
Processing Steel
Saukville WI Processing Plant
CHARTER STEEL

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Why Do We Process Green Rod?

- Rod diameter is reasonably round
- Very hard
- Very little ductility
- Pearlitic microstructure
- Surface scale, rust if old enough

Everything you ***don't*** want to cold head parts!

Charter Steel Processing operations increase value of steel rod and bar by improving size tolerance, ductility, and surface quality

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Cleaning Lines Review

- **P1 (South)** – Sulfuric Acid – **manual line**
- **P2 (North)** – Hydrochloric Acid – **automated line**
  - Limit (1 coil / hook)
- **P3 (West)** – Hydrochloric Acid – **automated line**

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Cleaning Line Setup

- **Acid Cleaning**
  - Surface preparation, removing scale, rust
- **Rinsing (cold/hot)**
- **Conversion Coating** - Zinc Phosphate
- **Neutralization**
- **Lubrication**
  - reactive soap, polymer, lime

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Step 1 - Acid Pickling of Steel

- Strong solutions of mineral acids (contain inhibitors)
- Provides a uniform etch, activates surface for phosphating
- Removes scale and rust (if present will significantly reduce tool life)

Control Parameters For Acid Pickling

- Acid Concentration
- Iron Concentration
- Immersion Time
- Temperature
- Drip Time

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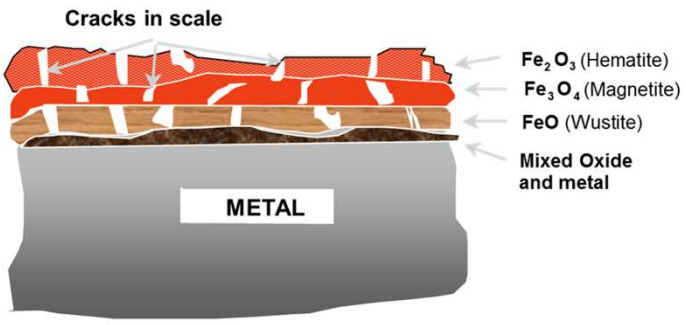
Composition of Scale



Fe_2O_3 (Hematite) **contains 30% Oxygen**
Slightly soluble is hydrochloric acid and insoluble in sulfuric acid

Fe_3O_4 (Magnetite) **contains 28% Oxygen**
Insoluble in sulfuric acid and soluble in hydrochloric acid

FeO (Wustite) **contains 22% Oxygen**
Soluble in both hydrochloric and sulfuric acid

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Acid Pickling – Hydrochloric vs. Sulfuric

Kind of Scale	Hydrochloric Acid (HCl)	Sulfuric Acid (H_2SO_4)

FeO (wustite)	• Good solubility
	  • With increasing acid concentration scale solubility increases
		• Good solubility
		  • With increasing acid concentration scale solubility increases

Fe_3O_4 (magnetite)	• Less soluble compared to FeO
	  • With increasing acid concentration scale solubility increases too
		• Less soluble compared to FeO
		  • Acid concentration has less influence on the scale solubility.
		  • Temperature is important

Fe_2O_3 (hematite)	• More difficult to dissolve within all concentration ranges	• **No solubility** irrespective of the concentration and temperature **Hematite forms pickling sludge**

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Step 2 – Cold and Hot Water Rinsing

Purpose

- Remove acid and metallic fines
- Prevent downstream contamination
- Preserve the integrity of the next solution in line
  - Warm up steel for Lime or Phosphate Coating

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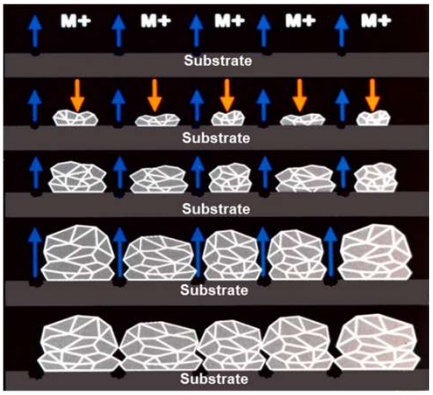
Step 3 - Zinc Phosphate Coating

How Do Zn-Phos Coating Form?

- Acidic dissolution of metal
- Continued dissolution of metal
- Initiate coating deposition
- Decreased dissolution
- Coating formation increases
- Further decreased dissolution
- Continue coating formation
- Terminate dissolution of metal
- Complete coating formation



Zinc Phosphate conversion coating is a non-metallic, crystalline, self-limiting coating that is chemically bonded to the steel surface

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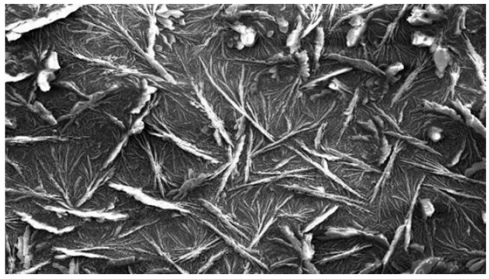
Advantages of the Zinc Phosphate Coating

- Improve lubricant adhesion
- Provide a physical barrier between work piece and tooling
- Expand without rupture
- Reduce friction
- Improve metal flow
- Corrosion protection



These coatings are sometimes called "lubricant carrier" coatings because the texture of the coating creates the ability for the surface to carry a lubricant into the die

The coating itself is not a lubricant

The coating acts as a separating layer between tool and work piece

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Step 4 - Neutralizing

Basic solution (high pH) neutralizes acidic phosphate residuals

- Conditions coating for reaction with lubricant
- Provides corrosion protection
- Extends lubricant bath life

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Step 5 – Final Coating

There are several options for coatings to be applied over Zinc Phosphate

- Phos & Neutralizer (no final coating)
- Phos & Lime
- Phos & Reactive Lube
- Phos & Polymer

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Lime (Calcium Hydroxide)

Applied directly to steel or over Zn-Phos base coating

- Coating thickness controlled by number of dips
- Adherence is inversely proportional to particle diameter
  - Small particles stay in suspension longer (longer settling rate)
- Lime recrystallizes at about 212 F - avoid reaching boiling temperature

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Reactive Lubricant

Purpose

- Provides high quality lubrication package with a phosphate coating

Reactive

- High purity sodium stearate soaps
- Reacts with the zinc phosphate crystals / will not adhere to steel surface w/o phosphate
- Finite bath life due to metals and contaminants accumulation

Features

- Superior adhesion, weight increases with increasing immersion time
- Flows with steel and phosphate coating

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Polymer

For Superior Tool Life

- Provide maximum lubrication at minimal lubricant film thickness
- Polymer lubricants are complex formulations based on long-chain organic molecules that are water soluble
- One Dip

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Coating Options

Coating	Abbreviation	Price	Tool Life	Rust	Appearance
Lime	MLIME	Lowest	Lowest	Poorest	White
Zinc Phos & Lime	MPHOSMLIME	Low	OK	OK	White
Zinc Phos & Reactive Lube	MPHOSMLUBE	Medium	Better	Best	Less White
Zinc Phos & Polymer	MPHOSPOLY	Medium	Best	Best	Clear

MPHOSLIME

MPHOSLUBE

MPHOSPOLY

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Annealing

- **Charter offers 3 types of annealing cycles**
  - Regular/Stress Relief (subcritical)
    - Reduce residual stresses for next operation
  - Lamellar Pearlite (inter-critical)
    - Machining
  - Spheroidization (inter-critical)
    - Forming / Cold Heading
- **Equipment**
  - 22 box furnaces
  - 2 continuous furnaces

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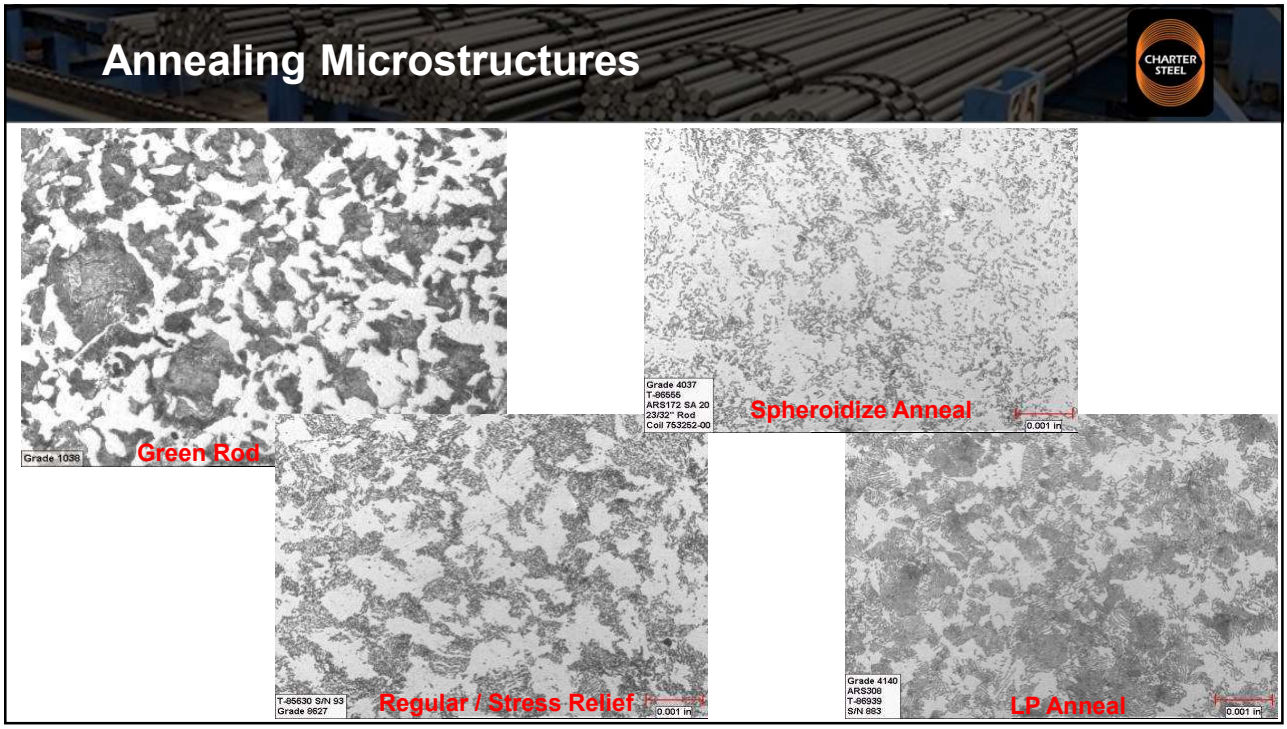
Annealing Microstructures
CHARTER STEEL
Grade 1038
Green Rod
Grade 4037
T-86555
ARS172 SA 20
23/32" Rod
Coil 753252-00
Spheroidize Anneal
0.001 in
T-85630 S/N 93
Grade 8627
Regular / Stress Relief
0.001 in
Grade 4140
ARS306
T-86939
S/N 883
LP Anneal
0.001 in

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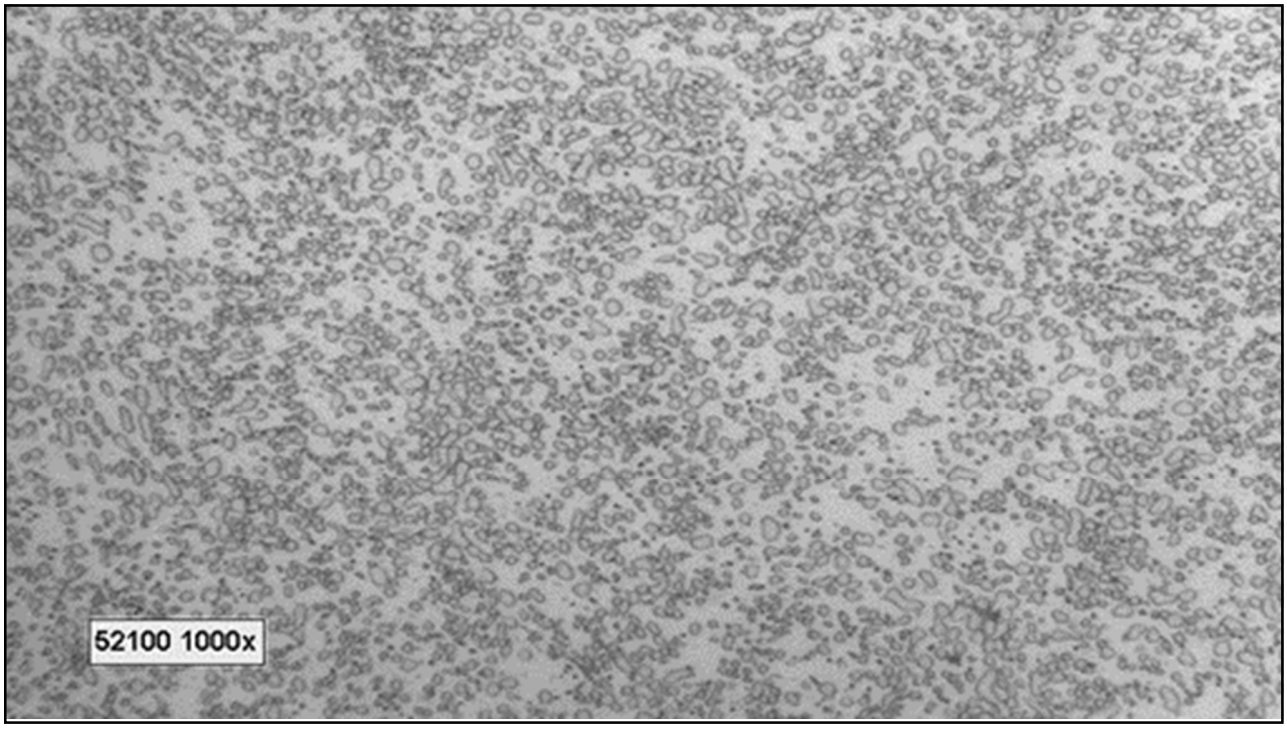
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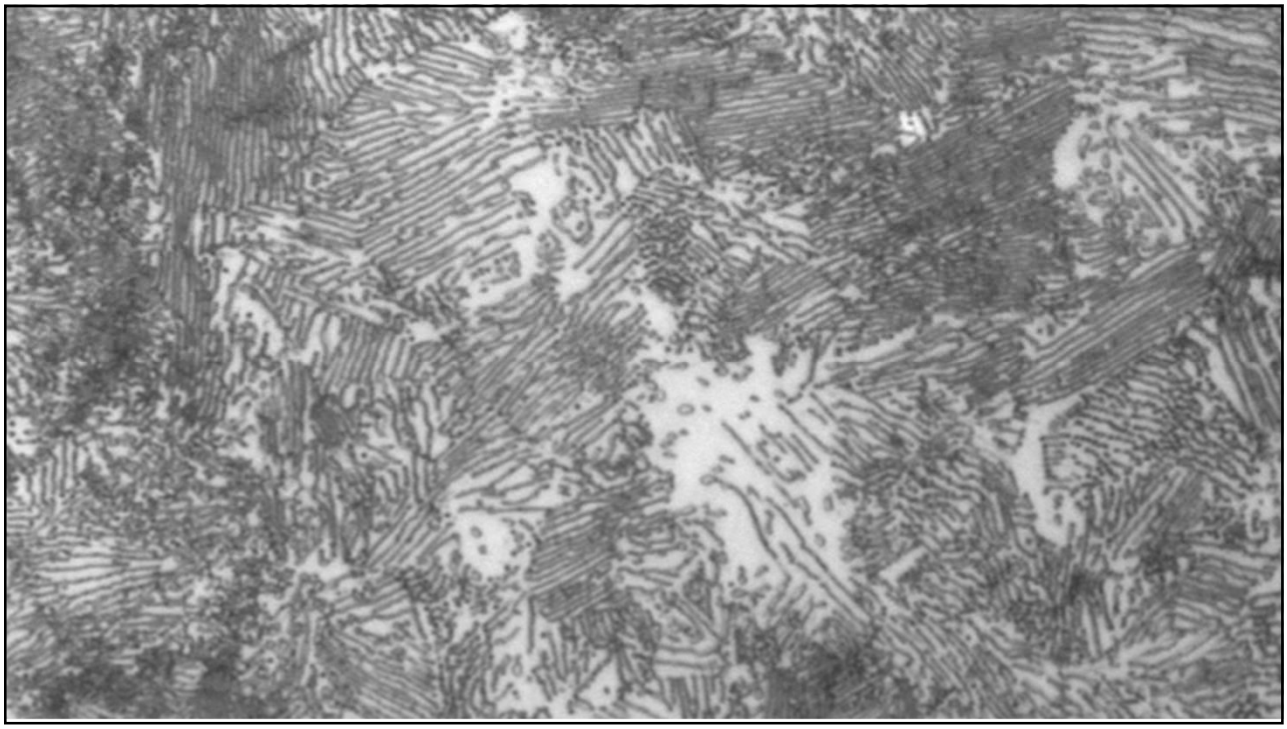

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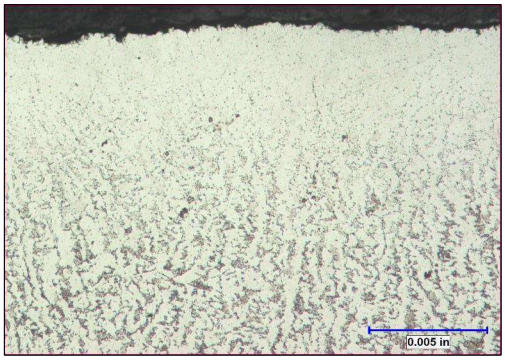
Why we use Endo (RX) Gas

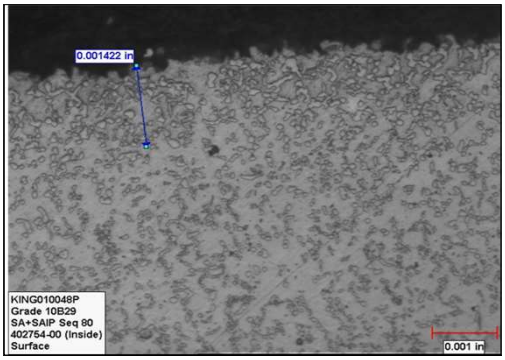
Prevent Decarburization by use of RX gas

- Endothermic gas generated onsite (40% N2, 40% H2, 20% CO)
- Inject CO2 to balance reaction $CO + CO \leftrightarrow CO_2 + C$ to prevent decarb

Requirements:

- Decarb: some decarb OK
- Recarb: no recarb allowed





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Recarburization

Recarburization can be detected visually on a tensile specimen

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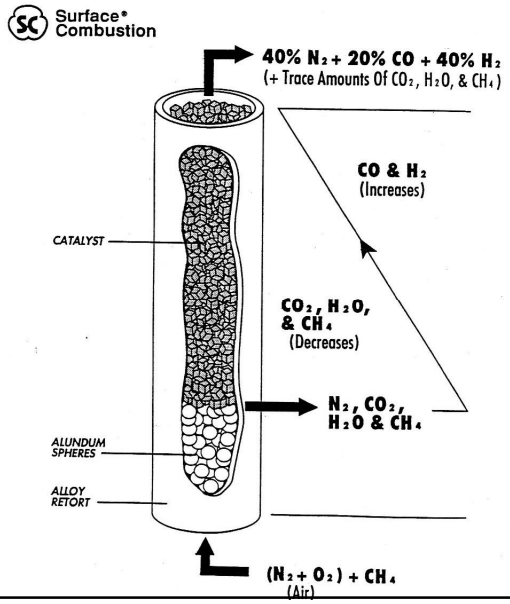
Generator Retort

Producing Endothermic Gas (where the magic happens!)

- Air-Gas mixture enters tube
- Tube is held at ~1900°F
- Nickel Plated Catalyst Lowers Reaction Energy
- Gas is cooled to lock in the reaction components
- Gas Transforms from N_2, O_2, CH_4 to N_2, CO, H_2

$$4N_2 + O_2 + 2CH_4 \rightarrow 2CO + 4H_2 + 4N_2$$



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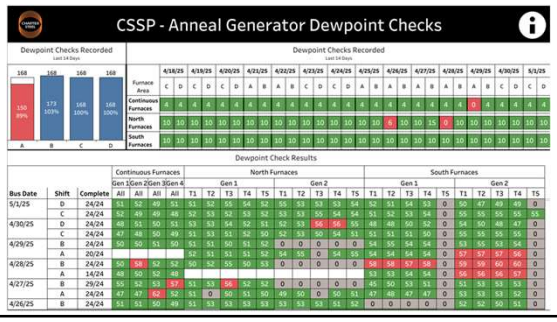
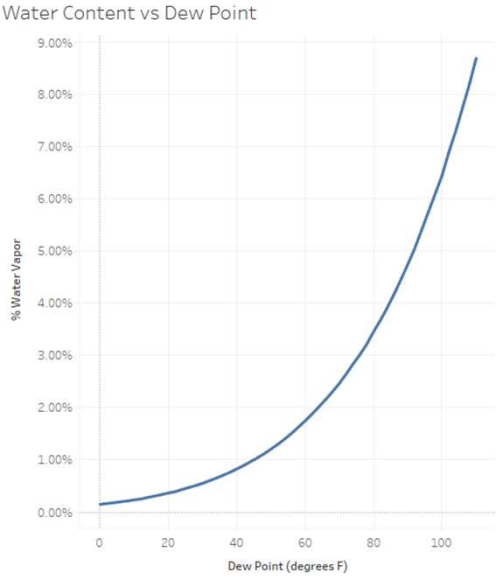
Dew Point

Measure of gas quality to protect the generator

- We use DP (water content) to **understand the gas makeup**
  - Target 50ºF
- As DP goes down, the amount of CO increases
  - LOW DP WILL DROP CARBON IN TUBES
- As DP goes up, the CO decreases and H2O increases
  - HIGH DP WILL DROP WATER IN TUBES





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Gas Conditioners

HISTORICAL FILTRATION

Furnace Results

Reprocess/scrap down ~80% since installation of gas conditioners

GAS CONDITIONERS

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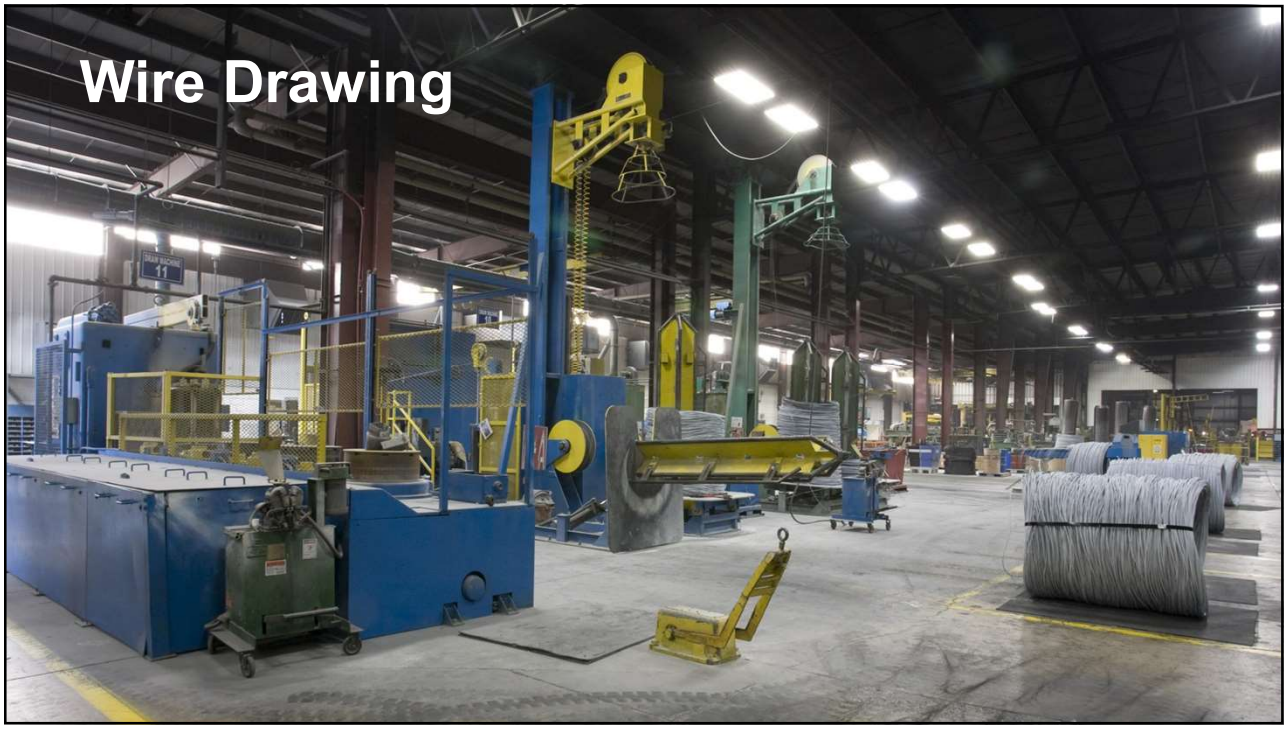

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Draw - New Draw Machine – D8b

- 9 draw machines
  - single-hole
  - multi-hole

Capabilities

- Size - 0.140” to 1.500”
- Tolerance - +/- 0.0015” for smaller sizes, +/- 0.003” for larger sizes

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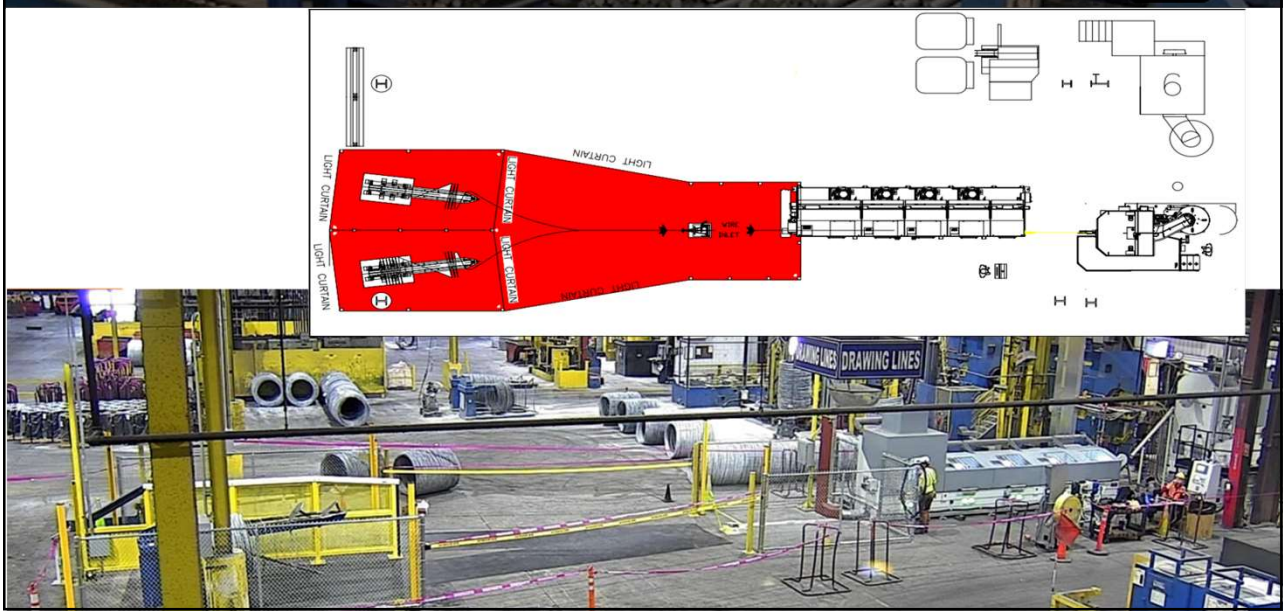
New Draw machine - D8b



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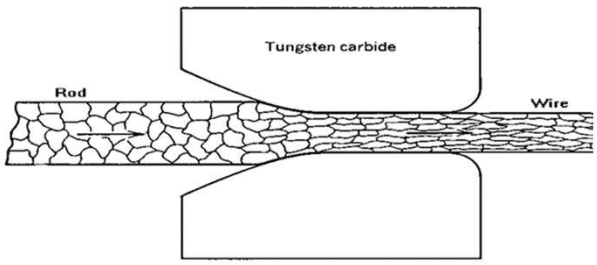
What is Drawing?

Pulling Rod/Bar through a sized die

- Cold forming operation
  - Extruding metal by pulling through a die
  - Using a lubricant to minimize friction and heat for optimum metal flow
  - Room temperature process
  - Increases the coil length
  - Increases
    - Tensile Strength
    - Hardness
  - Reduces
    - Reduction of Area (ductility)
  - Improves size tolerance
  - Improves the surface finish



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Drawing Green Rod

Direct Draw (DD)

- Greatly Increases Tensile and Hardness of green rod material
- Reduces Reduction of Area significantly (6-18%)
- Primarily done with low carbon steels due to the amount of “energy” and forces in the green rod from the rolling practice
- Customer feeds directly to cold former

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Drawing Annealed Rod

Draw from Spheroidize Annealed Rod (DFSAR)

- Rod/bar softened to be drawn
- Area Reduction 8-13%
- Dial in mechanical properties
- Increase tensile properties
- Finalize size requirements
- Customer feeds directly to cold former

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Annealing Drawn Wire

Spheroidized at Finished Size (SAFS)

- Returns the materials mechanical properties to its previous state as a rod or bar product
- Releases the “energy” and forces that the drawing operation has put into the material
- Lowering tensile
- Increase %RA (18-28%) - heavier draft by design for anneal microstructure response
- Higher formability
- Customer usually draws material before going to cold former (SAIP)

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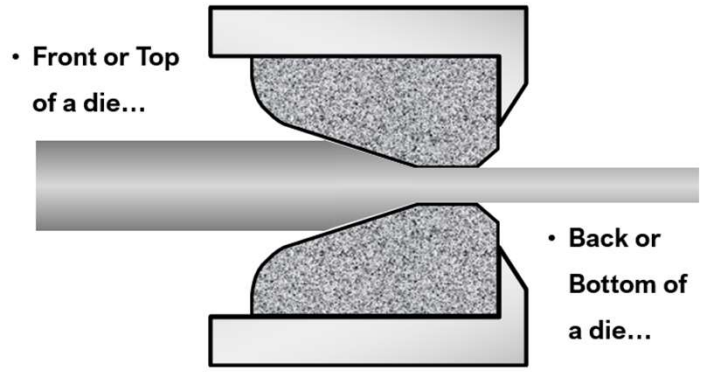
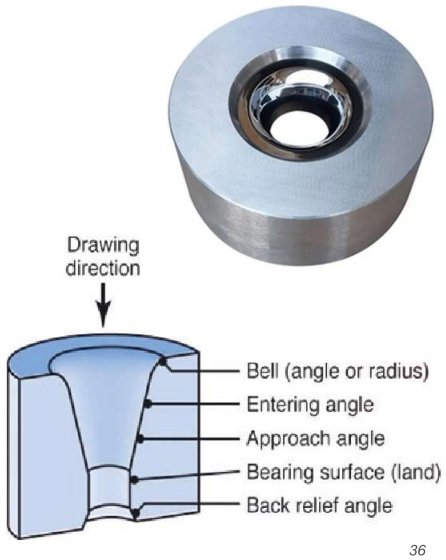
Draw Die Components





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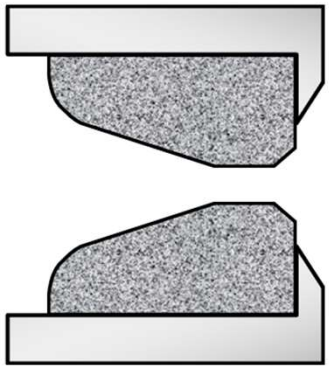
Draw Die Components

- **Steel Casing**
  - Provides a standard size (OD) for different carbide nibs
  - Structurally reinforces the carbide nib insert
  - Helps dissipate the heat generated with drawing wire



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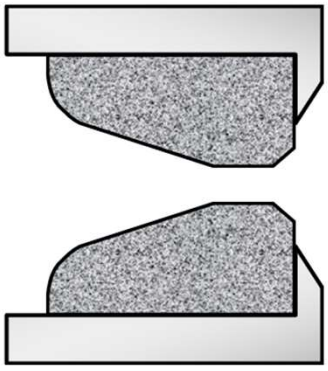
Draw Die Components

- **Carbide Nib (Insert)**

  This is the actual drawing die
  - 4 main parts or areas
    - Bell Radius
    - Approach Angle
    - Bearing
    - Back Relief



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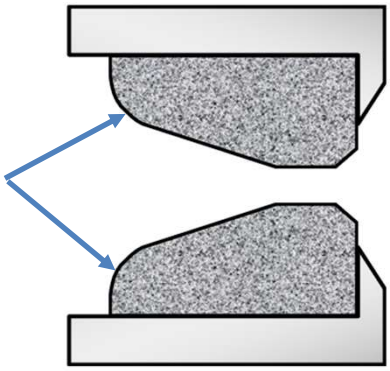
Draw Die Components

- **Bell Radius**
  - Acts as the final entry guide for the rod/wire and draw compound
  - Blended into the Approach Angle



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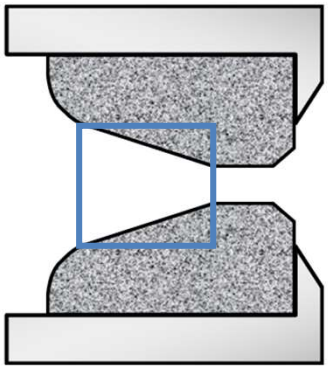
Draw Die Components

- **Approach Angle**
  - Where the actual drawing of the wire occurs
  - 3 parts/areas
    - Lubrication Zone
    - Contact Point
    - Reduction Zone



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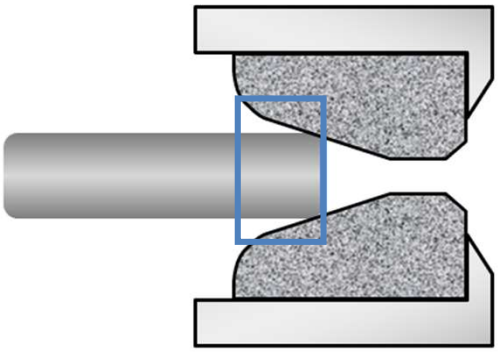
Draw Die Components

- **Lubrication Zone**
  - Area where heat & pressure melts the draw compound



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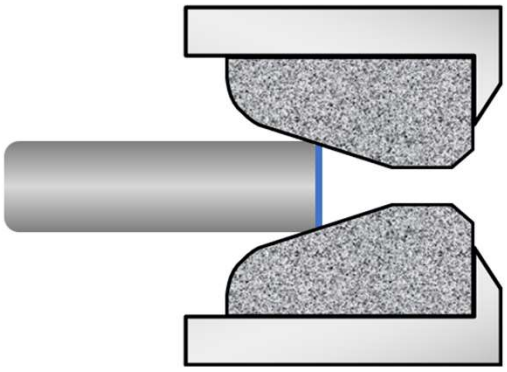
Draw Die Components

- **Contact Point**
  - The spot where the incoming rod/wire first “meets” the die



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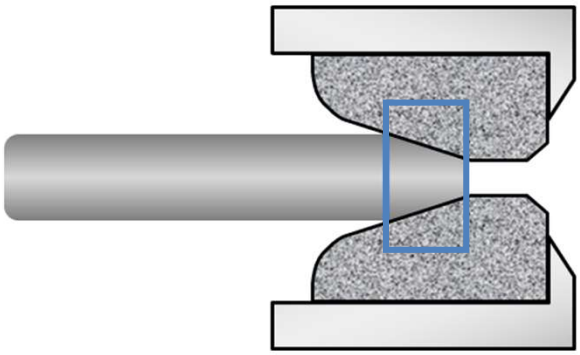
Draw Die Components

- **Reduction Zone**
  - Area where the size of the rod/wire is reduced down



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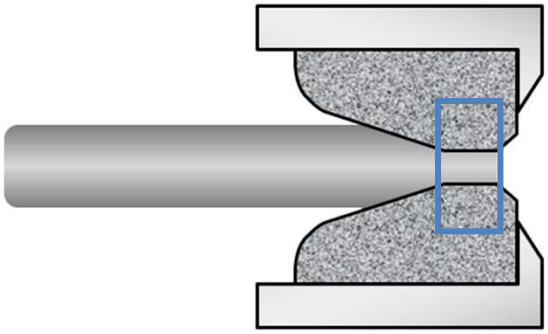
Draw Die Components

- **Bearing**
  - Determines the (finish) size to stop reducing the rod/wire



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Die Failures

Wear Rings

Form on the die's approach angle at the contact point – this wear is a normal part of a die's use and can cause die scratches

Cracked / Broken Dies

Often occurs where the wear ring forms and after prolonged use to a catastrophic failure

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ParaLoc Dies

- System used on smaller sizes
- Carbide nib can be swapped out for different sizes
- Difficult to make onsite
- Tolerances are tight
- Big dies are expensive, nibs for ParaLoc are inexpensive

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Product Types

Step	CLEAN & COAT	DIRECT DRAWN	HRAN HRSA HRLP	SAFS RAFS	DFSAR DFAR	SAIP	AN+SAFS SA+SAFS	AN+SAIP SA+SAIP
1	Clean/Coat	Clean/Coat	Clean/Coat	Clean/Coat	Clean/Coat	Clean/Coat	Clean/Coat	Clean/Coat
2	Ship	Draw	Anneal	Draw	Anneal	Draw	Anneal	Anneal
3		QC Check	QC Check	Anneal	QC Check	Anneal	QC Check	QC Check
4		Ship	Clean/Coat	QC Check	Clean/Coat	QC Check	Clean/Coat	Clean/Coat
5			Ship	Clean/Coat	Draw	Clean/Coat	Draw	Draw
6				Ship	QC Check	Draw	Anneal	Anneal
7					Ship	QC Check	QC Check	QC Check
8						Ship	Clean/Coat	Clean/Coat
9							Ship	Draw
10								QC Check
11								Ship

Increasing Formability

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Processing Path Optimization

Balance between raw material cost and material performance

- More wire processing = more formable = better tool life = more material cost
- Could a part currently using SAFS wire be made with a HRSA ? (cost saving)
  - With right tooling yes, grade dependent,
- Would a part currently using HRSA wire experience a tooling life improvement worth the additional material cost of SAFS?
  - Absolutely, softer material

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Maximum Ductility

- Charter's most formable processing path is X-Flow
  - Extra formable double annealed wire
  - Charter started development in 2017
  - Designated as SA+SAFSXF or SA+SAIPXF
  - Charter proprietary process that maximized formability
  - Used on Charter's customer's most difficult applications

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Packaging

- **Autobander**
  - 4 metal bands
  - Compacts coils from both P2/P3 cleaning lines
- **Manual Compactor**
  - 3 metal bands
  - Poly strapping (easier to apply as it is manual)

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Packaging

- Bands
- Belly Bands
- Carriers

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Packaging

Identification – Paint Stripes

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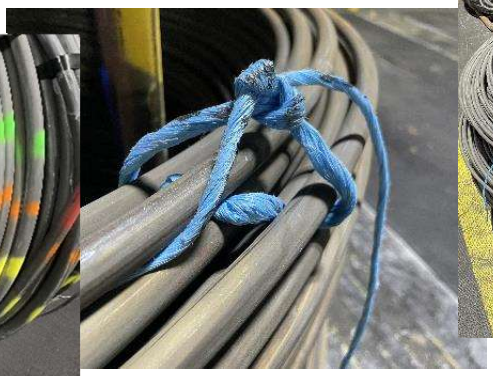
Packaging

End Control

- Paint Ends
- Hank Ties
- Bending the End



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Packaging

Surface Protection

- Cardboard Donuts
- Woven Poly Strapping
- Floor matting

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