Heat Treatment

Cooling Curves & I – T Diagram:

- *Cooling Curves is determined by placing thermocouples of at definite location in a steel sample & then measure the variation of Temperature with time.*
- *Consider fig. (11) below, various cooling curves on the I. T, diagram.*
- *Cooling curves (1) shows very slowly rate (annealing), it indicate that material will remain (γ) for a relating long period of time. The transformation will start when the cooling curve crosses the beginning of transformation at point (X_1), the transformation product will be very coarse Pearlite (P) with low hardness (R_c = 15).*
- *Cooling curve (2) illustrate Isothermal or Cycle anneal, this treatment produce a more uniform microstructure and hardness.*
- *Cooling curve (3) is a faster cooling rate than annealing (may be considered as a normalizing), the transformation will start at (X_3) with the formation of a medium (P).*
- *Cooling curve (4) is a slow Oil Quench, the microstructure will be a mixture of medium & fine (P) and with hardness (R_c = 40).*

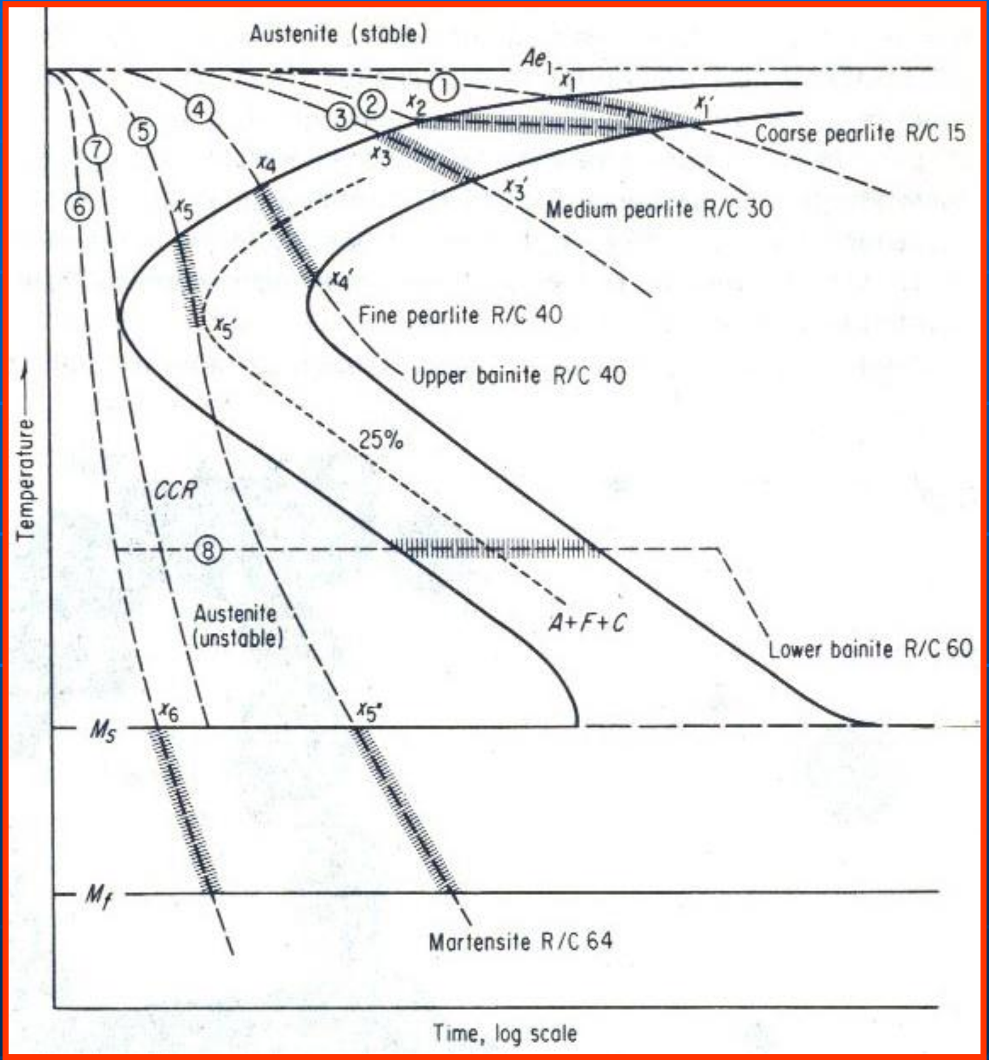

Fig. (11): Cooling Curves on I.T. diagram.

❖ *Cooling curves (5) is an intermediate cooling rate, it will start the transformation at (X_5) to produce fine (P) in a short time, the transformation to fine Pearlite (P) will continue until the curve become tangent to some percentage transformed (say 25%) at (X_5'), below this temp. the cooling curve is going in a direction of decrease percent transformation. Since (P) can't form (γ) on cooling, the transformation must stop (X_5'), the microstructure at this point will consist 25% of fine (P) largely surrounded by (γ) grain.*

It will remain in this condition until the (M_s) line is crossed at (X_5''), the remaining (γ) will transform to (M), and the final microstructure at Room temp. (R_T)will (75% M + 25% P (fine modular).

❖ *Cooling curve (6) (Drastic Quench) is rapid enough to avoid transformation in the nose region. It remains (γ) until the (M_s) line is reached at (X_6). Transformation to (M) will take place between the (M_s) & (M_f) line, the final microstructure will be entirely (M) of high hardness.*

❖ *It is apparent that to obtain fully (M) structure its necessary to avoid transformation in the nose region.*

❖ *It is possible to form 100% (M) or 100% (P) by continuous cooling but its not possible to form 100% Bainite (B).*

❖ *A complete (B) structure may be formed only by cooling rapidly enough to miss the nose of the curve and then holding in the (T) range at which Bainite if formed until transformation is complete, this is illustrated by cooling rate (6) then (8).*

❖ *There are only two factors that will decrease the (CCR) or move the I. T. diagram to the right, these factors are:*

1 – Increasing the %C and % alloying elements.

2 – Coarsing (γ) grain size.

Quenching Medium:

1) Water solution (10% NaCl).
2) Tap water.
3) Liquids salts.
4) Soluble oil.
5) Oil bath.
6) Air.

Hardenability: The property that determines the depth & distribution of Hardness induced by quenching (in a Ferrous alloy).

Hardenability Test (Jominy Test):

❖ (1 in.) round specimen (4 in.) long is heated uniformly to (γ) temp.

❖ Removed form the furnace and placed on a fixture where a jet of water is impinged on the bottom face of the specimen (see fig. 12), so that every specimen quenched in the fixture receives the same rate of cooling.

❖ After (10) min. on the fixture the specimen is removed and two parallel flat surfaces are ground longitudinally to a depth of 0.015 in. (4 mm).

❖ Rockwell C (R_c) scale hardness reading are taken at (/16 in.) interval from the quenched end.

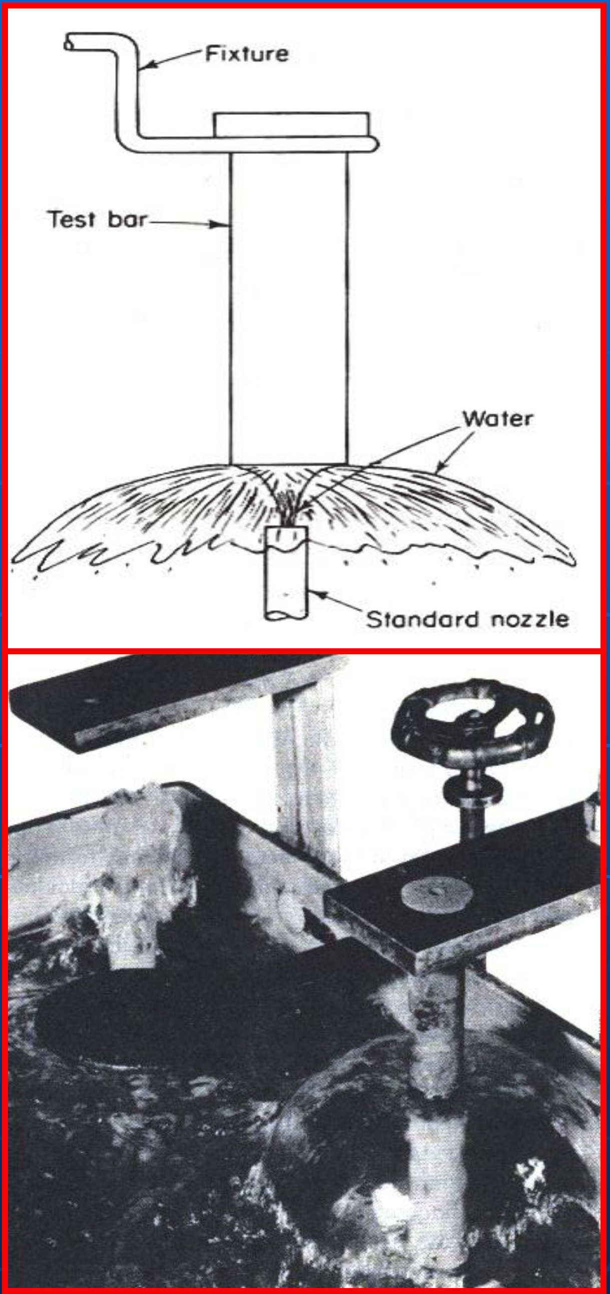

Fig. (12): Jominy Test.

- The results are expressed as a curve of hardness values versus distance from the quenched ends as shown in fig. (13).
- Each location on the Jominy test piece represents a certain cooling rate see fig. (14).

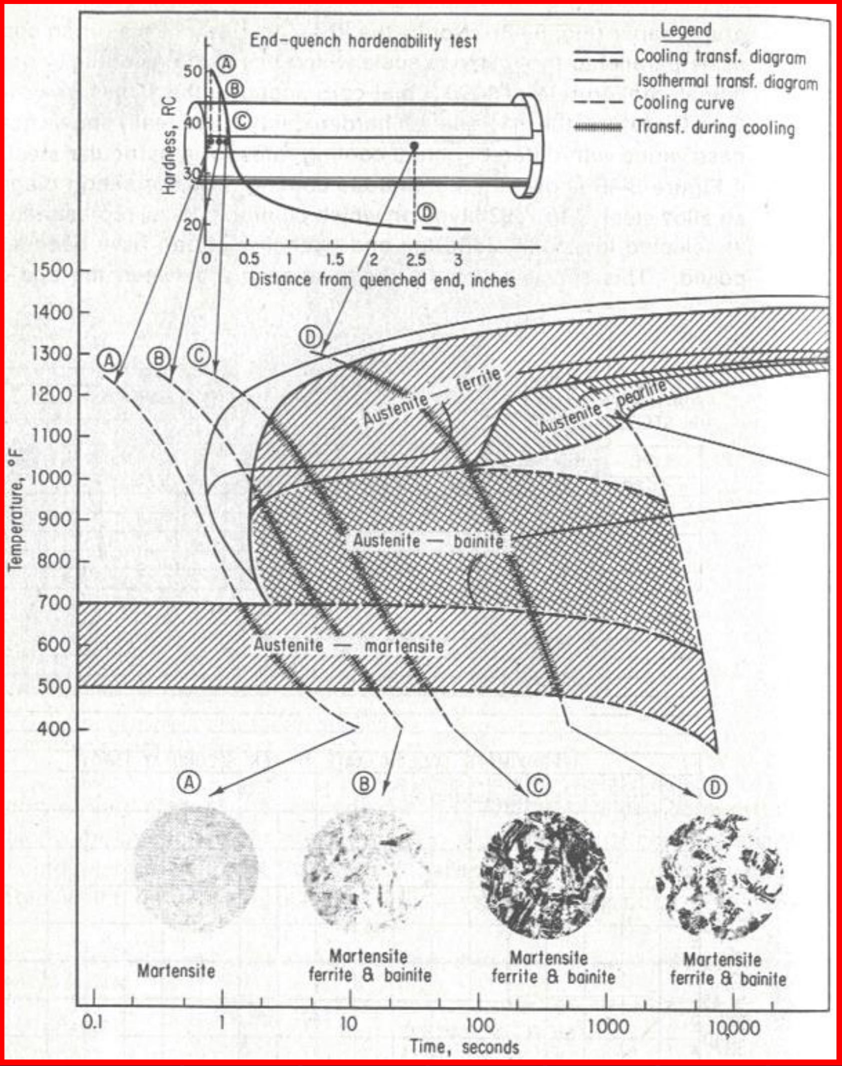

Fig. (14)

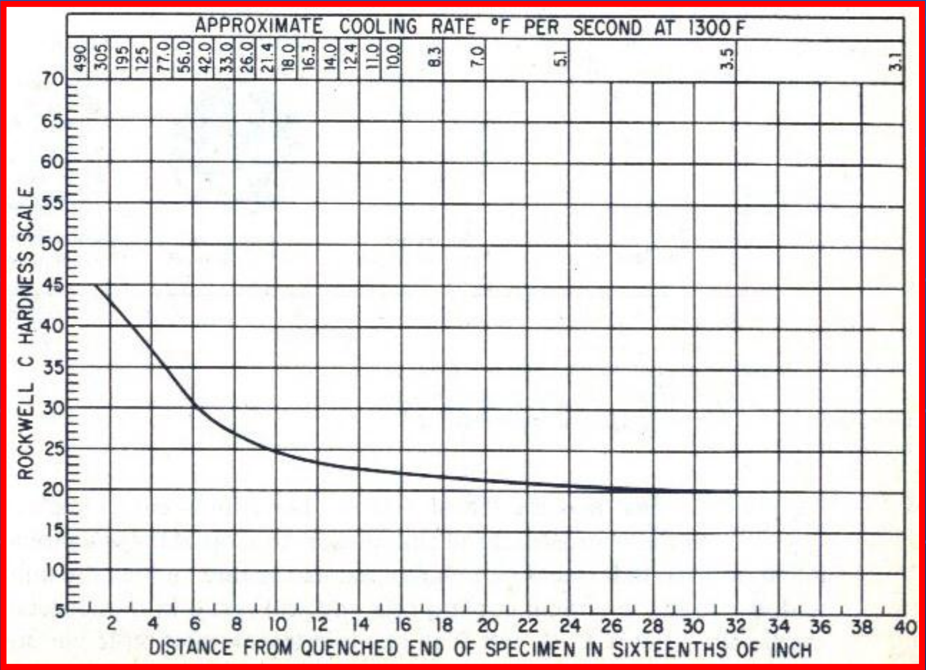

Fig. (13)