# Safety Hazards
# Material Processing Laboratory Room 232

**HAZARD:** Rotating Equipment / Machine Tools

Be aware of pinch points and possible entanglement

**Personal Protective Equipment**: Safety Goggles; Standing Shields, Sturdy Shoes
**No:** Loose clothing; Neck Ties/Scarves; Jewelry (remove); Long Hair (tie back)

**HAZARD:** Projectiles / Ejected Parts

Articles in motion may dislodge and become airborne.

**Personal Protective Equipment:** Safety Goggles; Standing Shields

**HAZARD:** Heating - Burn

Be aware of hot surfaces

**Personal Protective Equipment:** Safety Goggles**;** High Temperature Gloves; Welding Apron, Welding Jacket, Boot Gauntlets, Face Shield

**HAZARD:** Chemical - Burn / Fume

Use Adequate Ventilation and/or Rated Fume Hood. Make note of Safety Shower and Eyewash Station Locations.

**Personal Protective Equipment:** Safety Goggles; Chemically Rated Gloves; Chemically Rated Apron

**HAZARD:** Electrical - Burn / Shock

Care with electrical connections, particularly with grounding and not Using frayed electrical cords, can reduce hazard. Use GFCI receptacles near water.

**HAZARD:** High Pressure Air-Fluid / Gas Cylinders / Vacuum

Inspect before using any pressure / vacuum equipment.
Gas cylinders must be secured at all times.

**Personal Protective Equipment:** Safety Goggles; Standing Shields

**HAZARD:** Water / Slip Hazard

Clean any spills immediately.

**EXPERIMENT # 7**

# HEAT TREATMENT

**Goal:** To define the effect of heat treatment on the mechanical properties of offered plain carbon content steels

**Objectives:** To define the influence of cooling speed and heating rate on the mechanical properties of offered plain carbon steels, to study quenchinability of steels, to study effect of carbon concentration on martensite formation, to study the effect of heating temperature on martensite formation, to study effect of tempering on the mechanical properties of suggested steels and to learn hardening methods and tools.

**Equipment & Tools:** Standard Rockwell Hardness Testers & Brinell Hardness Tester, Indentors (penetrators): Ball & Brale, Hardness Standards, Specimen Tables, Ovens, Tongs, Gloves, Tins with water & oil, Surfmet Grinder.

**Conversion Tables and Diagrams:** Equilibrium and Non-equilibrium Diagrams, Conversion Hardness Chart.

**Materials:**
a) High carbon content steel (%C > 0.8)
b) Medium carbon content steel (0.6 > %C >0.4)
c) Low carbon content steel (%C < 0.25)

Each group of students has to complete one experiment on quenching and tempering, to measure the hardness of suggested specimens, to produce the Data Sheet, and to give the answers on the Set of Questions.

*A report has to be prepared according to the requirements of the General Instruction.*

## LABORATORY ASSIGNMENT

***In carrying out your assignment, follow the sequence given below:***

### *WEEK I*

1. Learn the principles of Iron-Iron Carbide Equilibrium Diagram;
2. Learn the effect of equilibrium and non-equilibrium cooling speed on microstructure development;
3. Learn how quenching can be achieved and martensite can be produced;
4. Learn the influence of carbon concentration on martensite formation;
5. Learn how to take readings from the Rockwell hardness tester using B, C & N scales;
6. Learn different Rockwell tester scales and their designations;
7. Learn how the hardness number is found by measuring the vertical movement of a penetrator under a given static load on the specimen;

8. Learn what penetrators and loads have been used in making the Rockwell hardness tests;
9. Learn the difference between the Brinell and Rockwell hardness tests and the method of converting one reading to the other;
10. Learn the microstructure and chemical composition of suggested materials;
11. Take the initial hardness of three low, and four high carbon content steel specimens assigned for these laboratory exercises using the Rockwell Ball Test (scale B) & Brale Test (scale C);
12. Draw the conclusion as to why different specimens exhibit different hardness and plot the hardness vs carbon concentration in steel.
13. Heat low and high carbon content specimens ( one of each) in furnaces at 960, 500, 200$^{o}$C and quench them in water. Also heat one high carbon content specimen at 960 $^{o}$C and quench it in oil;

**WARNING**

When placing the specimens into the furnace one has to consider that the temperature near the furnace door may be lower than that measured by the galvanometer because of the inflow of cold air. Specimens must therefore be placed at the middle of the furnace as close to the thermocouple as possible.

14. Check the hardness of treated specimens by the Rockwell tester ( scale C, load 150kg);
15. Give conclusions about the different hardness obtained after quenching for the specimens heated at different temperatures and cooled in water and oil;
16. Record all obtained results in your data sheet and get approval from the Instructor.

## ***WEEK II***

1. Take four high carbon content steel specimens and check their initial hardness by the Rockwell tester (scale C, load 150kg);
2. Heat the specimens at 960$^{o}$C and quench three of them in water and one in air;
3. Check the hardness by the Rockwell tester (scale C, load 150kg);
4. Explain the difference in hardness on the base of the TTT diagram due to the non-equilibrium cooling process;
5. Learn the difference between quenching and tempering and the purpose of these heat treatment processes;
6. Temper three water quenched specimens at three different temperatures, 500, 400 and 200$^{o}$C and explain the purpose of tempering, also predict the expected results;
7. Check the hardness of each specimen after tempering using the Rockwell tester (scale C, load 150kg) and explain the reasons for the different harnesses;
8. Plot the curve of hardness changes vs. tempering temperatures;
9. Discuss ( on the base of the TTT diagram) the structure changes of all specimens during heat treatment;
10. Convert the average Rockwell hardness numbers to Brinell hardness numbers (BHN) and fill in Table 7- 2;

Use the following empirical relationship between Rockwell and Brinell hardness numbers:

$$BHN = \frac{7{,}300}{130 - R_b} \qquad \text{for } 40 < R_b < 100$$

$$BHN = \frac{1.520{,}000 - 4500R_c}{(100 - R_c)^2} \qquad \text{for } 10 < R_c < 40$$

$$BHN = \frac{25{,}000 - 10(57 - R_c)^2}{100 - R_c} \qquad \text{for } 40 < R_c < 70$$

Where: Rb = Hardness Number on B scale of Rockwell Tester;
Rc = Hardness Number on C scale of Rockwell Tester.

11. Record all obtained results in your Data Sheet and get the Instructor approval;
12. Give the answers to the Set of Questions

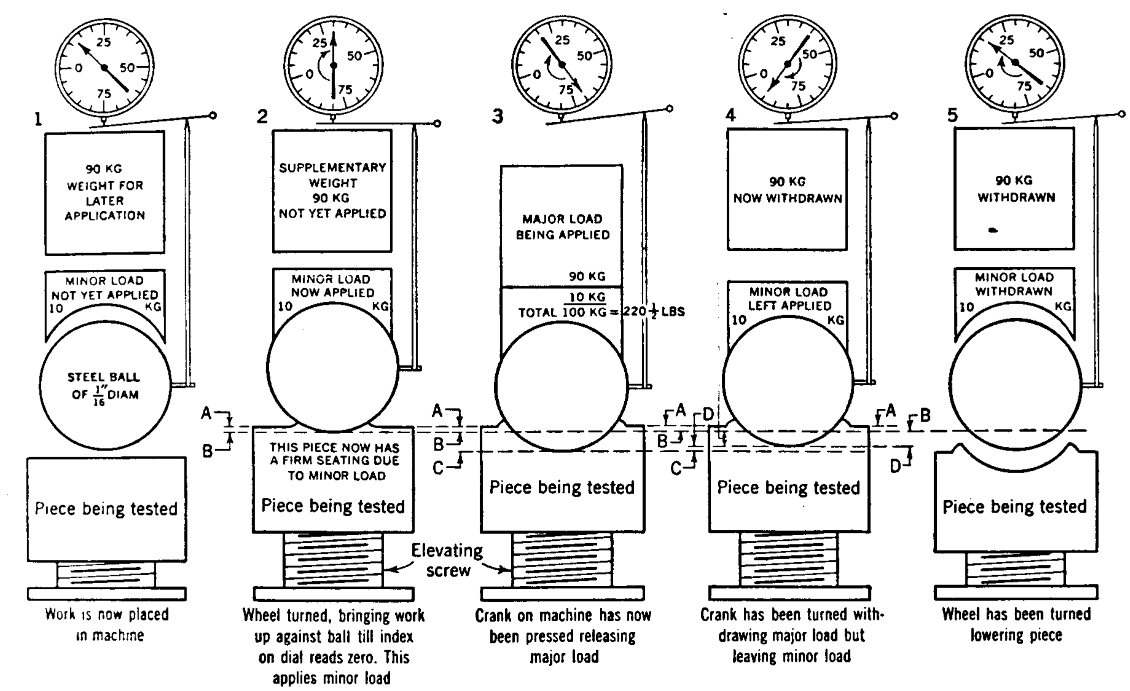



Fig. 7-1 Principle of operation of the Rockwell hardness tester.

# DATA SHEET FOR LAB. # 7

| | GROUP MEMBERS | | GROUP: | Group Leader: | Weeks: | Week 1 | Week 2 |
|---|---|---|---|---|---|---|---|
| | Week 1 | Week 2 | | | | | |
| 1 | | | | | Instructor's Approval | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | | | | | DATE: | | |
| 8 | | | | | | | |

**TABLE 7-1**

| Hardness / Steel | Before Quenching | | After Quenching | | |
|---|---|---|---|---|---|
| | | HRc | Temperature, $^0C$ | | |
| | Scale B | Scale C | 960 | 500 | 200 |
| **High Carbon Content** | | | | | |
| **Low Carbon Content** | | | | | |

**TABLE 7-2**

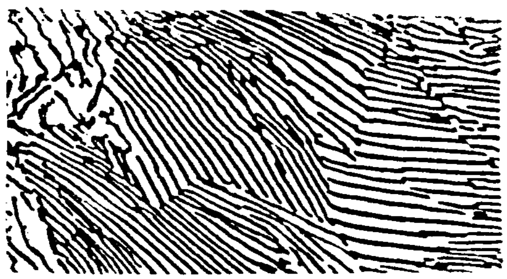
| WEEK TWO | Hardness / Steel | HR Before Quenching | | HRc After Quenching | | | HRc After Tempering | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Scale C | Media | | | Temperature | | |
| | | HRb | HRc | Water | Oil | Air | 500 $^0C$ | 400 $^0C$ | 200 $^0C$ |
| | **High Carbon Content** | | | | | | | | |

# SET OF QUESTIONS

1. Explain why the specimens of steel 1045, after being heated to 700$^{o}$C and 960$^{o}$C and then quenched from that temperature, have different hardness.

   Indicate the differences of obtained microstructure of these specimens after quenching.
2. Explain why the specimens of steel 1025 and 1060, after being heated to 960$^{o}$C and then quenched from that temperature, have different harnesses.
   Indicate the differences in the microstructure of these steels after quenching.

3. Is it possible to get the structure shown below by water quenching from an austenite state?



4. If the hardness of two metals were known, one by a Brinell number and the other by a Rockwell number, would converting one to the other system give a valid comparison of the hardness of the two metals?

5. What is the average hardness of a pearlite structure?

6. Is cementite harder than pearlite? If your answer is negative, give an explanation.

7. Is it true that the structure of hardened steel depends on the steel composition and hardening conditions?

8. What does the casehardening process mean?

9. Define the following heat treatment processes:
   a) normalizing;
   b) full annealing;
   c) process annealing.
   How these processes can be performed and what changes in mechanical properties can they provide?

10. What is martensite?

11. What is the purpose of tempering?

# SUGGESTED LITERATURE

1. E. Paul De Garmo, J.T. Black, R.A. Kohser, Materials and Processes in Manufacturing, $8^{th}$ Edition, Macmillan, NY, 1997.

2. Metals Handbook, Ninth Edition, Vol.1, American Society for Metals, Ohio, 1978.

3. C.A. Keyser, Basic Engineering Metallurgy, $3^{rd}$ Edition, Prentice-Hall, Englewood, NJ, 1969.

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6. M. P. Groover, fundamentals of Modern Manufacturing, Materials, Processes, and Systems, Prentice Hall, Upper Saddle River, NJ, 1996.

7. Herman W. Pollack. Materials Science and Metallurgy, $4^{th}$ Edition, Regents/Prentice Hall, NJ, 1988.