HEAT TREATMENT OF ROLLS

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INTRODUCTION

Rolls are typical class of components from the heat treatment point of view. Following types of rolls are manufactured for usages under different set of rolling conditions.

1. **Iron Base Rolls :** Alloy rolls are manufactured to be used in intermediate and finishing stands. Alloy iron rolls are further subdivided into categories mentioned below

1(i) *Clear Chill Rolls (cc rolls)* : These rolls are ordinary cast iron rolls with normal alloying elements like carbon, silicon, manganese, sulphur, and phosphorus. Percentages of silicon, manganese, sulphur are arranged in such away that they give a clear chilled (white) layer on the surface containing cementite and perlite only. Clear chill layer does not contain any graphite speck. Clear chill layer is followed by a thin mottle layer and then a gray structure towards the core of the roll cross-section. These rolls are used in the finishing stands in sheet mill and tin plate rolling and also in several non-metallurgical applications like rubber mixing, oil mills, food processing etc. etc. Clear Chill Rolls do not require any heat treatment.

1(ii) *Indefinite Chill Roll (IC rolls)* : These are alloy iron rolls containing chromium and Nickel besides the normal alloyings present in the cast irons. In these rolls even the top crust contains a few graphite specks. They are used in intermediate stands and in the finishing stands of section rolling. IC rolls do not require any heat treatment.

1(iii) *Indefinite Chill Double Poured Rolls (ICDP Rolls)* :These are double poured rolls where the top layer of the cross section is of IC material upto a predecided depth followed by gray, spharodized gray, steel or any other suitable material as core metal. The IC metal of the crust (shell) is very hard and the method of casting is such that some excess residual casting stresses are likely to be retained in the roll. Therefore these rolls are merely stress-relieved at a temperature of 350ºC-400º C (max) for times ranging from 30-40 hrs. Heating is done very slowly.

1(iv) *Spharodized Gray (SG) Cast Iron Rolls* : These rolls also contain residual stresses due to Magnesium treatment like ICDP rolls. Stress relieving is generally carried out for the acicular variety.

2. **Cast Steel Rolls :** Cast Steel Rolls are made in the important classes as under :

2(i) *Hypoeutectoid Cast Steel Rolls* : These rolls are very heavy rolls used in the roughing stands of plate mills, slabbing mills etc. The casting is done because to get forged roll in the weight range required for these mills are not possible to manufacture for the limitations of the press capacity. These rolls are normalised and tempered. Sometimes mist quenching is also resorted to.

2(ii) *Hyper eutectoid Cast Steel Rolls* : These rolls are quite popular in the rolling rails, beams, sections etc. because by alloying it is possible to maintain the depth of the hardness to a desired depth. Table-1 gives a few cast steel rolls compositions and figure-1 shows the drop of the hardness. These rolls are used in the roughing (later part) and intermediate standards. An elaborate heat treatment is given to these rolls.

3. **Forged Steel Rolls** : Like cast steel rolls forged rolls are also made in hypo as well as hyper (close to 0.8%C) eutectoid compositions. Hypoeutectoid compositions are used in back up rolls whereas hyper eutectoid compositions with carbon upto 0.9% alloyed with

2-5% chromium are used in the work rolls. Back up rolls are volume hardened followed by the induction hardening of the working layer to hardenesses as high as 104-105° Sh C.

4. **Elements of heat treatment of steel rolls:** Most of the rolls are manufactured with carbon in near eutectoid (hypo eutectoid compositions) or in hyper eutectoid compositions with carbon upto 2%. In most of the cases TTT or CCT curves are not available. Figure-2 shows the phases in steel with various percentages of carbon and figure-3 shows the divergence in strength in tension as well as compression. It can be seen that in steels with carbon 0.4% or more metastable phases like retained austenite start appearing in the final structure. So the cast is with the strength. The difference in strength in tension and compression start becoming wider and wider for carbon more than 0.4%. This is one basic reason as to why all critical load bearing and load transmitting components used in machines like shafts, gears, reciprocating links etc. are made from steels having carbon less than 0.4% as in case of EN8 or EN9. In rolls because of the requirements of wear and abrasion resistant coupled with higher UTS the steel compositions are much higher in carbon. This makes the steel very delicate from the heat treatment point of view. On one hand the cross section is massive and on the other hand the thermal conductivities are low. Working requirements do not allow more than 1-2% variation of mechanical properties along the barrel length. Microstructural constraints are also very stringent. Figure-4 and Figure-5 show the TTT curves of two typical hypereutectoid roll compositions. Heat treatment of all the hypereutectoid cast steel rolls is done in oil fired furnaces with gas fired pilot burns to give initial very show heat. There are three main objectives of the heat treatment in case of rolls :

(i) To get homogenised structure across the cross-section
(ii) To minimise the grain size as fine as possible
(iii) To achieve the desired hardness

The rolls are loaded in the hearth of the heat treatment furnace such that the flame never impinges on any part of the roll and there is enough scope for air circulation around the roll. Heating is started with the slow rate with the help of pilot gas burnes. Oil firing is started at around 200°C. Heating is never done beyond the prescribed rate of heating and soaking to homogenise the temperature when temperatures above AC1 are achieved carbides dissolve and in first quenching which is done in still air by unloading the rolls on stands outside the furnace small carbide precipitation occurures on the grain boundaries. The rolls are loaded back to the furnace and the temperature is slowly taken up to above A C1 and this time the quenching is done by unloading the rolls on the stands and putting forced air by mancooler fans. This faster air-cooling refines the grains and precipitates carbides evenly in the globular form. Figures-6 & 7 give two typical heat treatment cycles of the roll. One should notice the rate at heating and the duration of the soaking at various temperature. Tempering cycle towards the end is extremely important to control the properties and in particular the residual stresses.

4(i) *Heat treatment of the forged steel rolls*: Forged steel rolls also fall in two categories. One are for back-up rolls where compositions are on hypoeutectoid side of the Fe-C diagram. These rolls are given the volume hardening treatment. By volume hardening is meant that the entire volume of the rolls is subjected to the heat treatment. The roll is slowly heated in well type furnaces in the usual slow manner and id double normalised like cast steel rolls described above. To meet the hardness requirements many a times mist quenching is given.

The forged steel work rolls are first gives the volume hardening treatment to import proper grain size. micro structure and the hardness to the roll. After volume hardening the working layer is induction hardnessed by low or medium frequency induction hardening machines to import high hardness to it. As per the rule lower the frequency of the induction heater higher is the depth to which it can heat. In induction hardening machine the roll is held vertical. Inductor coil goes around it like a ring. It progressively advances up while it heats the rolls surface and right below are the advancing water jets to quench the heated portion. Figure-8 shows the schematic arrangement to do all this. The rolls thus hardened is tempered in salt bath at 120-150°C for a set duration.

It was pointed out in the beginning that the rolls are always having C in the vicinity of eutectoid composition (0.9%C in case of work rolls) and therefore they do contain a perceptable amount of retained austenite which is a metastable phase. In analysing the premature failures of rolls retained austenitic is attributed to be one of the major contributors. To minimise retained austenite a subzero treatment is given to the induction hardened layer by putting it in liquid nitrogen. All these operations are done under great care by properly shielding the roll with protective netting because the surface many a times is so very much under stress the broken pieces come like shells and can severely injure anybody around.

Like retained austenite is said to have adverse affect on the quality of rolls the other major factor to have adverse effect are residual stresses, whereas to have good grindability (for good surface finish) the surface must have compressive residual stresses upto the working thickness and excess of these stresses reduce the fatigue life of the roll sometimes resulting in the premature catastrophic failure. Although there are no rooms available to set the residual stress to an optimum value, this job should be done by the mutual cooperation between the user and the manufacturer.

5. Conclusion

Heat treatment of rolls is a very specialise class of heat treatment where many operative factors guide the heat treatment. Rate of heating in various temperature ranges, duration of soaking, and quenching operations are all very critical and to achieve them furnace controls and operator's alerness plays a vital role. A knowledge of operating metallurging constraints and mechanical constraints is essential on the part of the manufactures and the users.

Nominal Chemical Composition &
Mechanical Properties

% Chemical Composition						Mechanical Properties				
C	Si	Mn	Ni	Cr	Mo	Tensile Strength Kgf/mm^2	Bending Strength Kgf/mm^2	% Elon-gation	-Hardness Sh °C	Roll Matecial
0.5 -0:7	0.3 -0.5	0.6 0.9	0.6 max	0.8 -1.2	0.2 -0.4	45 - 60	100 - 110	2 - 3	30 - 35	ACS
0.9 1.4	" "	" "	" "	" "	" "	60 - 75	-do-	1 - 2	35 - 45	ASB
1.4 -1.8	" "	" "	" "	" "	" "	50 - 70	80 - 100	1 max	40 - 50	ASB
1.2 -1.5	" "	0.7 -0.9	0.8 -1.0	" "	0.3 0.5	60 - 70	90 - 100	-do-	50 - 55	ASB
S - 0.035 max						P - 0.050 max				

TABLE - 1:

HARDNESS DISTRIBUTION AND NORMAL COMPOSITION OF CAST STEEL ROLLS.

T/

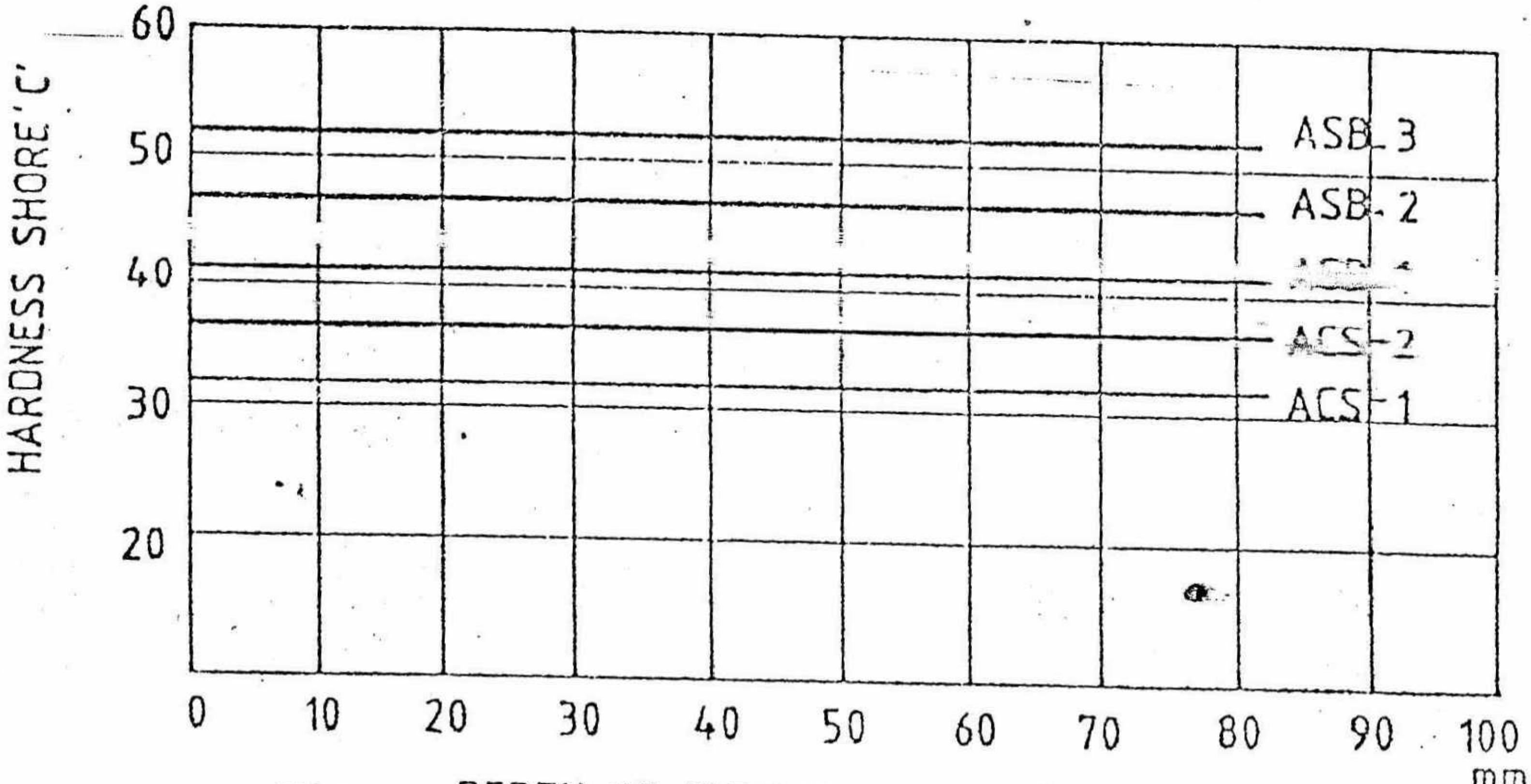


FIG:1: DEPTH OF SURFACE

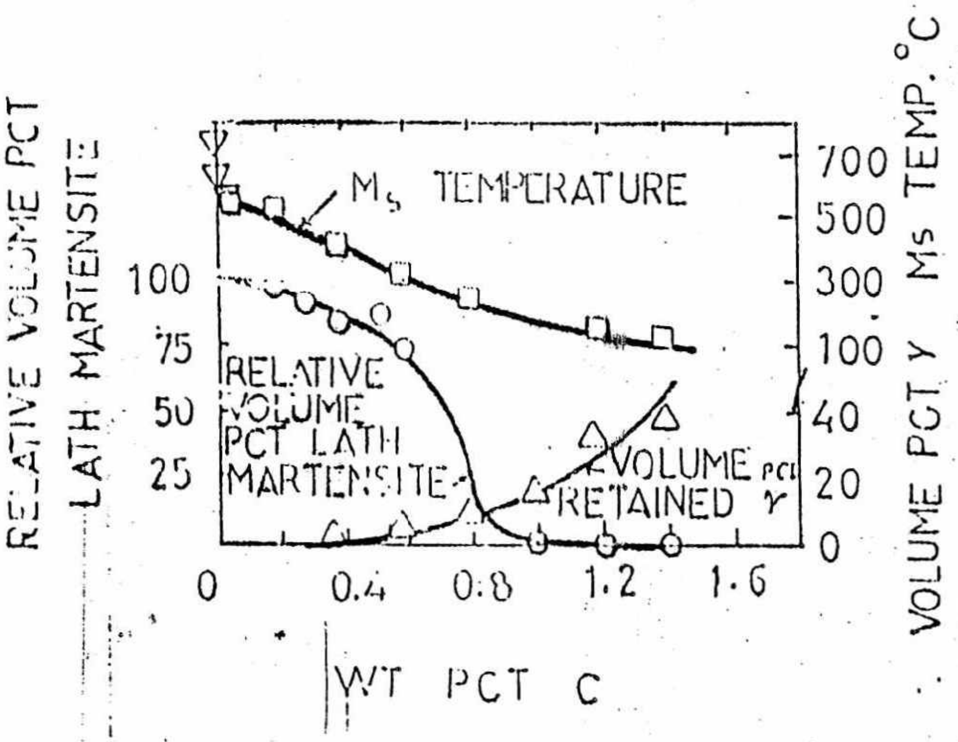


FIG 2: EEFECT OF CARBON CONTENT ON RELATIVE VOLUME PCT OF LATH AND PLATE MARTENSITE Ms TEMPERATURE, AND VOLUME % OF RETAINED AUSTENITE.

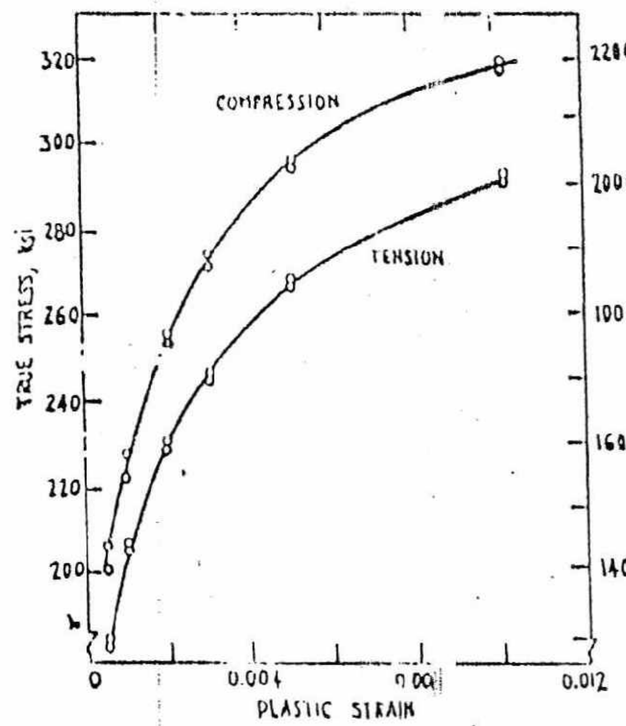


Figure . 4. True stress-plastic strain curves for as-quenched martensite in AISI 4330 steel, obtained from tension-compression specimens.

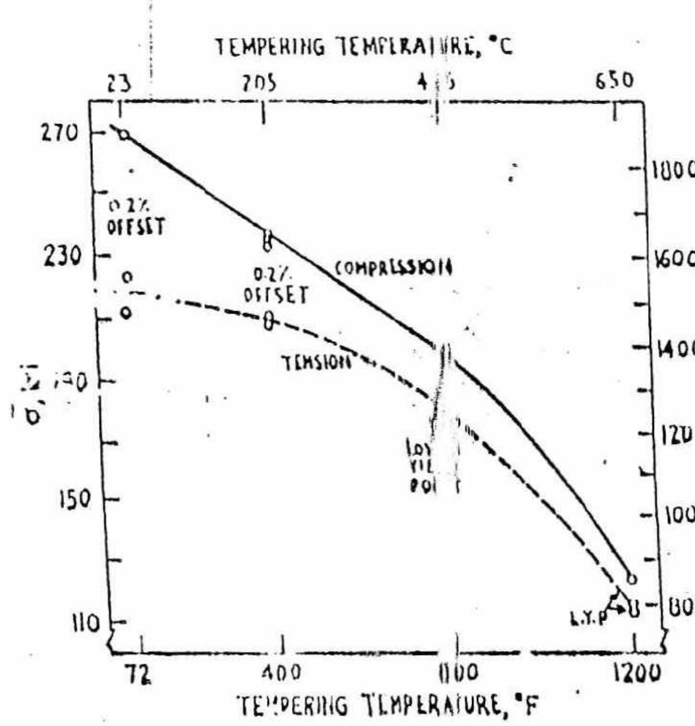
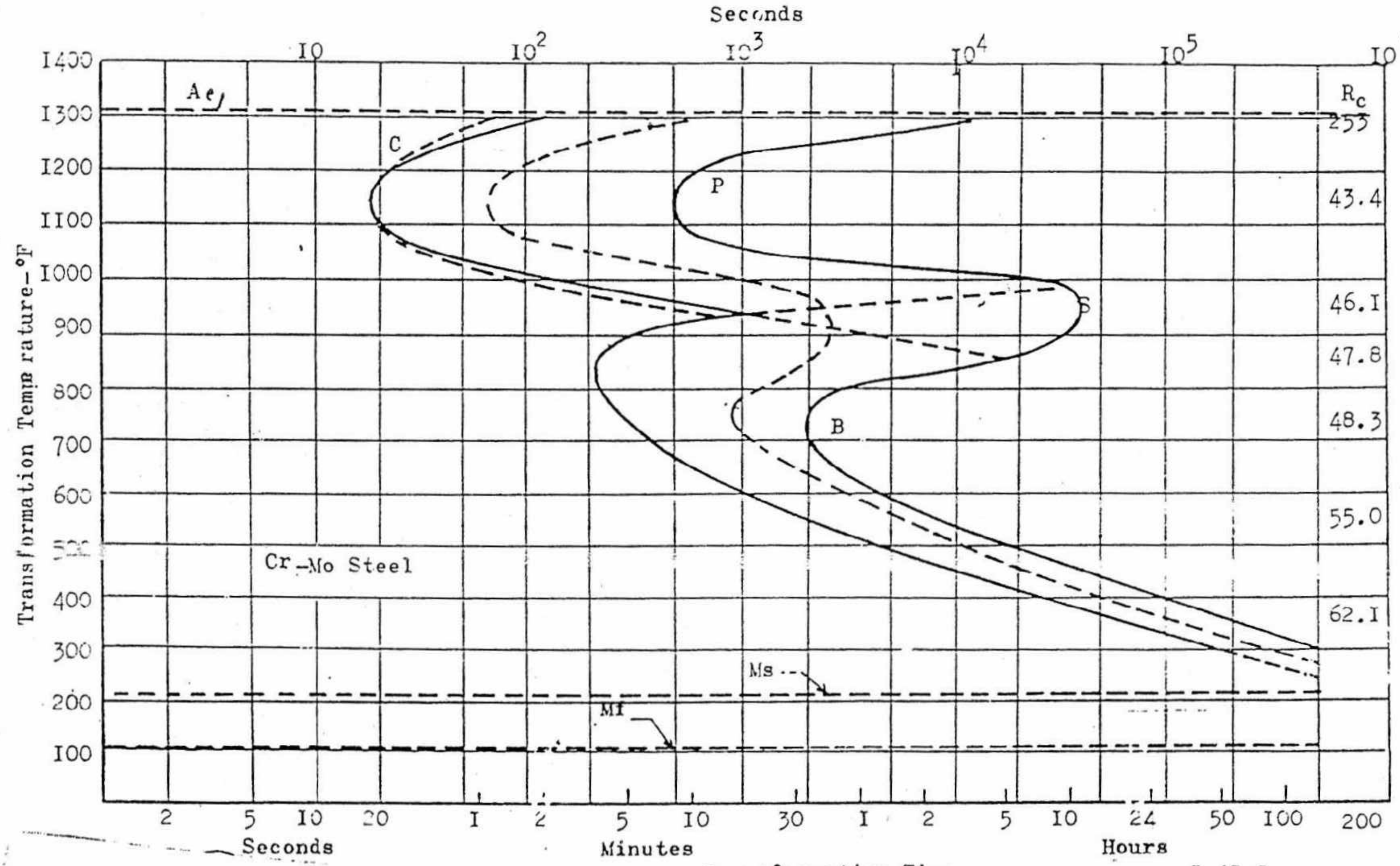


Fig.3: The effect of tempering on the yield strength of AISI 4330.



Transformation Time

Fig.4: T-T-T Diagram for the Chromium-Molybdenum Steel
C- Proeutectoid Carbide
P- Pearlite
B- Bainite
M- Martensite

1.45 C
150 Mn
N
.92 Cr
.51 Mo

Note: Undissolved carbides present in all samples examined.

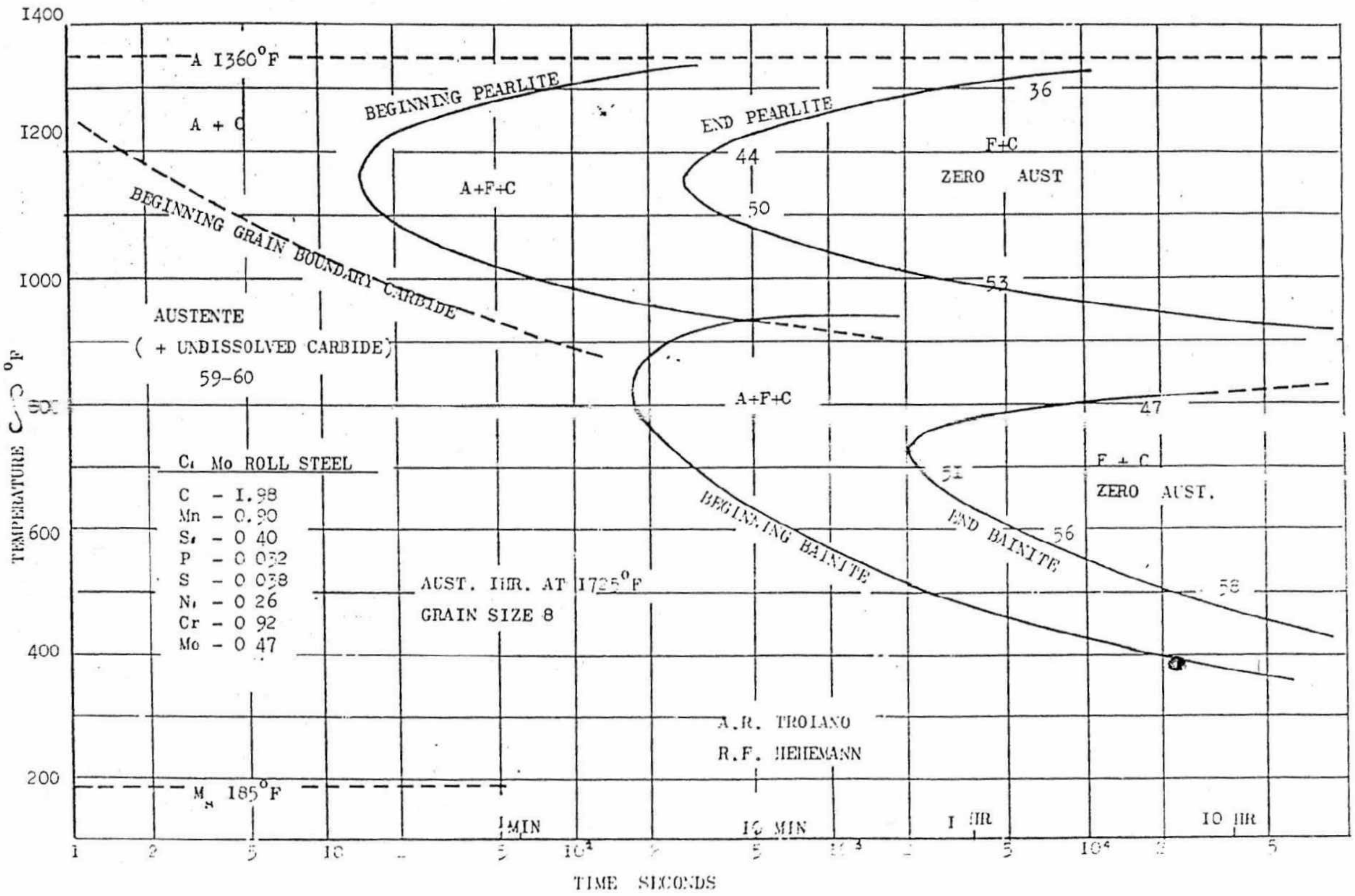


Fig.5: TIME-TEMPERATURE - TRANS...

No. 9

1,577ϕ X 5,619L	C	Si	Mn	P	S	Ni	Cr
	1.52	0.53	0.60		0.021	0.14	0.97

Structure ; Granular Cementite + Sorbite + Pearlite

Hs. 40-45°

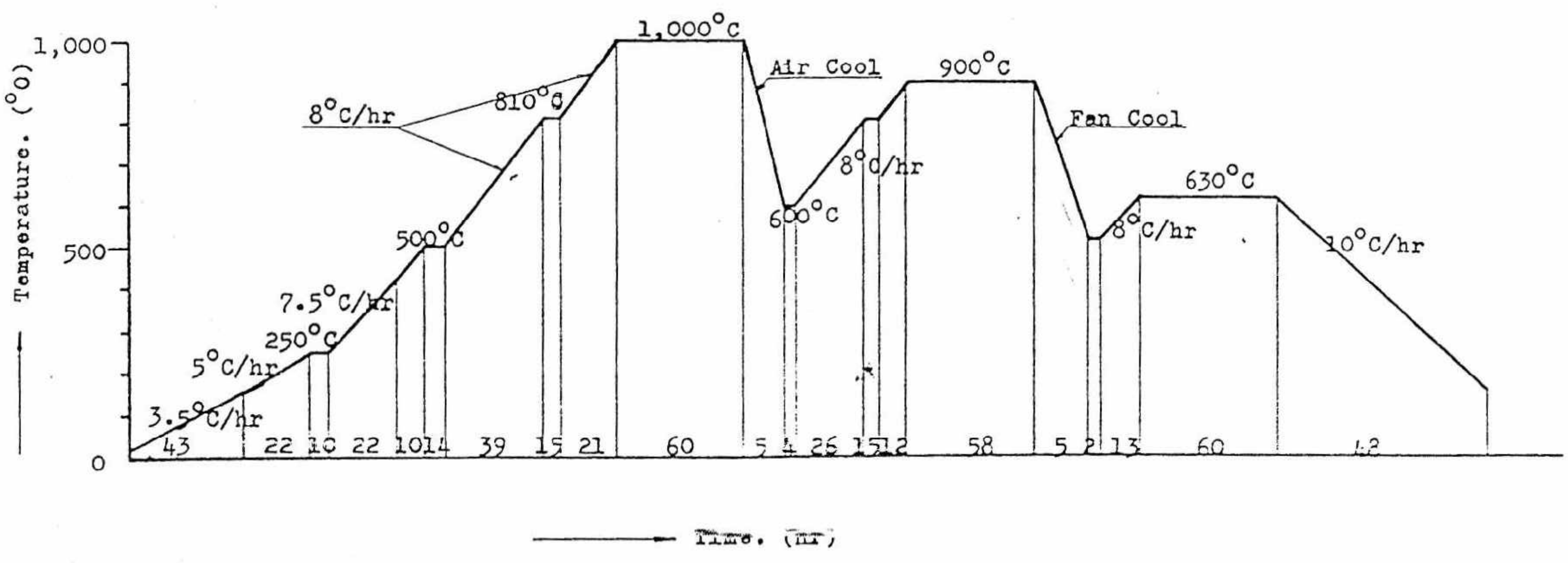


Fig.6

1,170ø X 2,290L

C	Si	Mn	P	S	Ni	Cr	Mo
1.22	0.51	0.81	0.047	0.025	0.47	1.16	0.35

Hs. 40°-43°

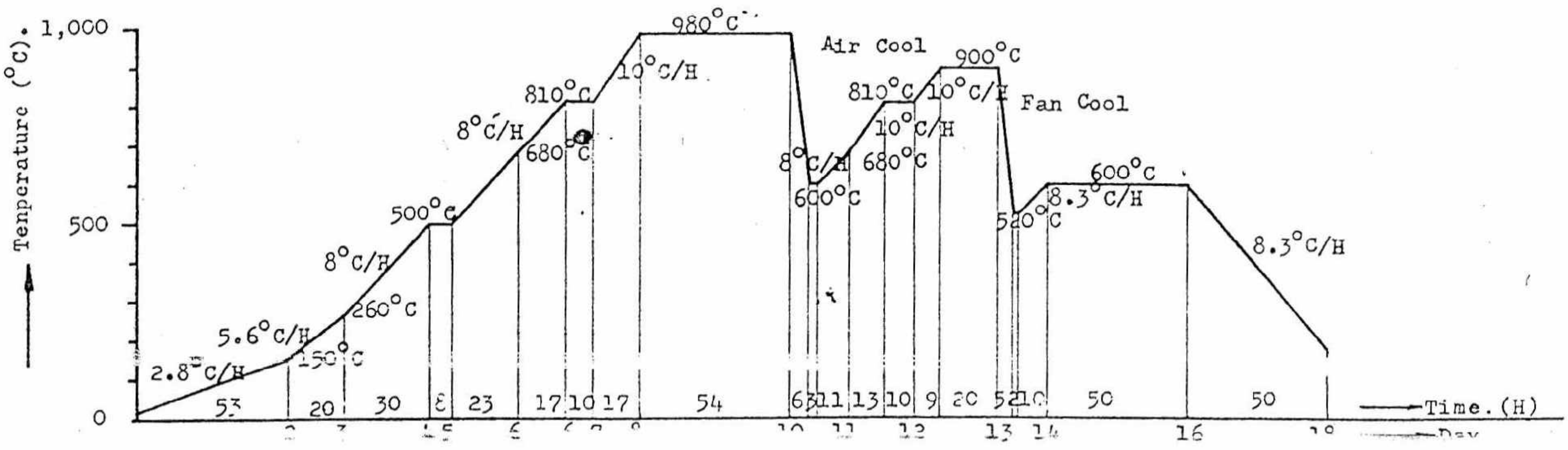
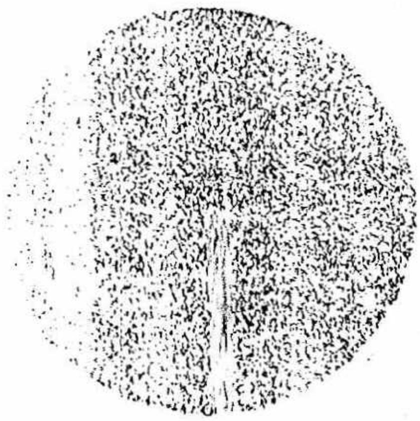
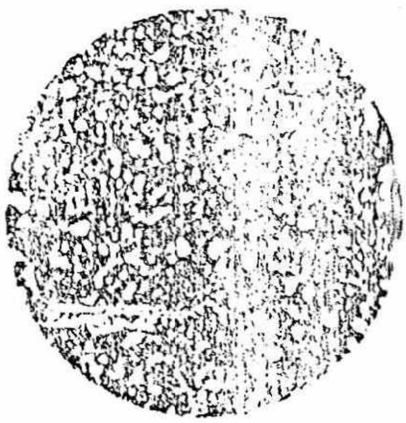


Fig.7:

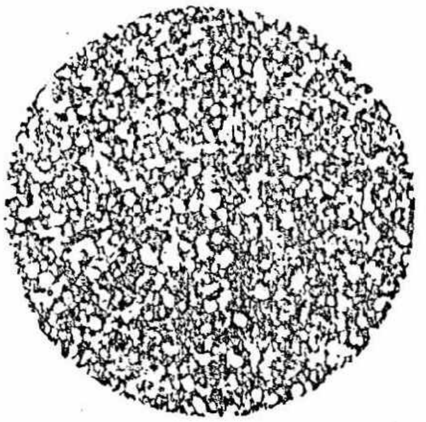
[illegible] - 0.7%



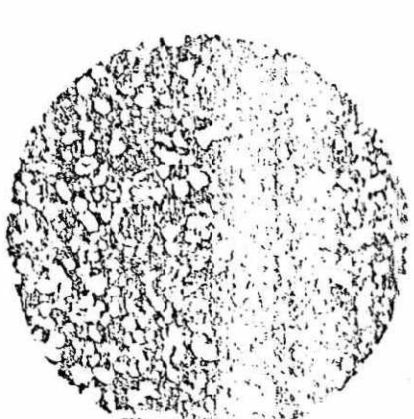
C. 1.3 - 1.4%



C. 1.5 - 1.7%



C. 1.8 - 2.0%



C. 2.0 - 2.2%

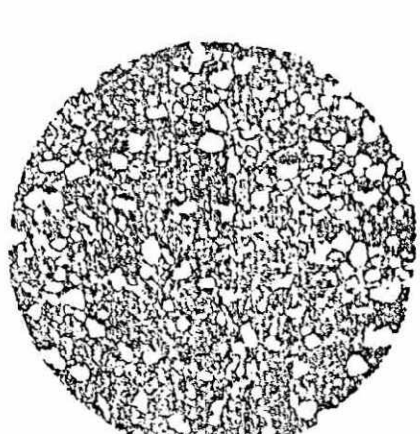


Fig. 8