

NF Wire Forum

Aurubis
Metals for Progress

BALLOFFET

BECHEM
LUBRICATION
TECHNOLOGY

Deutsches
Kupferinstitut

NIEHOFF
GRUPPE

NF Wire Forum

Copper Wire Rod

NF WIRE FORUM ONLINE EVENT

May, 2021

Aurubis AG, Dr. Cornel Abratis

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Agenda



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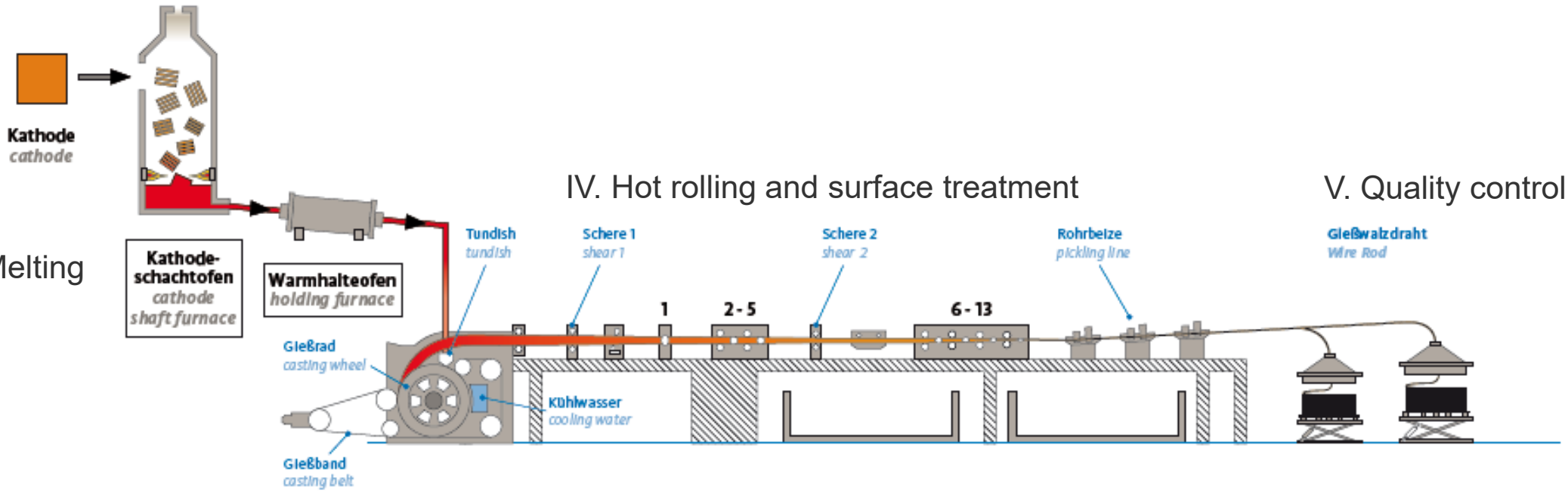
1. Copper Wire Rod – Cu-ETP1
2. Copper Wire Rod – Cu-OFE

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Influencing factors on good drawability of Copper Wire Rod

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I. Feed mix



II. Melting

IV. Hot rolling and surface treatment

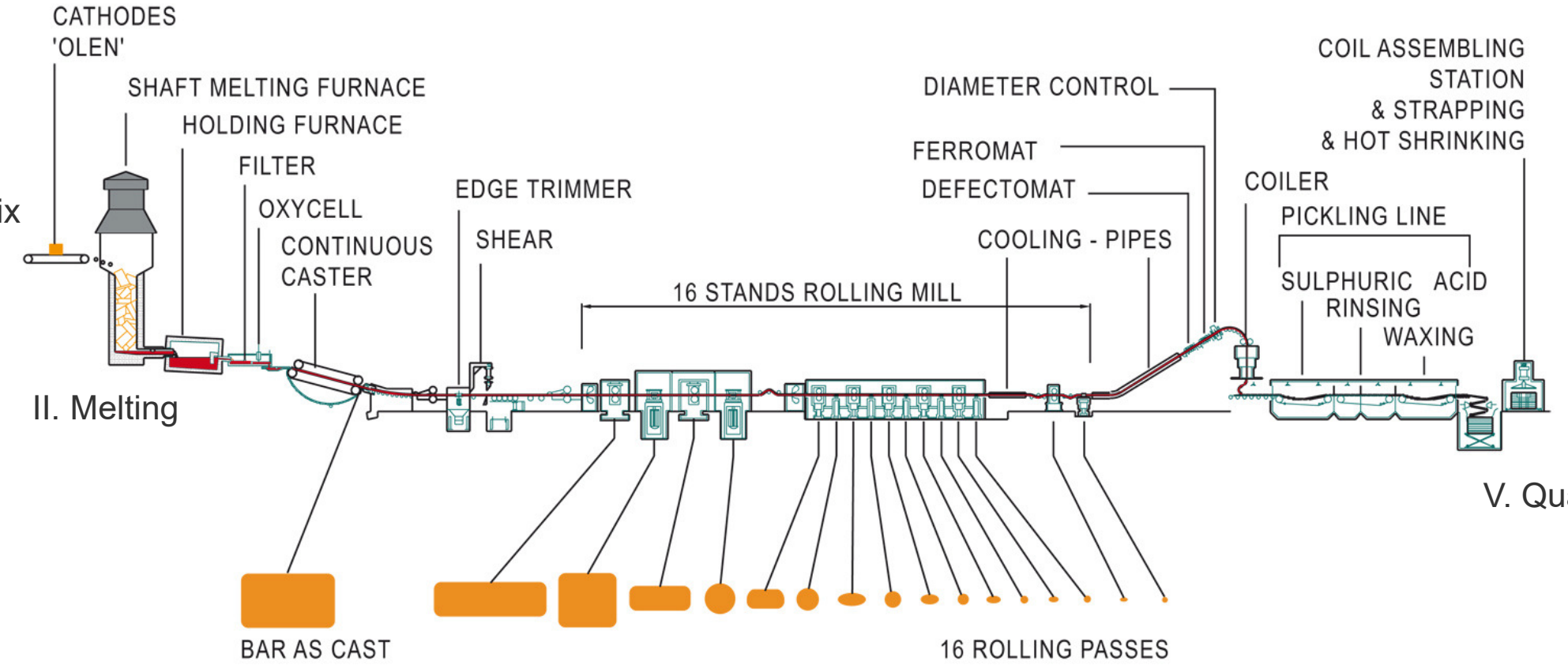
V. Quality control

III. Casting and Solidification

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I. Feedmix: Copper Cathodes

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- **Grade A cathodes** from 4 Aurubis tankhouses out of different production campaigns
- Purchase of grade A cathodes
- Cathode classification for internal and external cathodes in the Aurubis group is basis for production planning (grade A is not like grade A)
- **„correct“ cathode mix** is essential for
  - **fine wire** output of a rod line
  - compliance with **chemical purity**
  - homogeneous forming and softening behaviour
  - **high conducivity** and **SEN values**

Ag	As	Bi	Fe	Ni	Pb	S	Sb	Se	Sn	Te	max. impurities
<15	<1	<1	<2	<2	<1	<3	<1	<1	<1	<1	30

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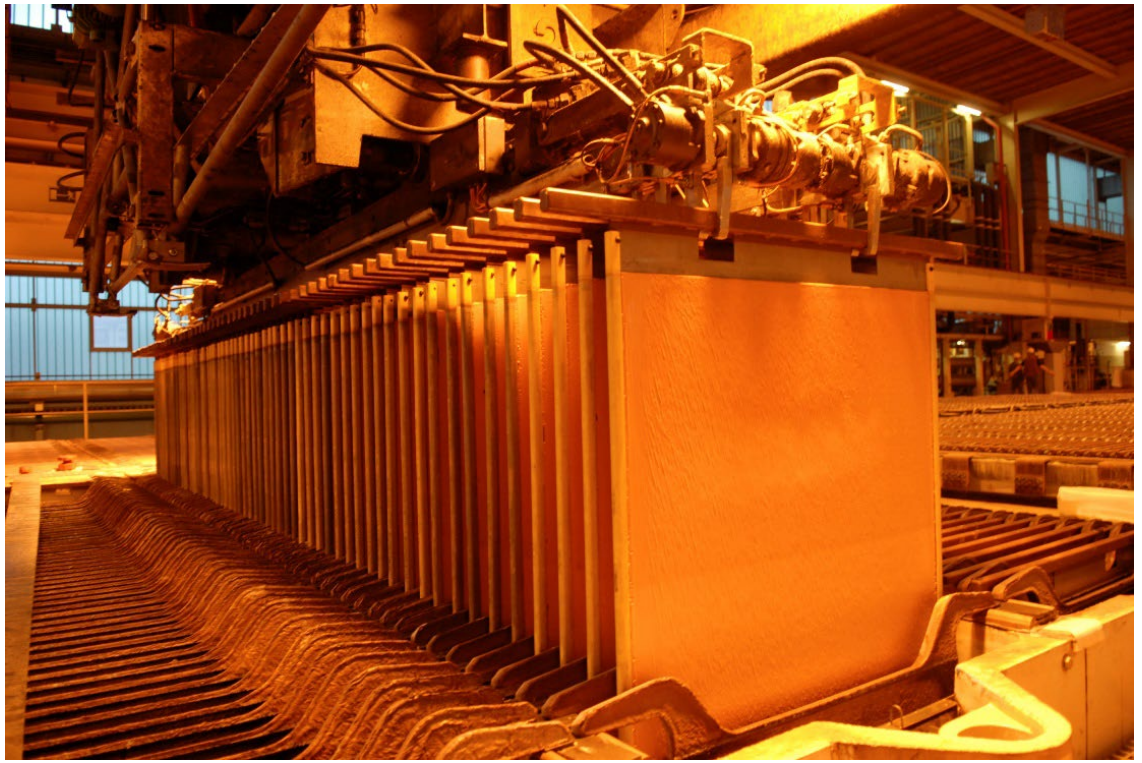
I. Feedmix: cathode capacity at Aurubis group

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Hamburg Tankhouse: 400.000t/a

Olen Tankhouse: 350.000t/a





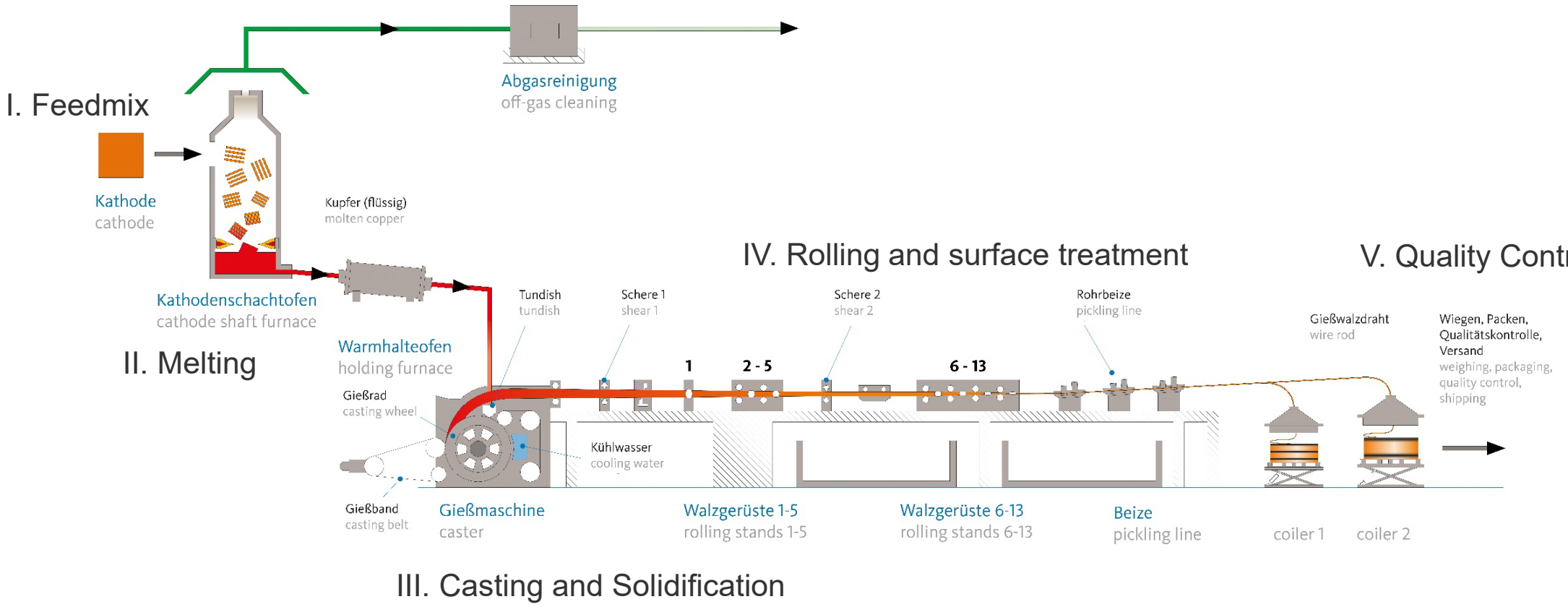
Lünen Tankhouse: 160.000t/a

Pirdop Tankhouse: 220.000t/a

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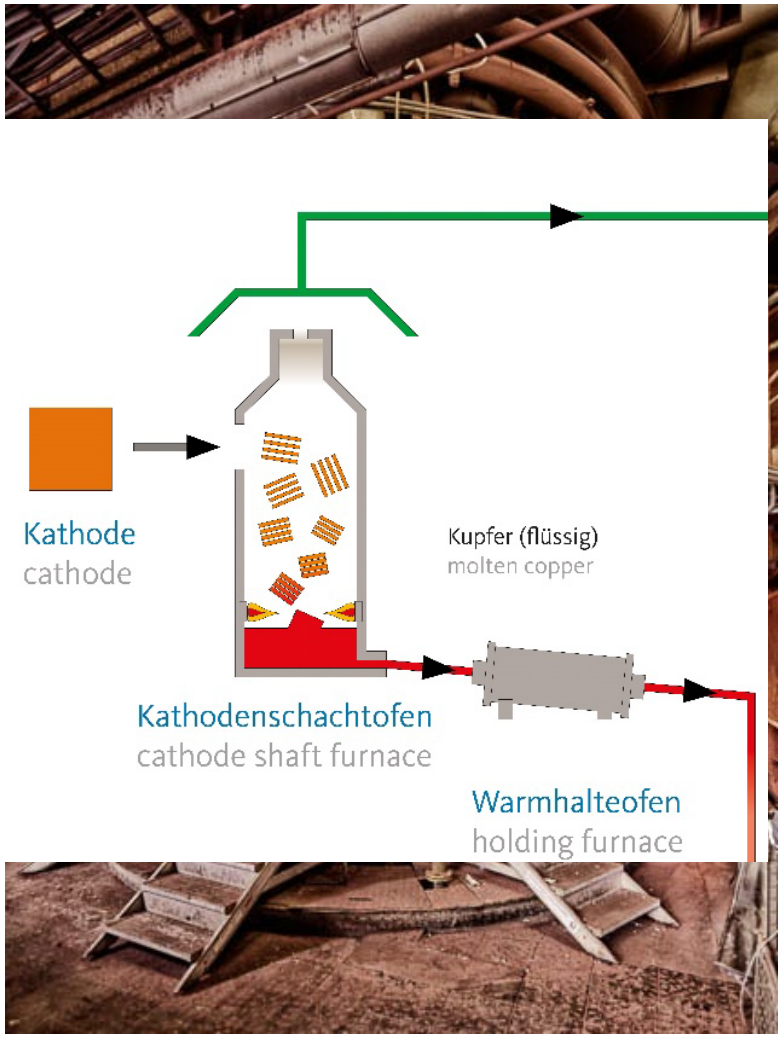
Influencing factors on good drawability of Copper Wire Rod

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II. Melting



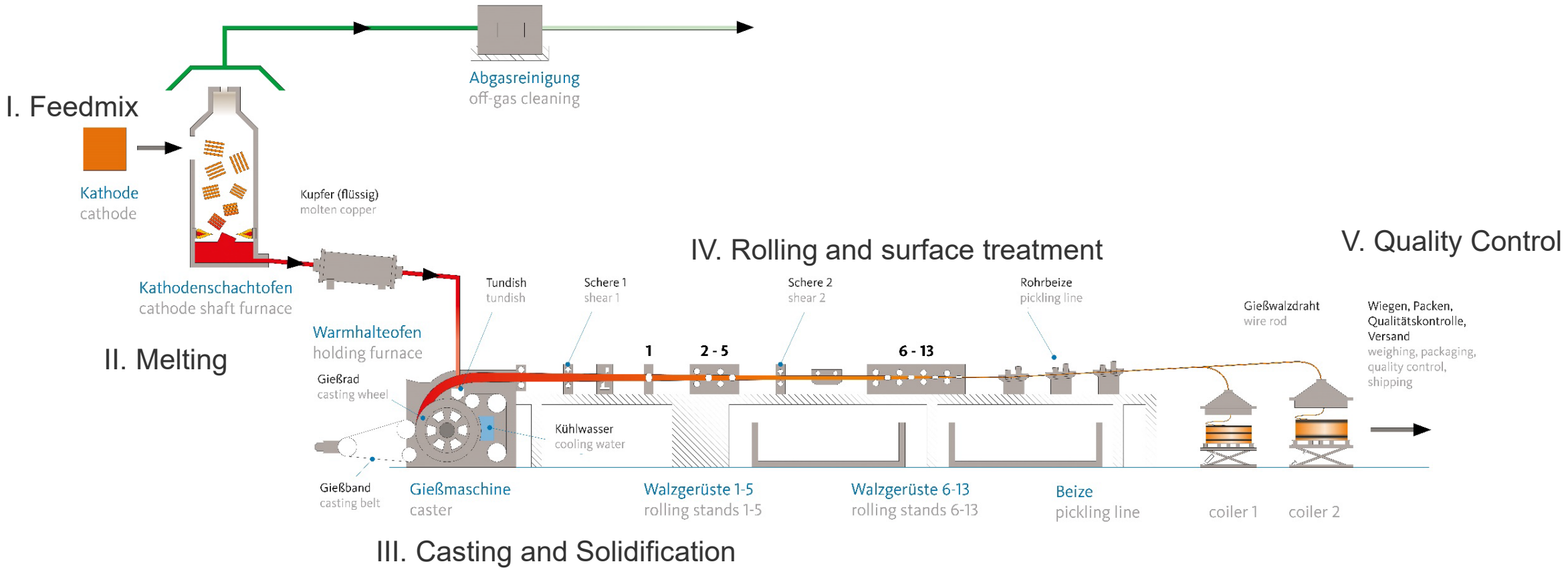
- Burner parameters in the shaft furnace, launders, holding furnace and tundish
- Temperature of the copper melt (shaft furnace, launders, holding furnace and tundish)
- Oxygen content of the copper melt
- Refractory material in shaft furnace, launders, holding furnace and tundish

Aim:

- Copper melt with oxygen content below 200ppm
- Gas in the melt
- Avoidance of anorganic refractory inclusions

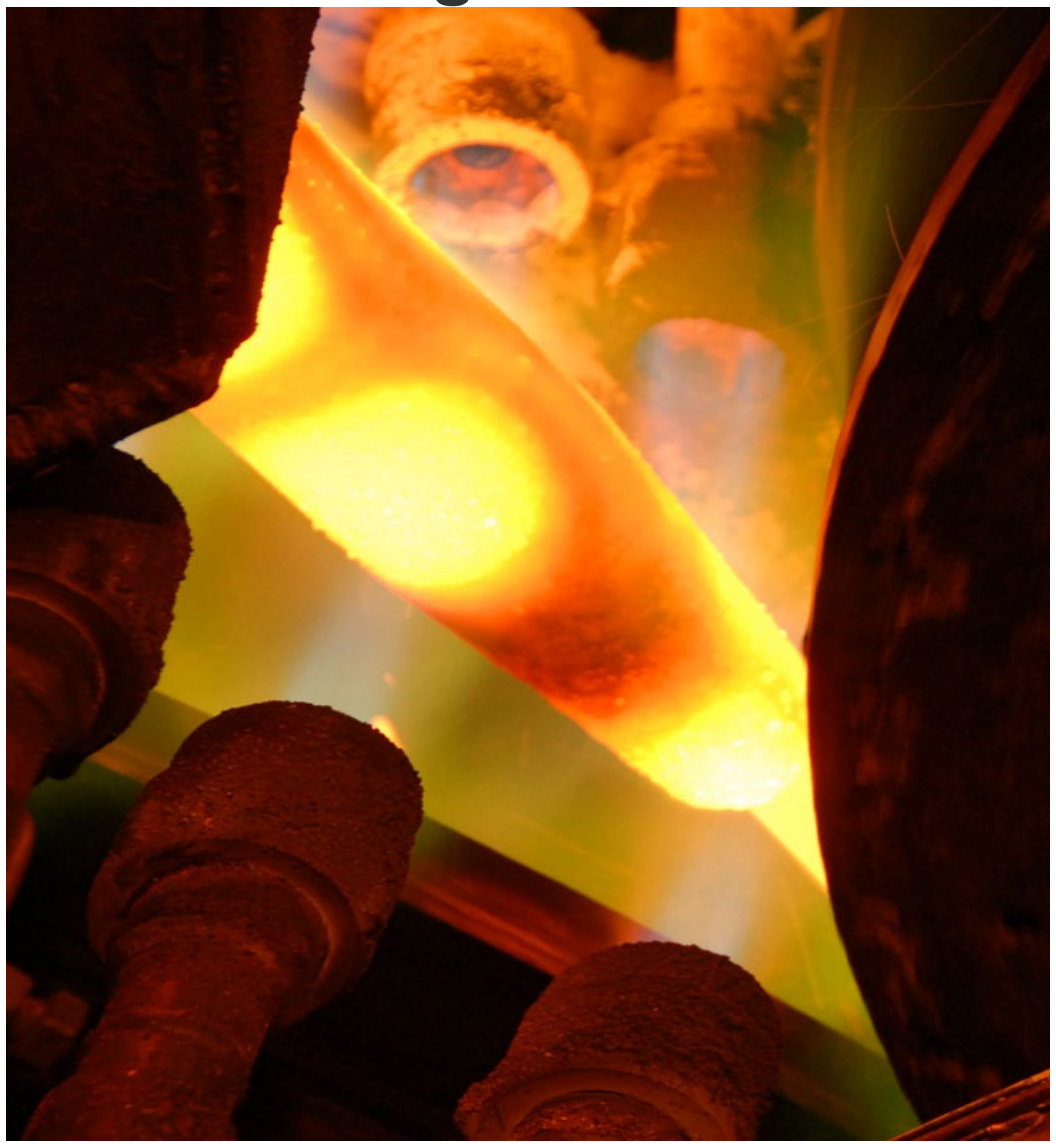
Influencing factors on good drawability of Copper Wire Rod

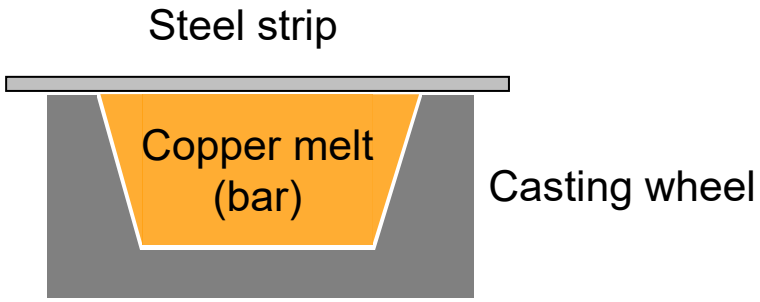
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III. Casting and Solidification SCR Principal





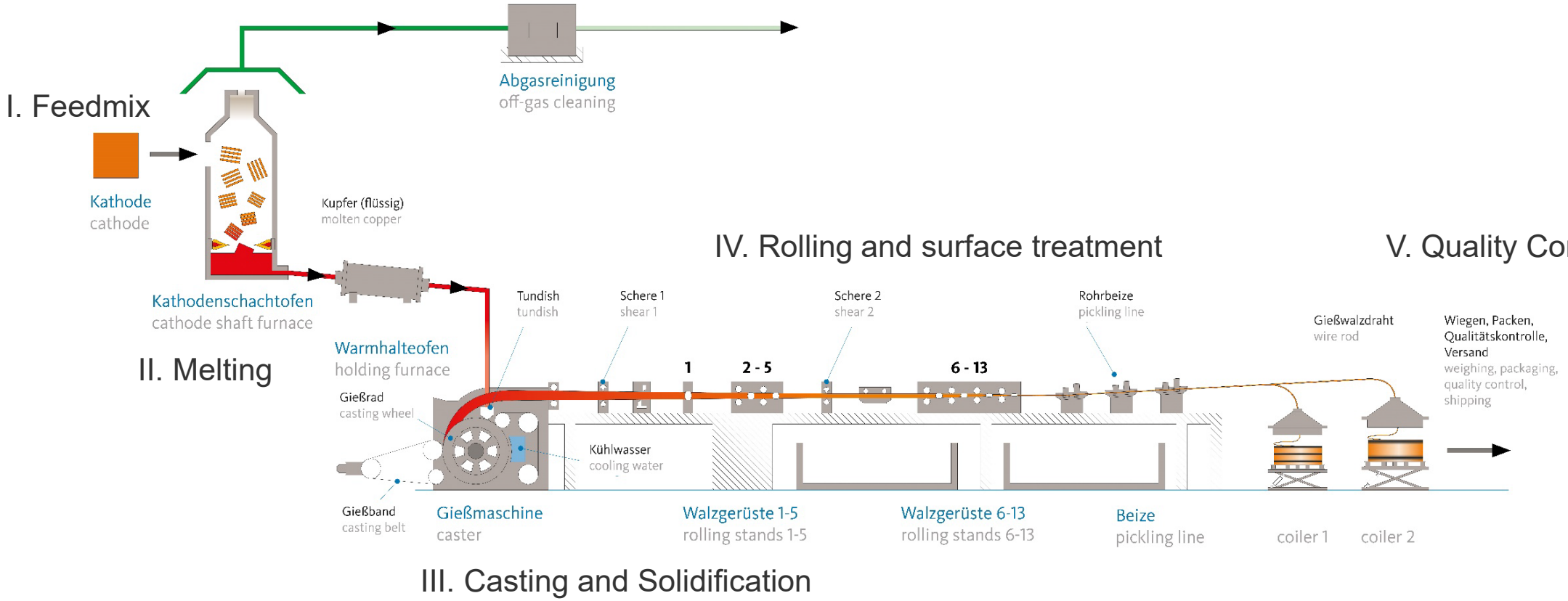
- copper melt temperature in tundish area
  $T_{Melt} > T_{Solidus}$
- homogeneous heat transfer in the casting wheel or Hazelett-Caster (soot layer / oil with graphite)
- homogeneous solidification and degassing of the remaining melt
- direct cooling water volume

Aim:

- Minimising of gas pores and blowholes

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IV. Rolling and surface treatment

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- Bar and wire rod temperature
- Rolling current in the pre rolling mills
- Surveillance of cooling and rolling lubricant
- Separated cooling lubricant systems for pre and finishing rolling mill
- Roll material, roll change frequency and preparation
- Inline control with eddy current and magnetising of the wire rod

Aim

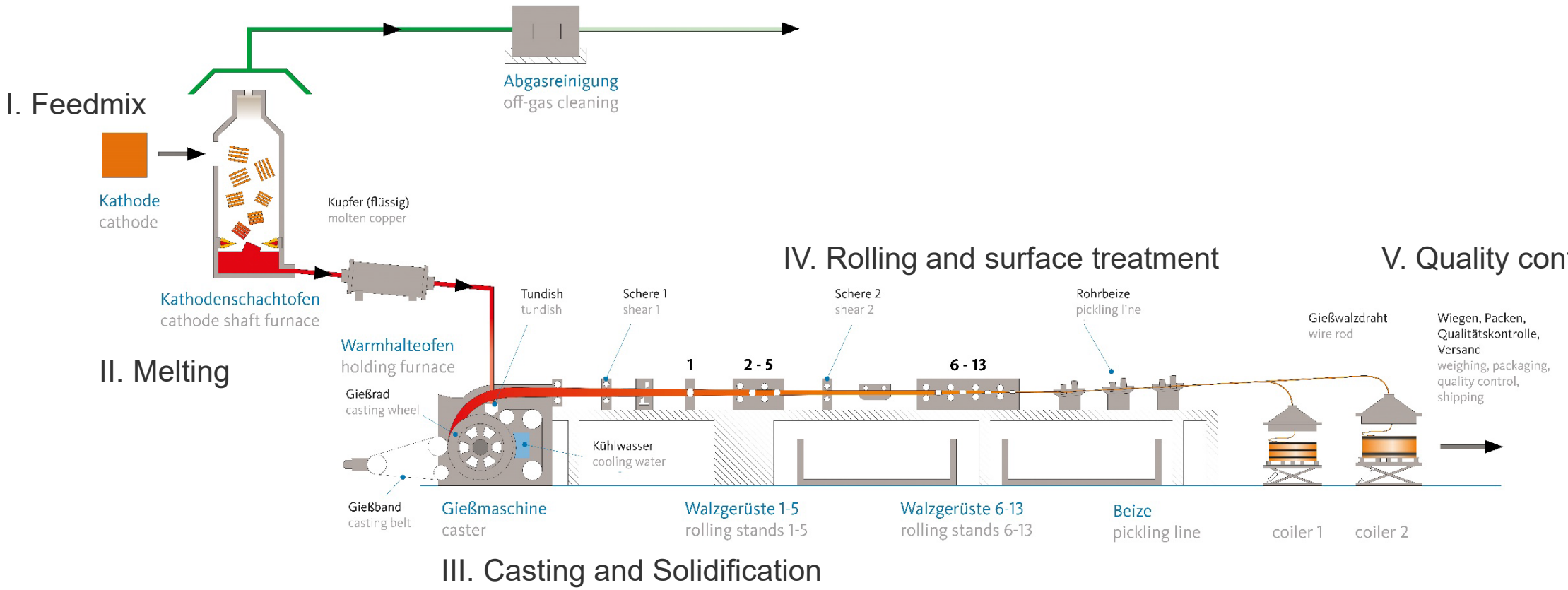
- Homogeneous, fine grain microstructure without inclusions



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V. Quality control: tests on wire rod

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- Twist test
- Oxygen level
- Diameter (in-line, off-line)
- Optical surface assessment
- Residual oxide layer
- Optical check of each coil



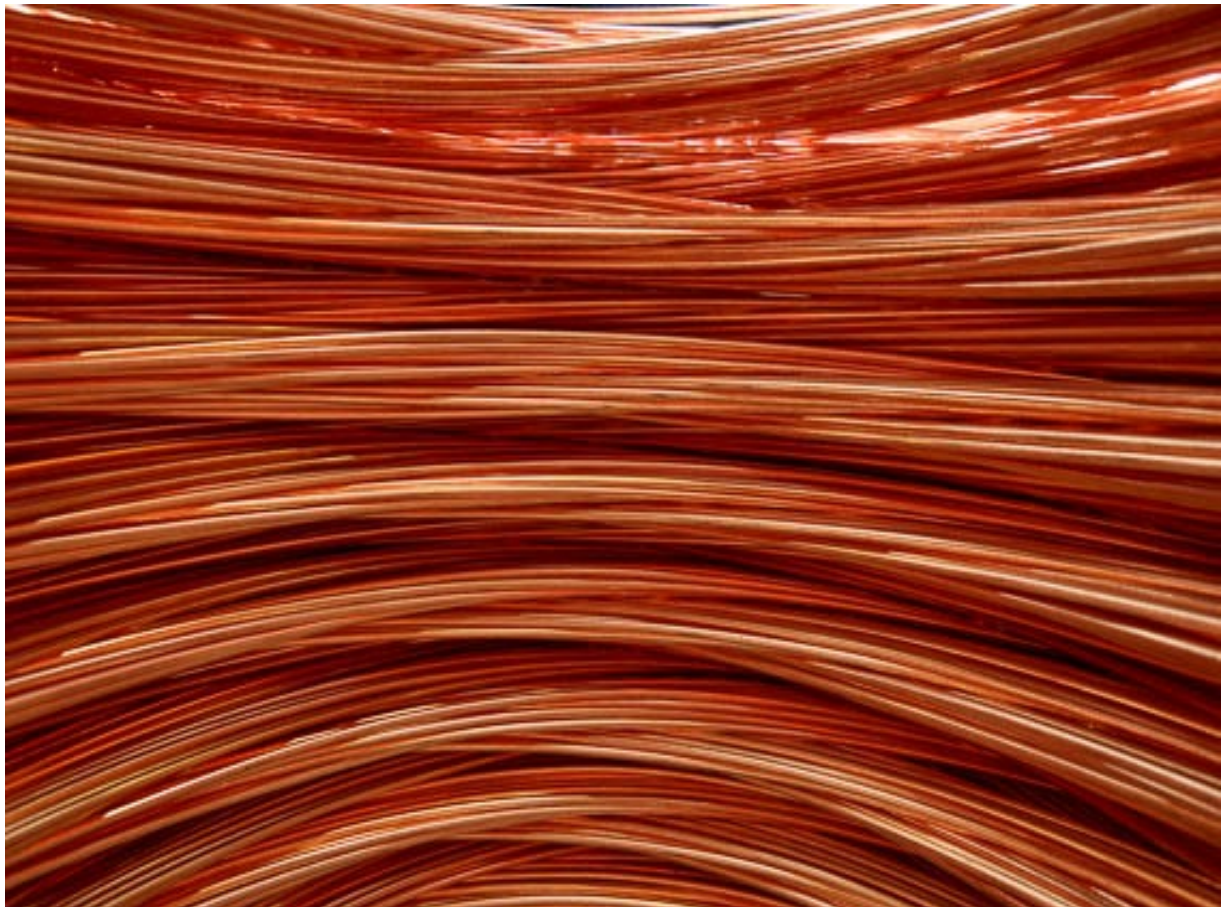
- Resistivity measurement
- Spiral Elongation Number (SEN)
- Chemical Analysis
- Tensile test for mechanical technological values (tensile strength, elongation at break)

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Selection criteria for good drawability copper wire rod

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- “best” feed mix with grade A cathodes
- Oxygen content < 250 ppm
- Δ temperature $T_{Copper\ melt} > T_{Copper\ solidus}$
- Cooling water
- Rolling current at rolling stands
- Low defectomat and ferromat signals
- Good twist test result
- Low residual oxide layer



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Aurubis ROD | RheinROD Cu-ETP1 – 8mm – Qualities

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FINE-MAGNET

- Best drawability down to 50µm and excellent surface -

FINE

- Best drawability down to 50µm -

MULTI-MAGNET

- homogeneous drawability and excellent surface -

MULTI

- homogeneous drawability and recrystallisation behavior -

ENERGY

- good drawability -

NOSV Special

- Excellent RRR values for Superconductors -

- ✓ Excellent conductivity
- ✓ Application in cables and magnet wires with minimal conductor diameters
- ✓ Based on excellent Aurubis Grade A++ cathode

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Join in:
Live Panel on May 11th at 14h CET

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Please send **your questions** until May 10th to nf-wire-forum@aurubis.com

We look forward to seeing you again virtually!

www.nf-wireforum.com



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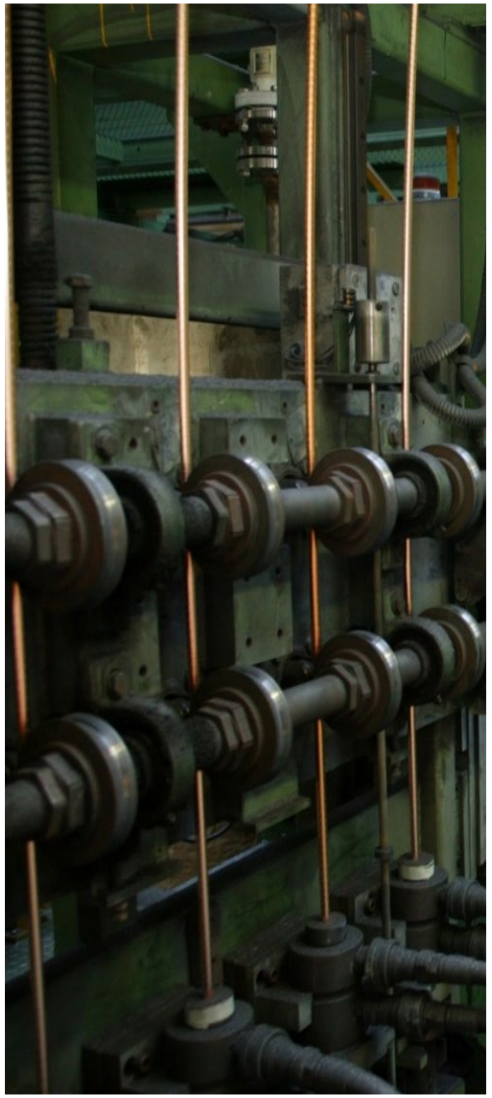


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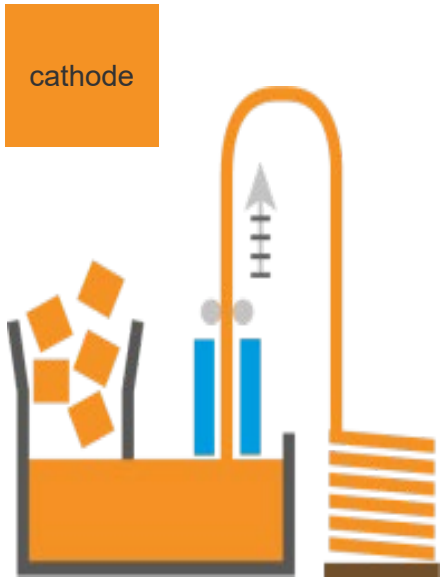
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Copper rod Cu-OFE – Aurubis FOXROD



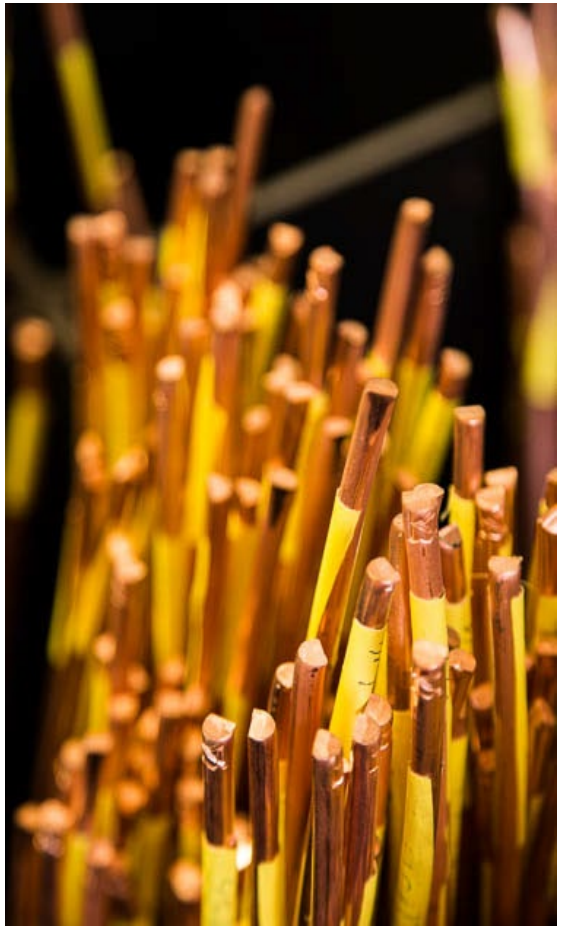
- Aurubis is an essential producer of oxygen free rod with a capacity of 40.000t/a
- Feedmix: grade A++ cathode from Olen tankhouse
- Graphite furnace and cover layer for oxygen free conditions
  - ➢ Oxygen will be erased from the melt by the reaction of carbon and oxygen and protects the melt of reoxydisation
- 6 Cu-OFE production lines (2 Upcast and 4 Rautomead)
- Efficient production method for OF and copper alloys



Aurubis FOXROD for FINE wire

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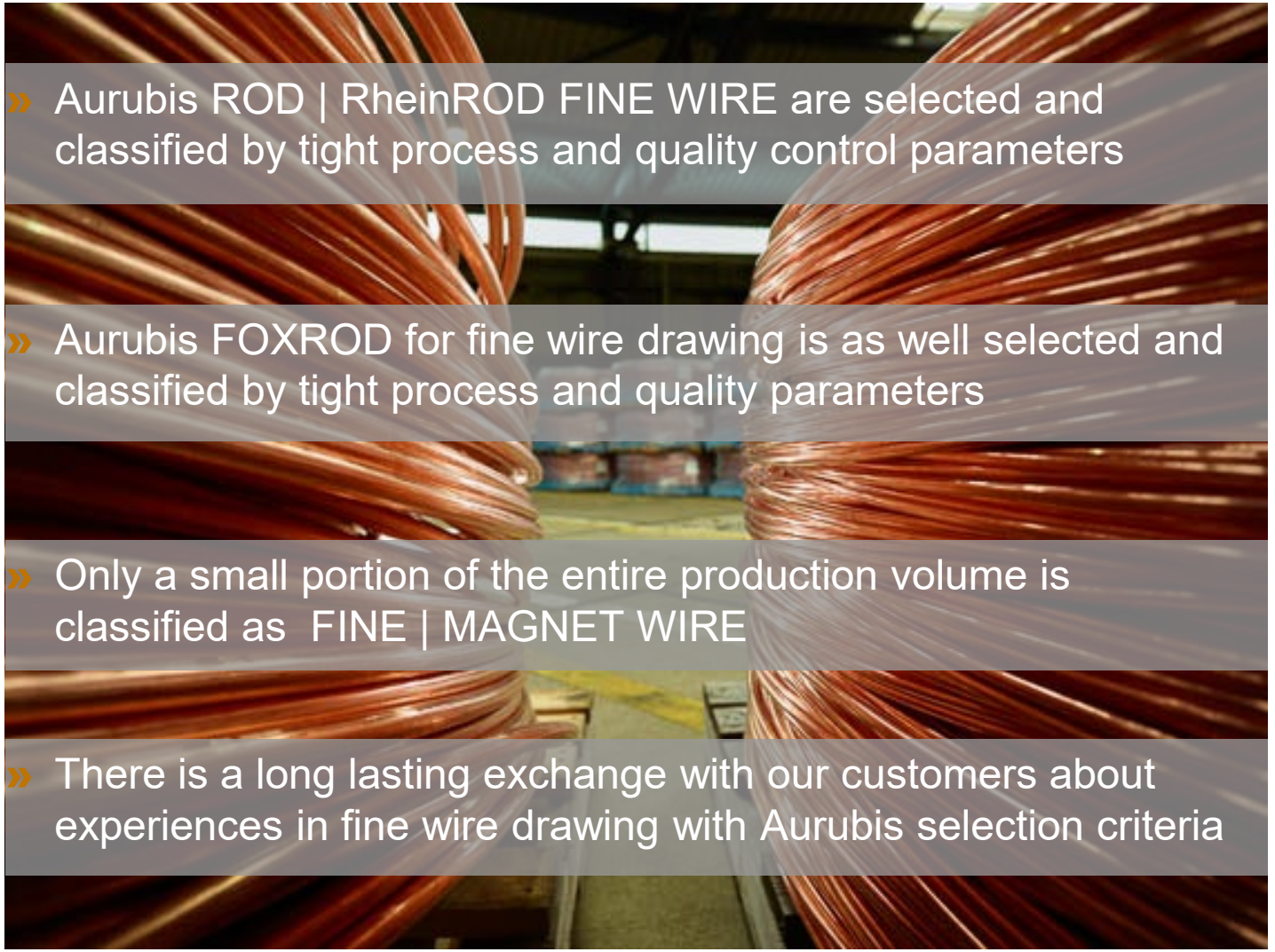
- Oxygen level lower than 4ppm
- Porosity test
- Diameter and ovality check
- Process parameter surveillance
- Special solidification equipment for 8mm production Aurubis FOXROD Cu-OFE
- Graphite furnace to avoid anorganic inclusions



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Summary

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- Aurubis ROD | RheinROD FINE WIRE are selected and classified by tight process and quality control parameters
- Aurubis FOXROD for fine wire drawing is as well selected and classified by tight process and quality parameters
- Only a small portion of the entire production volume is classified as FINE | MAGNET WIRE
- There is a long lasting exchange with our customers about experiences in fine wire drawing with Aurubis selection criteria

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Wire breaks

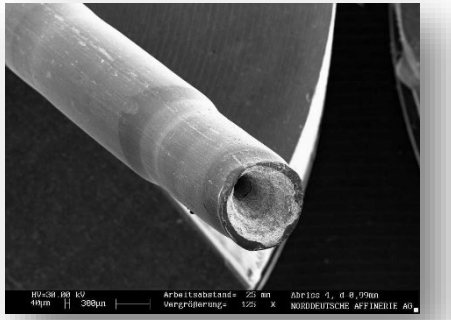
Features – damage mechanism – possible root causes

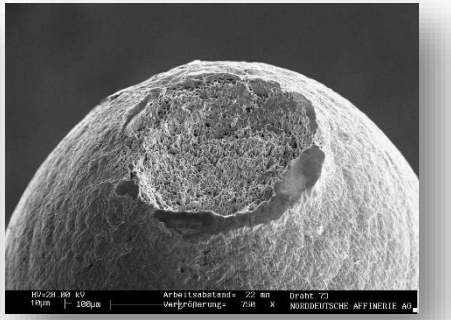
NE Drahtforum GbR

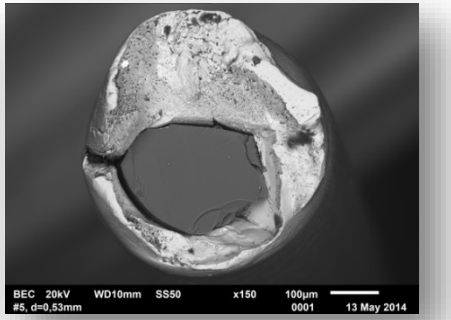
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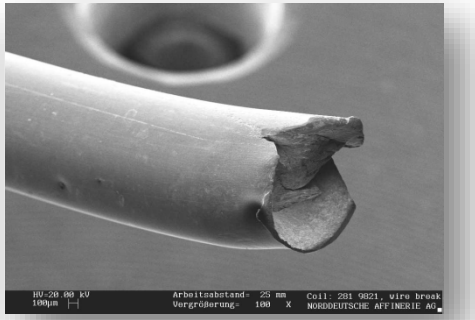
Introduction

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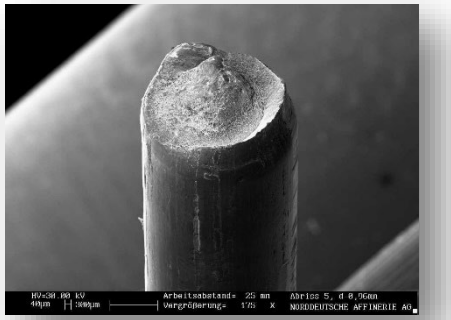


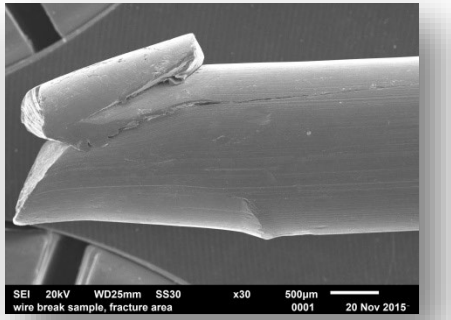


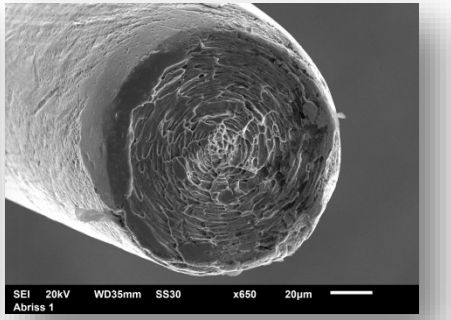


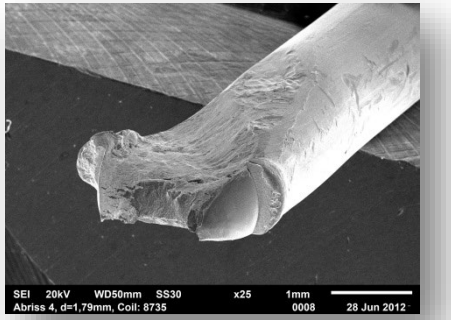
Wire Breaks

… are the undesired result of unfavorable interactions of adjacent forces, tensions and metallic/physical processes in the material exceeding beyond the material's stress limit.





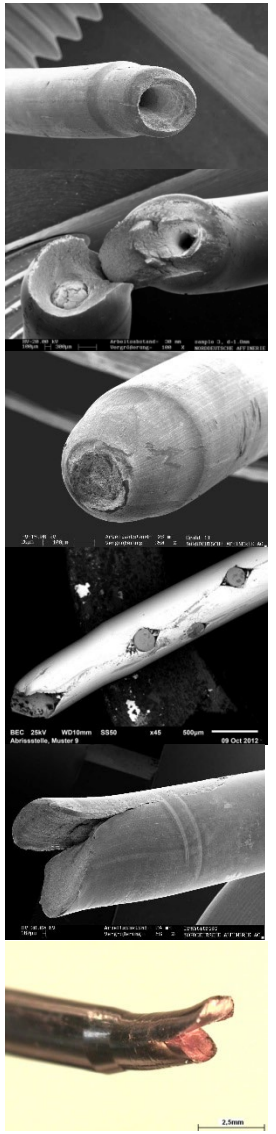




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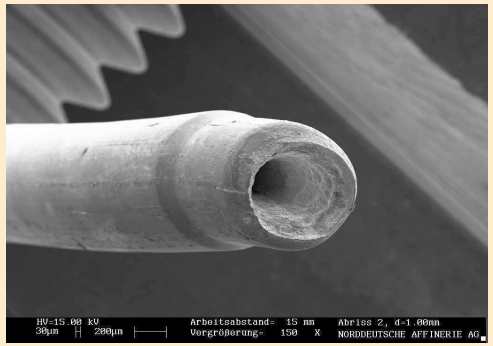
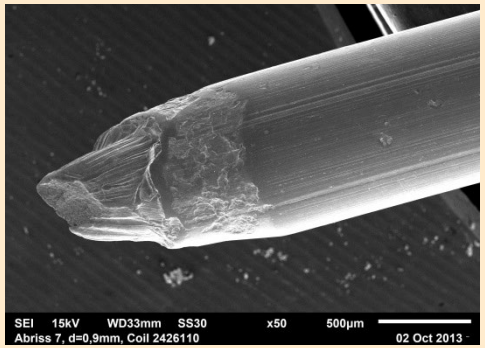
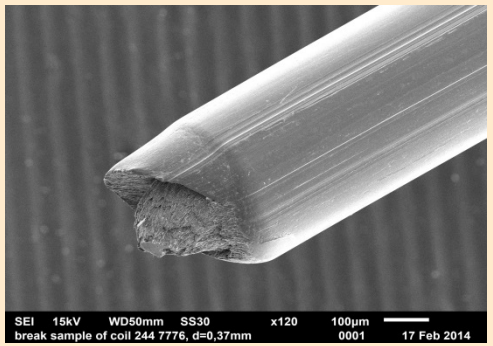
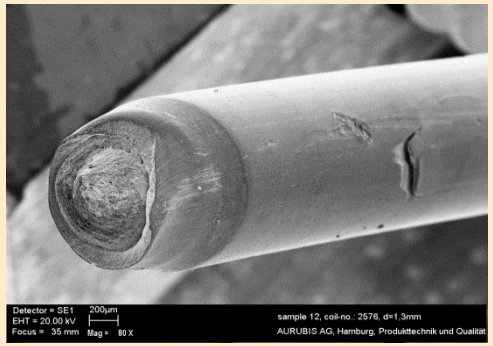
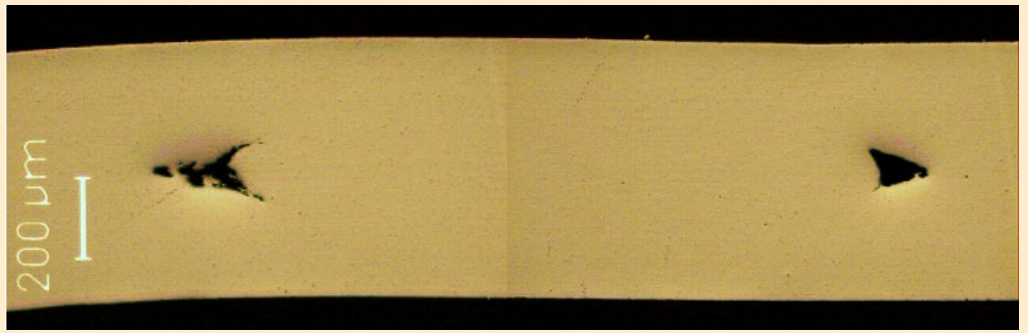
Typical Wire Breaks

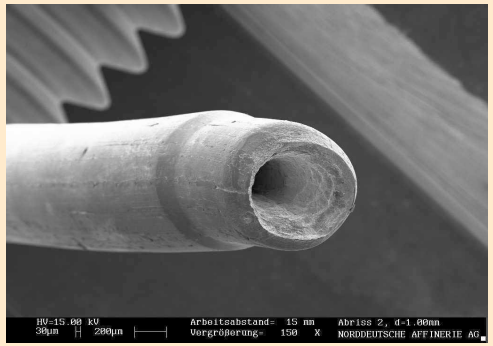
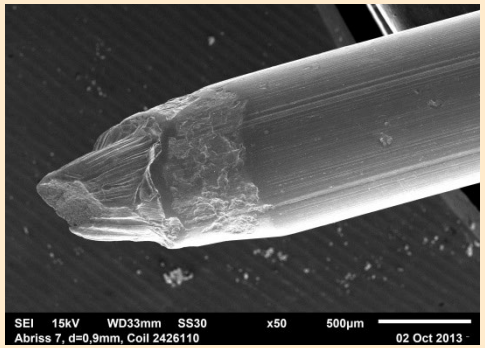
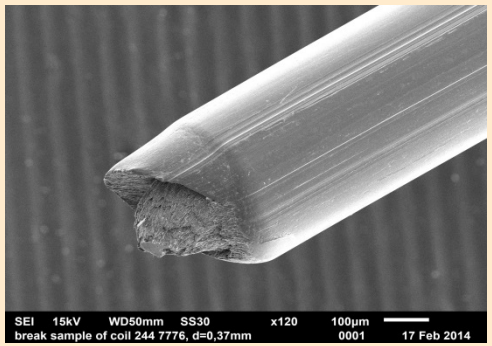
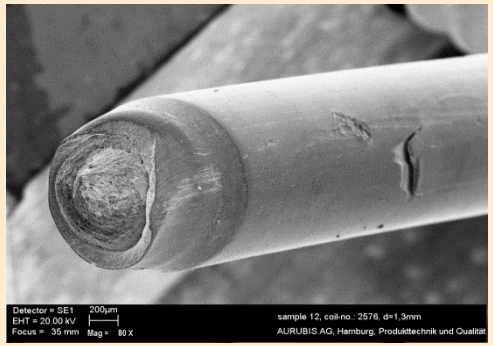
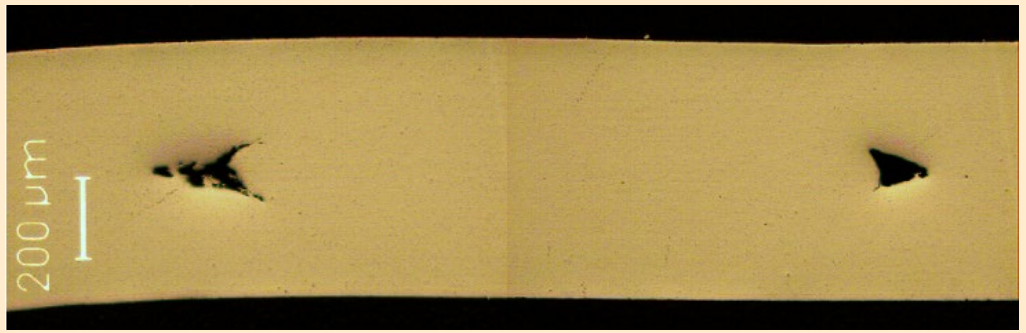
- Cup- and Cone break I (drawing conditions)
- Cup- and Cone break II (Cuprous enrichments)
- Ductile force break / strain break
- Inclusion break
- Force break by rolled-in or pressed-in chip / mech. surface damage (surface break)
- Weld break
- Annealing break

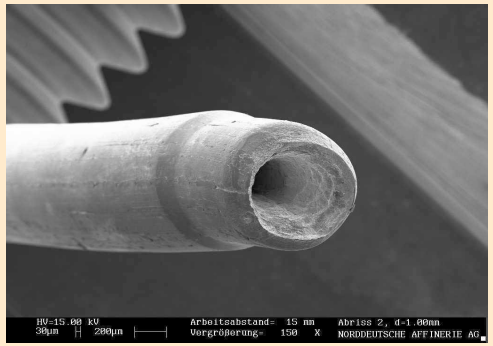
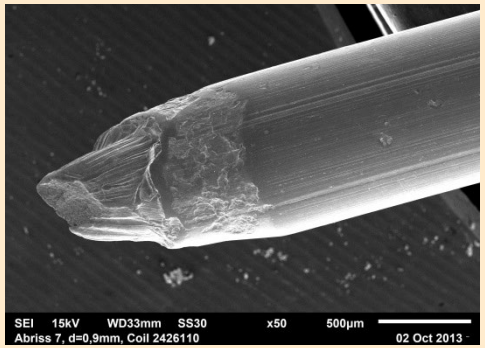
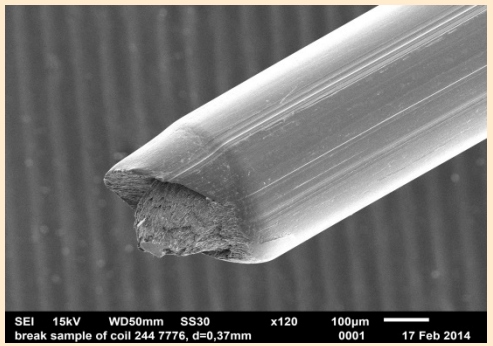
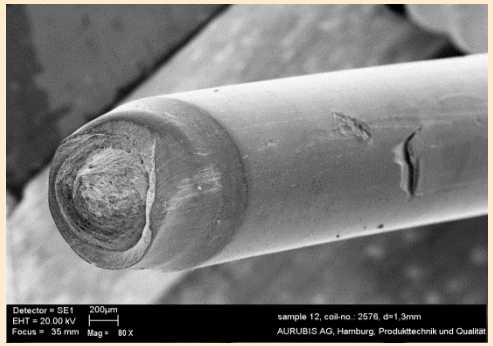
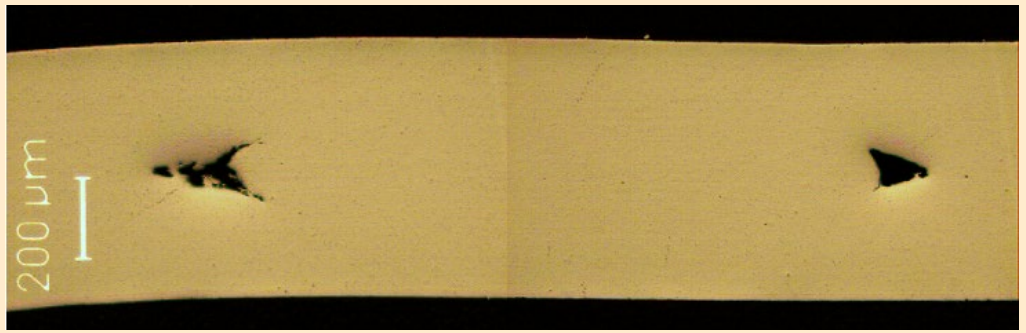


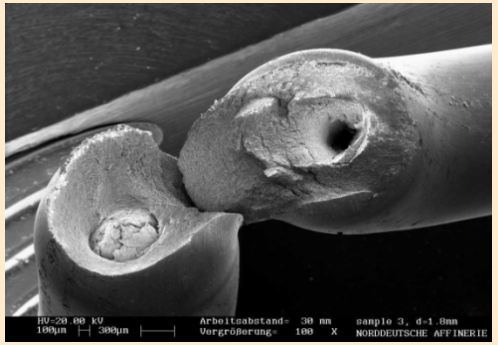
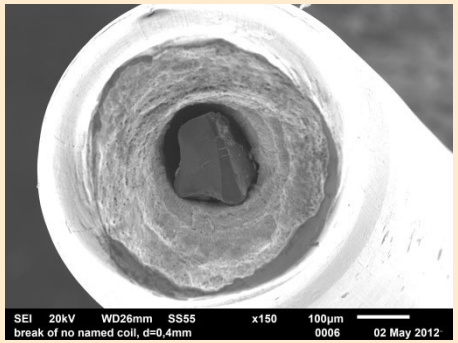
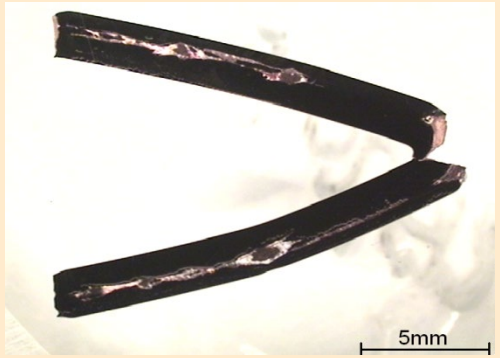
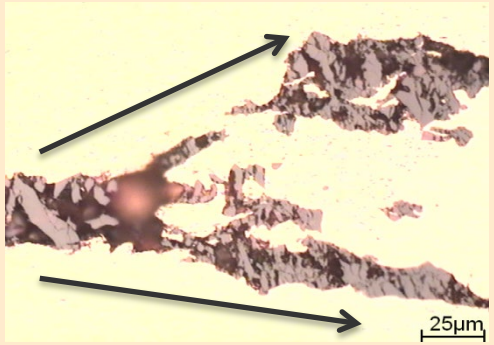
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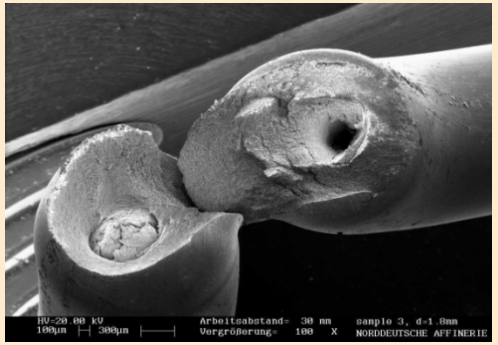
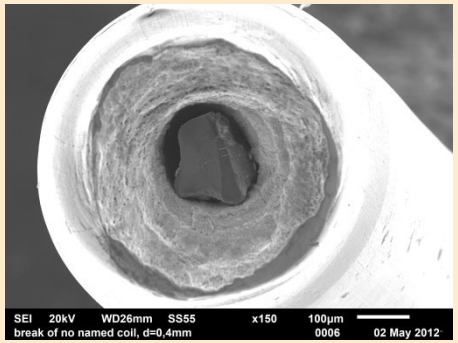
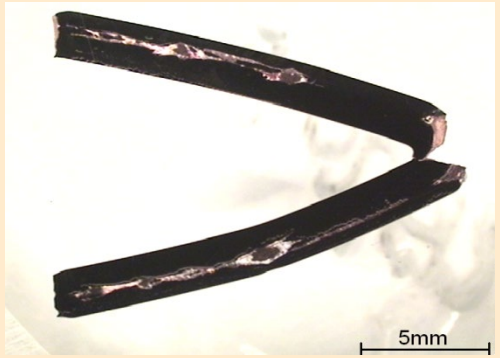
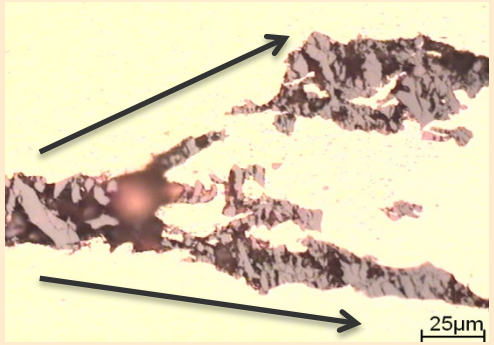
Break type	Cup- and Cone-break I (drawing conditions)
Examples	    
Features	- cup side with a deep whole in the middle of the wire or - cone side with a symmetrical necking and a tip - surface defects (draw marks, etc.) aside of the breakage area - inner cracks so called “craw feet” in longitudinal cross sections - no impurity phase agglomeration in the copper wire matrix

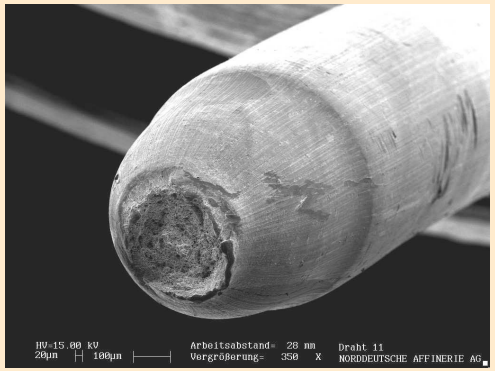
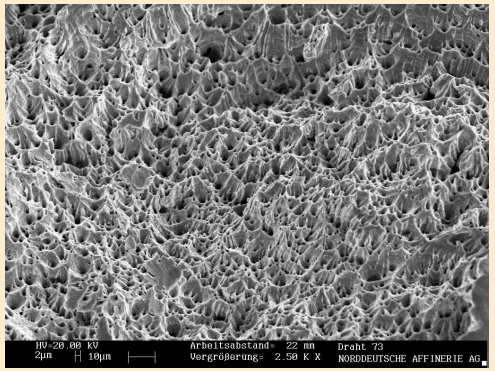
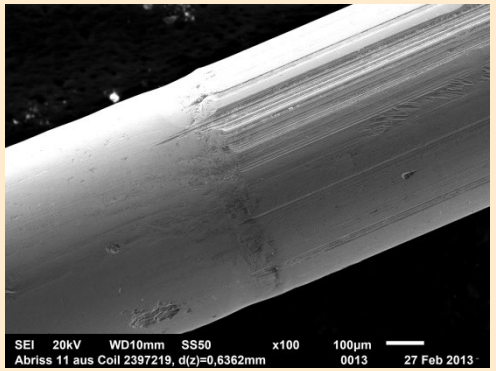
Break type	Cup- and Cone-break I (drawing conditions)
Examples	    
Damage mechanism	- high shear stresses between wire surface and neutral line induce local material failures where the max. material stress level is exceeded (inner cracks “craw feet”) - the tip of the “craw feet” is orientated in drawing direction - with additional strain, these cracks grow and reduce the load-bearing cross-section of the wire until the material fails or breaks

Break type	Cup- and Cone-break I (drawing conditions)
Examples	    
Possible root causes	- insufficient lubrication / shot instant of lubrication film in the drawing die - drawing die wear - drawing die clogged/ blocked - small drawing die angle with low diameter reduction and therefore inhomogeneous forming of the wire cross section

Break type	Cup- and Cone- Break II (wire rod)
Example	     
Features	- whole and conus at both break ends - necking at break area - second phase enrichment locally in the microstructure

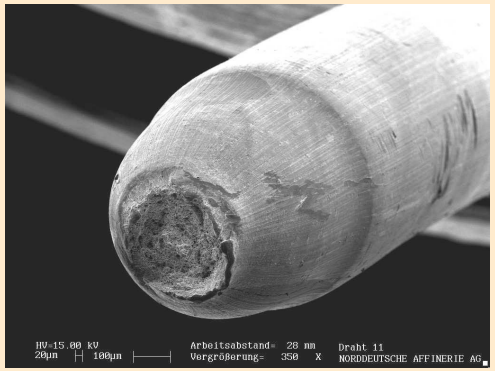
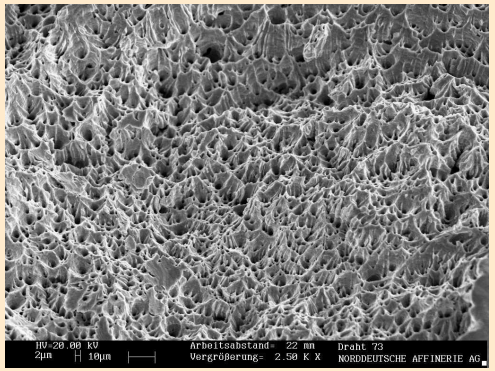
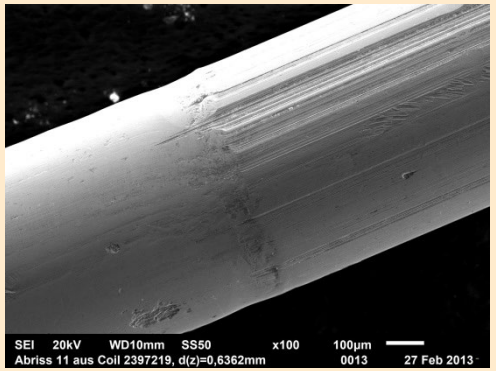
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Break type	Cup- and Cone- Break II (wire rod)
Example	     
Damage mechanism and root cause	- second phase enrichments cause tensions in the microstructure depending on size and distribution and the different forming behaviour - development of cracks, increasing of material separation, ductile breaking of the remaining cross section - Cuprous enrichments of a copper wire rod line

Break type	Force break/ strain induced break
Examples	  
Features	- local symmetrical necking - ductile break area with funnel / honeycomb structure - drawing marks and other surface failures in drawing direction next to the break area

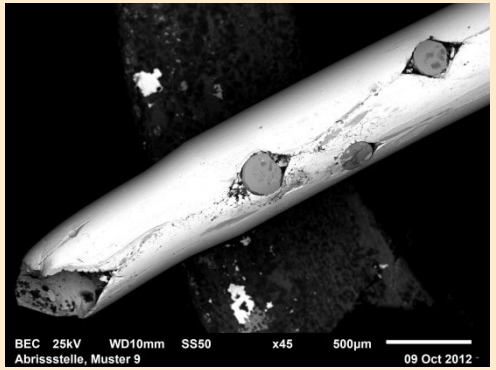
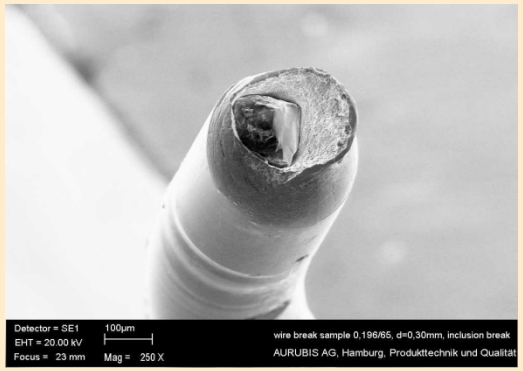
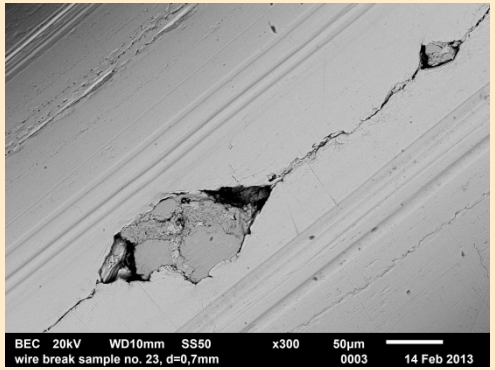
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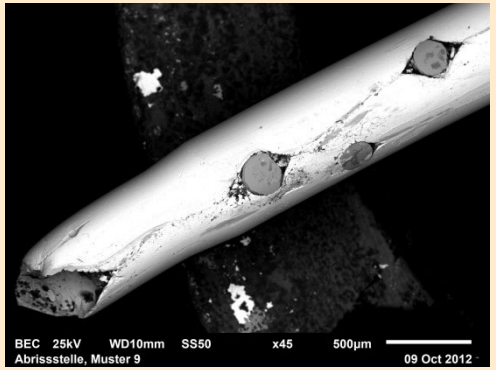
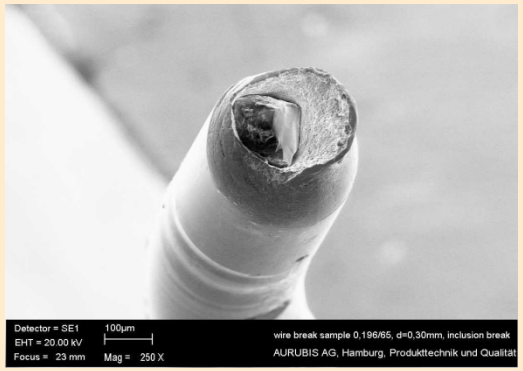
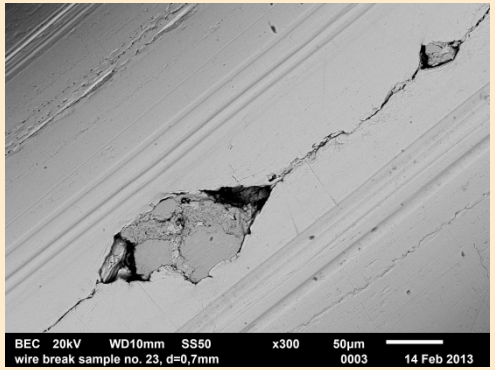
Break type	Force break/ strain induced break
Examples	  
damage mechanism and root cause	- geometrical softening / necking of the wire **>** physical hardening of the copper wire - uncontrolled local plastic deformation by tensile stress - blocked wires on the capstan - unfavourable conditions of wire, dies and process parameters

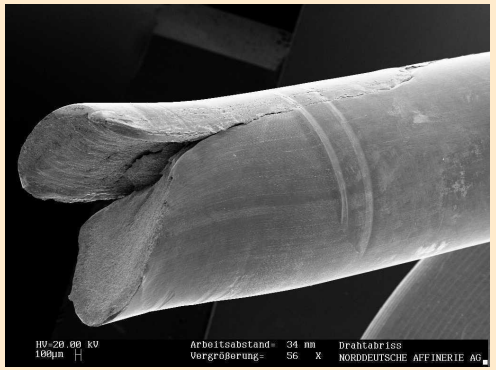
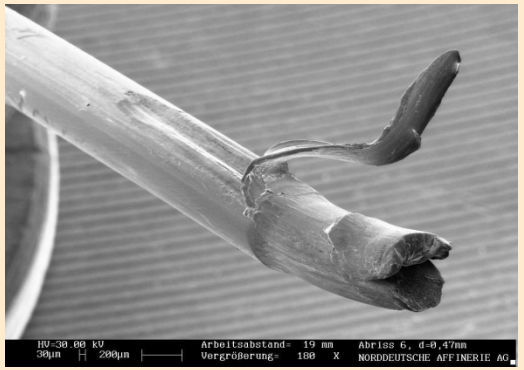
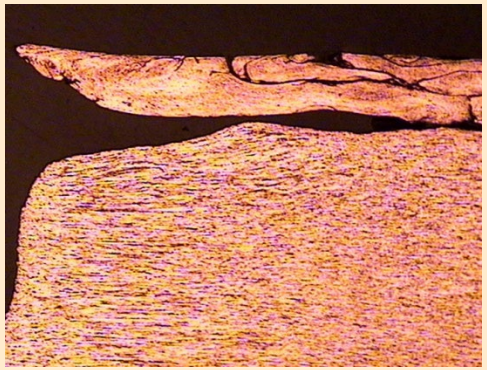
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Break type	Inclusion break
Examples	  
Features	- V-shapes break area with or without pressed-in or inner particles - surface crack in drawing direction as the case may be with further inclusion or particles rests

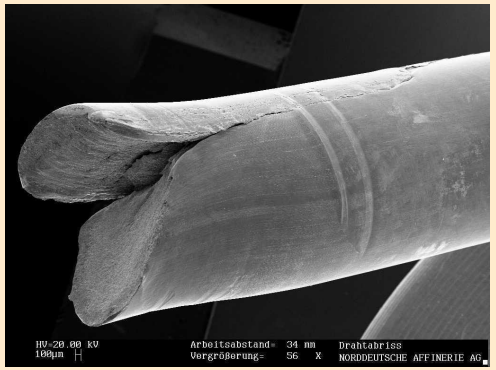
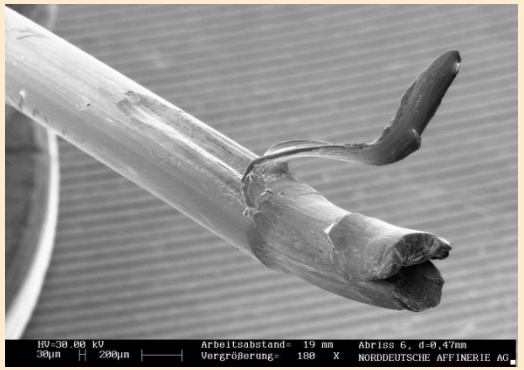
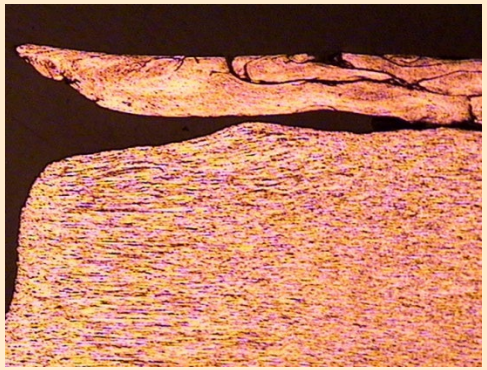
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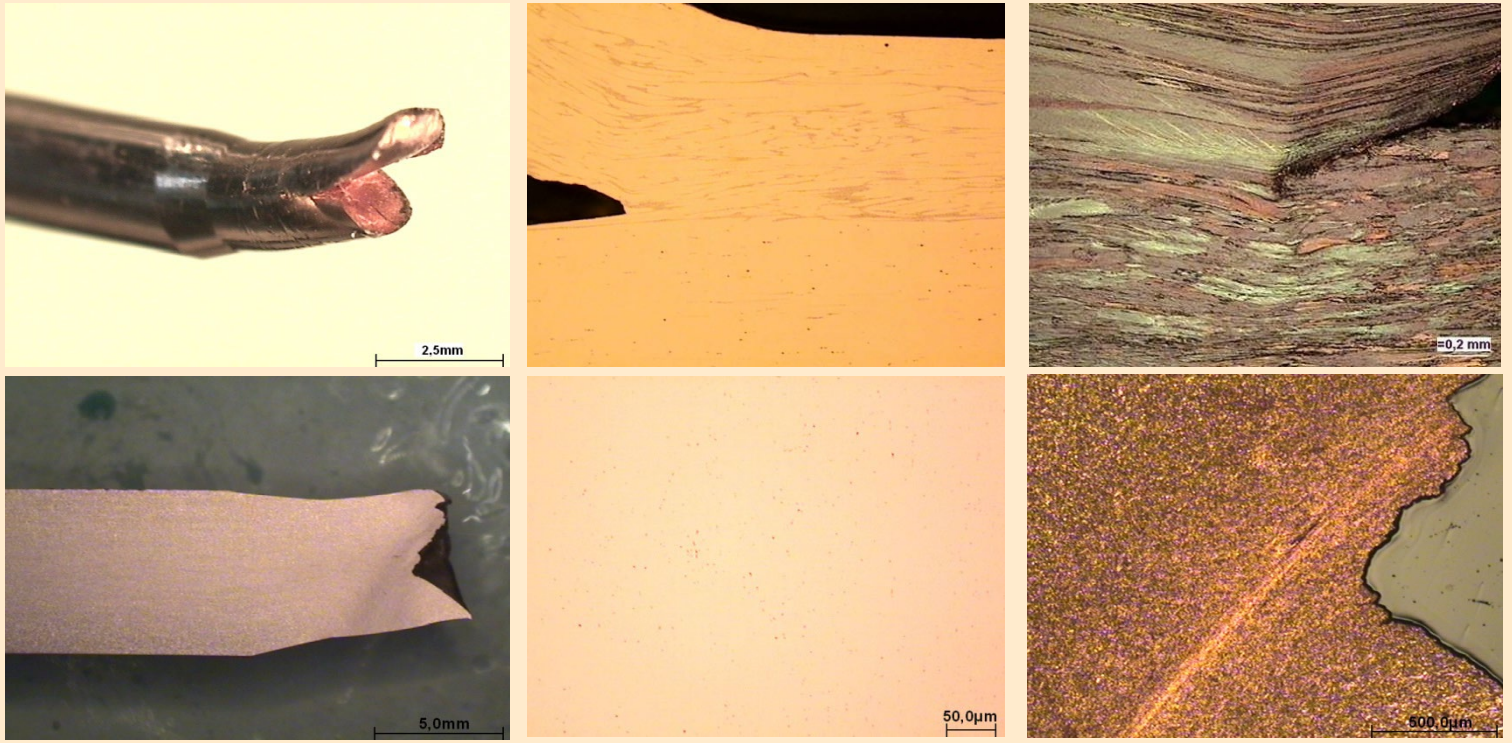
Break type	Inclusion break
Examples	  
Damage mechanism and root cause	- reduction of the load bearing cross section by particles or inclusion incorporating with wire diameter reduction - notch effect and exceeding failure stress - copper wire surface in contact loose particles of the entire process chain incl. transport and stocking - particles of the casting, rolling and drawing areas

Break type	Force break by rolled-in/ pressed-in particle
Examples	  
Features	- necking wire cross section - material takes off the surface in the break area e.g. a flake

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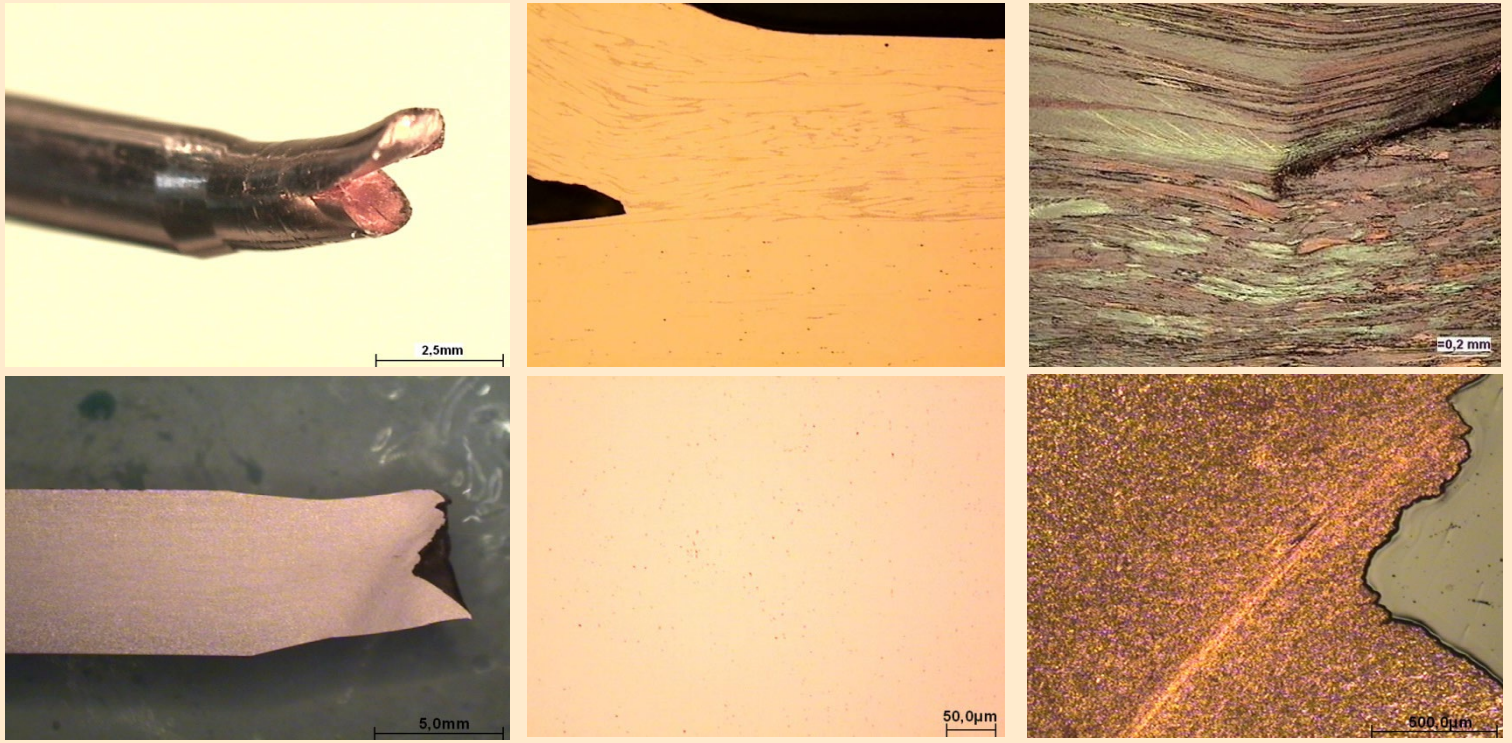
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Break type	Force break by rolled-in/ pressed-in particle
Examples	  
Damage mechanism and root cause	- particles/flakes from mechanical surface damages are pressed/ rolled in the surface - particles/flakes can negatively influence lubrication and cooling → increase of drawing force → exceeding of forming ability of the material - copper particles, flakes, flitters, etc. from different production steps

Break type	Weld break
Examples	
Features	- hot weld break: „fish mouth“ and cuprous network in the weld areas - cold weld: uniform microstructure on both sides of the joint

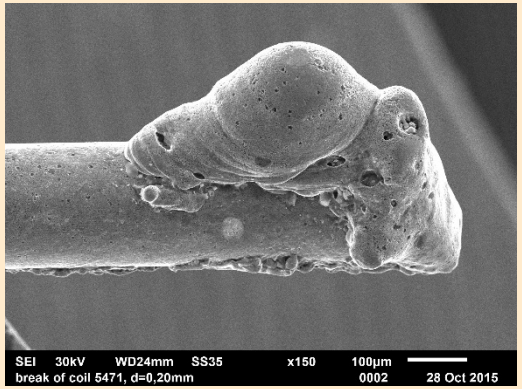
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Break type	Weld break
Examples	
Damage mechanism and root cause	- different microstuctures with different mechnical properties / oxide enrichments - unsuitable welding process or process parameters

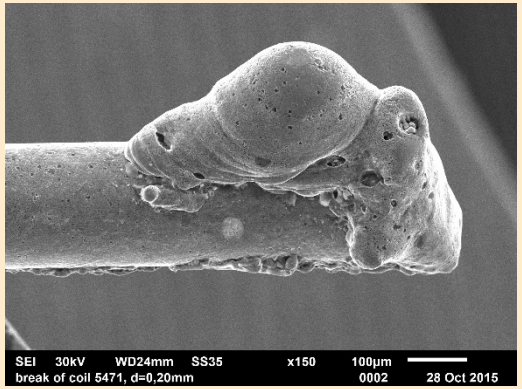
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Break type	Annealing break
Examples	 
Features	- smooth break area - molten material at the tip - further burnt spots on the break sample

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Break type	Annealing break
Examples	 
Damage mechanism and root cause	- melting of the wire by an eletric arc - badly guided wire on the contact roll - grooves on the contract roll

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Conclusion for wire breaks at fine wire drawing

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- ✓ **Break type** at **fine wire drawing** can be detected with **appr. equipment „on macroscopic level“** and is important to determine the root cause and implement **elimination measures**
- ✓ Scanning Electron Microscopy (SEM) is suitable for further investigations (e.g. inclusion material analysis)
- ✓ Preparation of cross sections of fine wire diameters are very complex and reveal no further information of the root cause
- ✓ Big portion of the **fine wire** breaks are **inclusion**, **strain induced and cup&cone break**

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Join in:
Live Panel on May 11th at 14h CET

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Please send **your questions** until May 10th to nf-wire-forum@aurubis.com

We look forward to seeing you again virtually!

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