Tempil®

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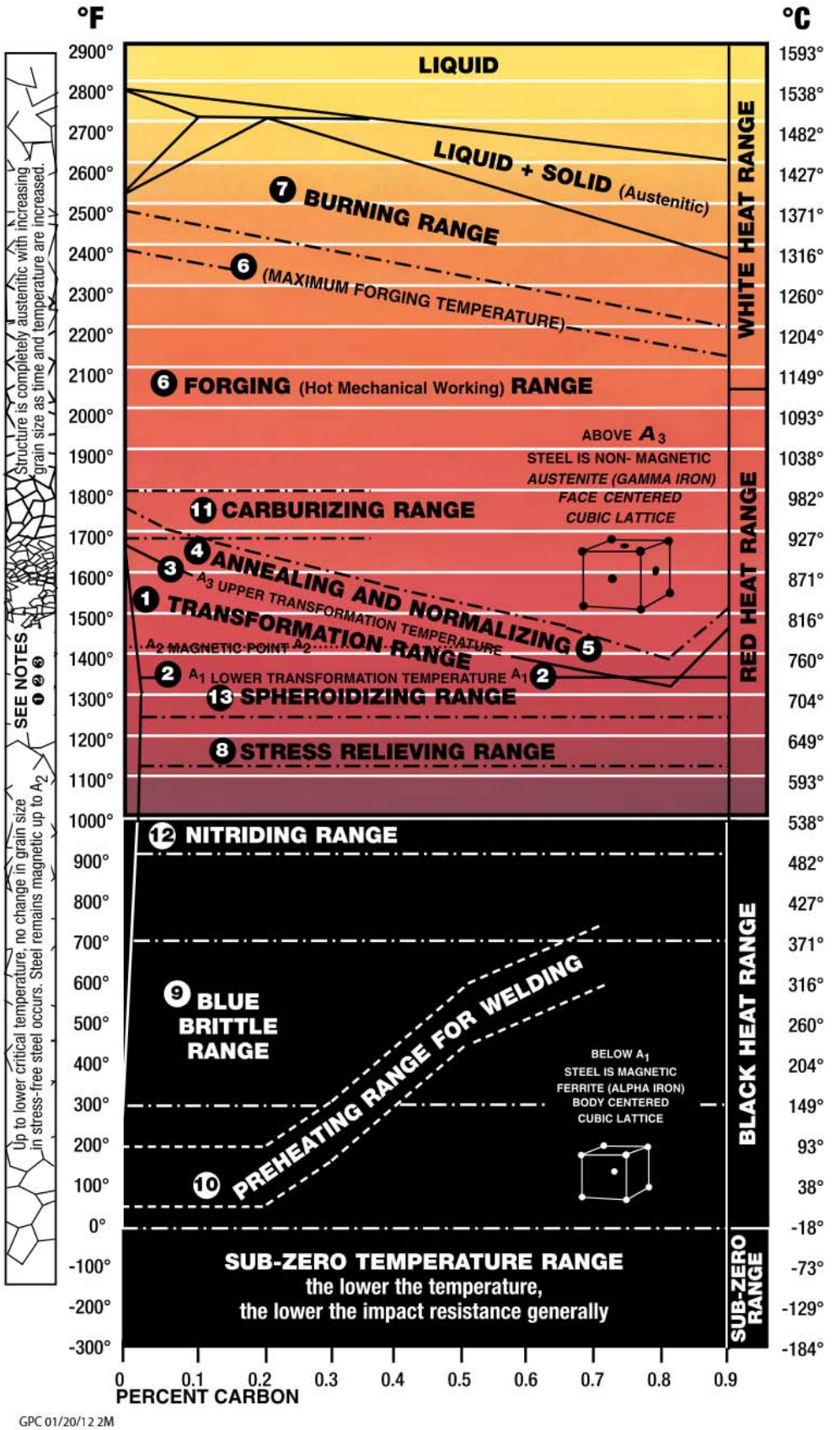
Basic Guide to Ferrous Metallurgy

50 years Basic Guide

50th Anniversary Commemorative Edition



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1. **TRANSFORMATION RANGE** In this range steels undergo internal atomic changes which radically affect the properties of the material.
2. **LOWER TRANSFORMATION TEMPERATURE (A_1).** Termed Ac_1 on heating, Ar_1 on cooling. Below Ac_1 structure ordinarily consists of FERRITE and PEARLITE (see below). On heating through Ac_1 these constituents begin to dissolve in each other to form AUSTENITE (see below) which is non-magnetic. This dissolving action continues on heating through the TRANSFORMATION RANGE until the solid solution is complete at the upper transformation temperature.
3. **UPPER TRANSFORMATION TEMPERATURE (A_3).** Termed Ac_3 on heating, Ar_3 on cooling. Above this temperature the structure consists wholly of AUSTENITE which coarsens with increasing time and temperature. Upper transformation temperature is lowered as carbon increases to 0.85% (eutectoid point).

- **FERRITE** is practically pure iron (in plain carbon steels) existing below the lower transformation temperature. It is magnetic and has very slight solid solubility for carbon.
- **PEARLITE** is a mechanical mixture of FERRITE and CEMENTITE.
- **CEMENTITE** or IRON CARBIDE is a compound of iron and carbide, Fe_3C.
- **AUSTENITE** is the non-magnetic form of iron and has the power to dissolve carbon and alloying elements.

4. **ANNEALING,** frequently referred to as FULL ANNEALING, consists of heating steels to slightly above Ac_3, holding for AUSTENITE to form, then slowly cooling in order to produce small grain size, softness, good ductility and other desirable properties. On cooling slowly the AUSTENITE transforms to FERRITE and PEARLITE.
5. **NORMALIZING** consists of heating steels to slightly above Ac_3, holding for AUSTENITE to form, then followed by cooling (in still air). On cooling, AUSTENITE transforms giving somewhat higher strength and hardness and slightly less ductility than in annealing.
6. **FORGING RANGE** extends to several hundred degrees above the UPPER TRANSFORMATION TEMPERATURE.
7. **BURNING RANGE** is above the FORGING RANGE. Burned steel is ruined and *cannot be cured* except by remelting.
8. **STRESS RELIEVING** consists of heating to a point below the LOWER TRANSFORMATION TEMPERATURE, A_1, holding for a sufficiently long period to relieve locked-up stresses, then slowly cooling. This process is sometimes called PROCESS ANNEALING.
9. **BLUE BRITTLE RANGE** occurs approximately from 300° to 700°F. Peening or working of steels should not be done between these temperatures, since they are more brittle in this range than above or below it.
10. **PREHEATING FOR WELDING** is carried out to prevent crack formation. See TEMPIL® PREHEATING CHART for recommended temperature for various steels and non-ferrous metals.
11. **CARBURIZING** consists of dissolving carbon into surface of steel by heating to above transformation range in presence of carburizing compounds.
12. **NITRIDING** consists of heating certain *special steels* to about 1000°F for long periods in the presence of ammonia gas. Nitrogen is absorbed into the surface to produce extremely hard "skins".
13. **SPHEROIDIZING** consists of heating to just below the lower transformation temperature, A_1, for a sufficient length of time to put the CEMENTITE constituent of PEARLITE into popular form. This produces softness and in many cases good machinability.

- **MARTENSITE** is the hardest of the transformation products of AUSTENITE and is formed only on cooling below a certain temperature known as the M_S temperature (about 400° to 600°F for carbon steels). Cooling to this temperature must be sufficiently rapid to prevent AUSTENITE from transforming to softer constituents at higher temperatures.
- **EUTECTOID STEEL** contains approximately 0.85% carbon.
- **FLAKING** occurs in many alloy steels and is a defect characterized by localized micro-cracking and "flake-like" fracturing. It is usually attributed to hydrogen bursts. Cure consists of cooling to at least 600°F before air-cooling.
- **OPEN OR RIMMING STEEL** has not been completely deoxidized and the ingot solidifies with a sound surface ("rim") and a core portion containing blowholes which are welded in subsequent hot rolling.
- **KILLED STEEL** has been deoxidized at least sufficiently to solidify without appreciable gas evolution.
- **SEMI-KILLED STEEL** has been partially deoxidized to reduce solidification shrinkage in the ingot.
- **A SIMPLE RULE:** Brinell Hardness divided by two, times 1000, equals approximate Tensile Strength in pounds per square inch. (200 Brinell ÷ 2 x 1000 = approx. 100,000 Tensile Strength, p.s.i.).