# NUTS & BOLTS

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TRUSTED PROBLEM SOLVER

## Our Philosophy

***New Hampshire Materials Laboratory*** *has one goal—to help you solve your technical problems at a reasonable cost. Tests help, but are not always enough. Our team of dedicated and experienced professionals has both the skills and the backup facilities to serve in the following:*

- Failure Analysis
- Material Certification & Compliance
- New Product Testing
- Mechanical Properties
- Tensile and Compression Testing
- Heat Treat Problems and Verification
- Reverse Engineering
- Weld & Life Testing
- SEM & EDS

## Hardness Testing

### Background

In metal working, hardness generally implies resistance to penetration. It may, however, include resistance to scratching, abrasion or cutting.

Indentation hardness is probably the most widely used mechanical testing procedure. It is a nondestructive test, relatively inexpensive, and can be done by semi-skilled operators.

### Why test for hardness?

These tests often supplement or can be substituted for tensile tests, since there is a fairly good relationship between the tensile strength and the hardness of many metals.

Hardness tests are used for specification purposes, to check heat treating procedure, to check the effectiveness of surface-hardening methods and as a substitute for tensile tests on parts that are too small for full scale tests.

### Which test to use?

*There are a number of hardness testing methods; however, the most commonly used are the Brinell, Rockwell and Vickers (Diamond Pyramid) methods.* The VIckers is a laboratory test. The Brinell and Rockwell tests are more adaptable to production. The selection of the particular method, generally depends on the application.

Time and time again we find specifications calling out a hardness specification that is not valid. The result is that they cannot reject a lot of material or parts whose hardness does not meet their needs.

### Valid specifications—Some common mistakes...

*This edition of Nuts and Bolts is a plea to all of our clients to please make sure that your hardness specifications are valid. These are the most common mistakes:*

#### Specs that call for a hardness test on tube, parts or shapes that can't support the required test load.

*The Rockwell tests measure depth of penetration.* If the sample collapses at all then the test is invalid. Assuming the ID and OD are clean, a press-fit mandrel can save the day however verification tests should first be run comparing a coupon and the tube.

*The Brinell test measures indentation diameter.* A little flattening can be tolerated but you need to run verification tests comparing a coupon and the tube. The loads are big so distortion is a real risk.

*The Rockwell scales using the diamond indentor can't go below 20.* The diamond indentor scales are Rockwell A, C and the T superficial scales. If a result below 20 is obtained scrap the results and go to the next softer scale.

No scales are supposed to be used beyond 100 however Rockwell B 101 and B 102 is sometimes seen.

### Specs that ignore curved surface corrections.

*Rockwell hardness tests made on curved surfaces require a correction based on the dial reading and the curvature.* For low dial readings the corrections are larger, as much as 12.5 units to be added for a dial reading of 0 and a sample diameter of 1/4 inch. With a dial reading of zero even a diameter of 1 inch requires a substantial correction.

*Post a table of curved surface corrections beside your Rockwell hardness testers.* On your data tables leave columns to enter the sample diameter, the correction and the adjusted value. Where a run of values is being averaged don't bother to enter the individual corrections. Only apply the correction to the average.

*The minimum diameter for a Brinell test is 2 inches.* Brinell cannot be run on concave surfaces. Curved surfaces are not allowed for either Barcol hardness tests or microhardness tests.

### Specs that call for using conversions from one scale to another.

*Mills and heat treaters don't accept conversions unless they have been written into the PO or contract.*

I quote from ASTM E10 paragraph 9:

"There is no general method for converting accurately Brinell hardness numbers to other hardness scales or tensile values."and, from ASTM E18 paragraph 8:

"There is no general method of accurately converting the Rockwell hardness numbers on one scale to Rockwell hardness numbers on another scale, or to other types of hardness numbers, or to tensile strength values."

"…Hardness Conversion Tables ASTM E140, for metals give... approximate conversions…"

## The Problem: Purchasing

In most instances mills will write specifications for yield, tensile and elongation but not hardness. *Where hardness values are supplied they are usually listed as "typical values".* As an example, ASTM B247 covers aluminum die forgings. The hardness values are "for information only". They happen to be a Brinell test using a 500 kg load. To write that value into a purchase specification and then for you to be able to reject a non complying shipment you would need to ensure that your parts meet the minimum section and surface finish requirements and that they don't distort while under the 500 kg load.

*Hardness is often written into heat treating and cold work temper specifications.* As before, Murphy's Law dictates that the industry specifications will be in a hardness scale that can't be applied to your work. You will need to negotiate with your supplier for a valid hardness scale and hardness number for the particular product.

**Example:** *You are writing a purchase specification for 0.030 inch thick 5052 aluminum in the O temper.*

*For the O temper the industry lists the typical hardness as HB(500) 47.* According to ASTM E10 the minimum thickness of metal for HB(500) 47 is 1/8 inch. Since your thickness is much less, you can't use that test. In fact, 5052 in the O temper is so soft that of the Rockwell tests only R15T can be used for 0.030 sheet.

| Thickness In. | HRA | HRB | HRC | HRF | R15T | R30T | R45T | R15N | R30N | R45N | Brinell 3000kg | Brinell 5000kg | Barcol 5000kg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .006 | | | | | | | | 92 | | | | | |
| .008 | | | | | | | | 90 | | | | | |
| .010 | | | | | 91 | | | 88 | | | | | |
| .012 | | | | | 88 | | | 83 | 82 | 77 | | | |
| .014 | | | | | 81 | 80 | | 76 | 78.5 | 74 | | | |
| .016 | 88 | | | | 75 | 72 | 71 | 68 | 74 | 72 | | | |
| .018 | 84 | | | | 68 | 64 | 62 | | 66 | 68 | | | |
| .020 | 82 | | | | | 55 | 53 | | 57 | 63 | | | |
| .022 | 79 | | 69 | | | 45 | 43 | | 47 | 58 | | | |
| .024 | 76 | 94 | 67 | 98 | | 34 | 31 | | | 51 | | | |
| .026 | 71 | 87 | 65 | 91 | | | 18 | | | 37 | | | |
| .028 | 67 | 80 | 62 | 85 | | | 4 | | | 20 | | | |
| .030 | 60 | 71 | 57 | 77 | | | | | | | | | |
| .032 | | 62 | 52 | 69 | | | | | | | | | |
| .034 | | 52 | 45 | | | | | | | | | | |
| .036 | | 40 | 37 | | | | | | | | | | |
| .038 | | 28 | 28 | | | | | | | | | | |
| .040 | | | 20 | | | | | | | | | | |
| 0.0625 | | | | | | | | | | | 602 | 100 | OK |
| 0.125 | | | | | | | | | | | 301 | 50 | OK |
| 0.1875 | | | | | | | | | | | 201 | 33 | OK |
| 0.250 | | | | | | | | | | | 150 | 25 | OK |
| 0.3125 | | | | | | | | | | | 120 | 20 | OK |
| 0.375 | | | | | | | | | | | 100 | 17 | OK |

FIGURE 1: Minimum Metal Thickness and Minimum Hardness for Each Thickness for Commonly Used Hardness Scales

You would have to negotiate an R15T purchase specification with your supplier. If you write the HB(500) 47 specification into your purchase spec it is practically a sure thing that you won't be able to reject a faulty lot!

## The Problem: Incoming Inspection

Some of your incoming case hardened parts need to be inspected. Your company specification calls for an HRC 58 case, 0.060 inches deep.

**Example:** *Incoming inspection reports the hardness on the surface, cuts off the sample using a water cooled abrasive wheel, etches the cross section, notes the depth at which the etching response changes from its surface appearance to the core appearance, and reports that depth.*

The result has almost nothing to do with hardness! This test doesn't assure the properties that Engineering was calling for!

Hardness profiles often show a slight drop in a thin layer at the surface. A little deeper there is a plateau having full hardness, and then the hardness follows an S curve to its core value. The hardness measured at the surface is often a little lower than the value slightly deeper. You may end up rejecting parts that are actually acceptable to Engineering.

Engineering probably called out the 0.060 depth because they needed a certain strength at that level. It would be mostly luck if the etching test was sensitive at that required strength.

A good case hardened spec requires testing on a cross section. Engineering calls out the depths at which they are counting on specific hardness values. They usually derive those values from both the tensile strength-hardness relationship for the specific steel and the contributions by both residual and applied stress to fatigue strength. The result might be, for example, a spec calling out minimum HRC 57 at 0.010 units, 48 at 0.060 units, 32 at 0.400 units and 27 at 0.800 units. Given this spec, Incoming Inspection cuts off the sample then measures and reports the hardness at the specified depths.

## Choosing a Valid Hardness Scale

Start with the metal thickness. A particular scale can be used as long as the hardness is greater than the number in the table. For example, if the metal is 0.020 inches thick then the HRA scale can be used if the hardness is greater than 82, R30T can be used for hardness greater than 55, R30T for hardness greater than 53, R30N for greater than 57 and R45N for hardness greater than 63. None of the other scales can be used!

## Greater thickness and higher hardness are OK to use.

### Vickers and Knoop Microhardness

The attached graph gives the minimum sample thickness for a given sample thickness and hardness. You can convert back and forth between Knoop and Vickers microhardness either by formula, by table, or using a graph. Call us if you need the conversions.

A metallographic surface finish is required and curved surfaces are not allowed.

### DPH or Vickers Hardness

The minimum sample thickness is 1 times the indentation diagonal. ASTM E82 lists correction factors for curved surfaces. The greater the load the greater the size of the indentation and the more surface roughness can be tolerated. Test loads of 1 to 120kgf can be used.

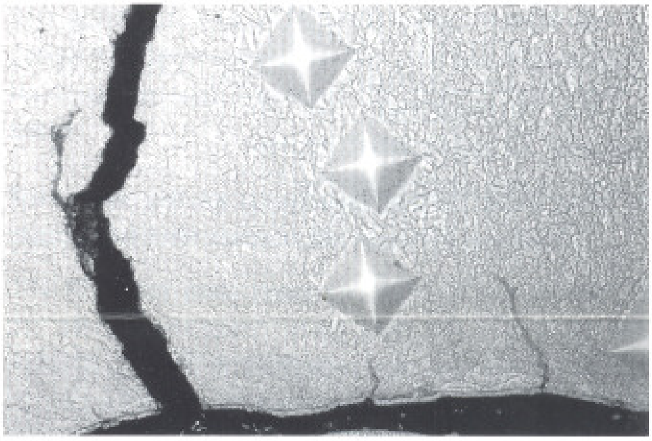

FIGURE 1: Vickers hardness test on brass

### Additional References

| Test | ASTM Specification |
|---|---|
| DPH or Vickers | E92 |
| Barcol | Aluminum - B648 |
| | Plastics - B2583 |
| Brinell | E10 |
| Knoop | Ceramics - C84 |
| | Glass - C730 |
| | Coatings - B578 |
| | General - E384 |
| Rockwell | E18 |
| Conversions | E |

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