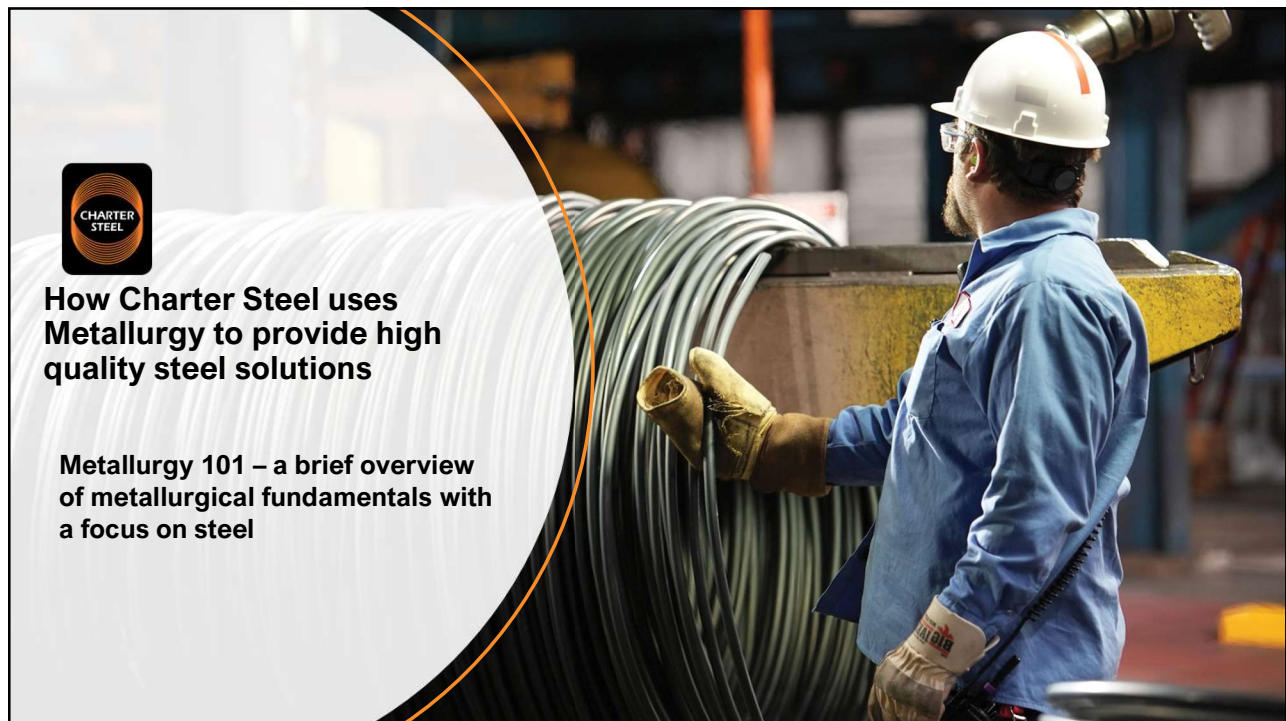




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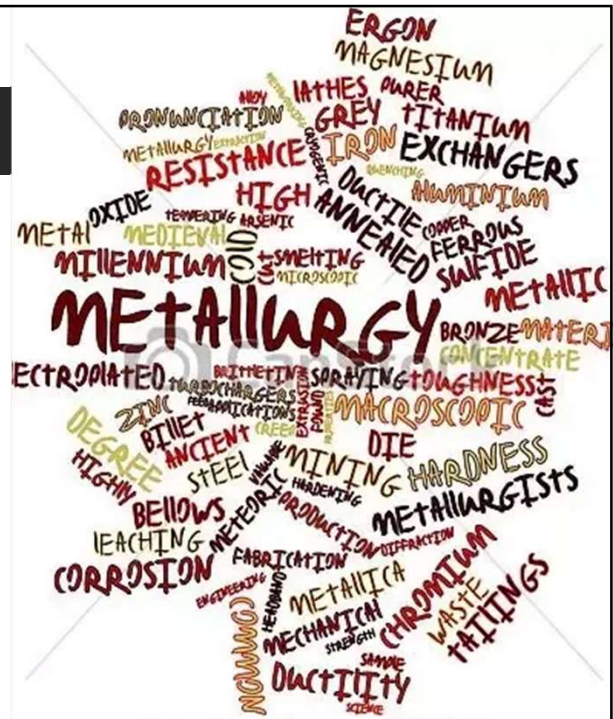


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# Agenda

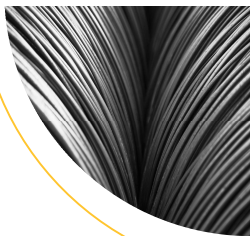
- **Metallurgy Basics**
- **What's a Metallurgist anyway?**
- **Melt Shop Metallurgy**
- **Rolling Mill Metallurgy**
- **Processing Metallurgy**
- **Questions**

3



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# Metallurgy Basics



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# Metallurgy

Metallurgy is the study of the physical and chemical properties of **metals** and **alloys**. It also involves examining the microstructure of metals to determine their mechanical properties.

## Metals

- “Any of a class of substances characterized by high electrical and thermal conductivity as well as by malleability, ductility, and high reflectivity of light. Approximately 75% of all known chemical elements are metals”

Examples: Fe, Ni, Cu, Mn, Cr, Mo, Ti, Al


## Alloys

- “Metallic substance composed of two or more elements, as either a compound or a solution. The components of alloys are ordinarily themselves metals, though carbon, a nonmetal, is an essential constituent of steel.”
- Examples: Steel, Brass, Bronze, Cast Irons, most highly used metals are alloys..

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Source: <https://www.britannica.com/>

5


**CHARTER**  
STEEL


1	2																	18																							
1	H																	2	He																						
3	Li	4	Be																	10	Ne																				
11	Na	12	Mg																	18	Ar																				
19	K	20	Ca	21	Sc	22	Ti	23	V	24	Cr	25	Mn	26	Fe	27	Co	28	Ni	29	Cu	30	Zn	31	Ga	32	Ge	33	As	34	Se	35	Br	36	Kr						
37	Rb	38	Sr	39	Y	40	Zr	41	Nb	42	Mo	43	Tc	44	Ru	45	Rh	46	Pd	47	Ag	48	Cd	49	In	50	Sn	51	Sb	52	Te	53	I	54	Xe						
55	Cs	56	Ba	57-71		72	Hf	73	Ta	74	W	75	Re	76	Os	77	Ir	78	Pt	79	Au	80	Hg	81	Tl	82	Pb	83	Bi	84	Po	85	At	86	Rn						
87	Fr	88	Ra	89-103		104	Rf	105	Db	106	Sg	107	Bh	108	Hs	109	Mt	110	Ds	111	Rg	112	Cn	113	Nh	114	Fl	115	Mc	116	Lv	117	Ts	118	Og						
57	La	58	Ce	59	Pr	60	Nd	61	Pm	62	Sm	63	Eu	64	Gd	65	Tb	66	Dy	67	Ho	68	Er	69	Tm	70	Yb	71	Lu												
89	Ac	90	Th	91	Pa	92	U	93	Np	94	Pu	95	Am	96	Cm	97	Bk	98	Cf	99	Es	100	Fm	101	Md	102	No	103	Lr												

## Common steel alloying elements

Source: <https://www.britannica.com/>

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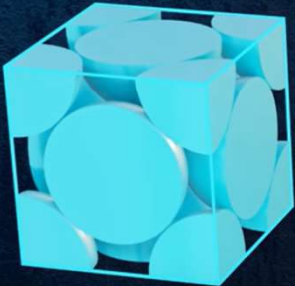


**CRYSTAL LATTICE**

*crystalline material*


- At elevated temps (~1340°F), a phase transformation occurs, which has an FCC cell as its basic structure.
- Carbon is soluble to near 2% in austenite.
- Atoms are more tightly packed in FCC than in BCC.

**74%**  
PACKING FACTOR




**FCC**  
FACE-CENTRED CUBIC

**68%**  
PACKING FACTOR



**BCC**  
BODY-CENTRED CUBIC

7

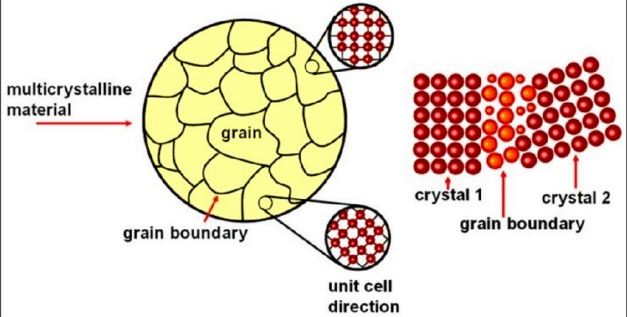


**CHARTER STEEL**

## Grain Structure

**As steel solidifies, the atoms arrange themselves into these unit cells and a lattice structure. This solidification starts at many points though and there are regions, or grains, of material with differing orientations**

- The interactions between these differently oriented cells are called grain boundaries
- The size of these grains can impact the properties of steel with smaller grains leading to increased strength and ductility



[https://www.researchgate.net/figure/Grains-and-grain-boundaries-in-a-polycrystal-To-the-right-defect-in-atomic-structure\\_fig1\\_335054869](https://www.researchgate.net/figure/Grains-and-grain-boundaries-in-a-polycrystal-To-the-right-defect-in-atomic-structure_fig1_335054869)

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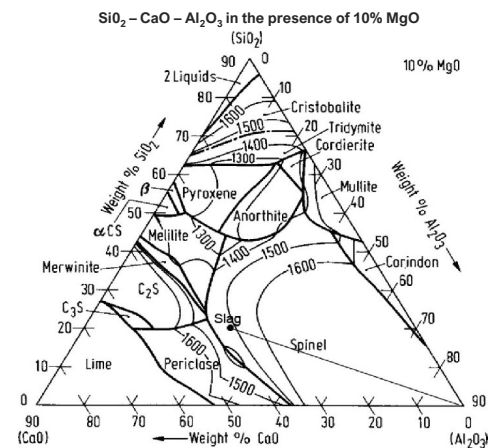
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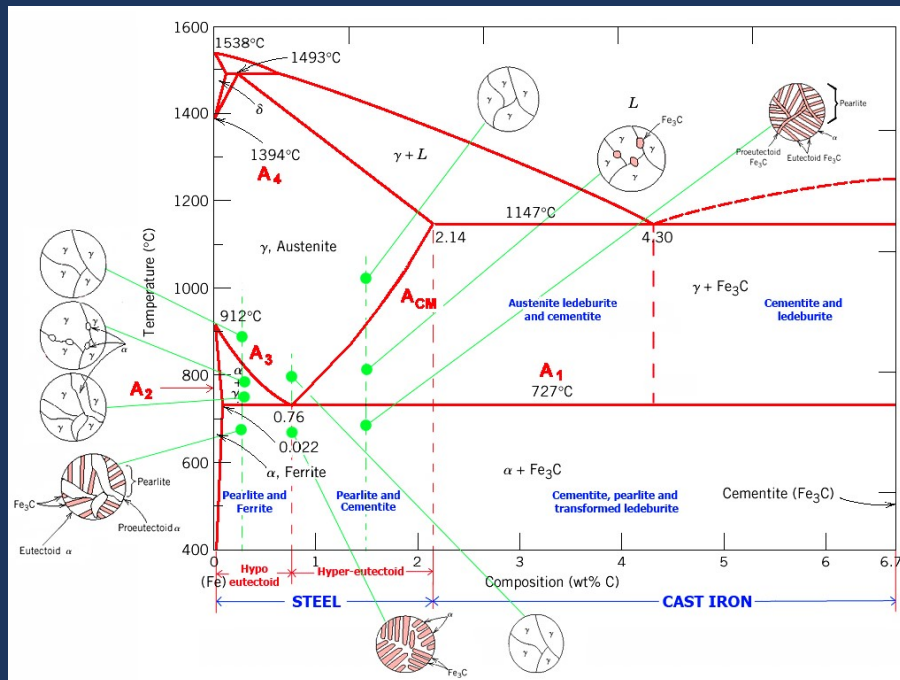
# Phase Diagram

Chart used to show conditions (temp, pressure, weight %) at which thermodynamically distinct phases occur and coexist at equilibrium.

- Can show phases of pure compounds
  - Water has 3 phases (solid, liquid, gas)
- Can show phases of mixtures or alloys like steel
  - Steel has multiple solid phases!
- Ternary (3 axis) phase diagrams are helpful for analyzing slags and inclusions



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[https://www.tf.uni-kiel.de/matwis/amat/iss/kap\\_6/illustr/s6\\_1\\_2.html](https://www.tf.uni-kiel.de/matwis/amat/iss/kap_6/illustr/s6_1_2.html)

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STEEL


# What's a Metallurgist anyway?



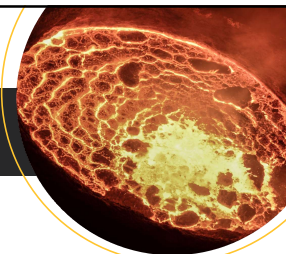


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STEEL

## Metallurgists at Charter Steel



A metallurgist is **an engineer who studies, designs, and develops industrial processes that transform metals into useful materials.** - AI


Metallurgist Roles at Charter Steel

- Materials Associates
- Process Metallurgists
- Technical Service Engineers
- Quality Technical Managers
- Principal Metallurgists
- Leadership Roles
- Metallurgical knowledge allows Charter Steel to improve our processes throughout the organization with a focus on Steel quality
- Charter has 55+ metallurgists on staff
- Allows Charter to better service our customers in many ways!

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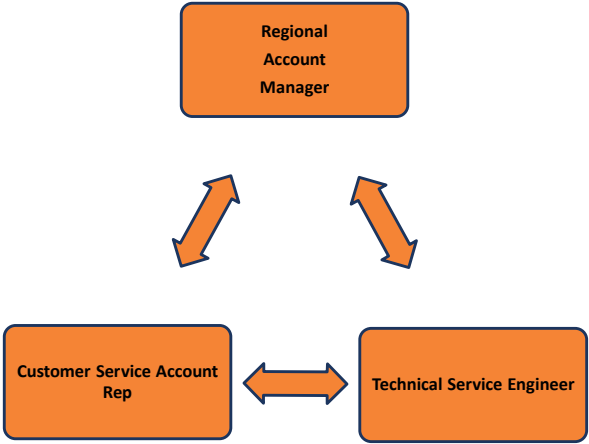




## Value Added

**Charter Steel service enhanced by our metallurgists**


- Process Metallurgists
  - Our operations are continuously improved and refined with a focus on our steel products every step of the way
- Technical Services
  - Charter supports each of our customers with a team approach
  - Our TSE's are your bridge from our process to yours, we are here to help you succeed



```

graph TD
    RAM[Regional Account Manager] <--> CSAR[Customer Service Account Rep]
    CSAR <--> TSE[Technical Service Engineer]
    TSE <--> RAM
            
```

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## Technical Overview

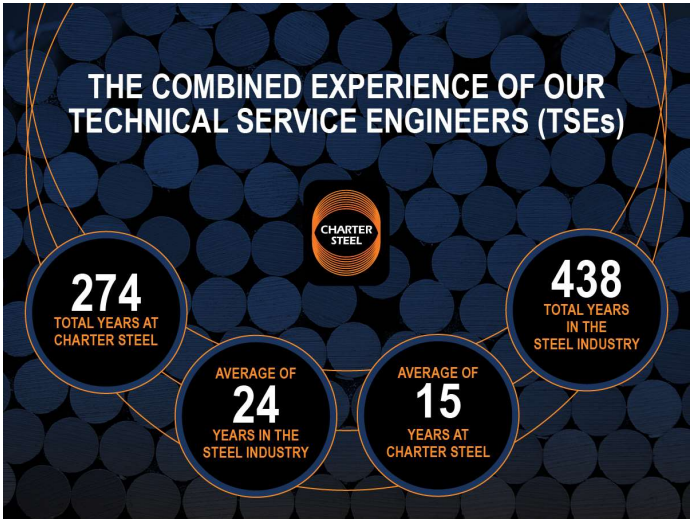
**Your Goals are Our Goals**

Charter Steel has some of the best Technical resources in the industry.

From a large team of materials engineers, and metallurgists to a world class technical lab, these resources are dedicated to solving problems and bringing solutions to market.

Boards and Memberships for TSE + Lab include:

- Board of Directors – Wire Association International
- ASTM Membership (voting member rod, wire and bar standards)
- AMS Carbon and Alloy Steel Committee Members
- Board of Directors (Former) - Spring Manufacturers Institute



**THE COMBINED EXPERIENCE OF OUR TECHNICAL SERVICE ENGINEERS (TSEs)**

- 274** TOTAL YEARS AT CHARTER STEEL
- 438** TOTAL YEARS IN THE STEEL INDUSTRY
- AVERAGE OF 24** YEARS IN THE STEEL INDUSTRY
- AVERAGE OF 15** YEARS AT CHARTER STEEL

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## Main Operations in CSMD

- Scrap steel is melted and primary refining done in the EAF
  - 'Vanilla' chemistry
- Steel is tapped into ladle and further refined in the VAD/LRF
  - Add the toppings to make final chemistry
  - Remove unwanted gases
- Ladle is then drained into a tundish and continuously casted into billets

Cross section view of how off gases from the EAF pass over the scrap in the preheat conveyor

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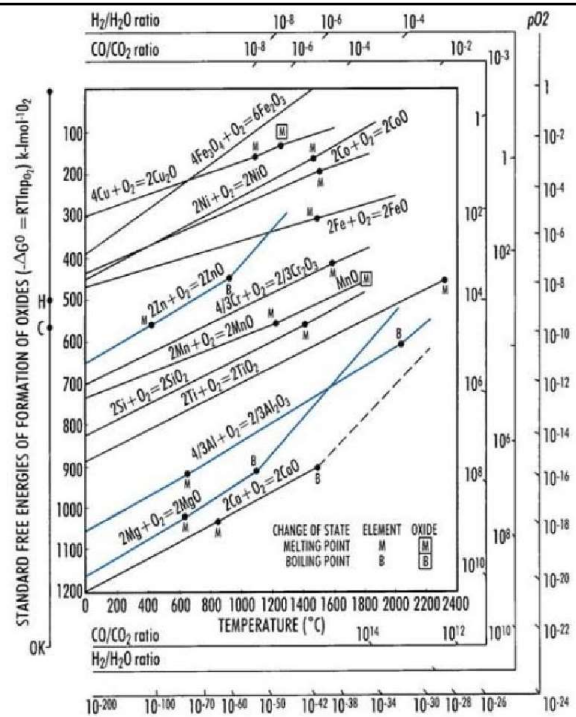
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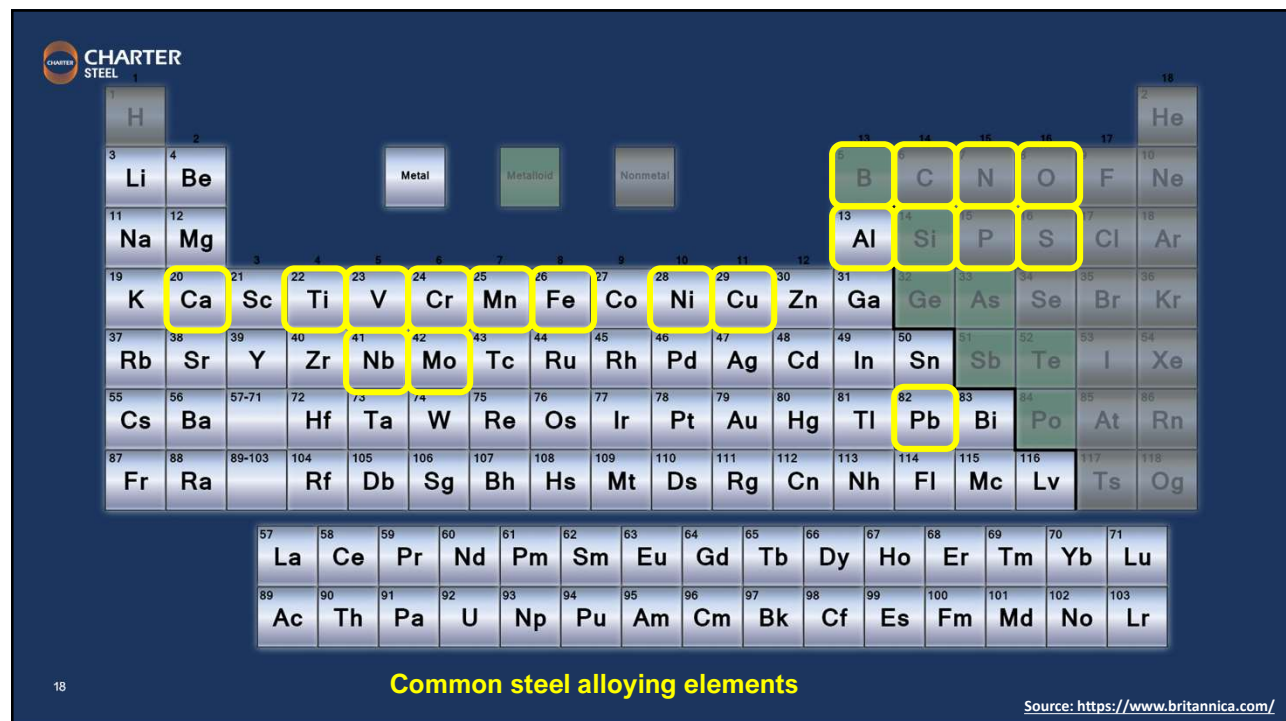
## Scrap Steel

- Scrap steel comes from a variety of sources with different residual levels
- Some residuals can't be oxidized out of the steel in the EAF
- Different applications and quality levels require different scrap recipes

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Common steel alloying elements

Source: <https://www.britannica.com/>

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# Alloying Elements

a substance composed of two or more metals or of a metal and a nonmetal intimately united usually by being fused together and dissolving in each other when molten

- Carbon
  - Hardenability
- Manganese
  - Hardenability, improve casting and rolling, ties up sulfur
- Silicon
  - Strong deoxidizer, improves properties in spring steels
- Vanadium
  - Grain refiner, improved work hardening
- Nickel
  - Increase strength & toughness, improve heat treatability
- Chromium
  - Hardenability, corrosion resistance, carbide former
- Molybdenum
  - Hardenability, improved creep strength
- Aluminum
  - Deoxidizer, grain refinement, ties up free Nitrogen
- Boron
  - Hardenability at very low levels
- Sulfur
  - Improved machinability

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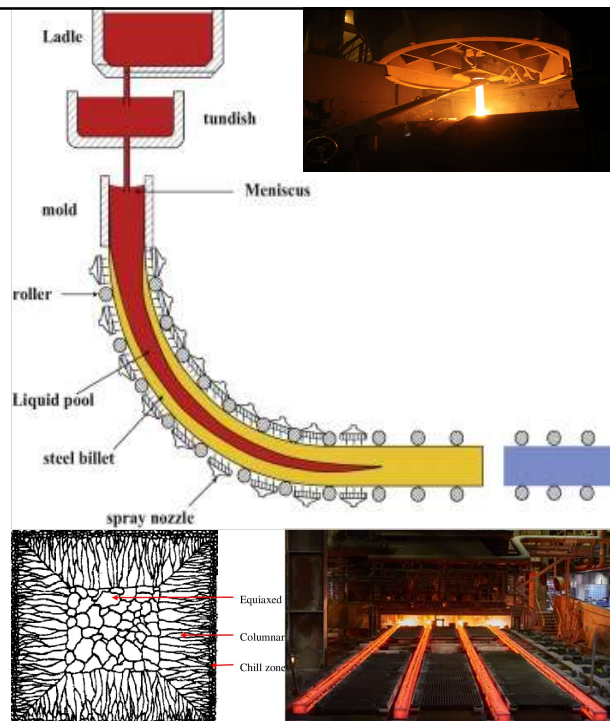


# Casting Metallurgy

- Prevent Oxidation, Oxygen really likes molten steel!
- Controls to avoid pulling in NIMs
- Mixing for homogeneity
- Cooling rates and surface quality

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STEEL**

## Rolling Mill Metallurgy





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STEEL**

## Operations in CSRD

- The billet is **heated** well into the *austenitic* range (about 2000° F.)
- The billet is **rolled** through a series of rolls or *stands*
- The coil is subjected to **controlled-cooling** on the *Stelmor®* or bar mill conveyor



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## Metallurgy in heating steel

Steel is reheated in furnace so we can hot roll it

- Decarb
- Scale
- Uniformity



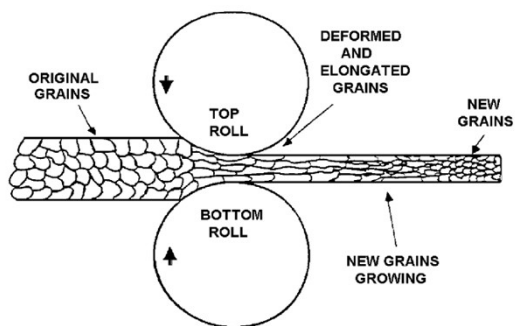
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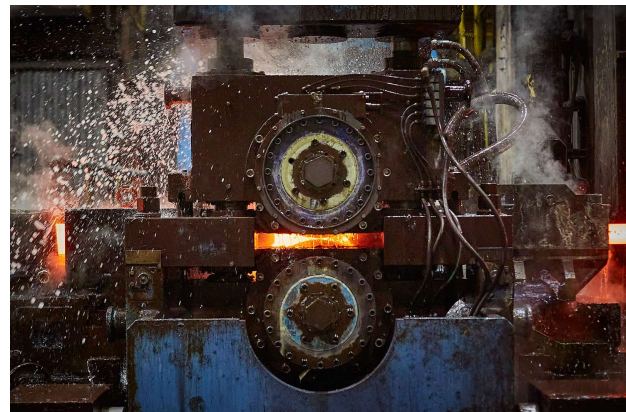


## What is hot rolling?

*Elongating* the billet and reducing its *section*, without changing its volume, by applying pressure with the rolls



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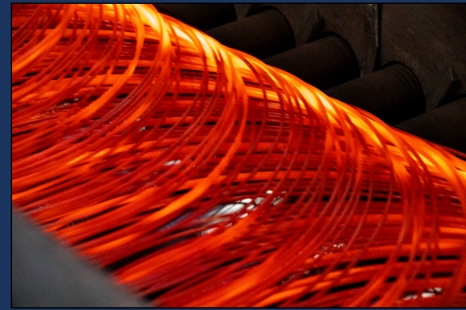




# Cooling on the Stelmor®

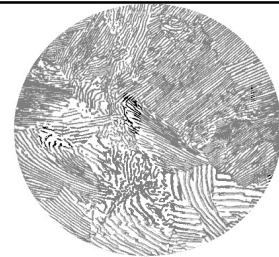
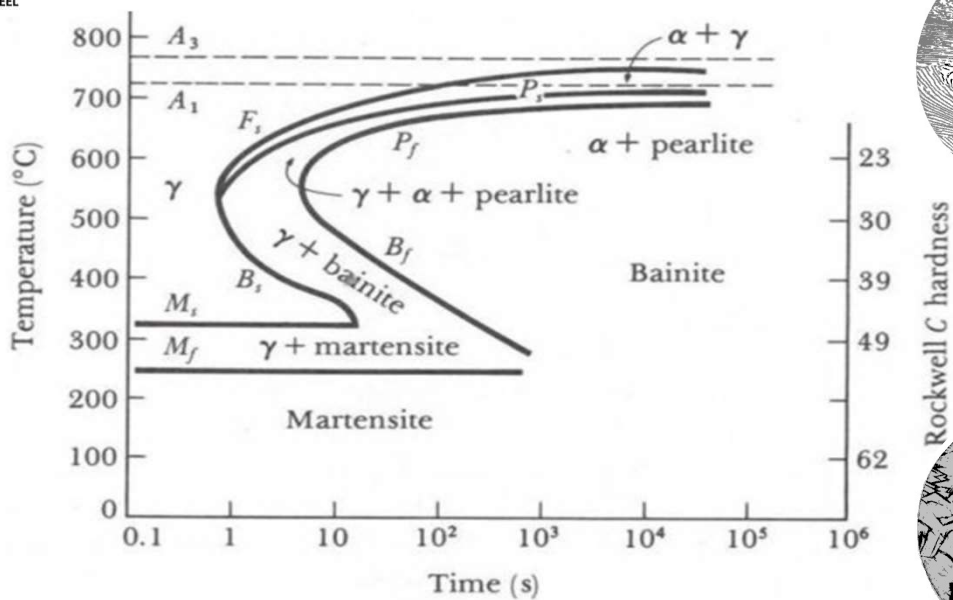
More than just a logo...

- Steel is hot: way into the austenitic range
- New grains have formed
- Cooling begins immediately
- Properties and structure are determined by cooling rates



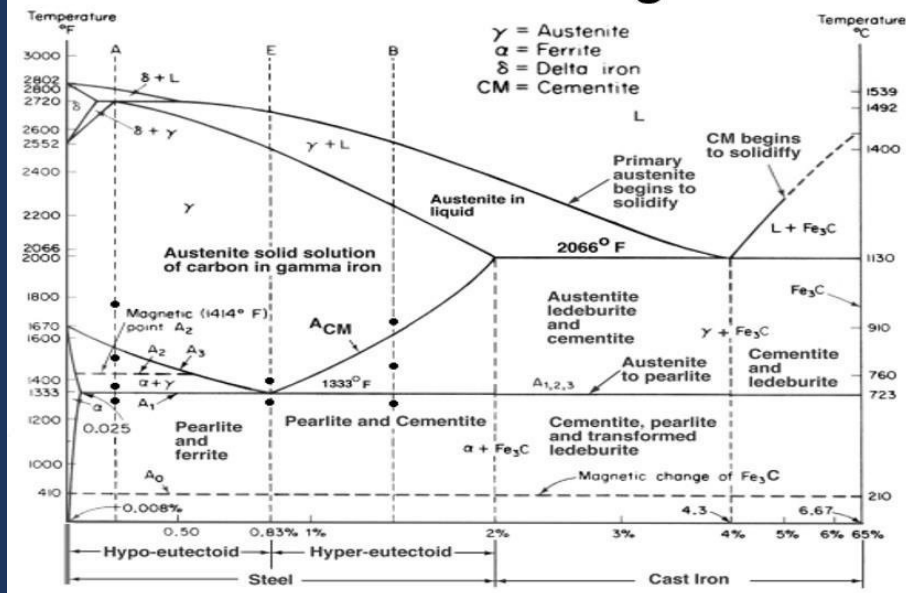
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## Iron-Carbon Phase Diagram



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Source: [https://www.researchgate.net/figure/Portion-of-Fe-C-equilibrium-phase-diagram5\\_fig5\\_320531737](https://www.researchgate.net/figure/Portion-of-Fe-C-equilibrium-phase-diagram5_fig5_320531737)

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## What's the Difference Between Coarse and Fine Pearlite?



- Spacing between plates of Fe and  $\text{Fe}_3\text{C}$  in grain
- Size of grain

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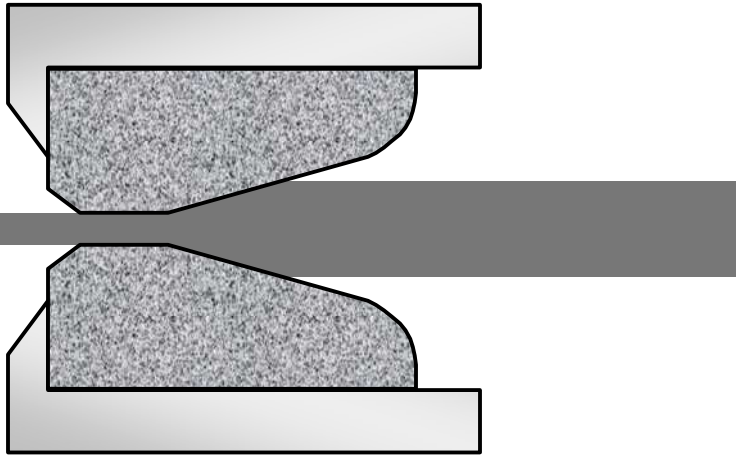
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## Wire Drawing



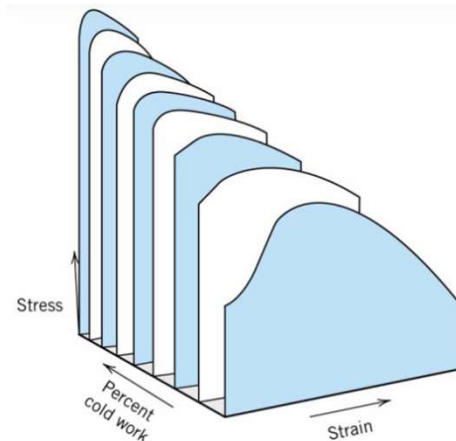
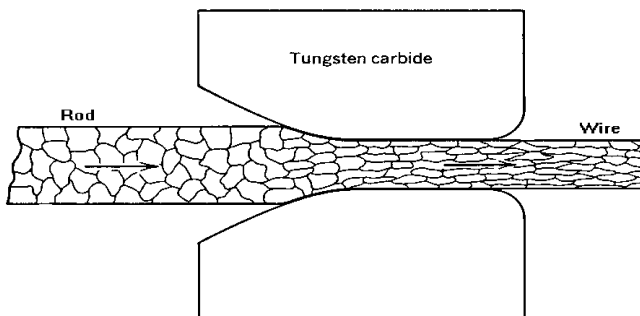
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## What Does Drawing do Metallurgically?

As steel is cold-worked, dislocations pile up, this increases strength of the steel and decreases ductility

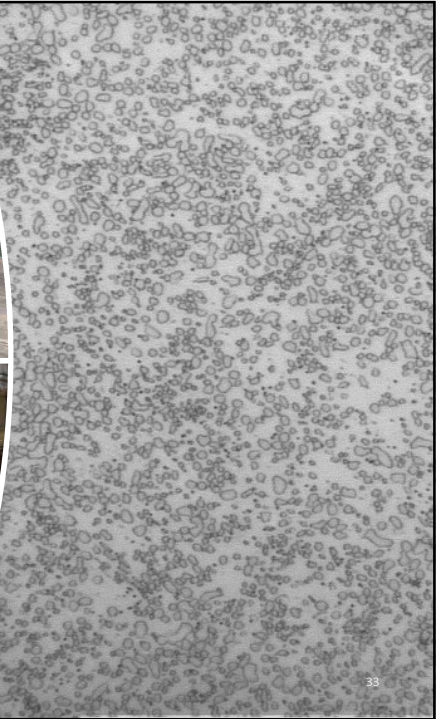


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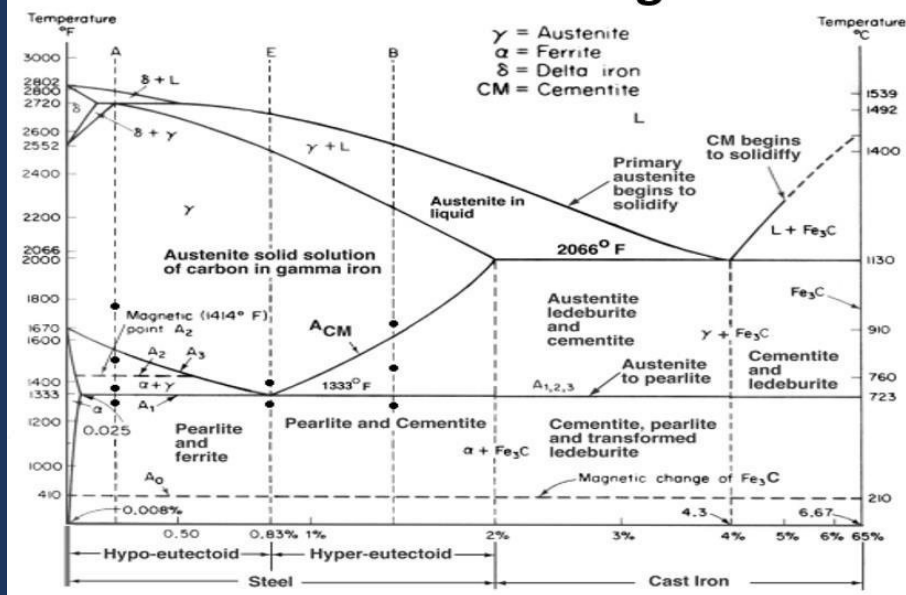
## Annealing

- Spheroidization
- Regular
- LP



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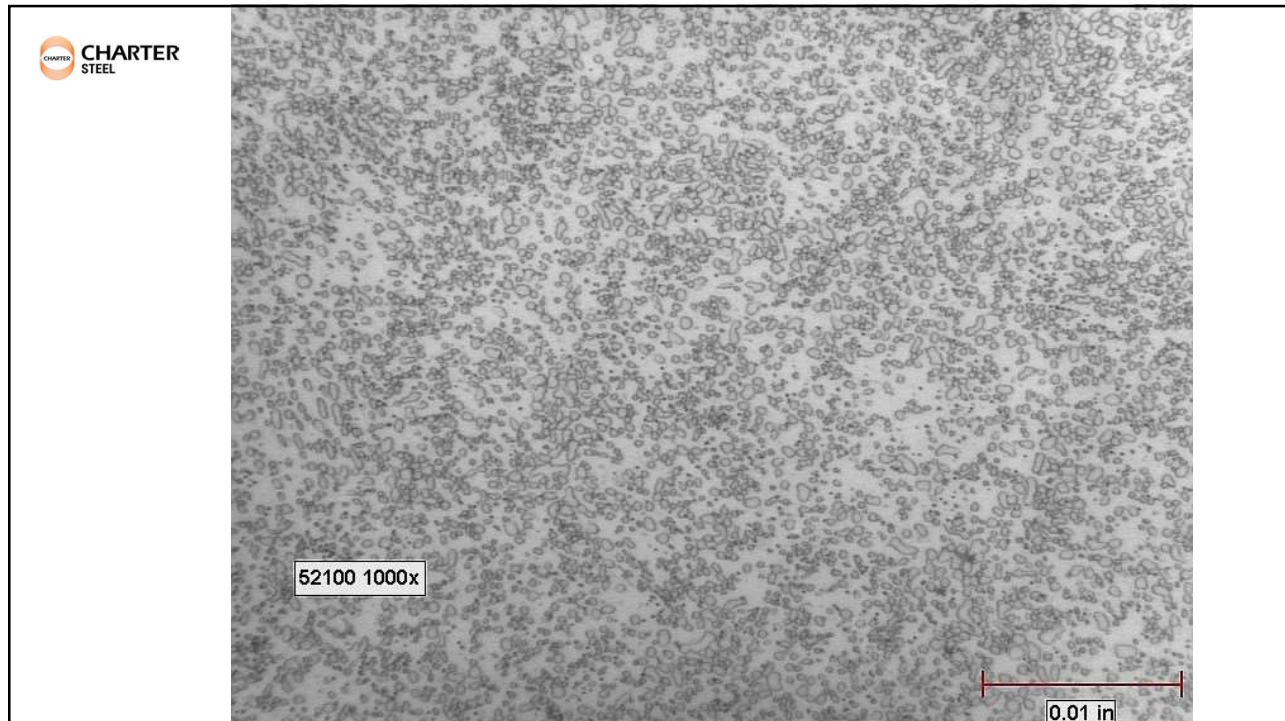
## Iron-Carbon Phase Diagram



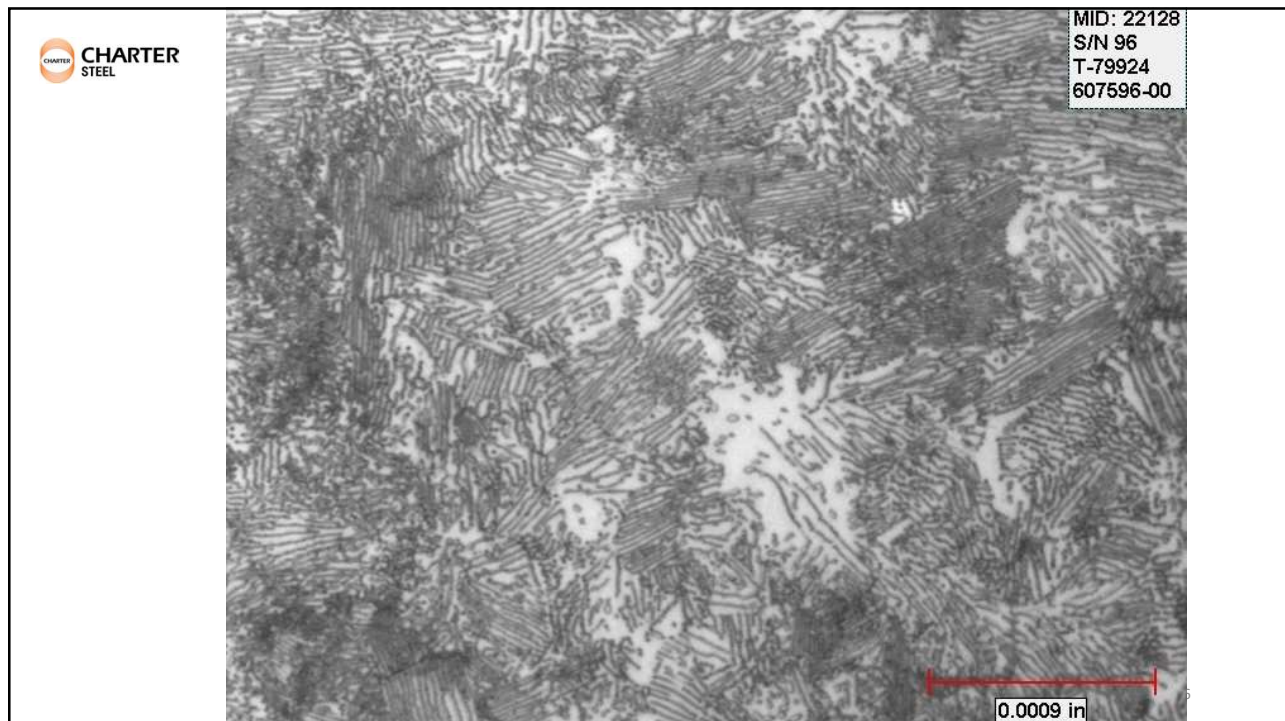
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Source: [https://www.researchgate.net/figure/Portion-of-Fe-C-equilibrium-phase-diagram5\\_fig5\\_320531737](https://www.researchgate.net/figure/Portion-of-Fe-C-equilibrium-phase-diagram5_fig5_320531737)

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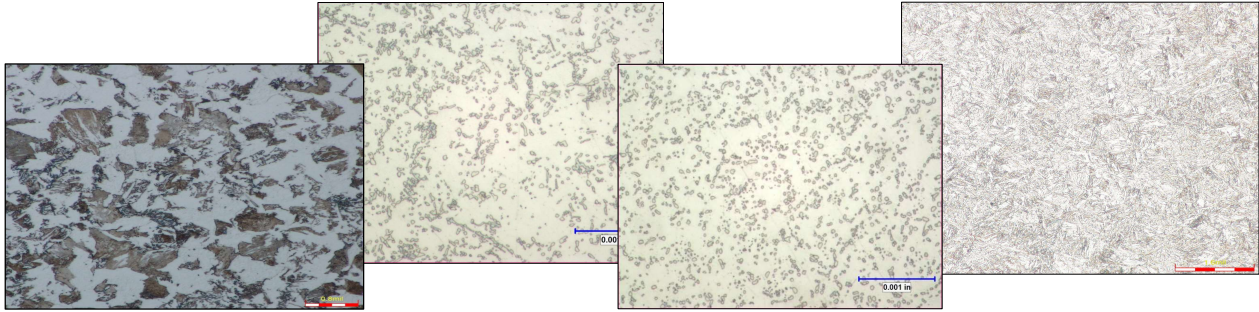


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## Property Impacts

Steel is one of the most versatile materials in the world, processing takes full advantage of it's metallurgical properties!



	As Rolled		Sphero Annealed		SA+SAFS		Quench and Temper	
Grade	Tensile	RA	Tensile	RA	Tensile	RA	Tensile	RA
4037	~96	~41	~73	~66	~66	~70	~177	~44

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Drill rod demo. Get 3 lengths of 3/16" drill rod (W1 ish) about 12" each. If you have an oven, that is ideal, but a torch can work. Normalize 1, quench the second, quench and temper the third. Have a smaller person bend the first, another smaller person snap the second, and the biggest person in the room fail to do much to the third.

**Models of FCC and BCC Structures, show carbon gapping for solubility**

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