Heat Treatment of Steels

MSE 201Lab IV

Samples

- AISI-SAE 1018 – 0.18 % C
- AISI-SAE 1045 – 0.45 % C
- AISI-SAE 1095 – 0.95 % C

- Austenitized at 870°C for 2 hours

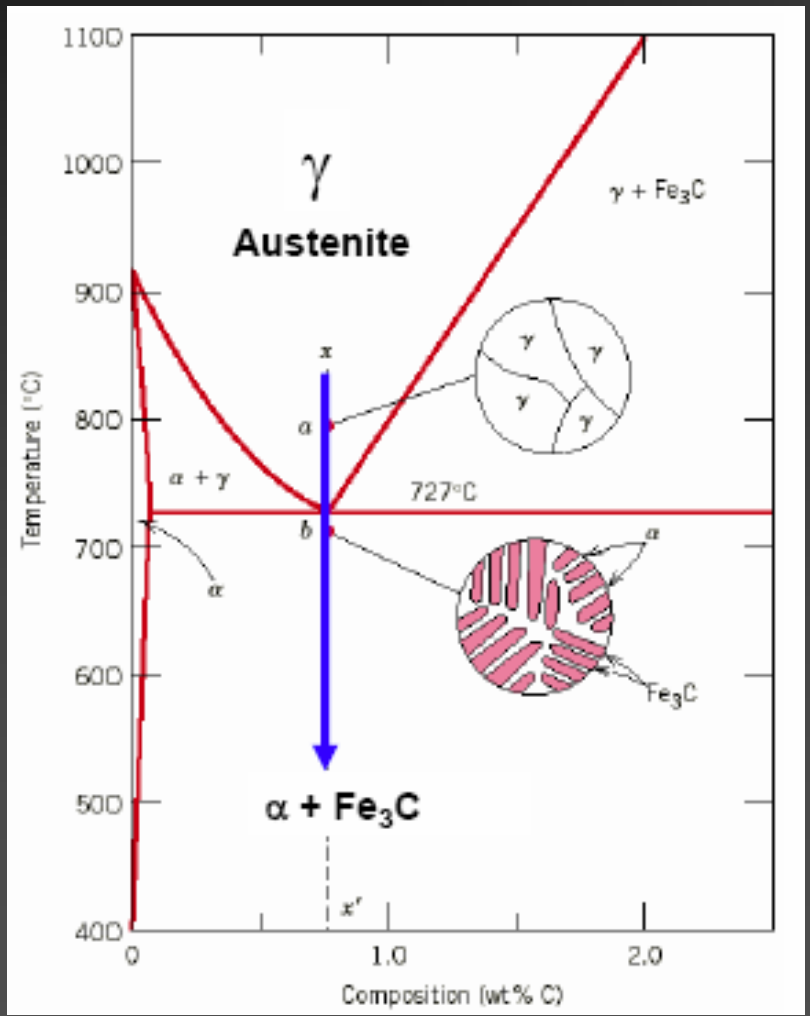
Heat Treatments

- **A** – Furnace Annealed – Slow cooled
- **N** - Normalized - Air cooled.
- **O** - Oil Quenched
- **WQ** – Water quenched.
- ***WT(370)***– Water quenched, tempered at 370°C for 1 hour.
- ***WT(705)***– Water quenched, tempered at 705°C for 1 hour.

Proceed to Furnace Room to:

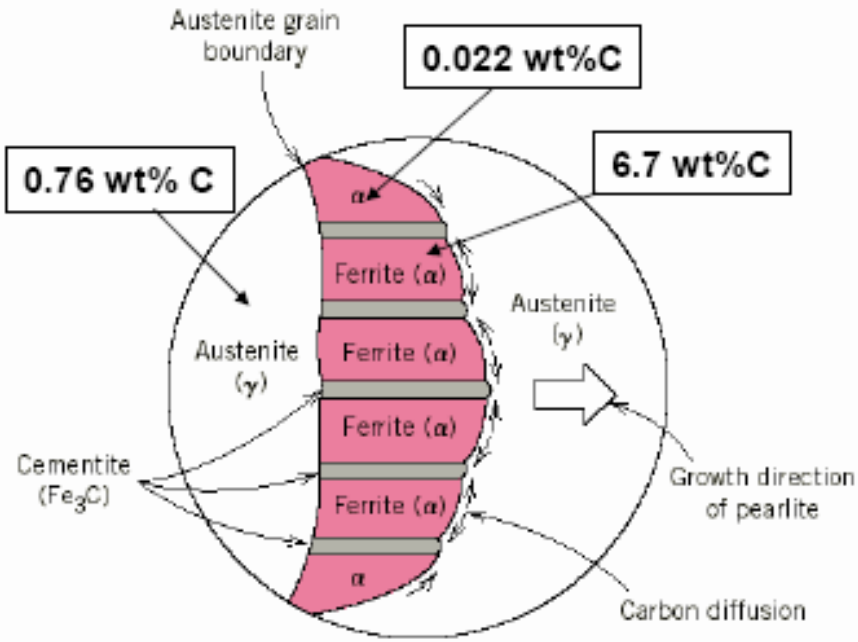
- Quench the samples (except the normalized ones)
- Place the tempering samples into Furnaces
- Jominy Test demonstration

Pearlite Formation



- Austenite precipitates Fe3C at Eutectoid Transformation Temperature (727°C).
- When slow cooled, this is Pearlite (looks like Mother of Pearl)

Diffusion of Carbon in Pearlite



- Schematic representation of the formation of pearlite from austenite
  - direction of arrows indicates carbon diffusion

- Micrograph of eutectoid steel, showing pearlite microstructure.
  - α ferrite (light)
  - Fe_3C (dark)

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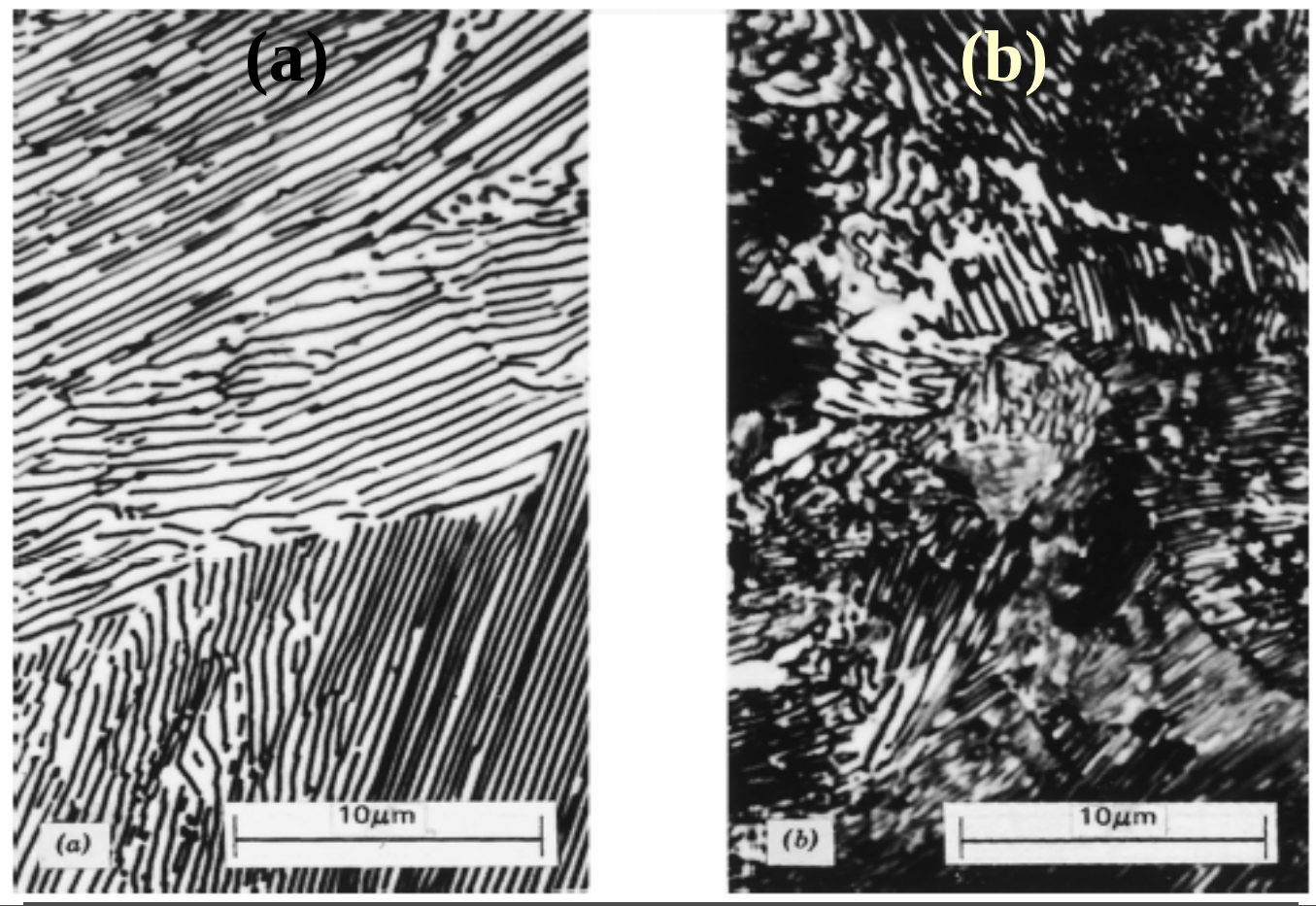
Morphology of Pearlite



(a) coarse pearlite (b) fine pearlite 3000X

What About Cooling Rates?

- Faster cooling gives “non-equilibrium microconstituents”…
  - Bainite
  - Martensite
  - And more!
- To know what microconstituents are present, you must look at cooling curve diagrams

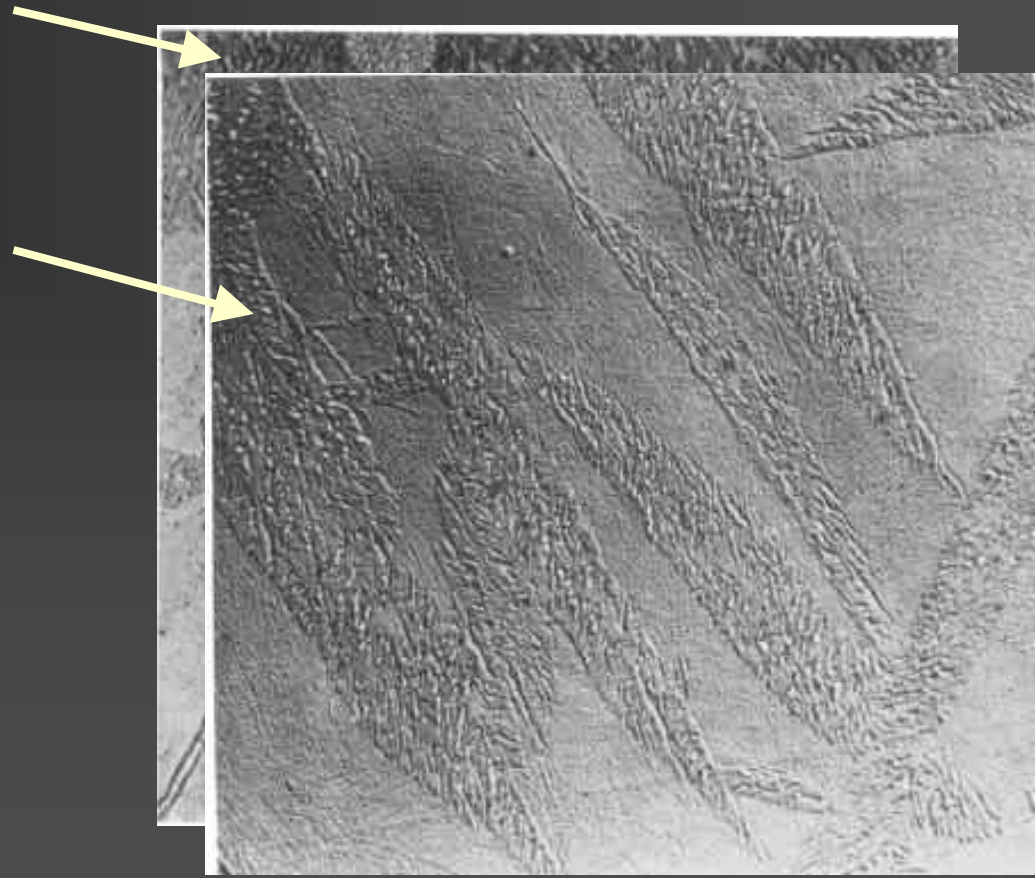
Microconstituents vs. Cooling Rate

In creasing Cooling Rate

- **Spheroidite:** Spherical “globs” of Fe3C in Ferrite
- **Pearlite**: Layers of α ferrite and Fe3C
  - Course Pearlite
  - Fine Pearlite
- **Bainite**: 200 – 500 °C Transformation
- **Martensite**: Rapid Cooling

Bainite

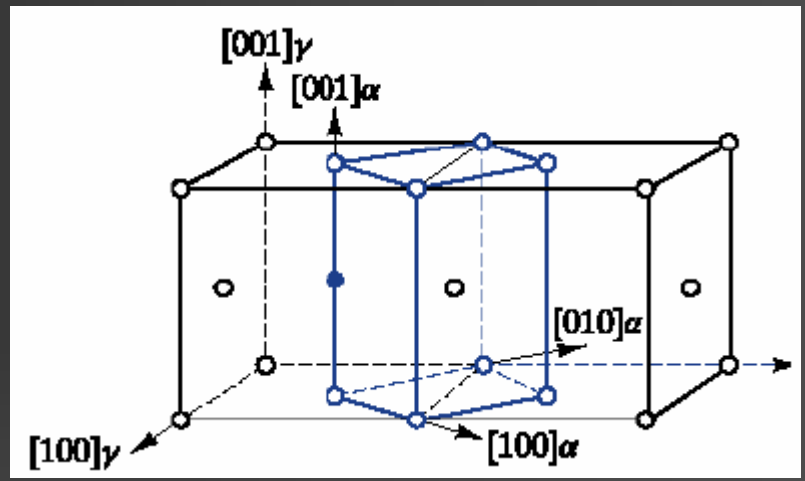
- Upper (550-350°C)
  - Rods of Fe3C
- Lower (350-250°C)
  - Fe3C Precipitates in Plates of Ferrite
- It is still Ferrite and Cementite! It’s just acicular.



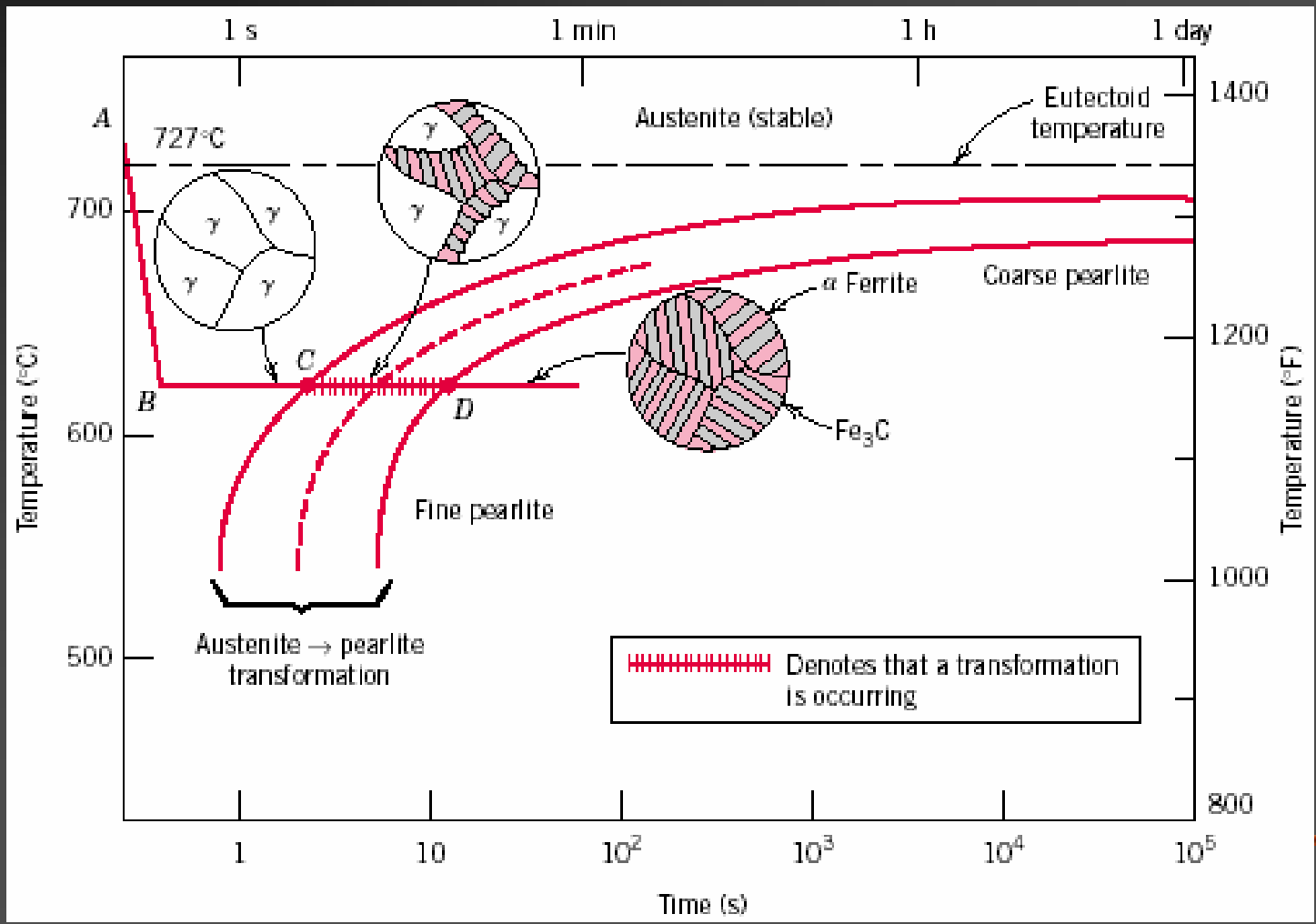
Martensite

- Diffusionless transformation

  of FCC to BCT (more volume!)
- Lenticular structure
- Very hard & very brittle.



TTT Diagrams



Full TTT Diagram

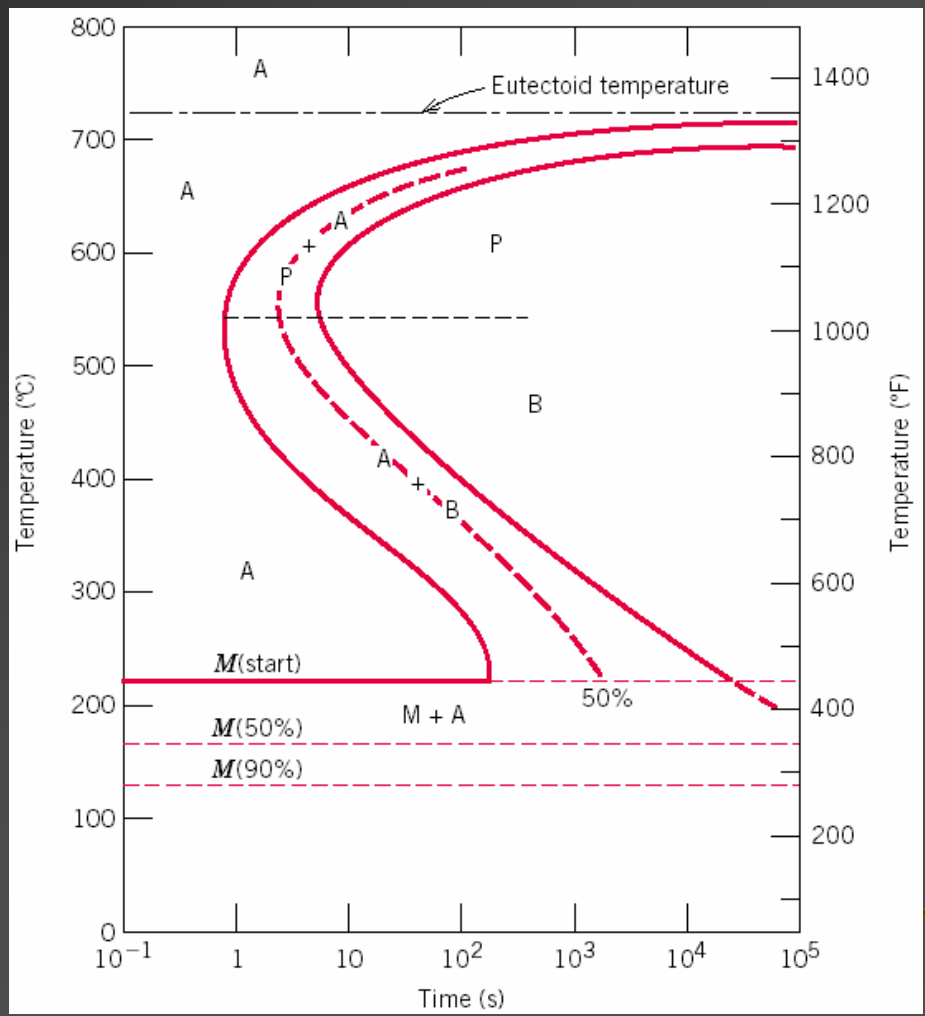
The complete TTT diagram for an iron-carbon alloy of eutectoid composition.

A: austenite

B: bainite

M: martensite

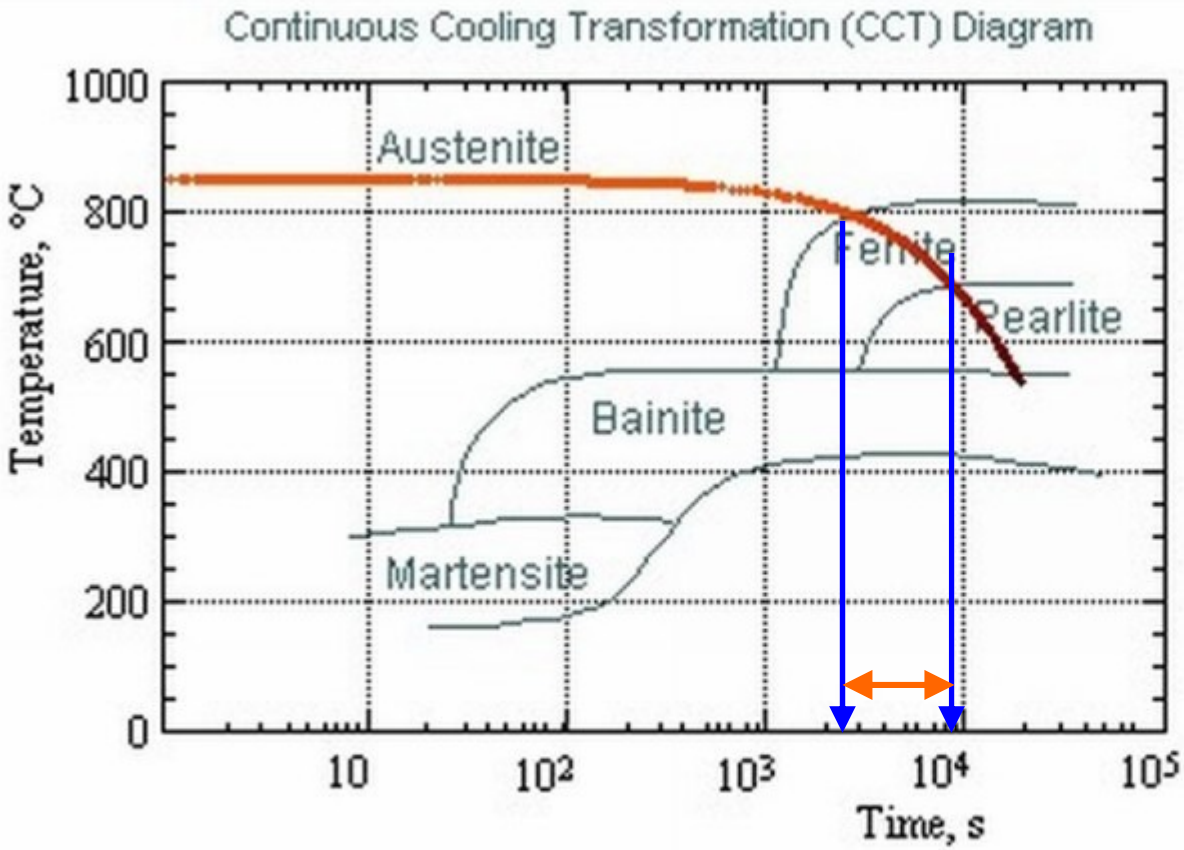
P: pearlite



So What's a CCT Diagram?

- Phase Transformations and Production of Microconstituents takes TIME.
- Higher Temperature = Less Time.
- If you don't hold at one temperature and allow time to change, you are "Continuously Cooling".
- Therefore, a CCT diagram's transition lines will be different than a TTT diagram.

Slow Cooling



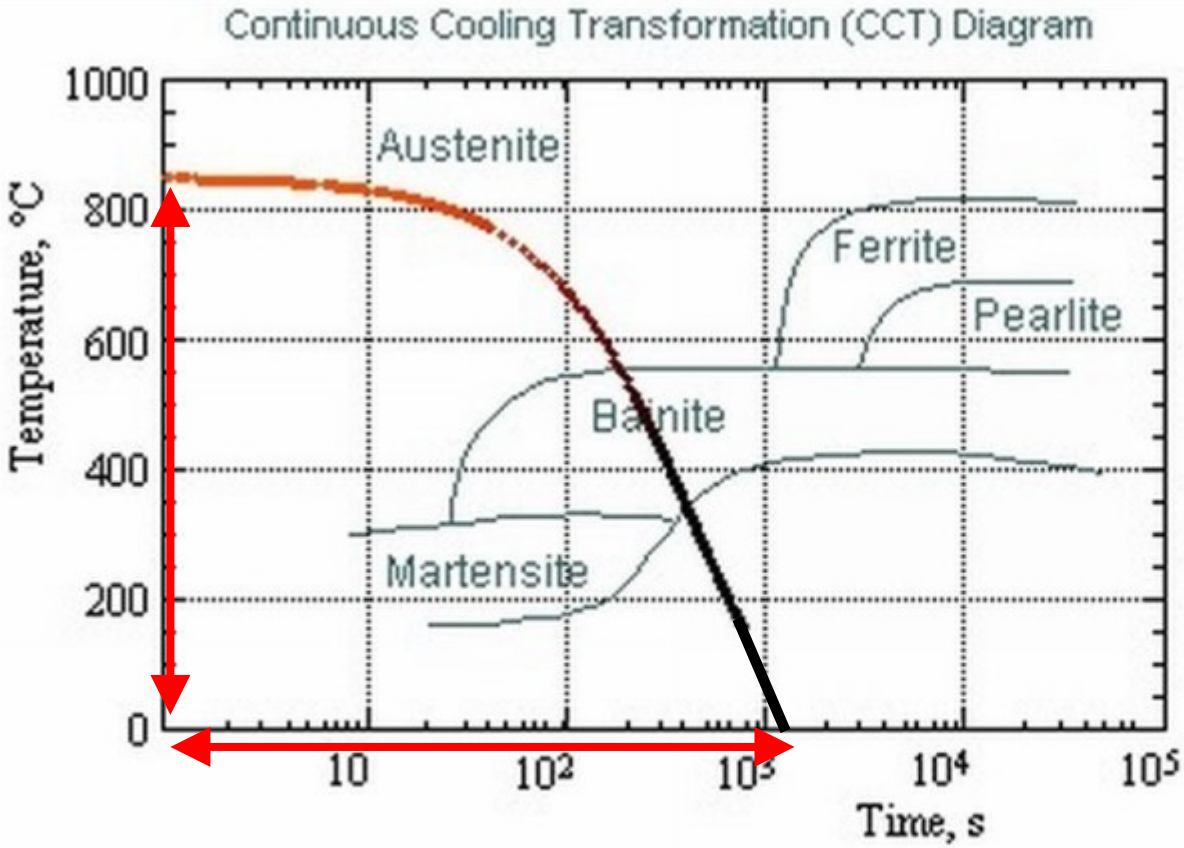
18803s, 538°C

Time in region indicates amount of microconstituent!

Slow cool | Medium cool | Fast cool | Simulation rate: ×1,000 | Start

Ferrite + pearlite

Medium Cooling



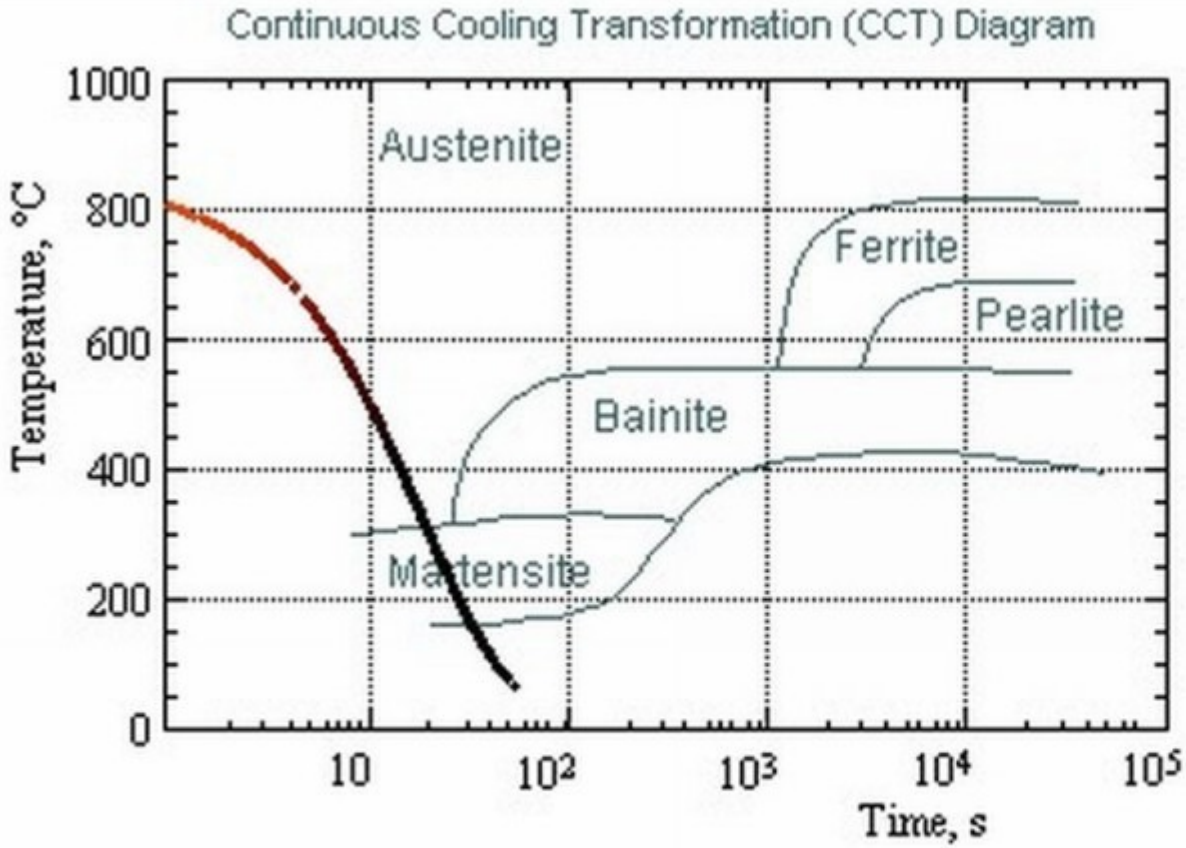
792s, 154°C

Cooling Rate, R, is Change in Temp / Time °C/s

Slow cool | Medium cool | Fast cool | Simulation rate: ×100 | Start

Bainite

Fast Cooling



56s, 64°C

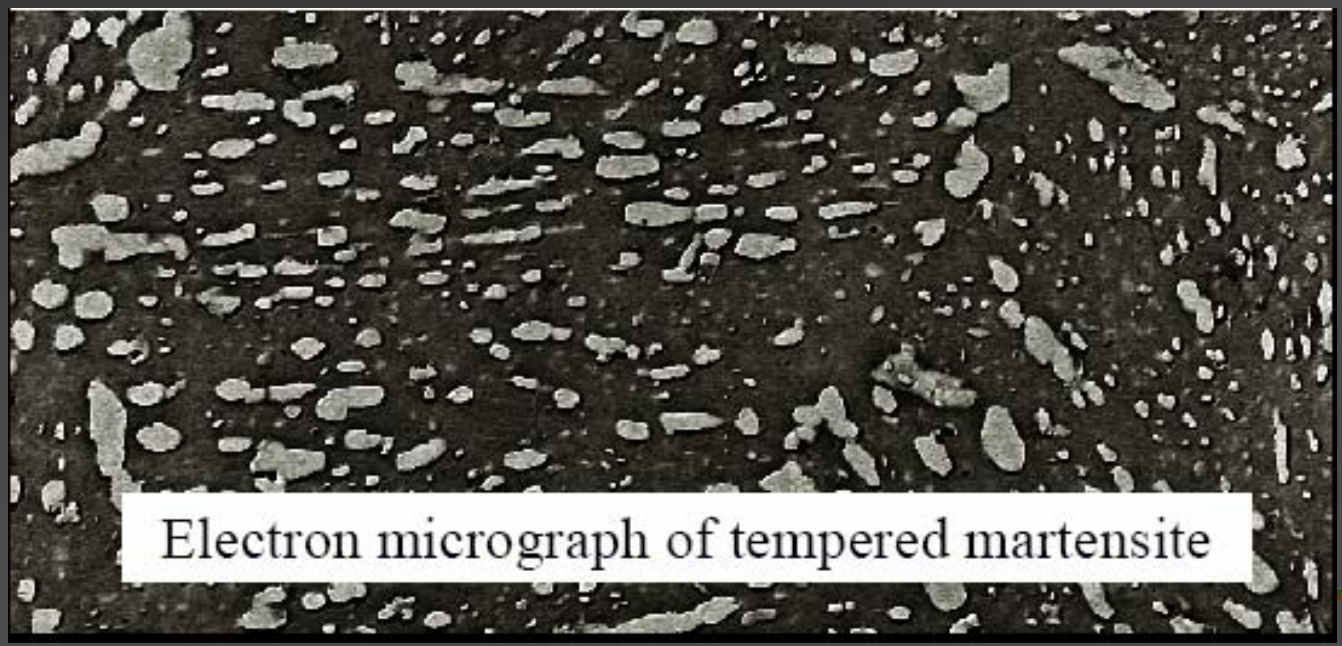
This steel is very hardenable… 100% Martensite in ~ 1 minute of cooling!

Slow cool | Medium cool | Fast cool | Simulation rate: ×10 | Start

Martensite

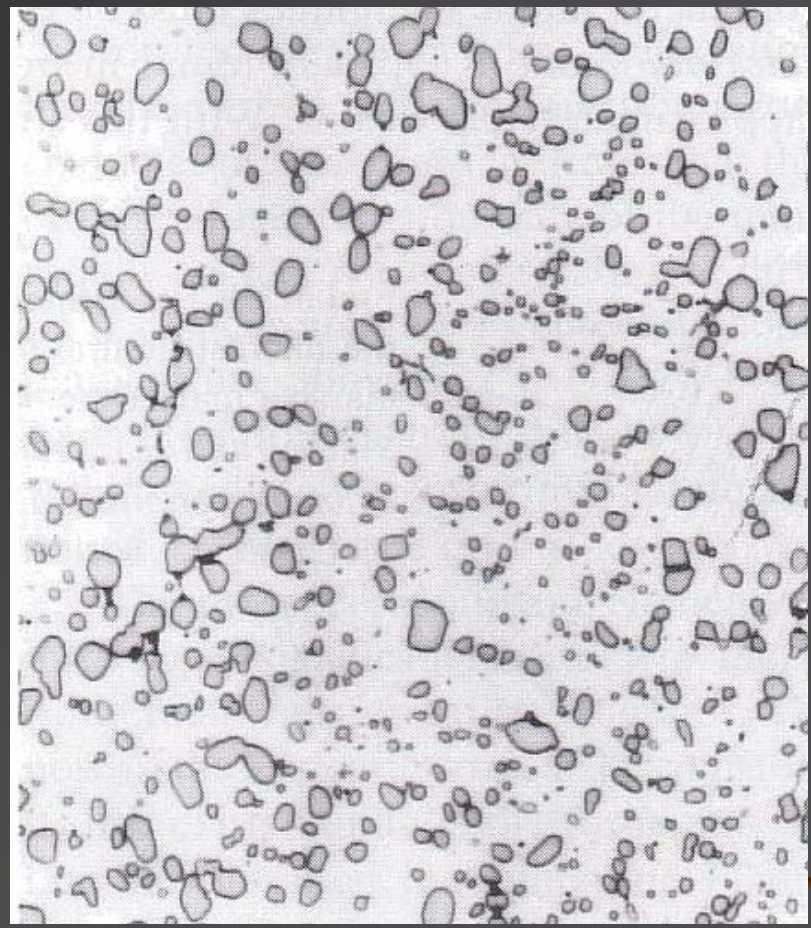
What is Tempering?

- Martensite needs to be tempered to get better ductility. This happens when Fe3C is allowed to precipitate from the supercooled Martensite.



Spheroidite

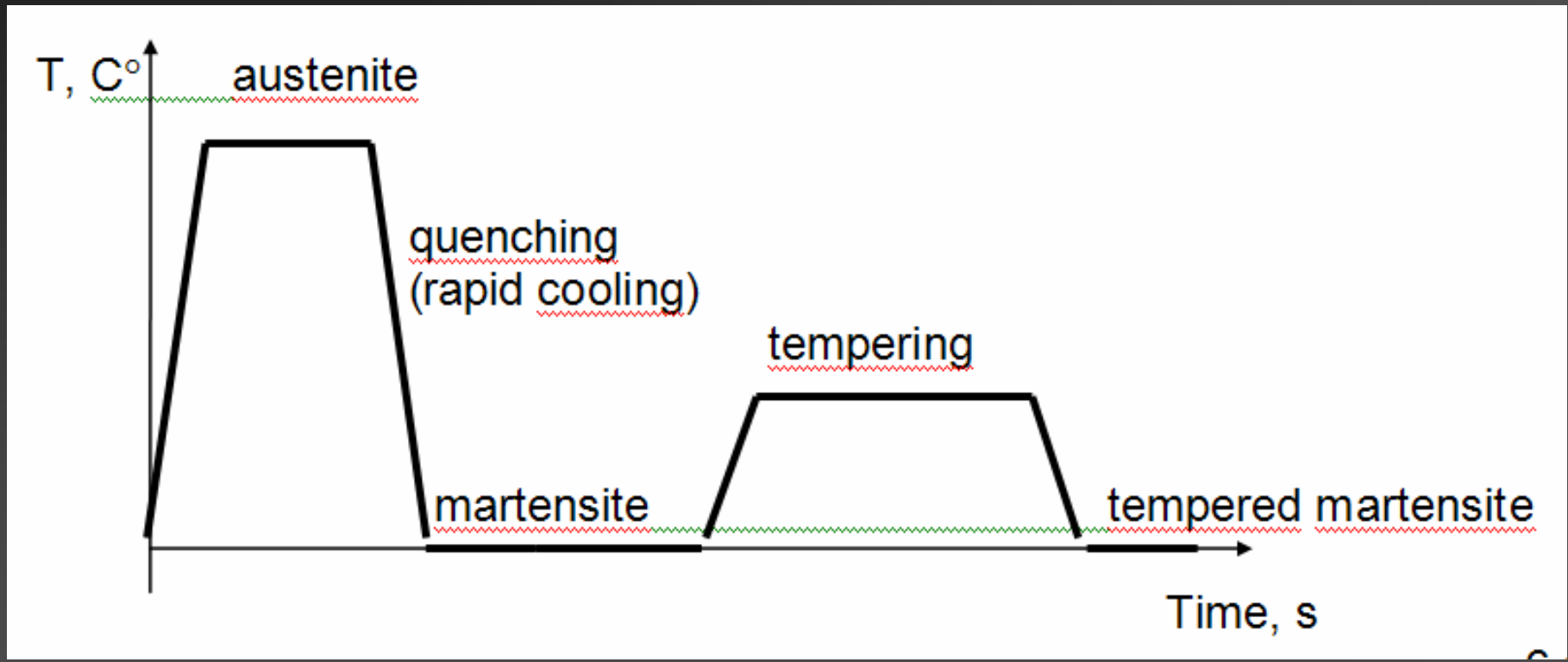
- If tempered for a long time, Fe3C forms “spheres” and grows inside Ferrite.
- Very soft, easy to machine



Tempering Demonstration

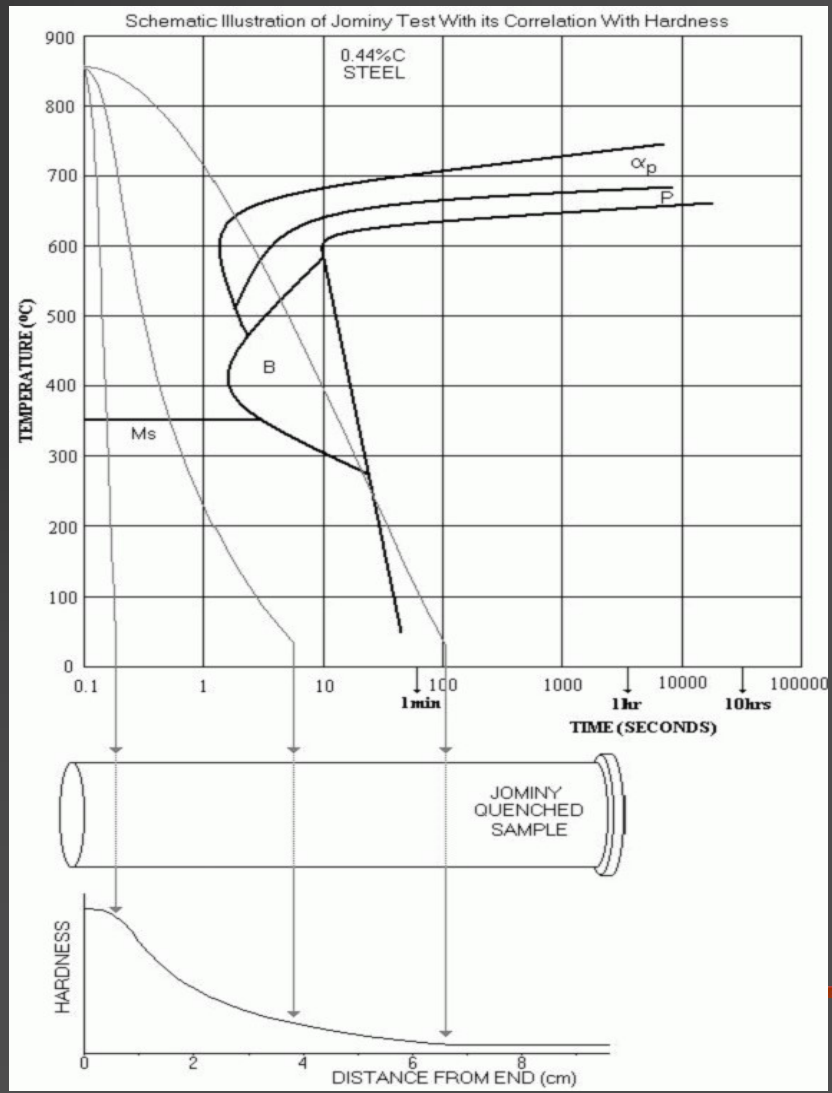
- Observe Steel Wire Experiment…
  - What causes wire to sag on heating?
  - When cooling, wire gets tight, then sags again. Why?
  - Why does steel snap like chalk when cooled fast, but tempering restores “strength”?

Quenching and tempering process



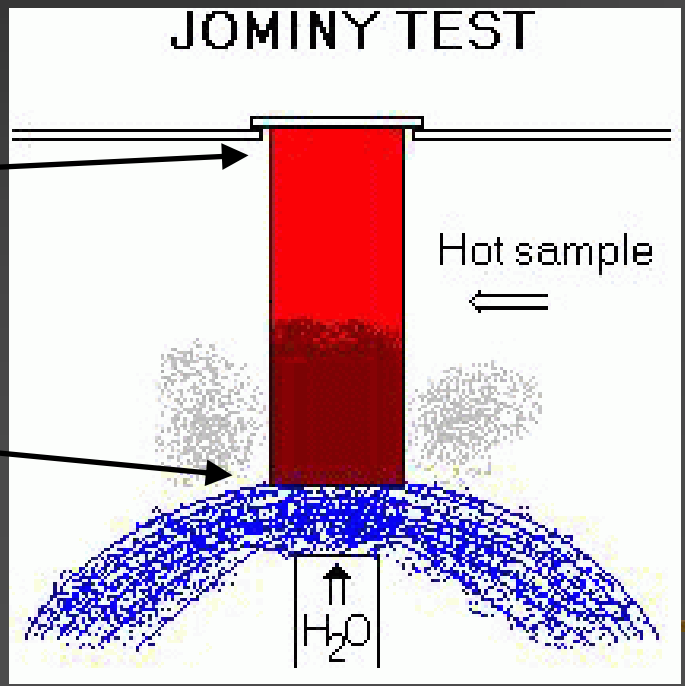
So What is “Hardenability”?

- Jominy Bar used to show how cooling rate affects hardness
- Alloyed steels (Cr, Mo, Ni, etc.) have higher hardenbility at same cooling rates than carbon steels



Jominy Test

Generally, the faster steel cools, the harder it will be. The Jominy bar measures the hardenbility of a steel



Typical Jomminy Curves

- 4340: Very hardenable, More expensive
- 1040: Less hardenable, Less expensive