Heat Treatment

**Hardening:**

The basic purpose of hardening is to produce a fully Martensite structure.

We have known previously that (\( \gamma \)) (f.c.c) will become (\( \alpha \))(b.c.c) .......

by Cooling (slow or moderate)

Nucleation.

Growth of nucleus.

\( \gamma \) \( \rightarrow \) \( M \) (Martensite) by rapid cooling.

\( M \) - Supersaturated Solid Solution of (C) trapped in body–centered Tetragonal structure (\( b\text{–}c\text{.}t \)), the highly distorted lattice structure

high hardness Martensite \( M \) – appear microscopically as white needlelike or a circular structure.

**Carbon (Solute) in Iron (Solvent) forms the basis for hardening steel.**

**Distorted lattice structure:** will exist in the region of the solute atom. This is the primary basis for the strengthening of a metal by alloying.
The Transformation is:

- Diffusionless (no change in chemical composition).
- Proceed only during cooling and ceased if cooling is interrupted.
- Depend on Temp. decrease and is independent on time.
- Thermal is opposite of Isothermal (transformation at constant Temp.).
- Can’t be suppressed.
- Is never completed and small amount of retained $\gamma$ will remain even at low Temp.

$M_s$: The temp. of the start of (M) formation can be changed by cooling rate and it is a function of chemical composition only.

$M_s$ formula: -

$$M_s = 1000 \ (\degree F) - (650 \times \% \ C) - (70 \times \% \ Mn) - (35 \times \% \ Ni) - (70 \times \% \ Cr) - (50 \times \% \ Mo)$$

$M_f$: (The Temp. of the end of (M) formation (see fig. 6).

Fig. (6): Influence of % C on (M) range.
**Critical cooling rate (C. C. R):** is the minimum cooling rate (°f/sec) that will avoid the formation of any of softer product of transformation and it is depend on:  
\[ \text{Chemical composition.} \]
\[ \gamma \text{ grain size.} \]

**Isothermal – Transformation Diagram (I. T. D):**

The steps that is usually followed to determine an (I. T. D) are:

1) *Prepare a large number of samples cut from the same bar (0.8%C), the samples are wire threaded through a hole.*

2) *Place the samples in a furnace at Temp. of (1425 °f) for a large enough time.*

3) *Then place the samples in a molten – salt bath which is hold at a constant subcritical Temp. (below A_1, (see fig. 1)), say 1300 °f.*

4) *Repeating step (3) for a varying time interval in the molten – salt bath, then each group of the samples is quenched in cold water (C. W.).*

5) *After cooling, each sample is checked for hardness & studied microscopically.*

6) *The above steps are repeated at different subcritical Temp. until sufficient points are determined to plot the curves of I. T. diagram.*

**Steps (3, 4, 5) above are shown schematically in fig. (7) below:**
Fig. (7): The progress of (g) transformation to coarse Pearlite at 1300 °f as related to the structure at room temp. (R_T).
The typical Isothermal Transformation Curves at 1300 °f and several microstructure are shown in fig. (8) below:

Fig. (8): The Typical Isothermal – Transformation Curve of (γ → P) at 1300 °f.

- Notice that the transformation from (γ → P) is not linear.
- As a result of this experiment, two points may be plotted at 1300 °f namely the time of beginning & the time for the end of transformation.
The entire experiment is repeated at different subcritical Temp. until sufficient points are determined to draw one curve showing the beginning of transformation & the other curve shows the end of transformation, the dotted curve in between showing 50% transformation, as shown in fig. (9):

**Fig. (10): I. T. Diagram of (0.8% C) Steel.**

The I. T. diagram for (0.8% C) is shown in fig. (10) above.

**Fig. (9): Diagram showing how measurements of Isothermal – Transformation are summarized by the I. T. diagram.**