

Materials for Automobiles

Lecture no 4A

11 August 2011

Hardness

Depending on the back ground of the person

- Metallurgist: resistance to indentation/permanent deformation.
- Design engineer: Measure of Flow stress.
- Mechanical engineer: resistance to wear
- Mineralogist; Resistance to scratch

Types of Test

- Static indentation test;
- Indenter(ball, Diamond cone or pyramid)
- Forced into the material being tested.
- Measure of hardness: relationship between, Test force to un recovered area or depth of indentation.
- Rockwell, Brinell, Knoop, Vicker & ultrasonic.

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Types of Test

- Dynamic; An object of standard mass and dimension is bounced from the work piece.
- Measure of hardness: height of bounce.
- Scleroscope and some miscellaneous
- Scratch test: One material is judged as capable of scratching another.
- Mohs scale, file hardness test

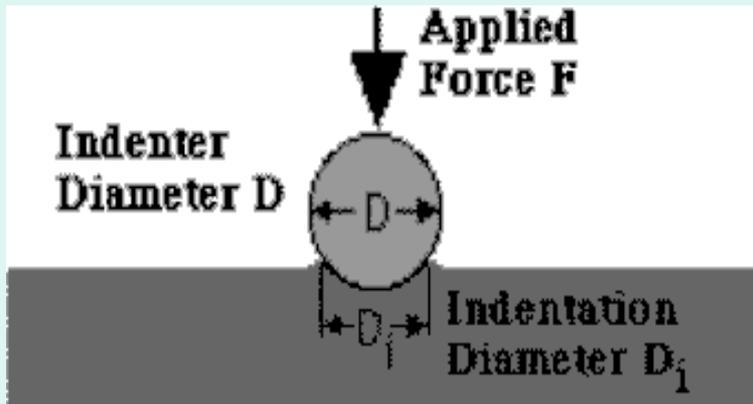
Indentation Hardness Testing of Metals

- **Brinell Hardness Test (ASTM E 10)** - Commonly used.
- **Rockwell Hardness Test (ASTM E 18)** - Commonly used. Indentor and loads are smaller than with the Brinell test.
- **Vickers Hardness Test (ASTM E 92)** - Similar to Rockwell. Uses a square-based diamond pyramid for the indenter.
- **Knoop (Tukon) Hardness Test** - used for very thin and/or very small specimens.

Brinell Hardness Test

- The Brinell hardness testing consists of indenting the test material with a 10 mm diameter hardened steel or carbide ball(10mm) subjected to a load of 500 to 3000 kg for 10 to 30 second.
- The full load (3000 Kg) is normally applied for iron and steel for 10 to 15 seconds
- The load can be reduced to 1500 kg or 500 kg for 30 second to avoid excessive indentation for softer materials
- The Brinell hardness number is calculated by dividing the applied load with the surface area of the indentation.

Brinell Hardness Test



$$\text{BHN} = \frac{F}{\frac{\pi}{2} D \cdot (D - \sqrt{D^2 - D_i^2})}$$

Brinell Hardness Test

- The diameter of the indentation left in the test material is measured with a low powered microscope.
- The diameter of the impression is the average of two readings at right angles.
- Brinell hardness number table can simplify the determination of the Brinell hardness number.
- A well structured Brinell hardness number reveals the test conditions, and looks like this, "75 HB 10/500/30" which means that a Brinell Hardness of 75 was obtained using a 10mm diameter hardened steel with a 500 kilogram load applied for a period of 30 seconds.

Brinell Hardness Test: Indenter

- Hardened steel ball used for testing up to 444HB (2.9 mm dia of indentation).
- Special hardened steel ball up to 500HB.
- Tungsten carbide ball 444-627 HB (2.9-2.45 mm dia of indentation).

Load Selection

- Size of impression 2.5-6mm (25 -60% of ball dia).
- Specimen thickness (ten times the depth of indentation)

Test surface

Normally Flat surface

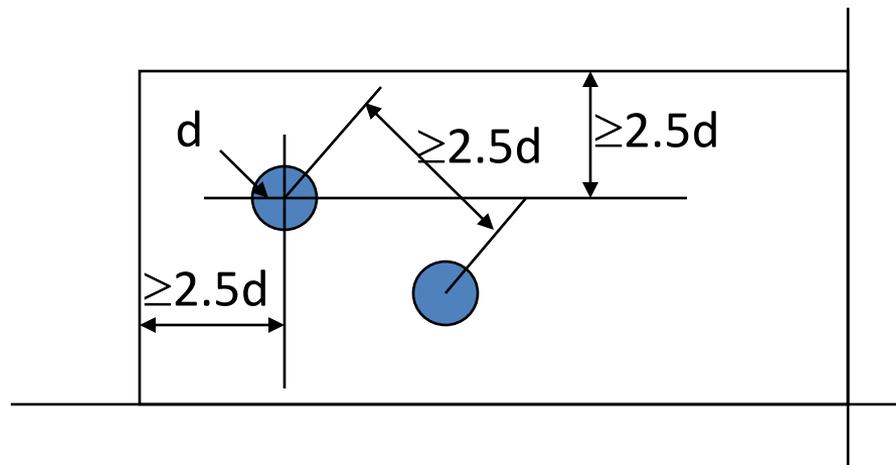
Materials to be Tested

- The Brinell ball makes the deepest and widest indentation, so the test averages the hardness over a wider amount of material, which will more accurately account for multiple grain structures and any irregularities in the uniformity of the material.
- This method is the best for achieving the bulk or macro-hardness of a material, particularly those materials with heterogeneous structures.
- Virtually all steels except case hardened, cast Iron, Nonferrous metals

Important Bhn Variables IV

Proximity to **edge** or other test **locations**:

- If an indentation is made too near the edge of the specimen. It may be both too large and unsymmetrical.
- The **distance** of the center of the indentation from the **edge** or from **the center of adjacent indentations** ≥ 2.5 times the **diameter** of the indentation.



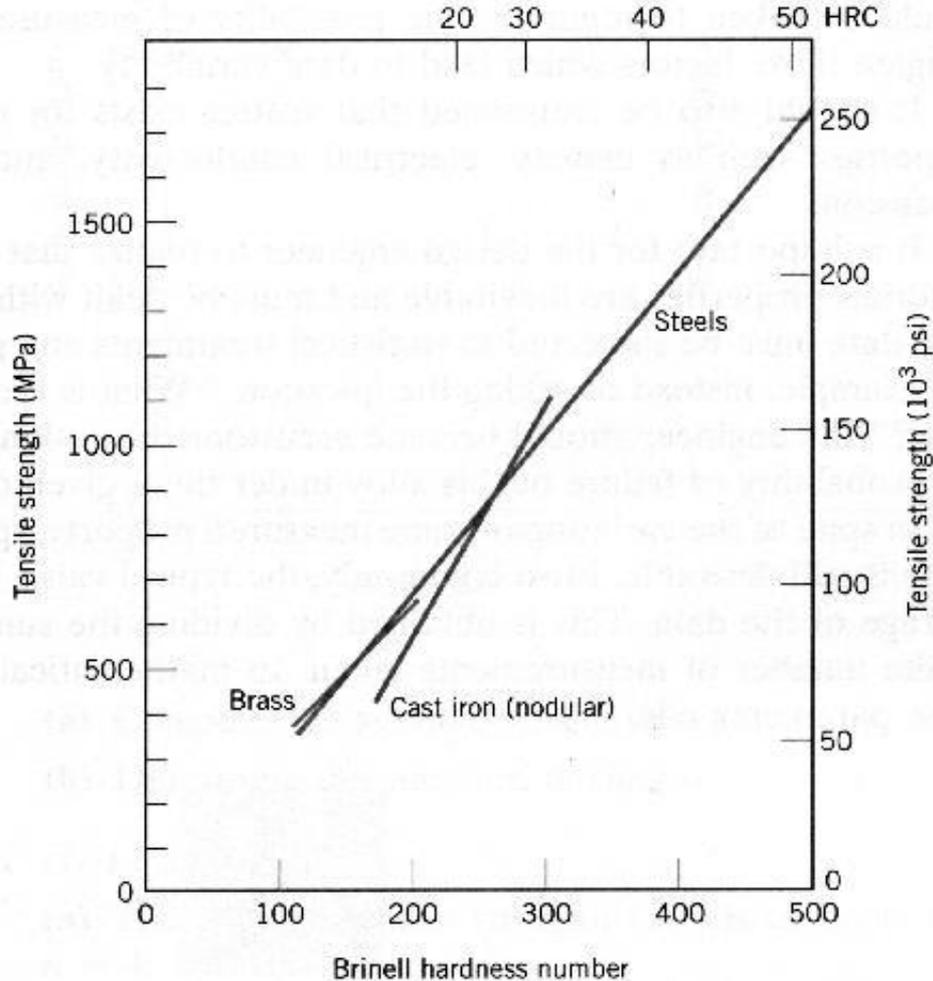
Important Bhn Variables III

Thickness of Specimen:

Thickness of specimen (mm)	Minimum Brinell hardness for which a Brinell test may safely be made		
	500 kg load	1,500 kg load	3000 kg load
2	79	238	476
4	40	119	238
6	26	79	159
8	20	60	119
10	16	48	95

Specimen is too thin  Too large indentation  Too small Bhn
 Not acceptable

Strength from Brinell Hardness



Steel:

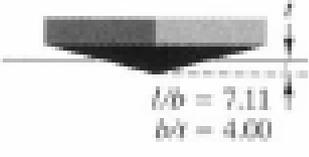
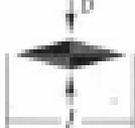
$$S_u = 3.45 \text{ HB (MPa)}$$

Cast Iron:

$$S_u = 5.35 \text{ HB} - 500 \text{ (MPa)}$$

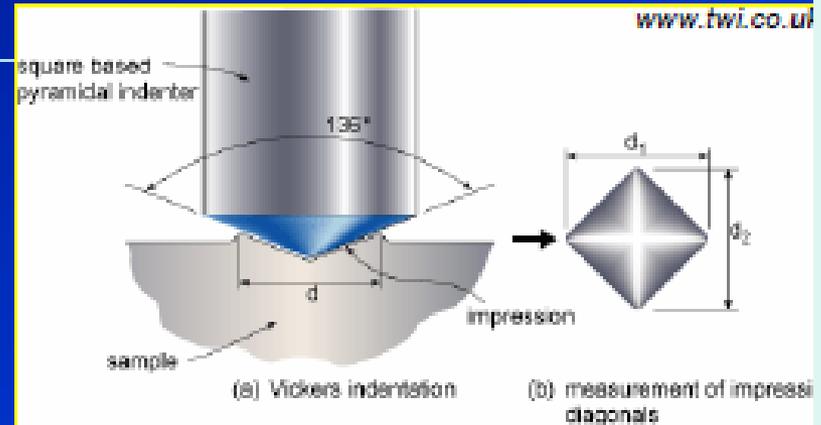
Brass:

$$S_u = 2.9 \text{ HB} + 50 \text{ (MPa)}$$

Test	Indenter	Shape of indentation		Load
		Side view	Top view	
Brinell	10 mm sphere of steel or tungsten carbide			P
Vickers	Diamond pyramid			P
Knoop microhardness	Diamond pyramid			P
Rockwell				
A } C } D }	Diamond cone			60 kg 150 kg 100 kg
B } F } G }	$\frac{1}{16}$ in. diameter steel sphere			100 kg 60 kg 150 kg
E } H }	$\frac{1}{8}$ in. diameter steel sphere			100 kg 60 kg

Vickers hardness

- **Vickers hardness test** uses a **square-base diamond pyramid** as the indenter with the included angle between opposite faces of the pyramid of 136° .
- The **Vickers hardness number (VHN)** is defined as the load divided by the surface area of the indentation.



Note: not widely used for routine check due to a slower process and requires careful surface preparation

$$VHN = \frac{2P \sin(\theta/2)}{L^2} = \frac{1.854P}{L^2}$$

Eq.6

Where **P** is the applied load, kg
L is the average length of diagonals, mm
θ is the angle between opposite faces of diamond = 136° .



Vickers hardness

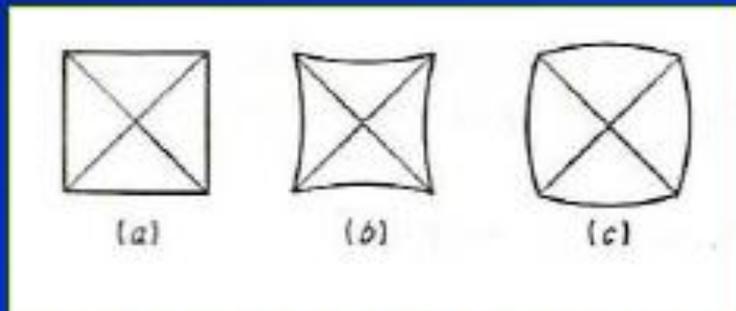
- **Vickers hardness test** uses the loads ranging from 1-120 kgf, applied for between 10 and 15 seconds.
- Provide a fairly **wide acceptance for research work** because it provides a continuous scale of hardness, for a given load.
- **VHN** = 5-1,500 can be obtained at the same load level → **easy for comparison**).



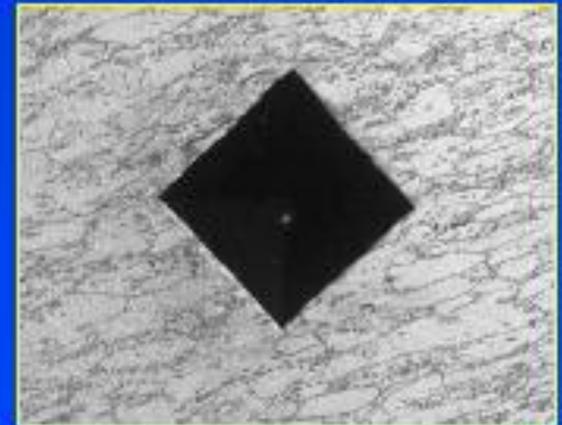
ZHV30 micro and macro Vickers with automatic impression measurement

Impressions made by Vickers hardness

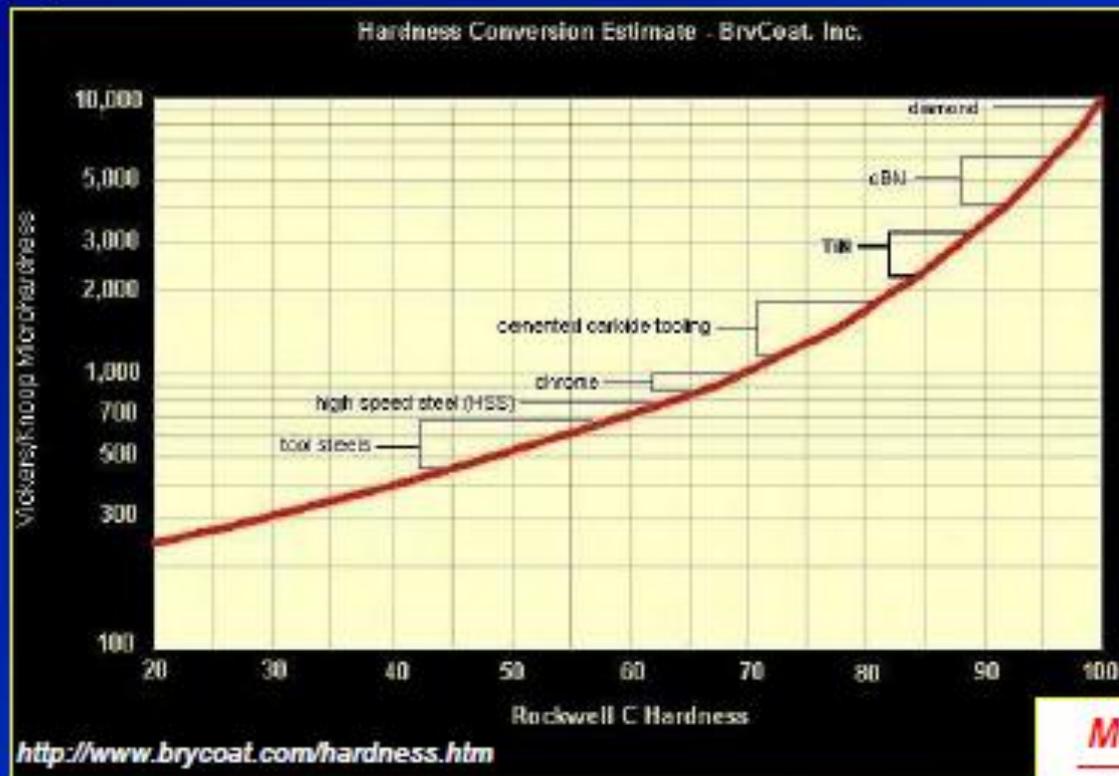
- **A perfect square indentation (a)** made with a perfect diamond-pyramid indenter would be a **square**.
- **The pincushion indentation (b)** is the result of sinking in of the metal around the flat faces of the pyramid. This gives an overestimate of the diagonal length (observed in **annealed metals**).
- **The barrel-shaped indentation (c)** is found in **cold-worked metals**, resulting from ridging or piling up of the metal around the faces of the indenter. Produce a low value of contact area → **giving too high value**.



Types of diamond-pyramid indentation (a) perfect indentation (b) pincushion indentation due to sinking in (c) barrelled indentation due to ridging.



Vickers hardness values of materials



<i>Materials</i>	<i>H_v</i>
Tin	5
Aluminium	25
Gold	35
Copper	40
Iron	80
Mild steel	230
Full hard steel	1000
Tungsten carbide	2500

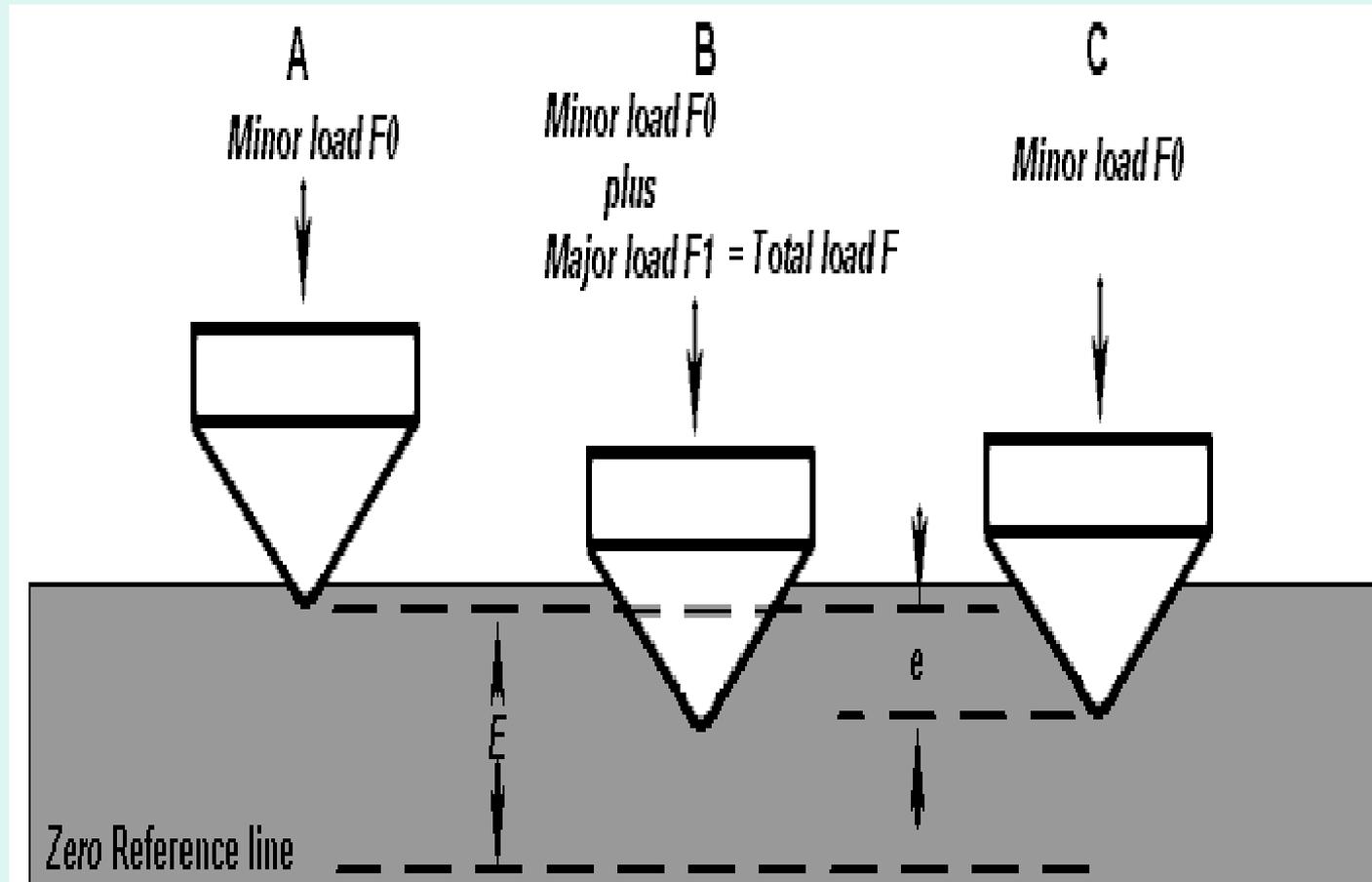


Rockwell Hardness Testing

- **Test Principle:**

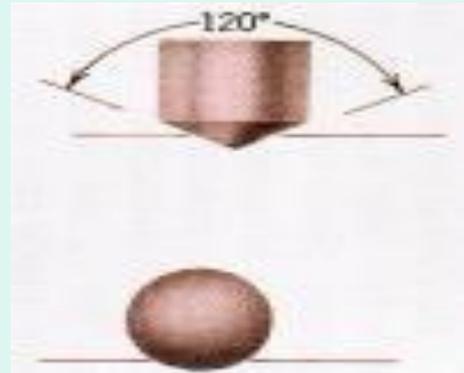
Rockwell hardness Number (RHN) based on an inverse relationship to the measurements of the additional depth to which an indenter is forced by a heavy (major) load beyond the depth resulting from a previously applied (minor) load.

Rockwell indentation



One dimension on the dial gage - a depth of 0.002mm.
Zero reference line -100 for C scale and -130 for B scale

- **Indenter:**
- 120 degree sphero-conical diamond indenter is used for hard material.
- Hardened steel ball indenter with diameter of 1/16, 1/8, 1/4, 1/2 inch.





Range of Indenters

Types of Test

- Two types of test based on load

Load	Rockwell	Superficial
Minor	10Kg	3 Kg
Major	60,100,150 Kg	15,30,45 Kg

Rockwell Scales

- There are 30 different scales ,depending on the combination of the indenter and the load.
- 64 HRC means RHN of 64 on C- scale, (diamond indenter and 150 Kg major load)
- 100 HRB means RHN 100 on B-scale (1/16 inch steel ball and major load 100Kg)
- 81 HR 30 N means SHN 81 on 30 N-scale (30 N diamond indenter and major load 30 Kg)

Factors that control Scale selection

- -Type of material,
- -Specimen thickness ,
- -Test location ,
- -Scale limitation.

Test location

- If an indentation is placed within the cold worked area (previous indentation).
- The reading usually will be higher than that obtained had it been placed outside this area.
- As a precaution three diameters from the centre of one indentation to another is sufficient for most material.
- The distance from edge should be minimum of 2.5 diameters of indentation.

Scale limitation

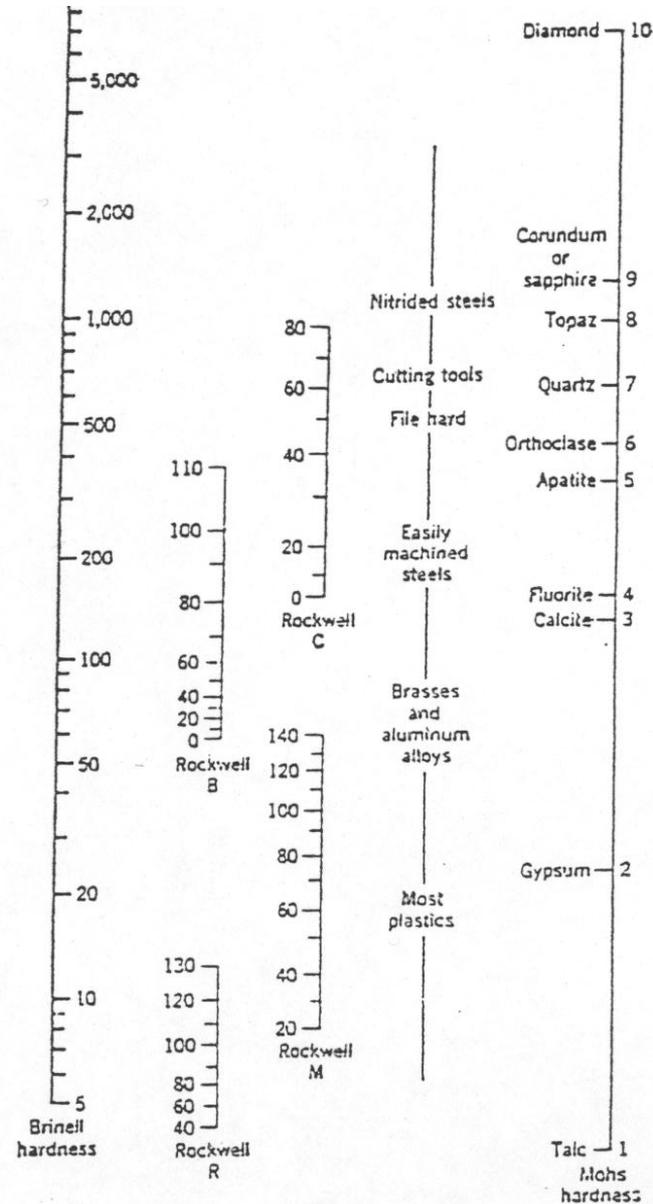
- No upper limit to the hardness of a material that can be tested with a diamond indenter.
- However C scale should not be used on tungsten carbide (material may fracture or indenter may damage). A scale is acceptable in this case.
- Diamond indenter are not calibrated below values of 20.

Rockwell testing Machines

- Test load can be applied either dead weight or through springs.
- Measuring device - a dial or digital meter.
- Microprocessor to control the test process.
- Bench type testing machine.
- Production type.
- Portable type machine

Standard Brinell Numbers

- Steel, Aluminum, Copper (Brasses)
- Big range for each material



Summary

	<p>Hardness tests can be based on indentation principle or rebound principle. Indentation hardness test methods : Brinell, Rockwell and Vickers are highly popular and are used for mass production and also for investigation. Indentation hardness testers are very useful for portable hardness and for hardened metals.</p>
	<p>Hardness testers are used with heavier loads for metals with heterogeneous structure. For hardened steel and for superficial hardness lighter load is preferred.</p>
	<p>Conversion between hardness scales and tensile strength is easily done with established conversion charts. Separate charts should be used for steel, Cast iron or soft metals.</p>