

How to measure coating hardness using the Wolff Wilborn Pencil Hardness Test

If a coating does not dry (or cure) properly, this can affect its performance; resulting in flaws, poor adhesion, and premature coating failures.

This is why we test coating hardness, as this indicates how well it has cured – typically the harder the coating, the more complete the cure, and the better its overall performance.

One of the most common methods of determining coating hardness is the pencil hardness test, also known as the Wolff-Wilborn method, where a pencil of a known hardness is pushed across the coating at a specified angle, under a constant force. The pencil hardness is increased from B (soft), through HB (medium) to H (hard), until the coating is scratched. Alternatively, depending on the test method, you may start with the hardest pencil, and then decrease the pencil hardness until the coating isn't scratched.

This rapid, inexpensive method is not only used by coating manufacturers during developmental work and as an indication of the coating's performance; but also as a field test during post-application inspection.

The pencil hardness test can be completed free-hand using the Elcometer 3080, which includes a set of 14 pencils (grades 6H to 6B), two specialised pencil sharpeners, and an abrasive paper block to prepare the pencil for testing. Alternatively, some Standards state you should use a specially designed tester, such as the Elcometer 501; which also includes a set of 14 pencils (again, 6H to 6B), the two specialised sharpeners and abrasive paper block, and a setting block of a predefined size for preparing the tester.

So, how do you complete a test?

Please note, while this video is a guide to completing the pencil hardness test, as you'll discover certain test methods and Standards differ slightly on how the method should be completed, and how the results should be recorded. So, we recommend you always refer to the test method or Standard you are working to directly before testing.

Regardless of which test method you are following, to begin, prepare the pencil by using the special sharpener provided, to remove around 5 to 6 mm of wood from the pencil, not including the point, taking care to leave the exposed lead unmarked. Please note, there are two different sharpeners provided to suit the different hardnesses of lead – one for softer pencils, the other for harder pencils - so use the correct one accordingly.

Next, hold the pencil at 90° to the abrasive paper provided, and rub the lead until you achieve a flat, smooth, circular cross-section, which is free of chips or nicks. You are now ready to perform the test.

If you are completing the test free-hand, using the Elcometer 3080, with the test panel on a level, firm, horizontal surface; hold the pencil firmly at a 45° angle to the surface, and push it away from you about 6mm (0.25") at a uniform speed, applying sufficient downward pressure to either cut or scratch the coating, or crumble the edge of the lead.

Some Standards however, such as ISO 15184, specify the amount of downward force that should be applied to the pencil during the push. This is where the Elcometer 501 Pencil Hardness Tester comes in.

With the tester resting on the setting block provided, simply fit the pencil into the body with the tip resting on the surface, lock it in place using the thumbscrew, and your pencil is instantly held at 45°

under the predefined force of 7.5N. Simply remove the setting block, place the tester down carefully ensuring not to damage the surface or pencil lead, and push the tester away from you 6mm (0.25") at a uniform speed to complete the test.

Even if the test method or Standard you are working to does not specify a downward force, using the Elcometer 501 Pencil Hardness Tester ensures that every push, with every pencil, is undertaken using exactly the same angle and downward force, ensuring repeatable and comparable results.

With the push complete, you now inspect the surface.

Carefully remove any pencil marks from the surface using either a soft cloth or cotton wool with inert solvent, or a soft eraser; taking care not to affect the hardness of the coating in the test area or the result of the test.

You then assess the test area through close visual inspection, by touch using a fingernail, or both. And if agreed, it is even possible to inspect using a magnifier of x6 to x10 magnification, such as the Elcometer 137.

So, what are you looking for?

Well, this depends on the test method or Standard you are working to.

Some Standards, such as ASTM D 3363 for example, state that you should start testing with the hardest pencil, and continue down the scale, testing with softer and softer pencils, until you find either of two results:

- you find the hardest pencil that makes a cut which is less than 3mm long out of the 6mm test push – this is known as the gouge or pencil hardness;
- or you find the hardest pencil that doesn't scratch the film at all – this is known as the scratch hardness.

So if we take a look at this test panel, which has results from 6B (soft) all the way through to 6H (hard), and we work down from the hardest pencil, what we can see is that the hardest pencil to make a scratch in the film that's less than 3mm long is H – so this is the gouge hardness, as all the scratches made by harder pencils are over 3mm in length.

As for the scratch hardness, we carry on going from hardest to softest to find the hardest pencil test result that leaves no marking at all – and as you can see here, the result is F.

Alternatively, other Standards such as ISO 15184, don't actually specify which pencil you need to start testing with, although many in the industry tend to start with the softest pencil and continue up the scale, until you find the pencil that leaves a mark of *over* 3mm long out of the 6mm test push. That mark can be defined as either one, or a combination of two defects:

- a permanent indentation or scratch that does not cut through the coating (known as plastic deformation);
- or a visible tear or rupture in the surface of the film (known as a cohesive fracture).

So, let's go back to our test panel. If we were to start at the softest pencil and work up, the softest pencil to leave a mark of over 3mm long is 2H. Examining the results a little closer, you can see that the majority of the mark is a cohesive fracture, so it has cut through the film. And on the edges of the results, you can also spot a little bit of plastic deformation.

All tests should be done at least twice to ensure repeatability and reproducibility. If the two results differ by more than one unit of pencil hardness, then both results should be discarded, and you repeat the test.

It's worth mentioning that if you are doing a comparative test you should ideally use the same set of pencils, as variations might be found between different ranges of pencils from different manufacturers.

For more information on Elcometer's range of pencil hardness testers, simply visit Elcometer.com, or click on one of the links on screen to watch another video.

And please, don't forget to subscribe to the Elcometer Channel to be notified of any new videos.