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# Tensile Strength and Hardness of Steel

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# Pacific Metallurgical Inc.

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- Heat treatment company
- Aerospace and Automobile parts
- Vacuum heat treating
- Metal Test Inc.





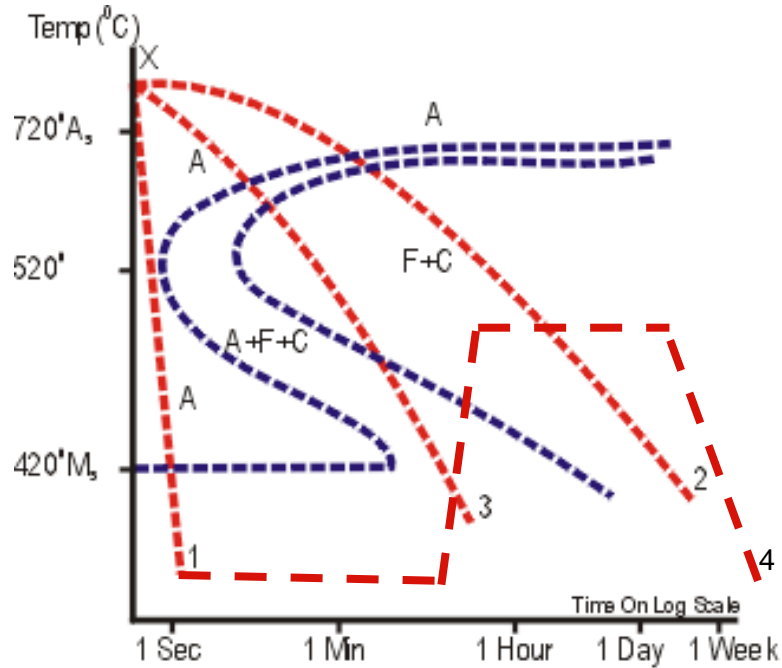
# Steel Background

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- Steel is an alloy of iron and other elements, primarily carbon
- Adding impurities and performing heat treatment can be used to control the hardness and tensile strength of steel



# Time-Temperature Transformation Diagrams



- 1- Quenching
- 2- Annealing
- 3- Normalizing
- 4- Tempering

# Thermochemical Processes

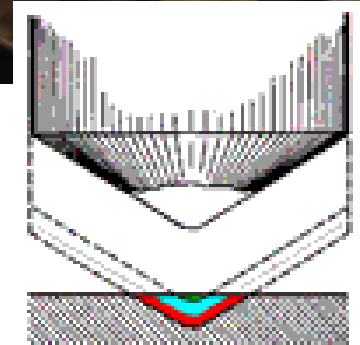
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- Carburizing
- Nitriding



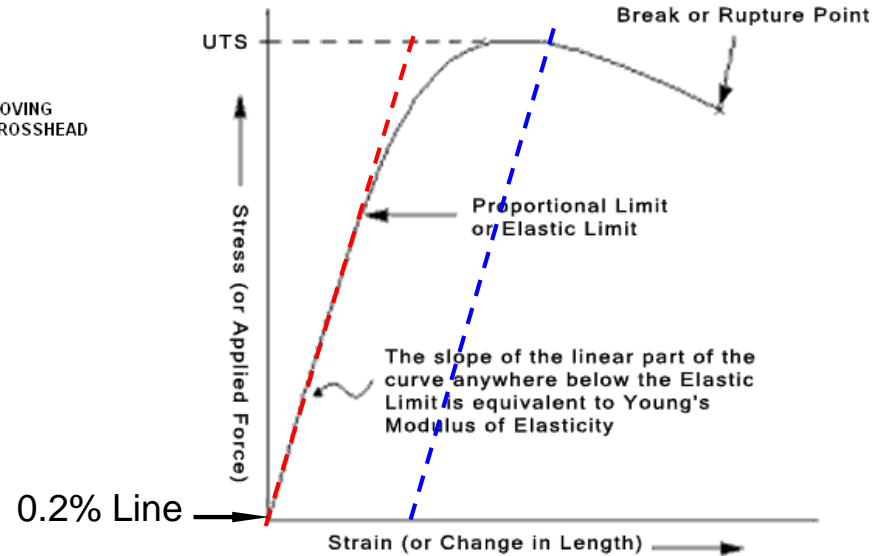
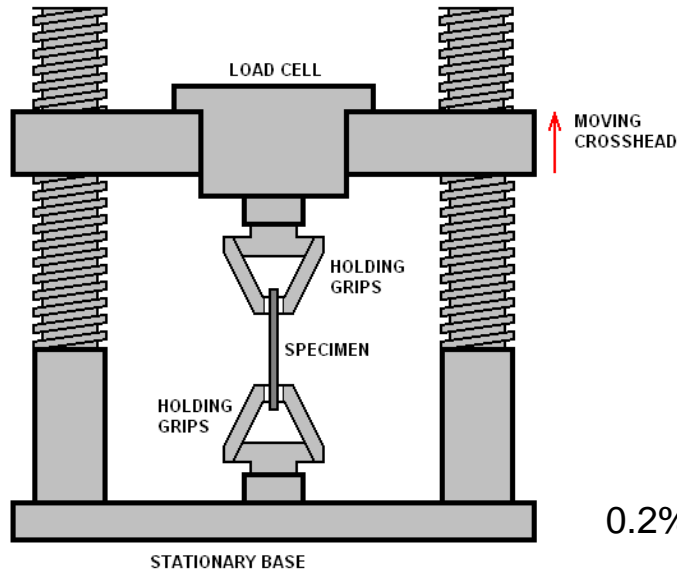
# Hardness Testing

- Hardness is “one of several measures of resistance to indentation, deformation, or abrasion.”
- The Rockwell hardness test is used to find the hardness of materials
- Minor load is 10 kgf, the major load is 60 (HRA), 100 (HRB), or 150 (HRC) kilogram-force.
- 1kgf  $\approx$  2.2 pounds of force



# Tensile Testing

- Tensile testing, also known as tension testing, is used to find the “the resistance of a material to breaking under tension.”

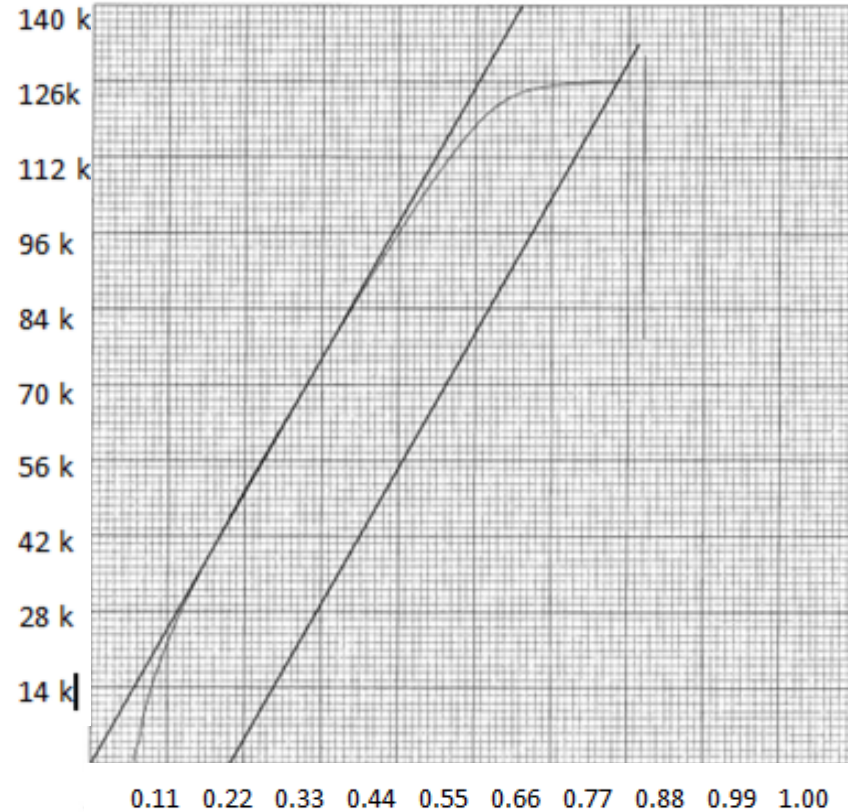


# Sample A

Temperature (F)

1250 ± 10

	Tensile KSI	Rockwell Hardness
Actual	130.8	27.7 HRC







# Results of All Samples

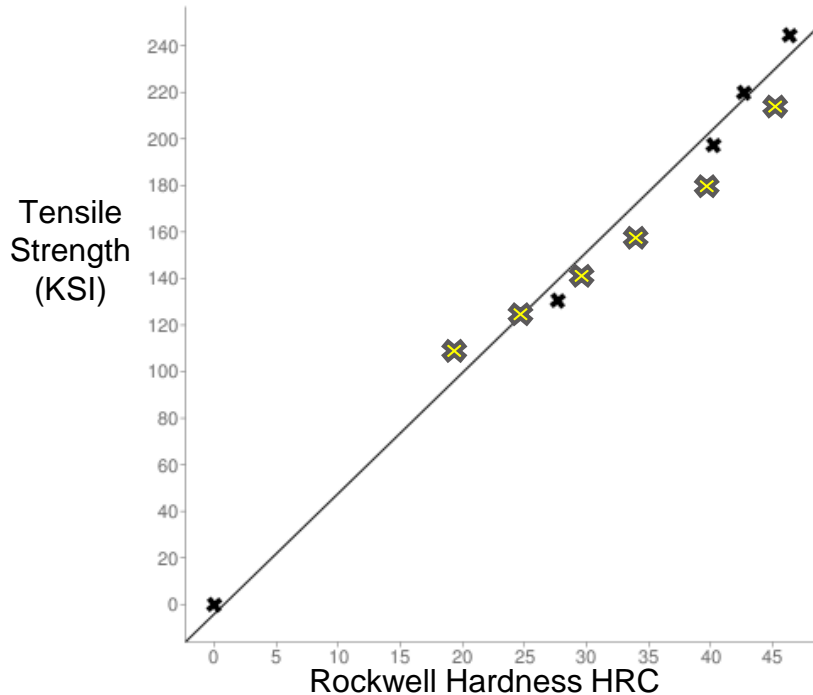
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	A	B	C	D
Tempering Temp	1250 ± 10	950 ± 10	750 ± 10	575 ± 10
Tensile Strength	130.8	197	219.7	244.6
Hardness (HRC)	27.7	40.17	42.63	46.37

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# Summary of Results

## Rockwell Hardness and Tensile Strength Correlation



**Measured** and Expected Values

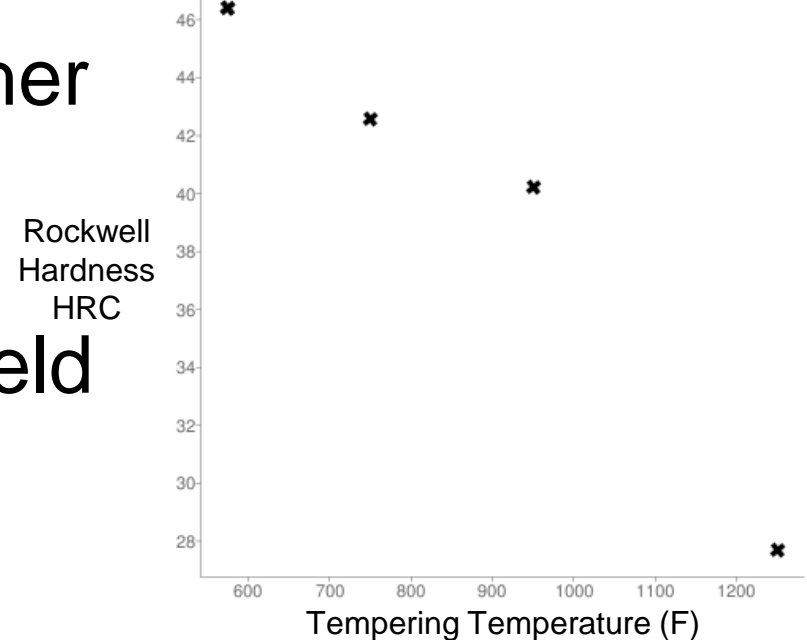
Approx. Tensile Strength (ksi)	HRC
351, 338, 325, 313, 301	59, 58, 57, 56, 55
292, 283, 273, 264, 255	54, 53, 52, 51, 50
246, 238, 229, 221, 215	49, 48, 47, 46, 45
208, 201, 194, 188, 182	44, 43, 42, 41, 40
177, 171, 166, 161, 156	39, 38, 37, 36, 35
152, 149, 146, 141, 138	34, 33, 32, 31, 30
135, 131, 128, 125, 123	29, 28, 27, 26, 25
119, 117, 115, 112, 110	24, 23, 22, 21, 20

# Other Trends

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- Metals treated at lower temperatures have higher tensile strength and Rockwell hardness
- Higher temperatures yield softer metals

Tempering Temperature vs. Rockwell Hardness



# Sources

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- <http://www.chemistryexplained.com/St-Te/Steel.html>
  - [http://www.azom.com/article.aspx?ArticleID=543#\\_The\\_Hardening\\_Processes](http://www.azom.com/article.aspx?ArticleID=543#_The_Hardening_Processes)
  - <http://www.instron.com/en-us/our-company/library/test-types/hardness-test/rockwell-hardness-test?region=North%20America>
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  - [www.dictionary.reference.com](http://www.dictionary.reference.com)
  - [www.instron.com](http://www.instron.com)
  - <http://www.alcula.com/calculators/statistics/scatter-plot/>
  - Data from tensile and Rockwell testing at Pacific Metallurgical
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