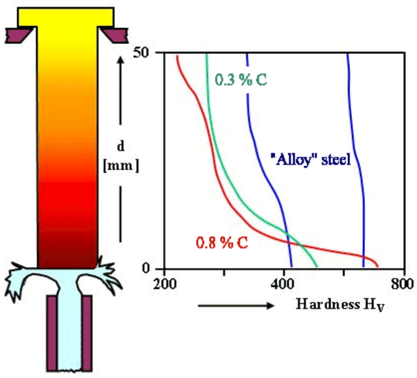
Jominy Test and Hardness Depth

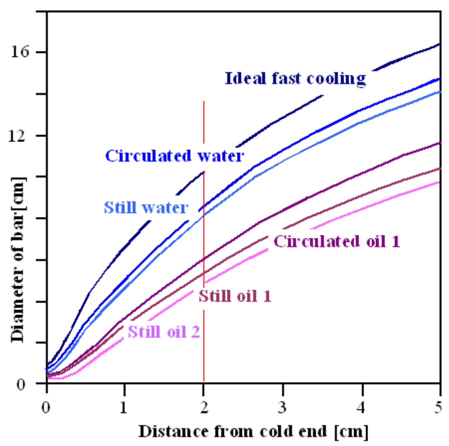
Illustration

- Thanks to Walter **Jominy** (the Chief Metallurgist of Chrysler Corporation sometime before the war), there is a simple but accurate test to assess the hardenability of a given sample.
  - Just take a standard size sample (25.4 mm (= 1") diameter, 102 mm (= 4") long), heat it to some high temperature where austenite is formed, and then spritz water (at defined conditions, of course) at one end as shown below. The cooling rate will be different from one end to the other of the sample, and all you do after it has cooled down completely, is to measure the hardness along its length. What you might find is shown to the right of the test set-up.



Jominy test for hardening depth

  - Plain carbon steel with sufficient carbon (e.g. **0.8 %**) may become very hard in the region where the cooling rate was very high, but the bulk of the sample remains "soft" (red curve), while very mild steel with little carbon (e.g. **0.3 %**) has te same hardening depth but smaller hardness (green curve).
    Now add some **Cr**, **V**, **Mn**, **Ni**, or **Mo** (or some other suitable elements), and if you do everything right, you may obtain the blue curves - steels with good hardenability and a much larger hardening depth.
    The hardening depth is around 10 mm for the carbon iron (the exact number depends on how you define it) in this example. For the alloy steel it is larger, they are hard for at least 25 mm. However, the high-carbon steel is the hardest for the first few millimeters.
- You can also use the Jominy test for checking the efficiency of your cooling fluid. The next picture tells it all:



Efficiency of coolants. See text for details.

Adopted from a "Key to Metals" article

  - Assume that a steel bar with a certain diameter is cooled completely in a medium as shown. What is shown is the relation of the hardness values you get throughout the material relative to the hardness you get at a certain

distance from cooling only the end in the same medium is what is shown
For example, if you can live with the hardness you get 2 cm from the end of a bar in a Jominy test (red line), your bar can gave a diameter of about 10 cm (blue line) and will have that hardness everywhere if you cool with maximal cooling rate (liquid nitrogen, for example). Cooling in some well circulated oil is less efficient, the bar diameter goes down to about 6 cm (violet line).
We now could assess the efficiency of all that disgusting stuff the ancient smiths used for quenching their steel: various kinds of urine, blood, slaves..., keeping in mind that these kinds of coolant might also add a little carbon or nitrogen to the outer layer. *You* do the experiments.
I subscribe to the scientific insight, first understood by Réaumur around 1720, that the differences between different **quenching agents** comes only from their different thermal conductivity, i.e. how fast they can take the heat out of the steel.