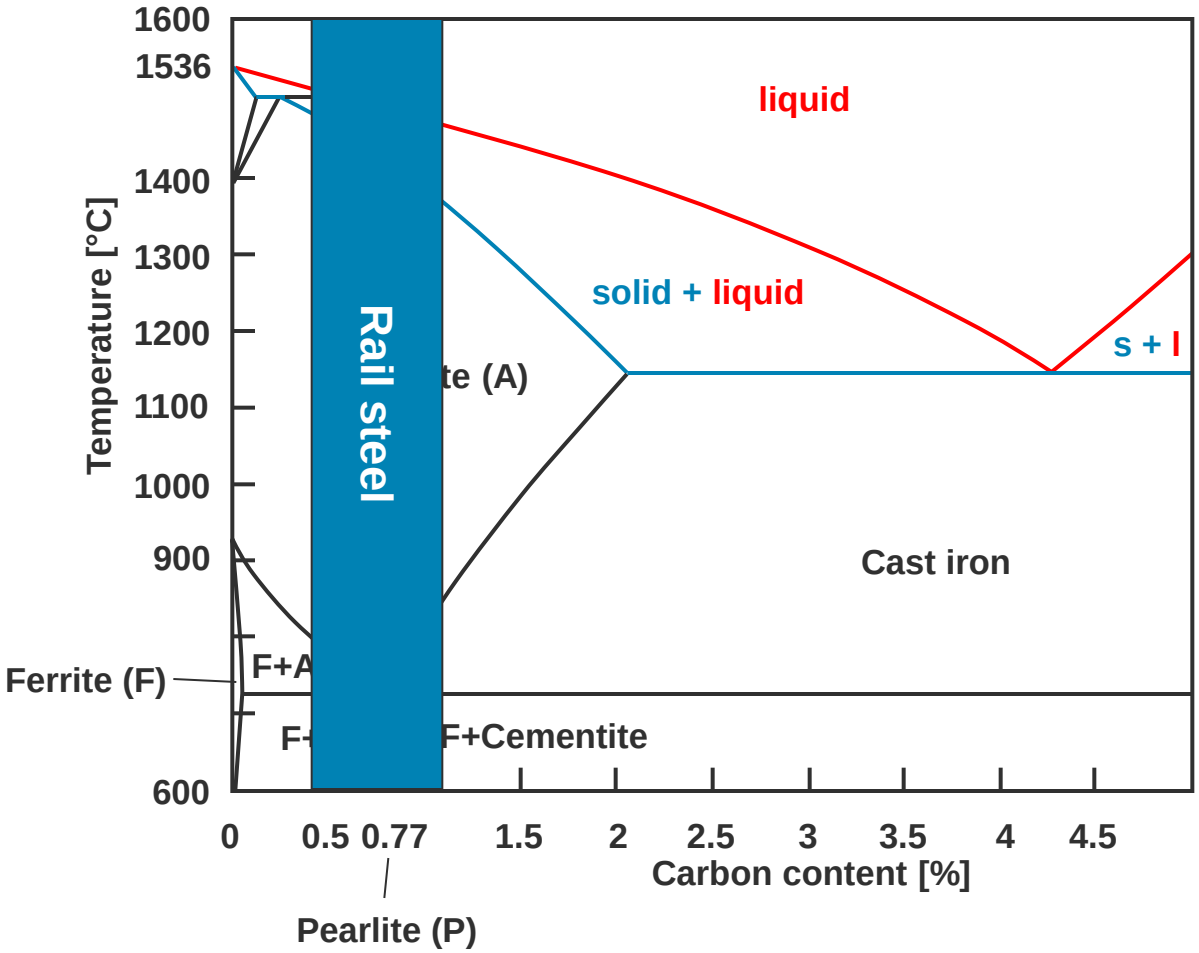
- Europe´s leading rail manufacturer
- Variety of approx. 80 rail sections in length up to 120m (394ft)
- Special rail sections (grooved, tongue and guard rails)
- Complete product range available in HSH®-Premium-quality
- JIT-Delivery of Ultra-long Premium Rails (120m or 394ft)
- Staff: 550

Inside Rail



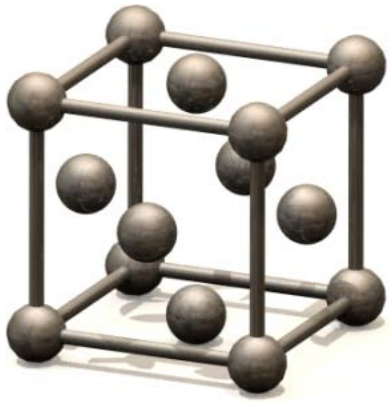
Fe – C Diagram (simplified)

- Iron: melting point :1536°C (2796.80 °F)
- Iron Phases:
  - Austenite (Gamma)
  - Ferrite (Alpha)
- Carbide: Cementite
- Pearlite structure
- Rail steel: 0.4 – 1.1 % C

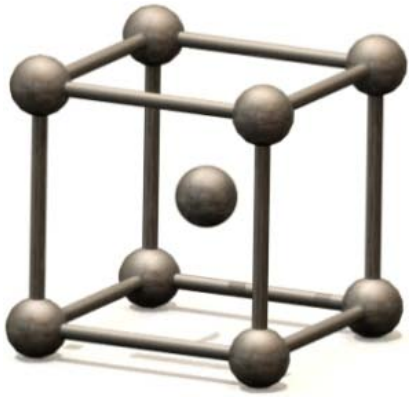


Lattice structure of steel

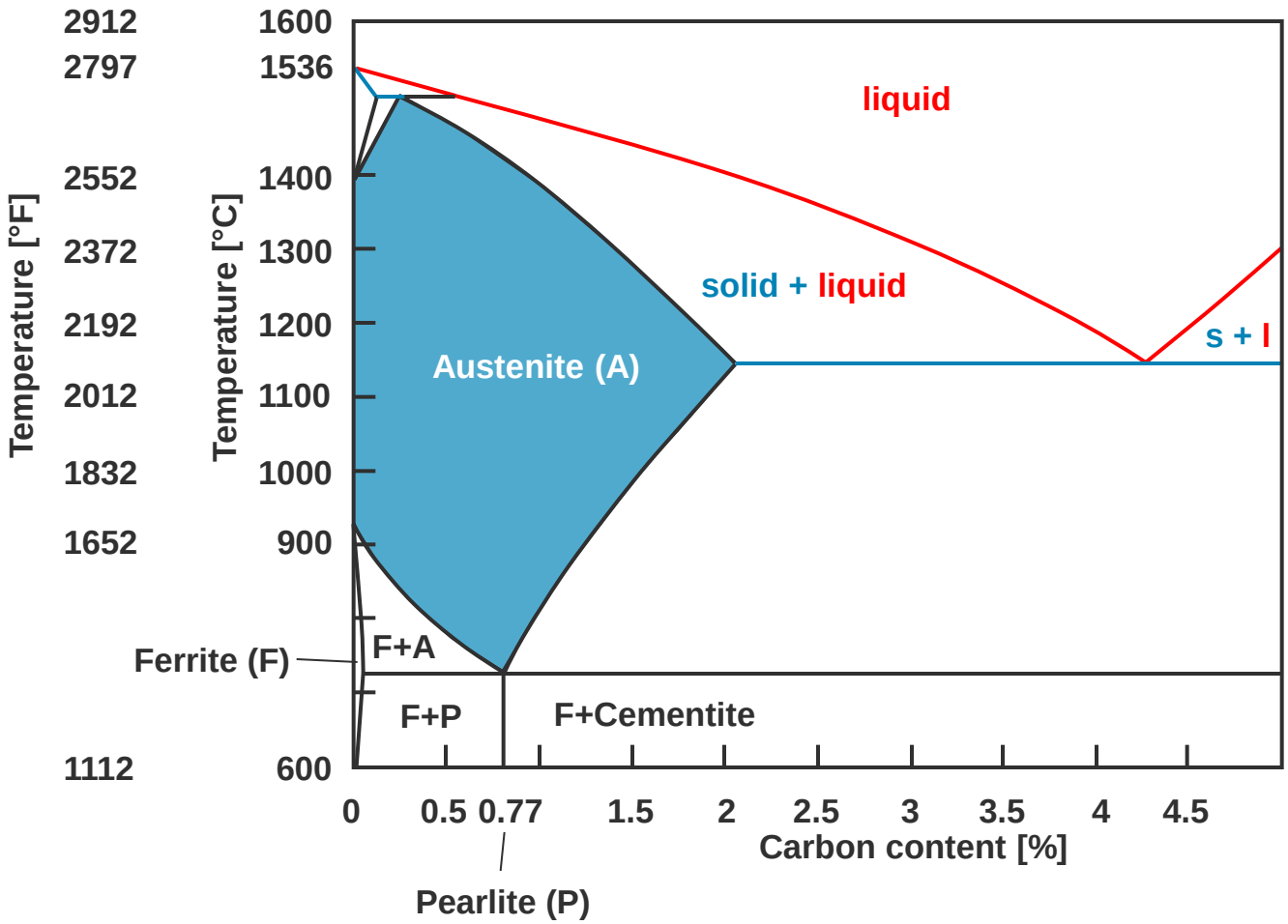
- Face centered cubic (fcc)
  - Austenitic Steel
  - Enough space to dissolve C - atoms



- Body centered cubic (bcc)
  - Ferritic Steel
  - No space to dissolve C - atoms

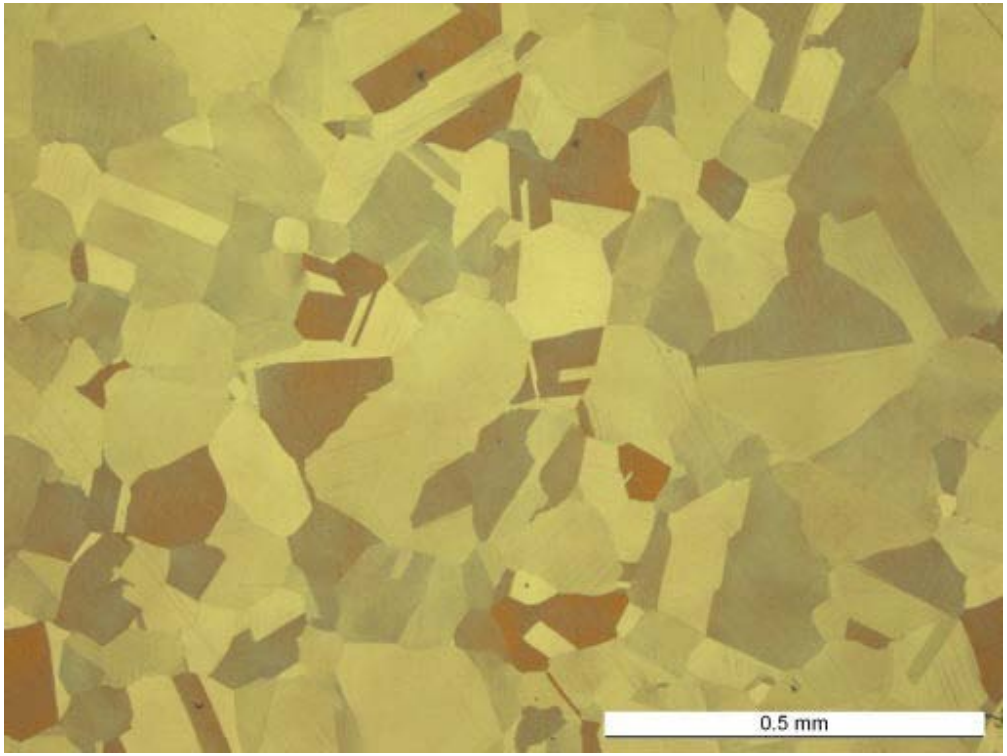


Austenite

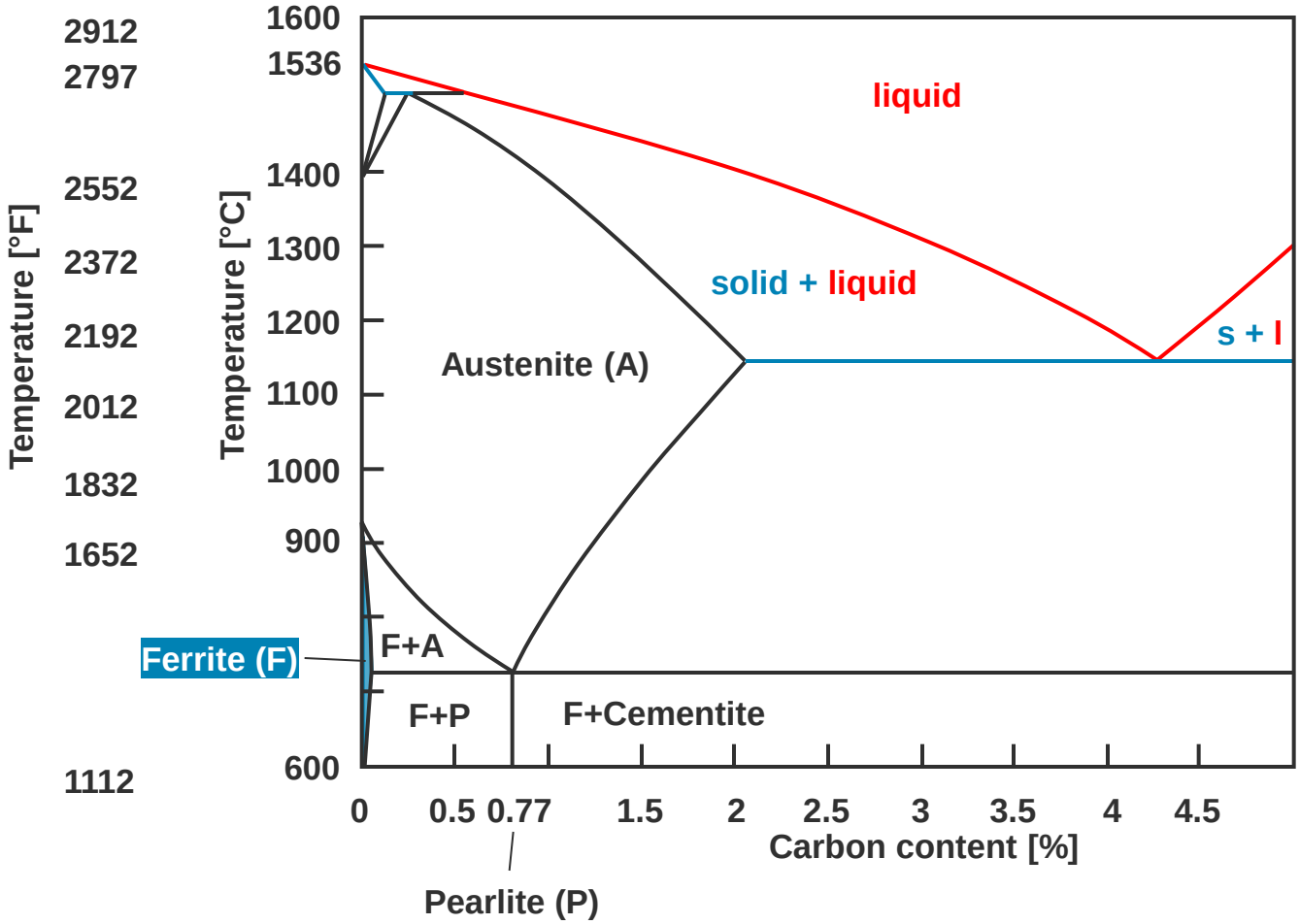

2912
2797
2552
2372
2192
2012
1832
1652
1112
Temperature [°F]
1600
1536
1400
1300
1200
1100
1000
900
600
Temperature [°C]
liquid
solid + liquid
s + l
Austenite (A)
Ferrite (F)
F+A
F+P
F+Cementite
0
0.5
0.77
1.5
2
2.5
3
3.5
4
4.5
Carbon content [%]
Pearlite (P)

Austenite

- Gamma-phase (face centered cubic)
- Low hardness
- Strength increased by cold-working
- Stable above 723°C (1333°F) or at RT by alloying Ni, Co, Mn
- Can contain up to 2.06 % C
- Main part of corrosion resistant steels, shape memory alloys
- Not (ferro)magnetic
- Not useable in rails



Ferrite


2912
2797
2552
2372
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Temperature [°F]
1600
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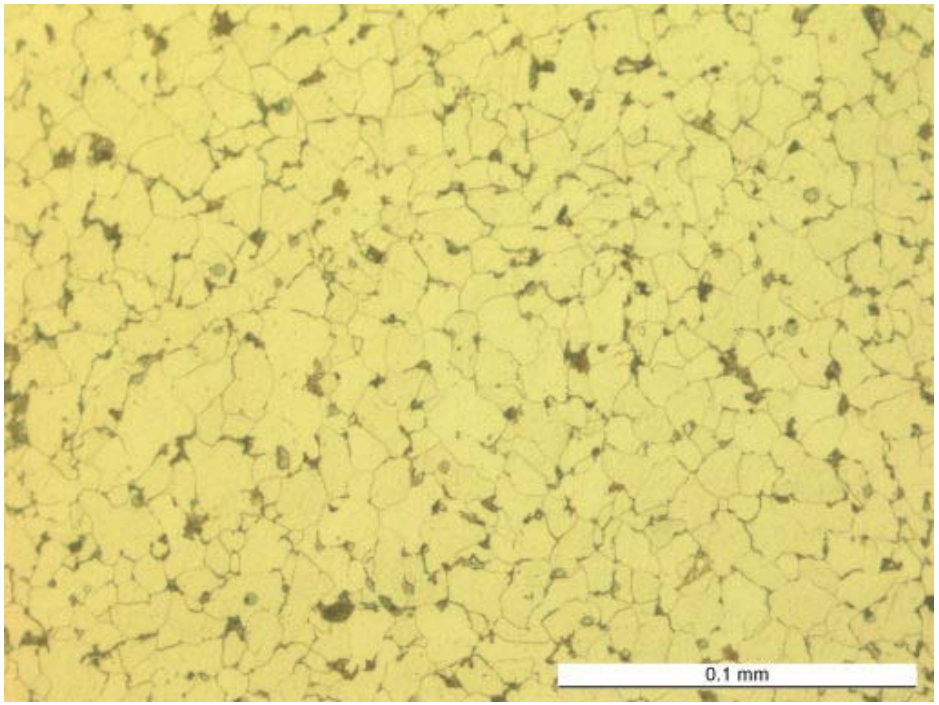
1300
1200
1100
1000
900
600
Temperature [°C]
liquid
solid + liquid
s + l
Austenite (A)
Ferrite (F)
F+A
F+P
F+Cementite
0
0.5
0.77
1.5
2
2.5
3
3.5
4
4.5
Carbon content [%]
Pearlite (P)

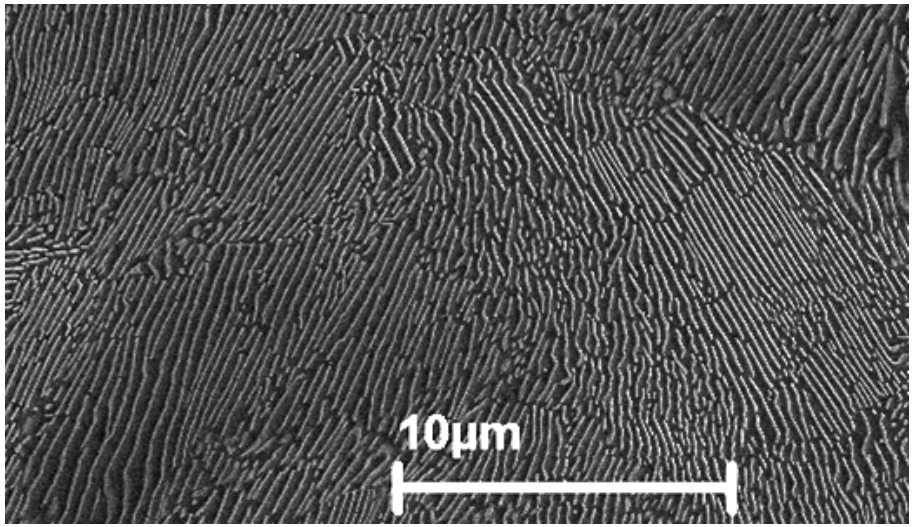
Ferrite

- Pure iron (almost no carbon dissolved)
- Alpha phase (body centered cubic)
- Soft
- Can contain up to 0.02% C
- (ferro-)magnetic
- Low resistance against corrosion
- Always a part of any iron-carbon alloy
- Used as mild and low carbon steel (C < 0.29%)

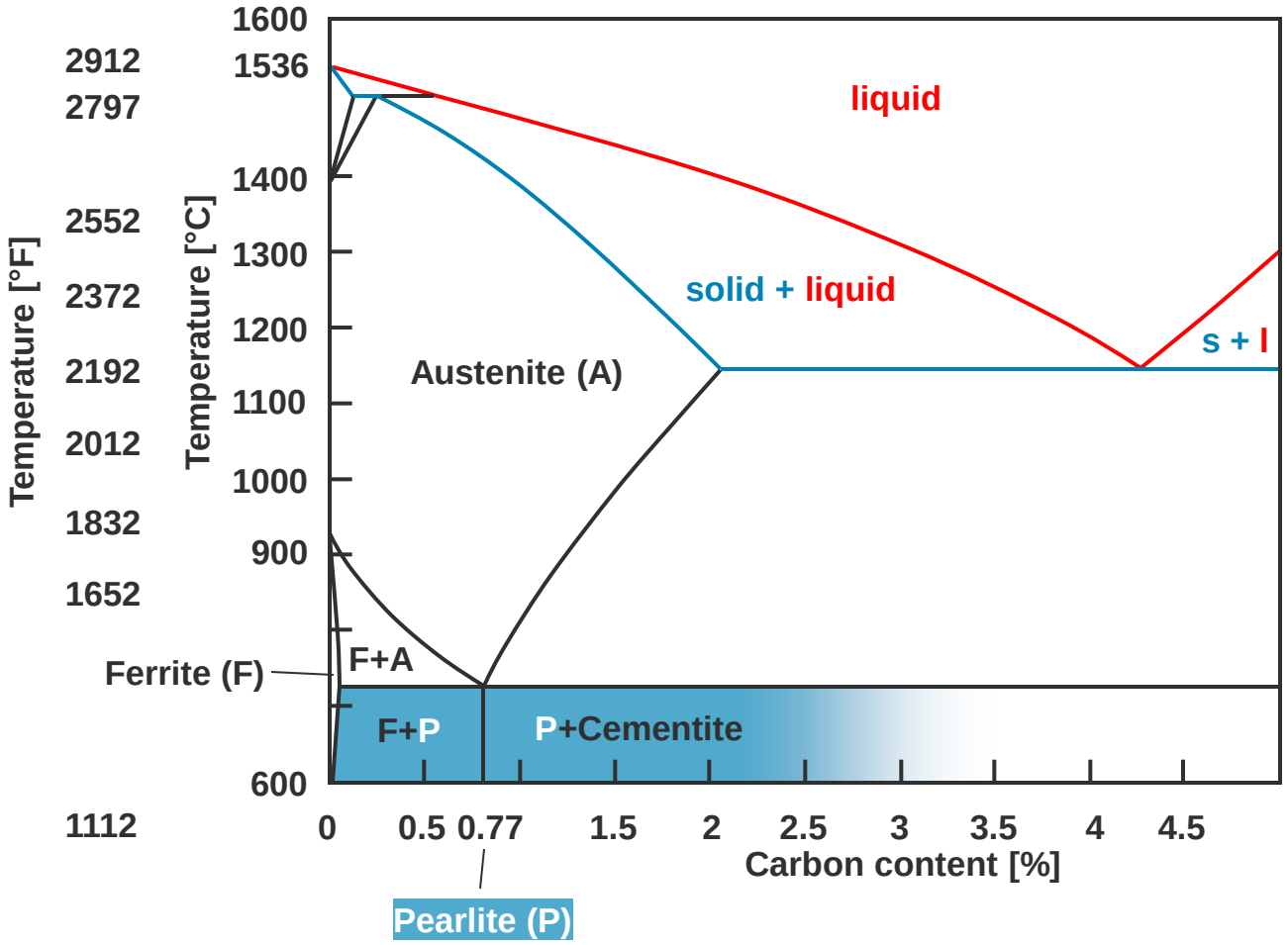


Cementite (iron-carbide)

- Fe_3C
- 6.67% C content
- Hard, brittle, wear resistant
- part of pearlitic structure and cast iron



Pearlite


Temperature [°F]
Temperature [°C]
2912
2797
2552
2372
2192
2012
1832
1652
1112
1600
1536
1400
1300
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1100
1000
900
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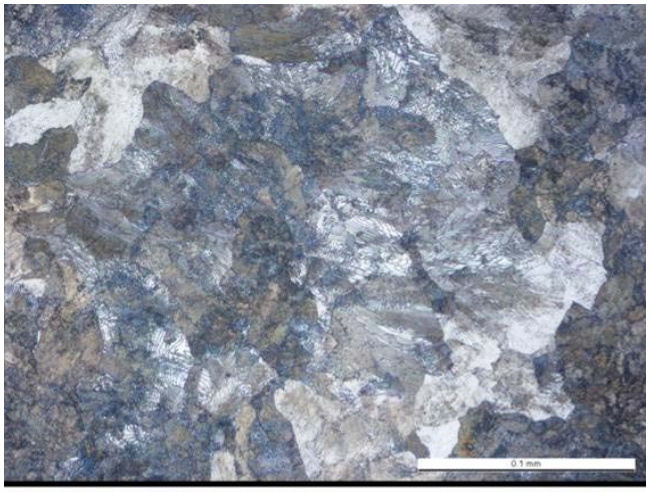
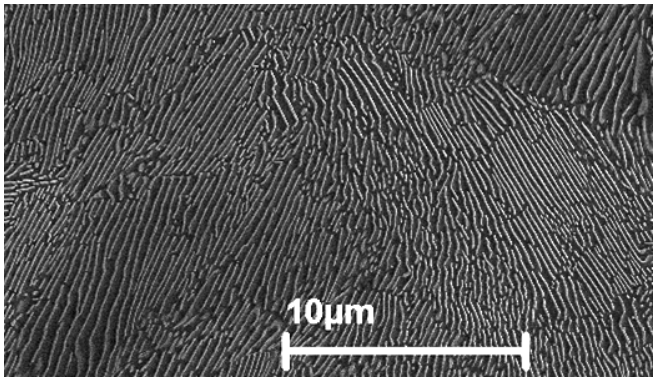
liquid
solid + liquid
s + l
Austenite (A)
F+A
Ferrite (F)
F+P
P+Cementite
0
0.5
0.77
1.5
2
2.5
3
3.5
4
4.5
Carbon content [%]
Pearlite (P)

Pearlite

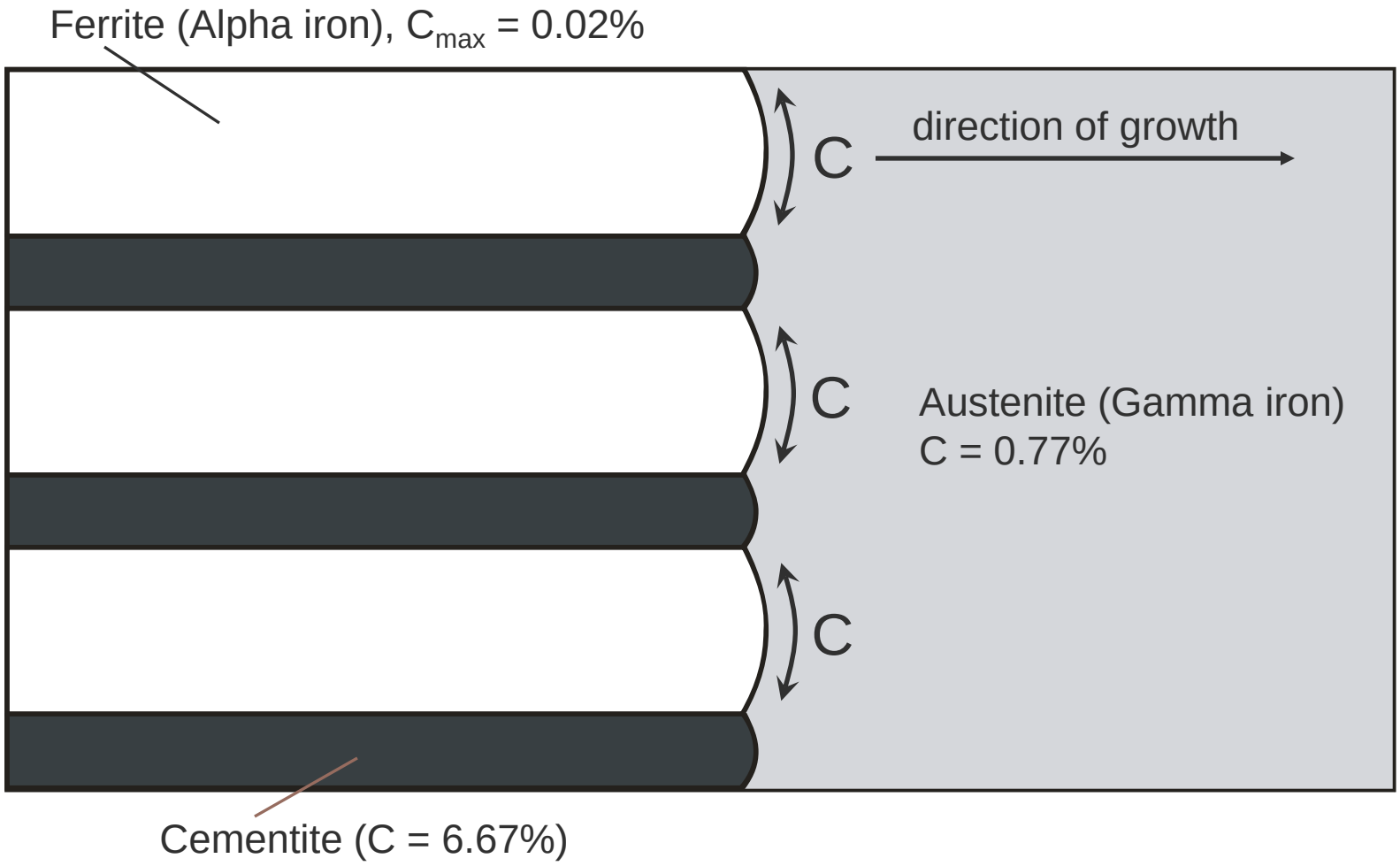
- Two phase material: Ferrite & Fe_3C
- Lamellar or layer structure
- Pure pearlitic structure at 0.77% C – Eutectoid point
- C < 0.77%: pre-eutectoid Ferrite
- C > 0.77%: pre-eutectoid Cementite
- Lamella spacing defines hardness properties without influencing the toughness
- Used for all kind of steels
- Used in rails for standard and premium grades



Perlit 260HB



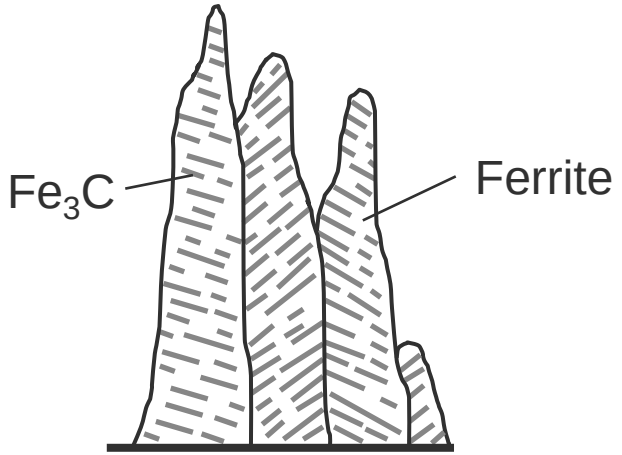
Austenite – Pearlite formation (simplified)

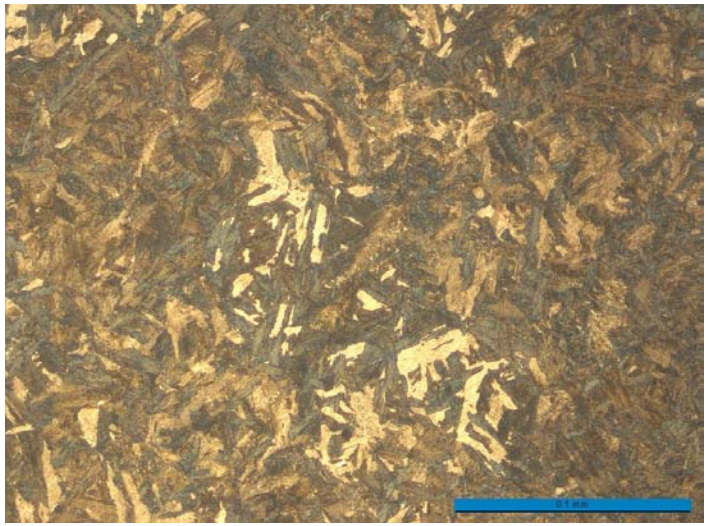


Bainite

- Two phase material: Ferrite & Fe_3C
- High toughness and hardness
- Produced by accelerated cooling or alloying
- Intermediate structure, needle like or plate structure of ferrite and carbide
- Upper, lower or carbide free Bainite

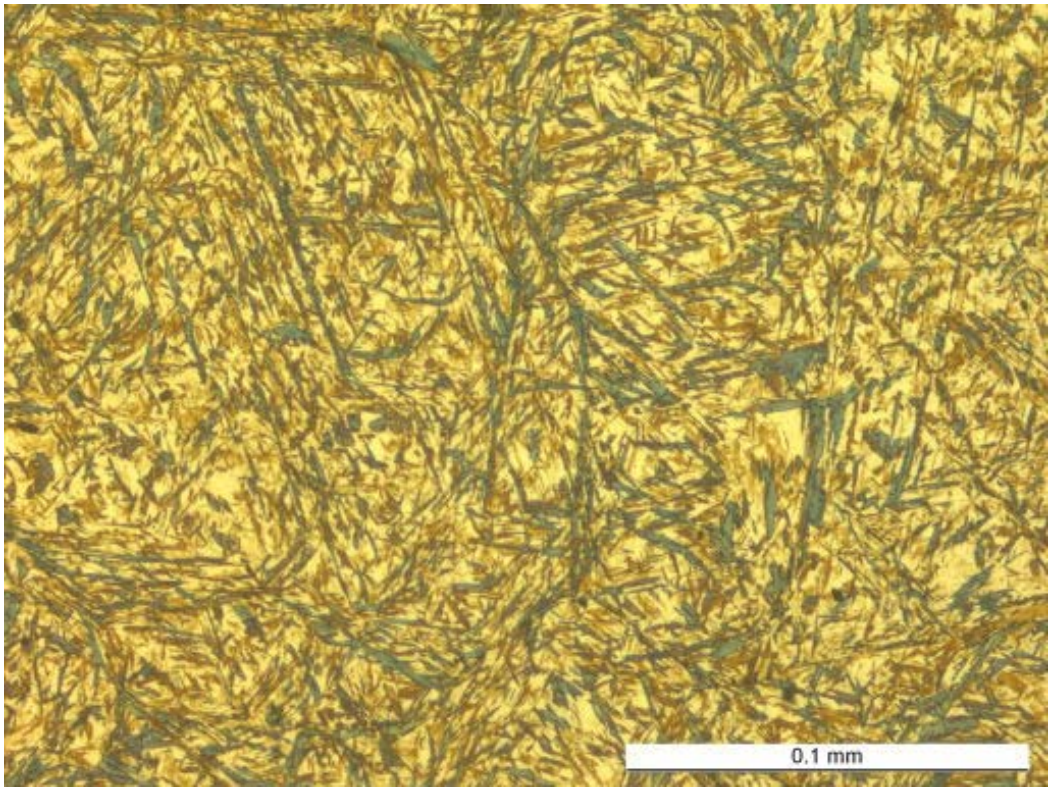
- In track testing





Martensite

- Produced by high cooling rates, alloying
- Hard and brittle structure
- Tool steels (cold working-, hot working-, high speed steels)
- Trip Steels (transformation induced plasticity)
- Must not have for rails



Steel grade comparison

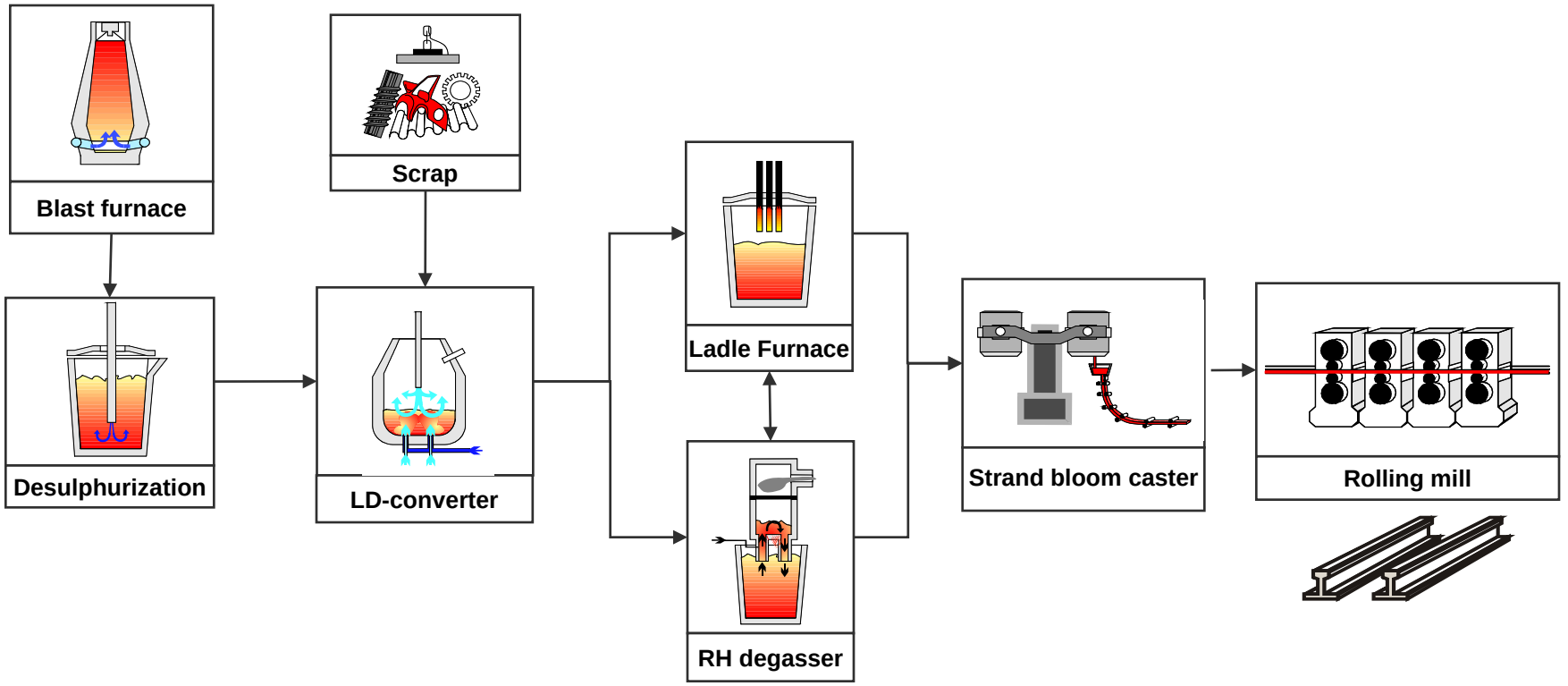
Steel grades according to EN 13674-1:2011 and AREMA									
	Chemical composition (%)						Mechanical data		
grade	C	Si	Mn	P_{max}	S	Cr	R_m [Ksi] min	Ellong. [%] min	Hardness [HB]
R260	0.62-0.80	0.15-0.58	0.70-1,20	0.025	0.08-0.025		127	11	260-300
SS	0.74-0.84	0.10-0.60	0.75-1.25	0.020	0.020	0.25	120	10	300
LA	0.71-0.82	0.10-0.50	0.80-1.10	0.020	0.020	0.25-0.40	142	10	300
IH	0.71-0.82	0.10-1.00	0.70-1.25	0.020	0.020	0.40-0.70	147	8	325
R350HT	0.72-0.80	0.15-0.58	0.70-1.20	0.020	0.025		170	10	350-390
R350LHT	0.72-0.80	0.15-0.58	0.70-1.20	0.020	0.025	<0.30	170	10	350-390
HH	0.74-0.84	0.10-0.60	0.75-1.25	0.020	0.020	0.25	171	10	370
LH	0.71-0.82	0.10-1.00	0.70-1.25	0.020	0.020	0.40-0.70	171	10	370
R370CrHT	0.70-0.82	0.40-1.00	0.70-1-10	0.020	0.020	0.40-0.60	185	10	370-410
R400HT	0.90-1.00	0.20-0.40	1.20-1.30	0.020	0.020	<0.30	185	10	400-440

Several hypereutectoid grades and Bainitic grades

From rock to rail

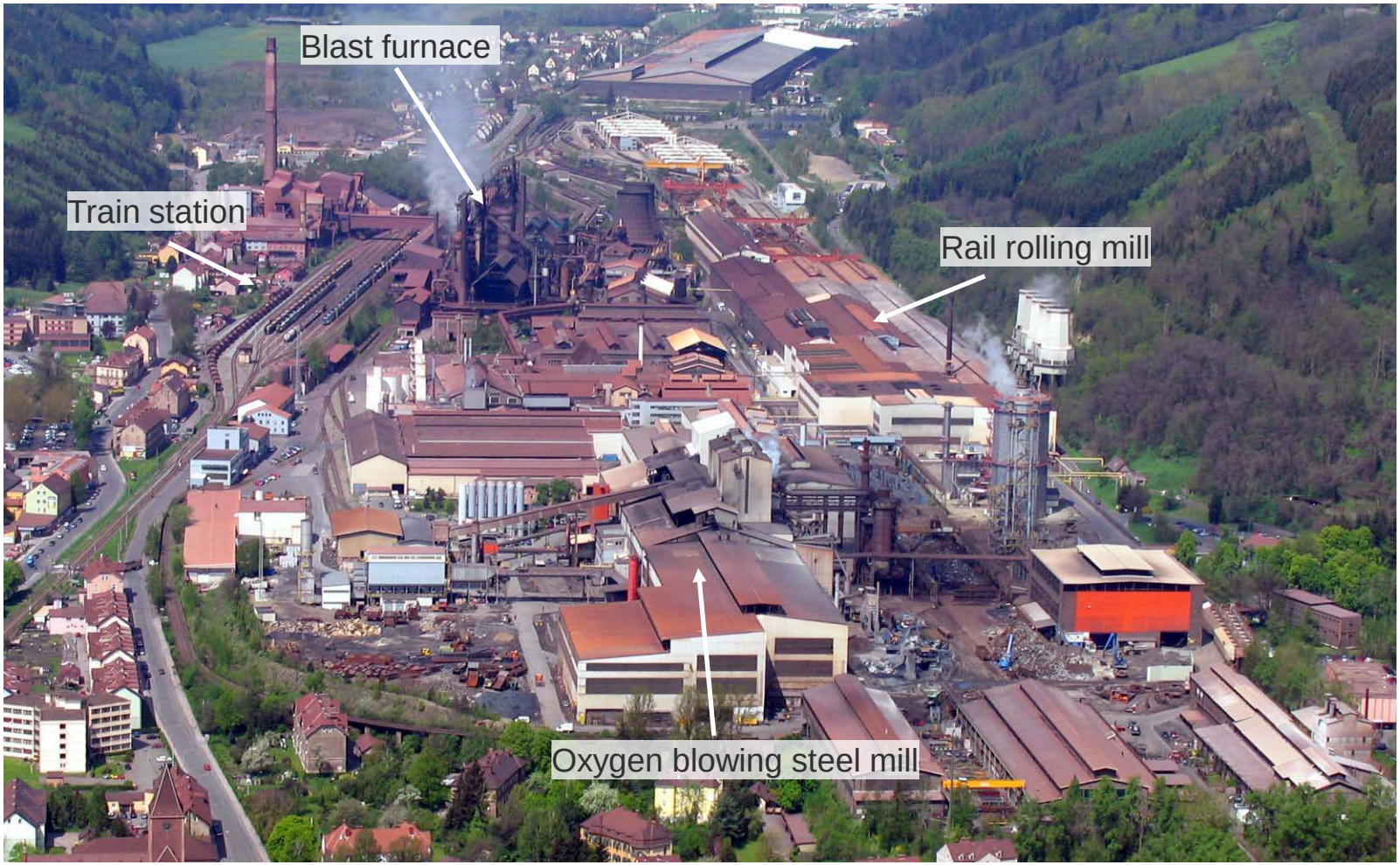
Ore Transport by train

From ore to steel

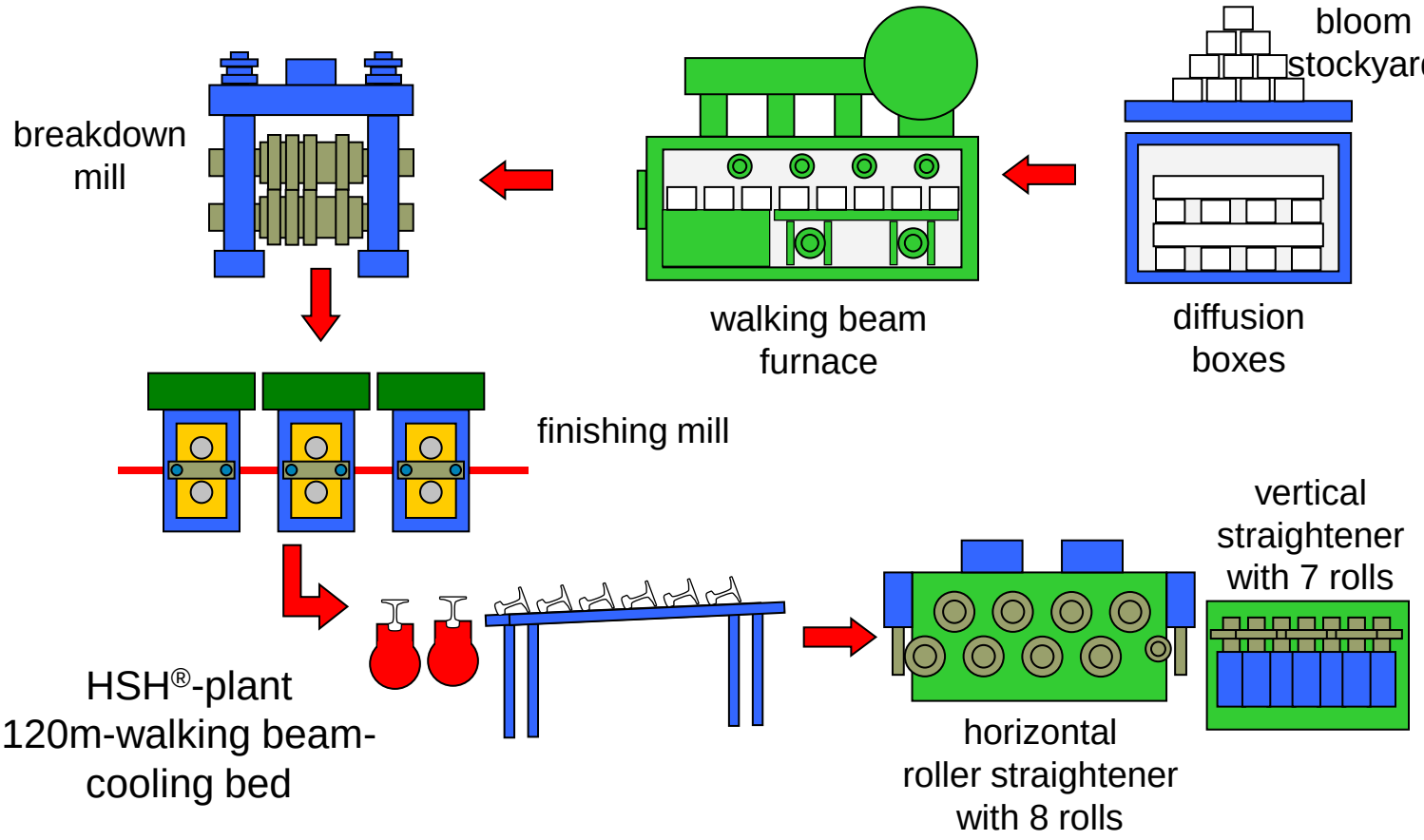


raw iron | raw steel | secondary metallurgy | continuous casting | rail

Production site in Donawitz / Austria



Production Flow Rolling-Mill

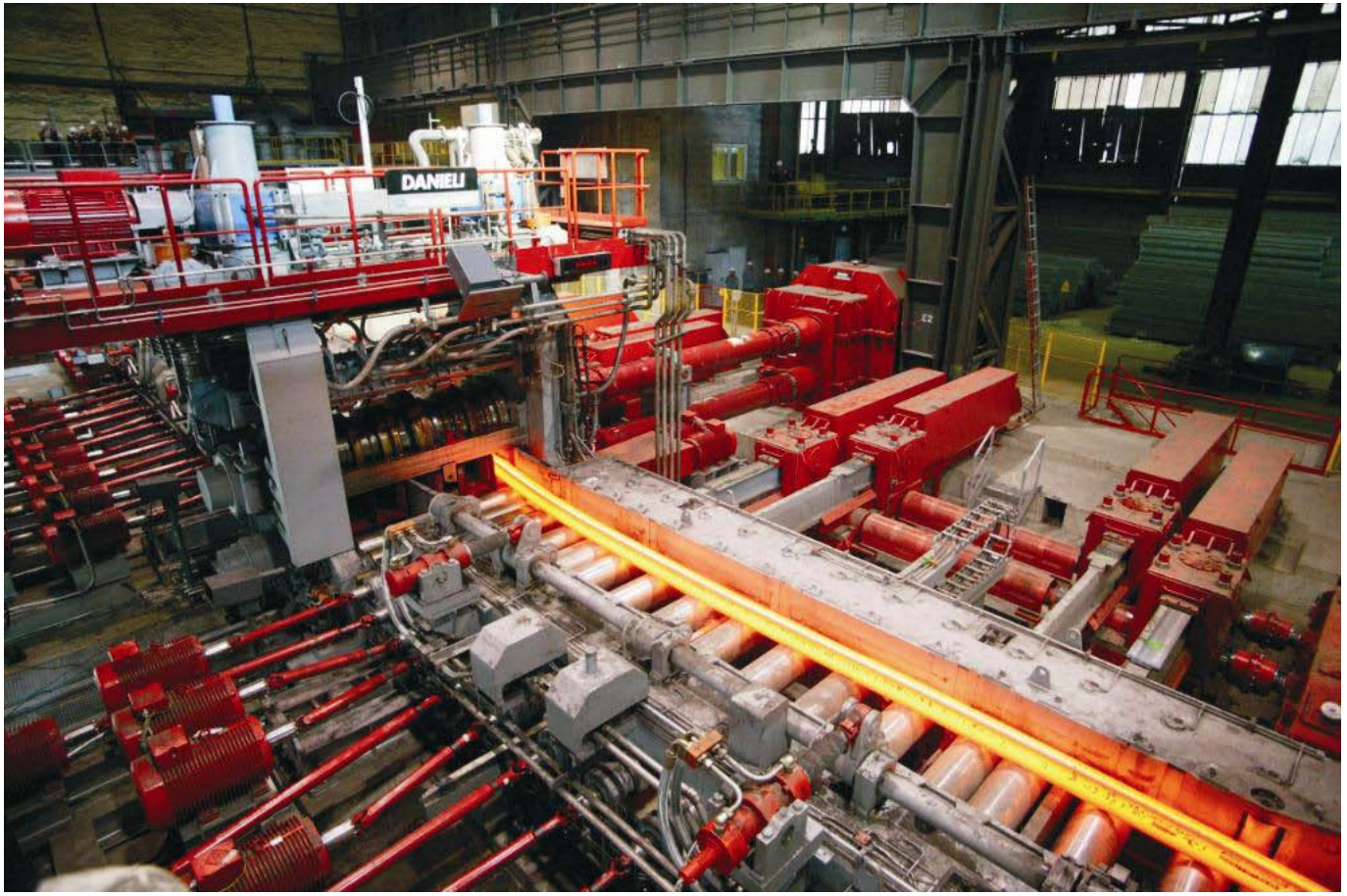


Bloom storage

Walking Beam Furnace

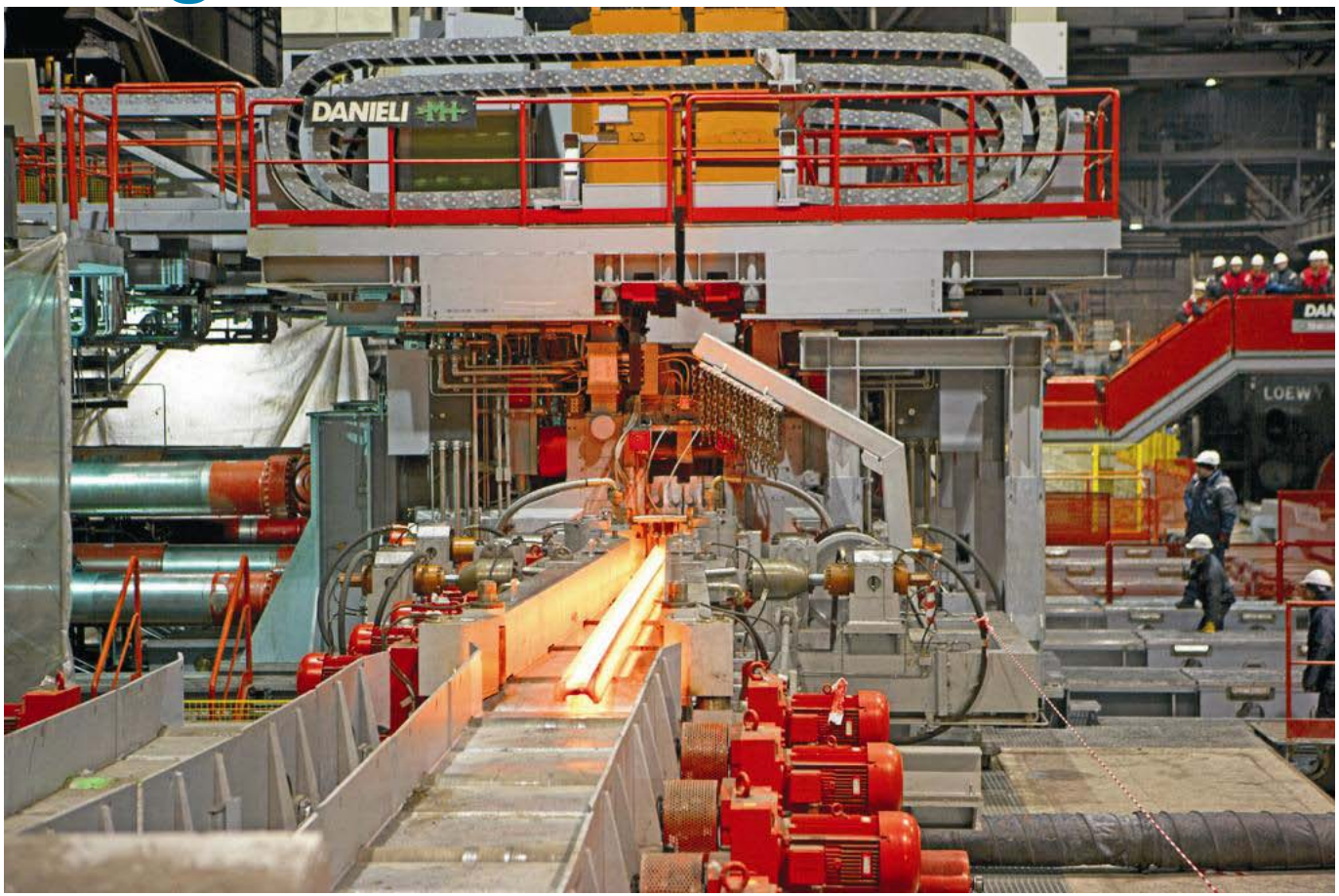
- Bloom heating
- 2.5 – 3 h heating time
- 1200 - 1300 °C rolling temperature

Break Down Mill (BDM)



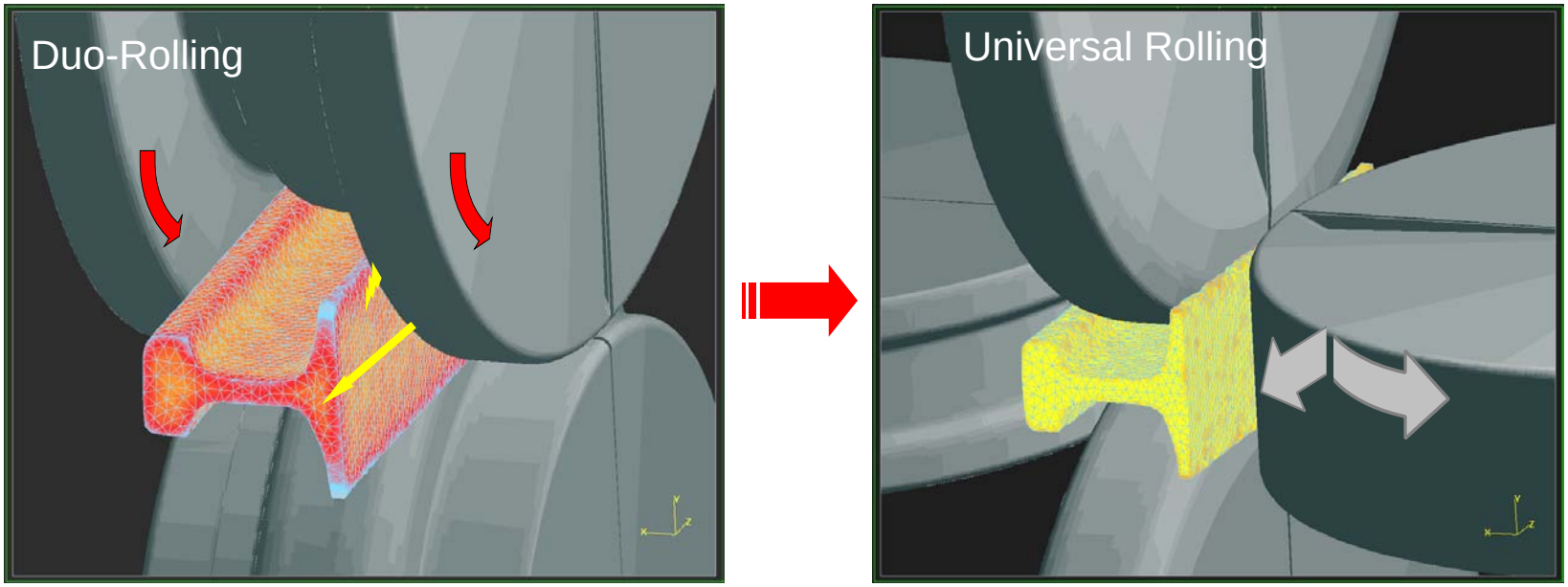
- From the bloom to a pre-rail profile

Finishing Mill - Ultra-flexible Rail Mill



- Final rail profile

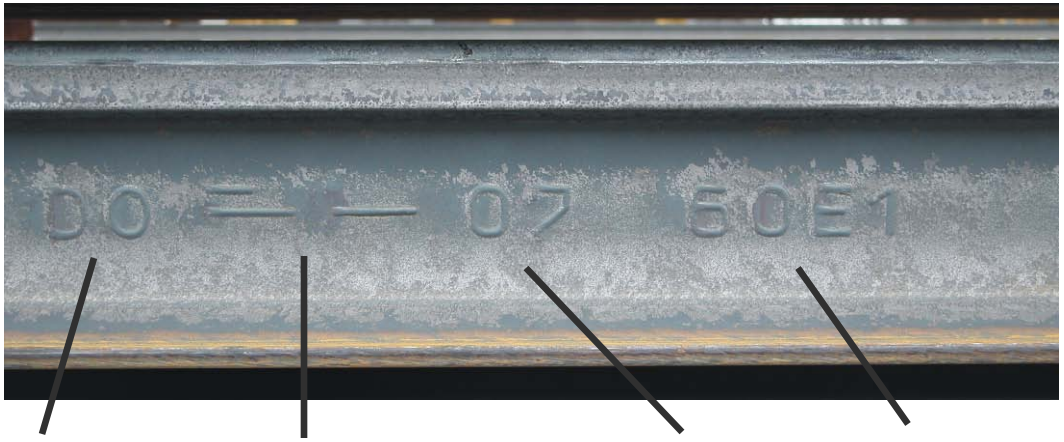
Rolling techniques



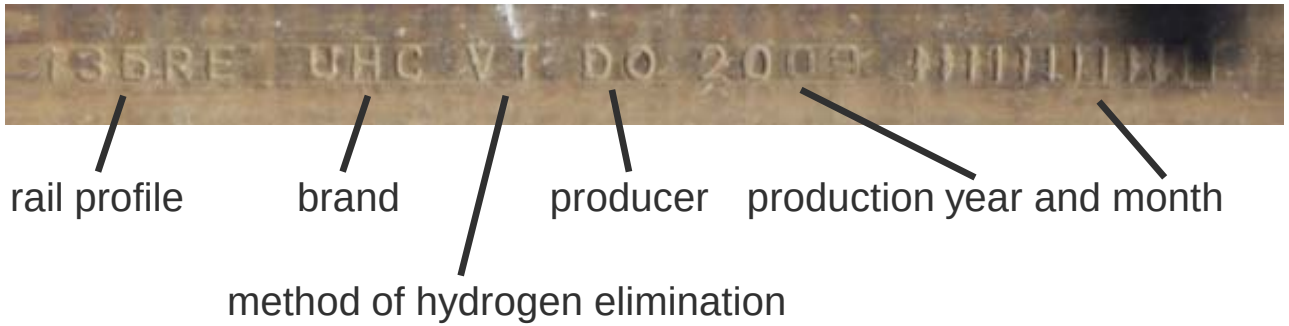
- significant reduction of tolerances
- improved surface quality
- Higher flexibility (25 min roller change)

Identification in track

- Rolling mark – EN
  - General information



- Rolling mark – AREMA



Walking Beam Cooling Bed and HSH® In-Line Heat Treatment

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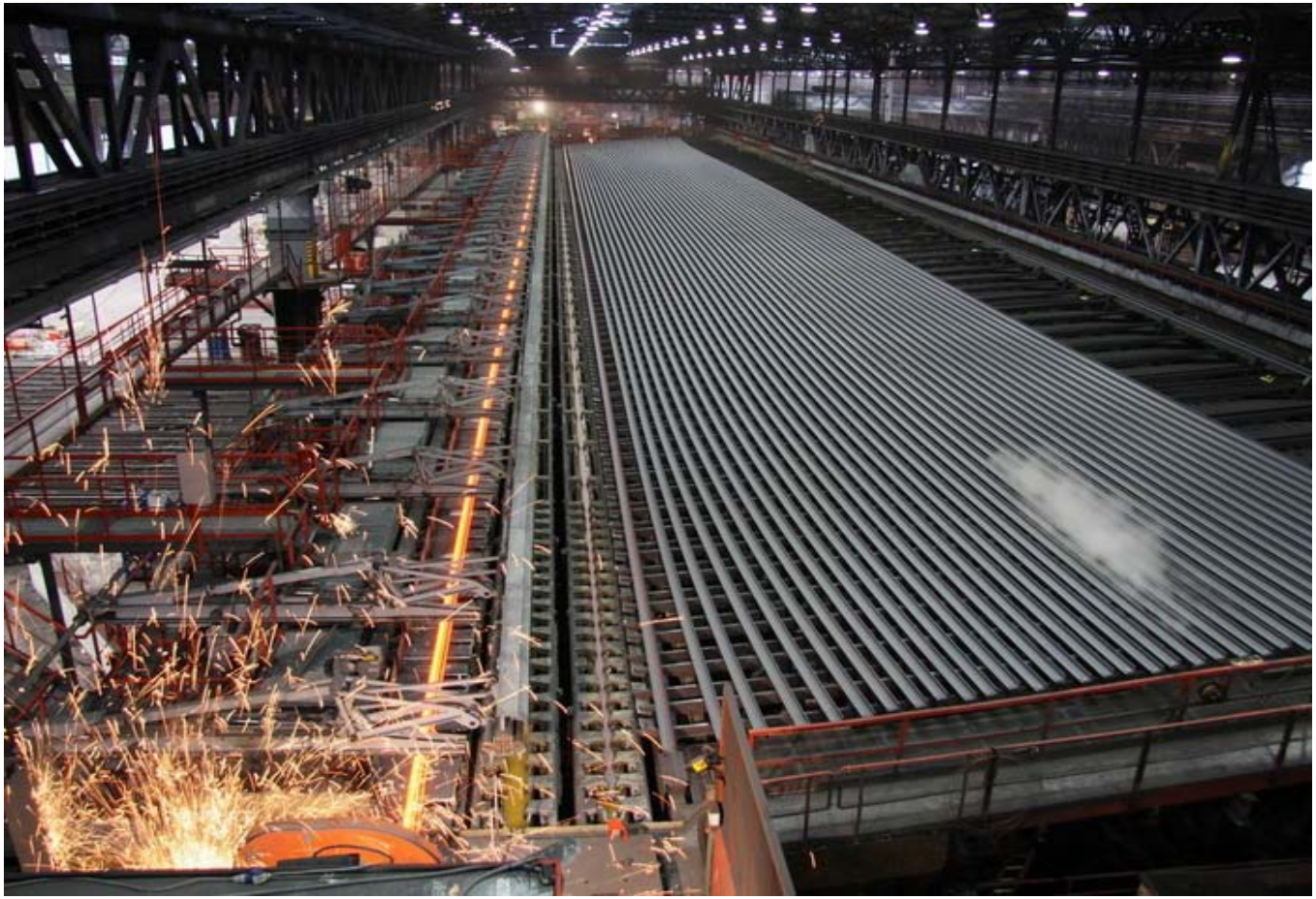
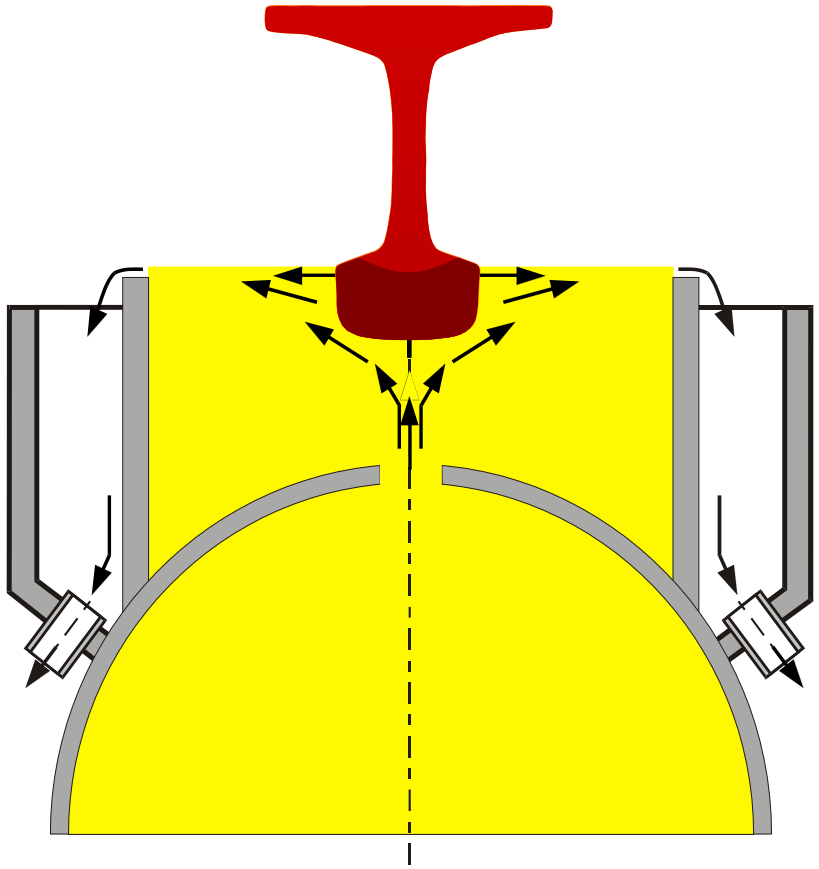
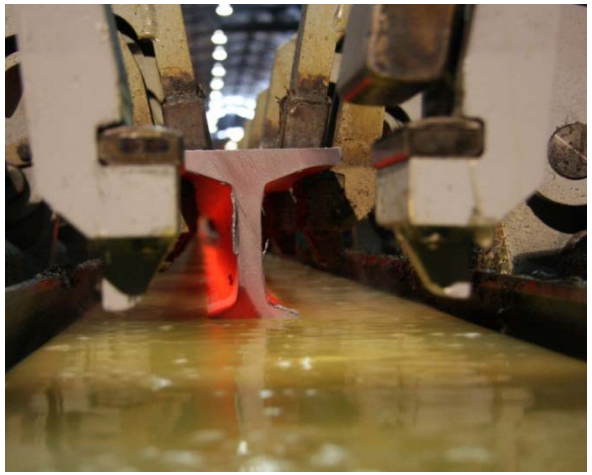


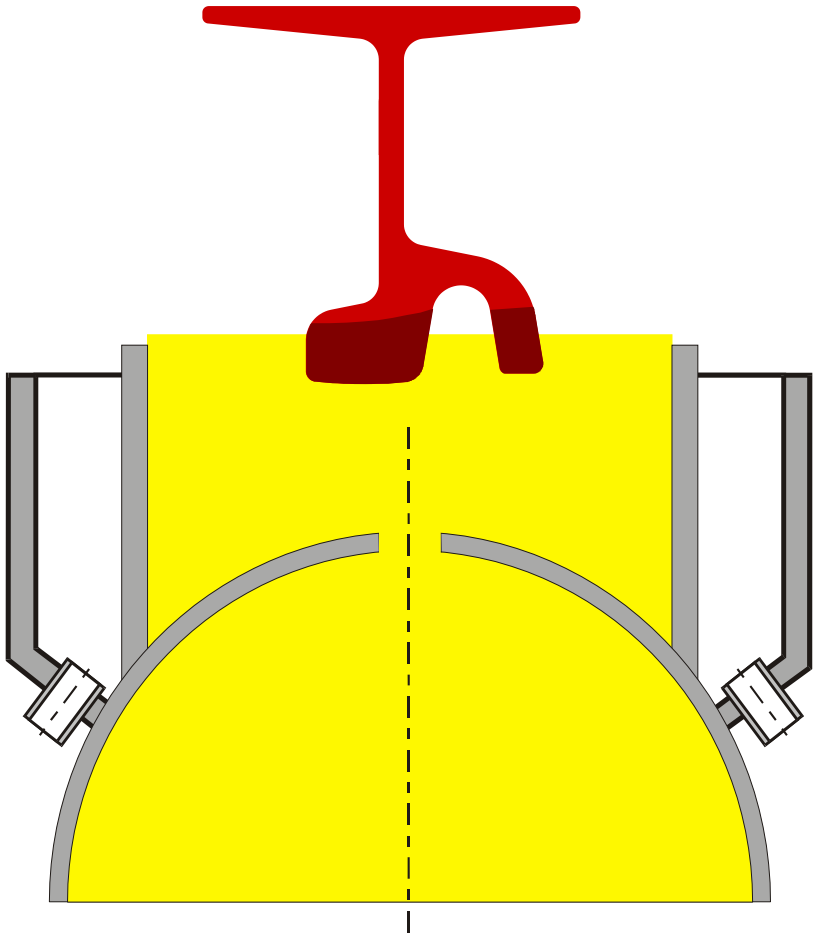
- 120 m lengths (394 ft)
- Heat treatment
- Cooling to room temperature

HSH® – Head Special Hardened rails



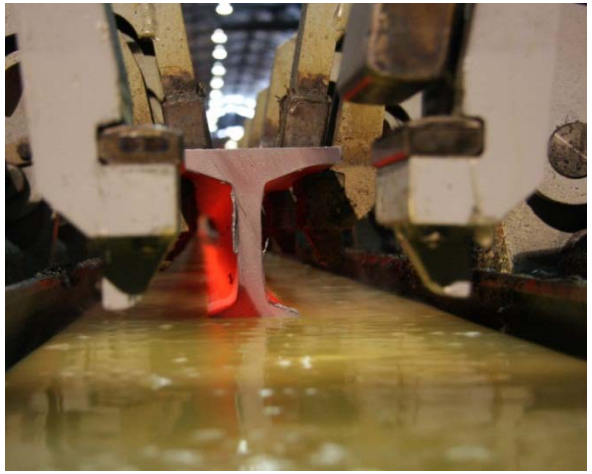


HSH® – heat treated premium girder rails



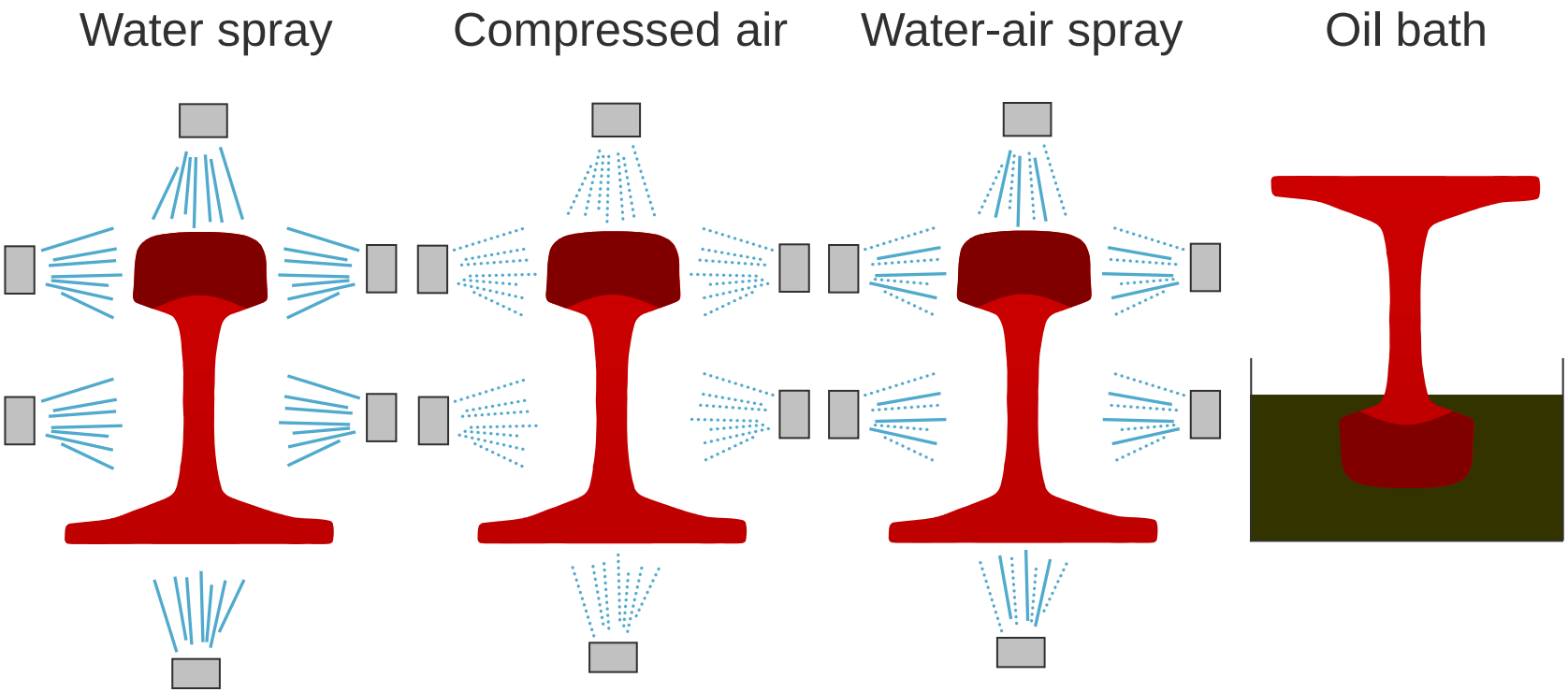
HSH® – Heat treated premium rails

- in line process
- accelerated cooling of the rail head
- fine-pearlitic structure – premium rail
- highest quality, highest productivity
- all rail profiles (T- rails, tongue rails, grooved rails)



Other head hardening techniques

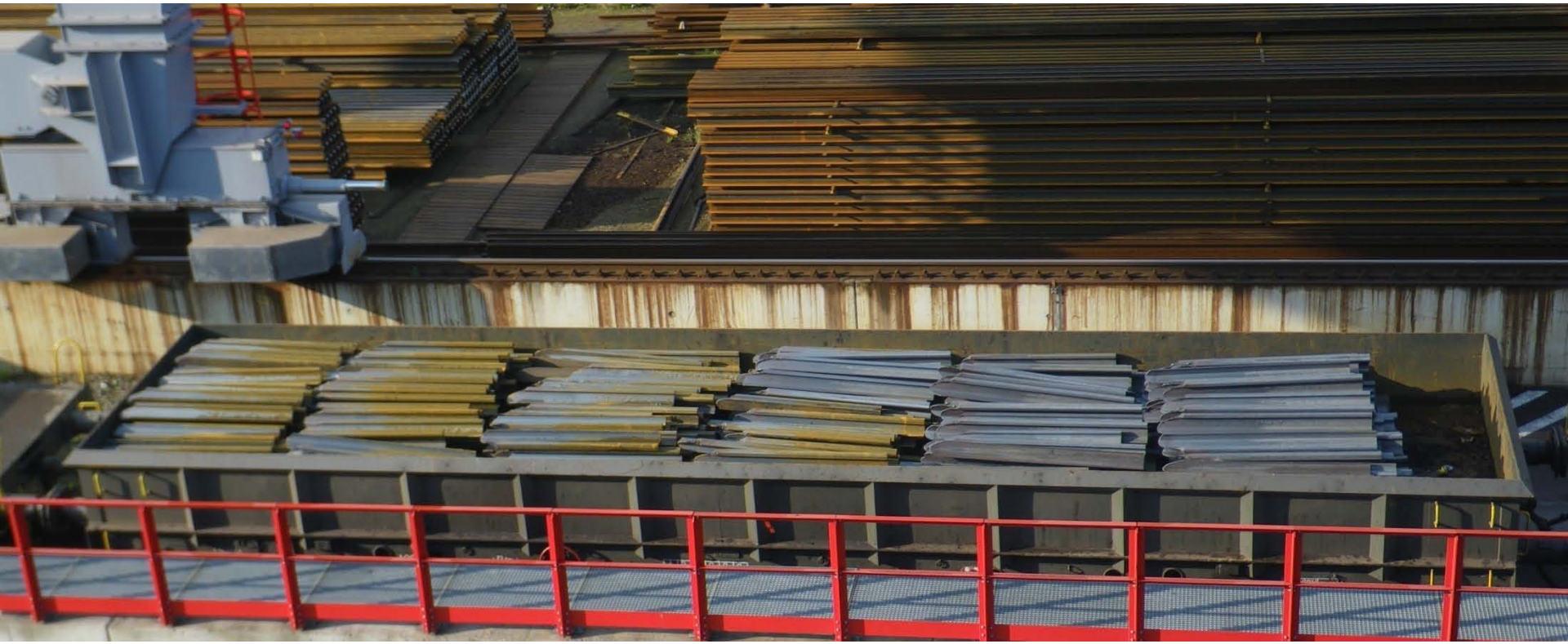
In-line: using the heat of the rolling process – economic
Offline: reheating the rail before hardening – additional energy



Two-Stage Roller Straightener

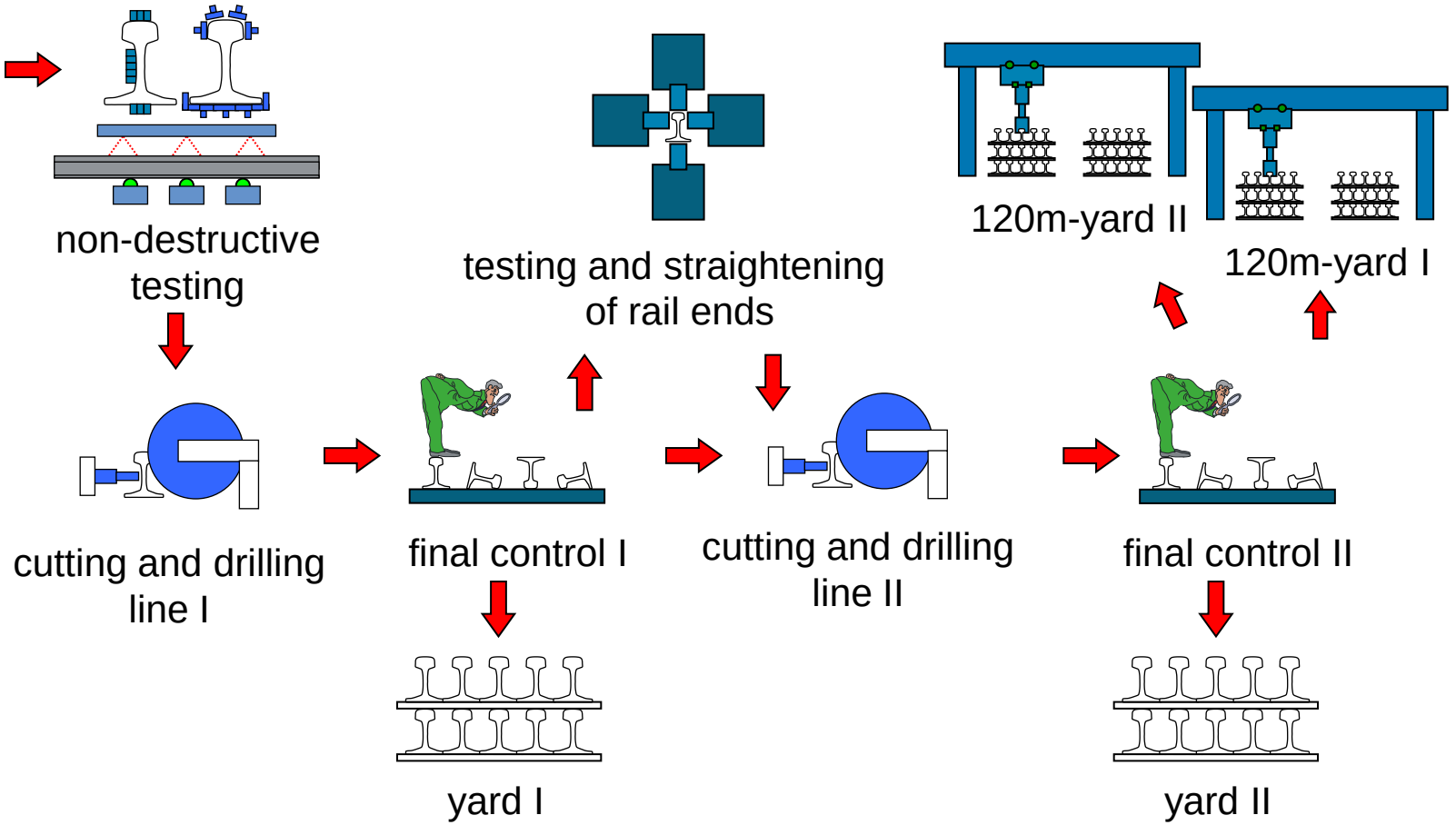
- Perfectly straight rails – vertically and horizontally

Unstraightend ends

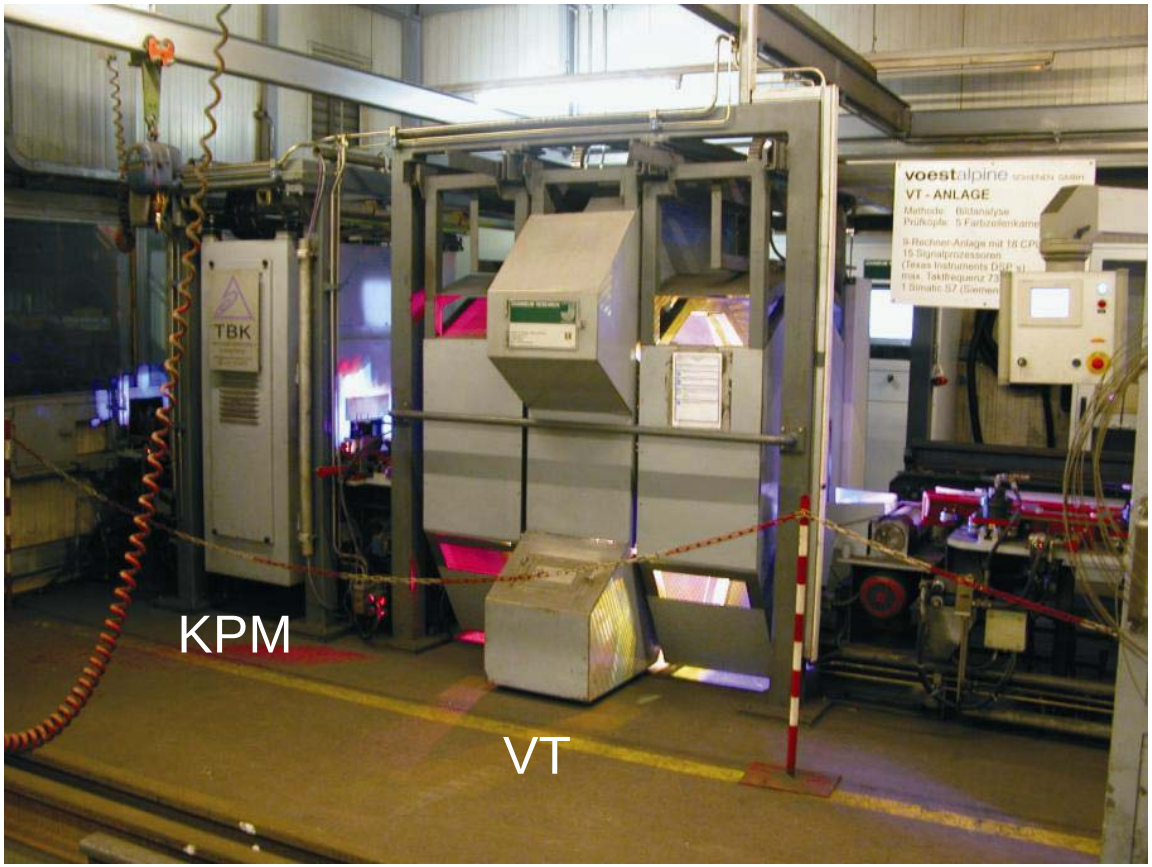


- Unstraightend ends cut off (recycled) to provide ultra-flat rails

Production Flow – Finishing Mill

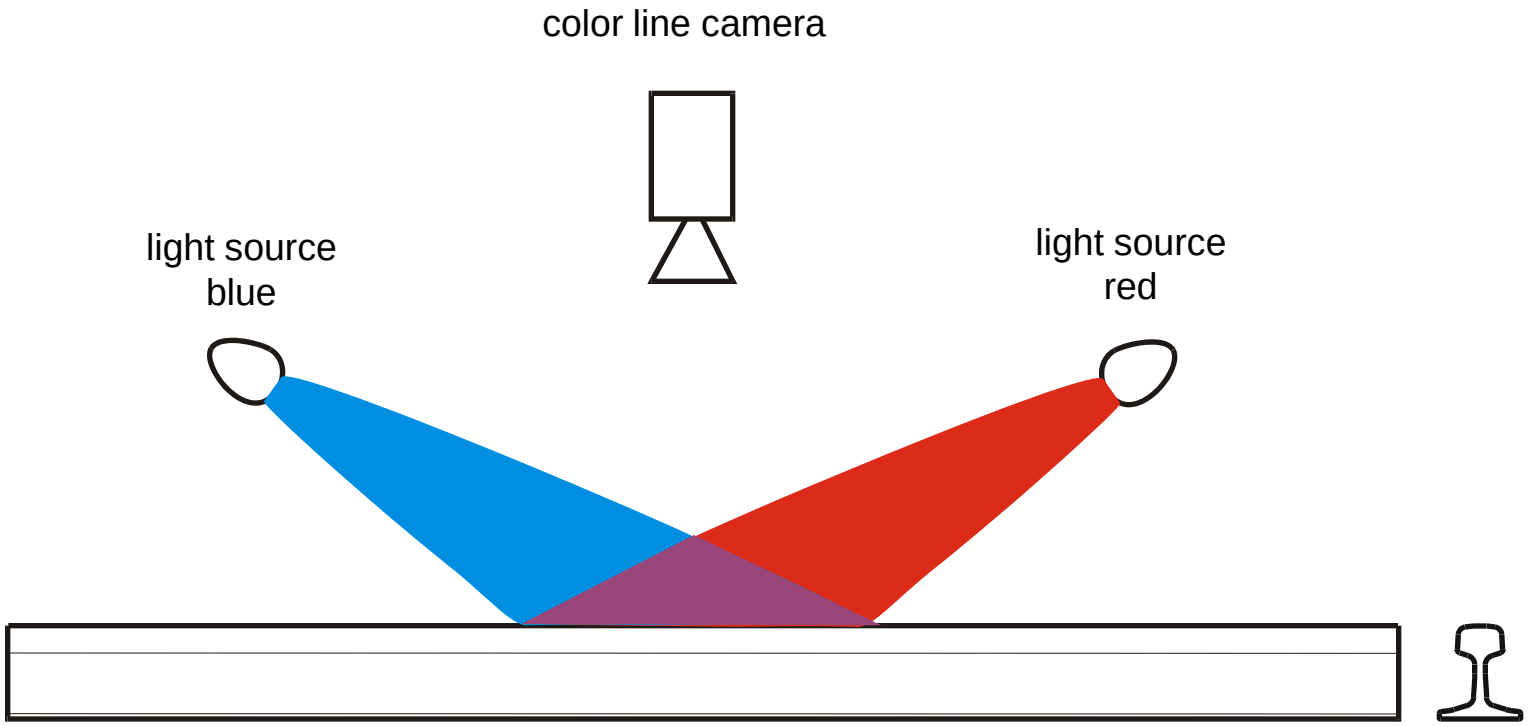


Cold-Profile-Measuring – KPM-Facility and Visual Testing – VT-Facility

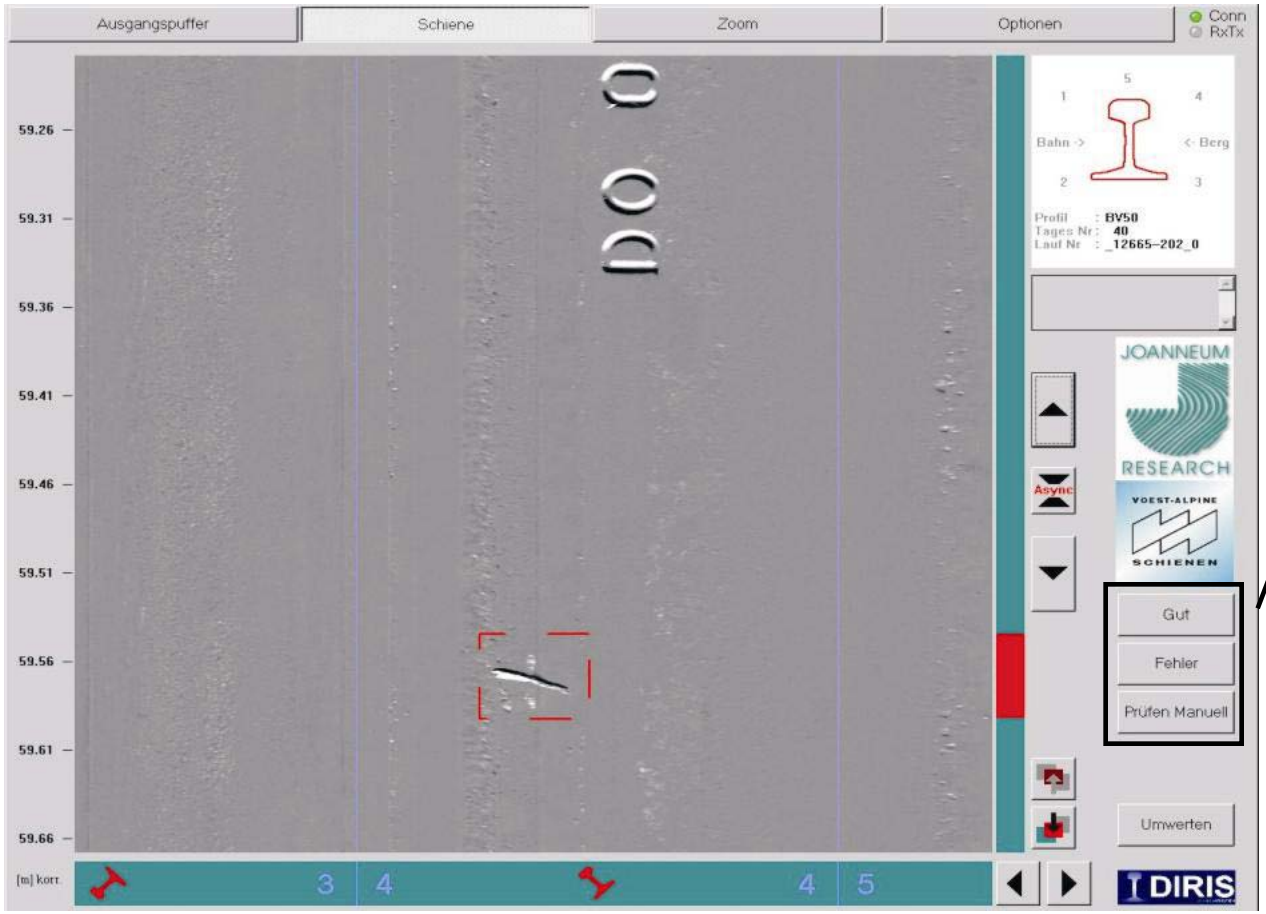


- KPM-facility
  - laser-cut method
  - 8 lasers
- VT-facility
  - fully automated checks entire rail surface
  - detects dips and scratches
  - Cracks detected separately

VT-Facility – Principle

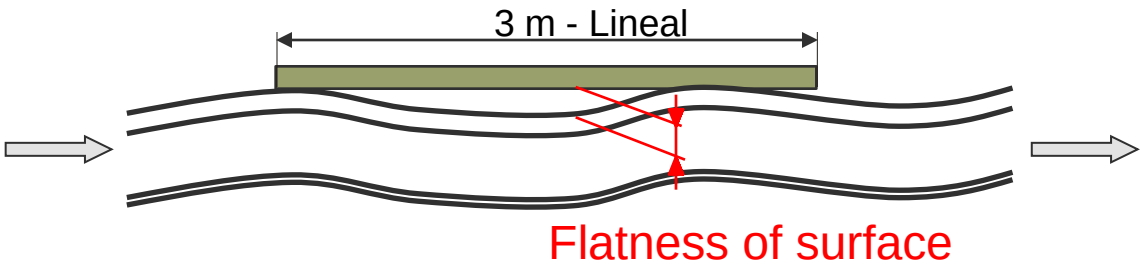


VT-Facility – Testing Result



decision on-site and in the production flow

Surface Flatness Testing – FT-Facility



- two sets of each five lasers
- 0.01 mm (0.004 inch) precision
- 0.5 – 3.0 m wave length (1.6 – 9.8 ft)
- 1.5 m/s (5 ft/s)

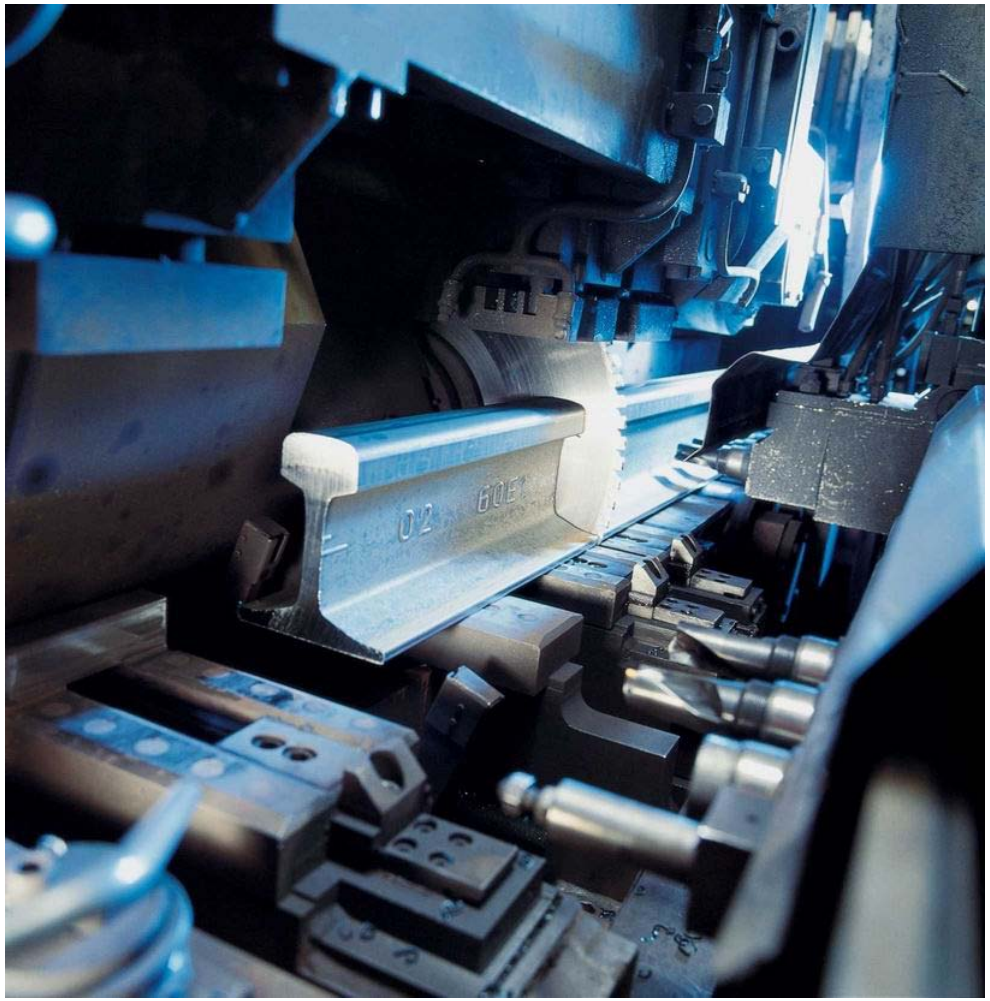
Testing for Surface Cracks – ET-facility

- eddy current testing
- rotating probes for foot and head
- segmented coils for gauge corner and foot tips
- detects cracks on the surface
- connected with VT device

Testing for Internal Defects – UT-Facility

- ultrasonic testing
- detects internal defects
- whole rail can be tested

Cutting and Drilling



- Cuts the rails to specified lengths
- Drills holes for fishplates etc.

Bending of rails

- Pre-bending for construction sites
- Especially for grooved rails for tramways.
- For very small radii

Stockyard for Ultra-long Rails

- two stockyards for 120 m
- only one operator
- fully automated

Loading of Rails

- Loading to trains or trucks
- Up to 120m rails (394 ft)

Long Rail Train

- transport to customer
- 60 % of production are long rails
- 108 – 120 m
- 36 pieces/load
- 260 to/load
- approved by all European countries
- Just-In-Time logistics

Unloading System – Railputler

- developed in cooperation with Robel
- precise positioning
- no detrimental distortion
- up to 1.700 m/h
- down to 250 m radius (6° curve)
- approved by all European countries

Thank you for your attention!!!

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