

# Vacuum Heat Treatment of Tool Steel, Process Parameters and Grade Schedules

A vacuum furnace hardens tool steel without the atmosphere that oxidises or decarburises it, and the vacuum level itself becomes a process variable, because the alloying elements in a high chromium grade will evaporate if the pressure is held too low while the part is at temperature. The tables below set the vacuum level against the heating temperature, give the factors used to calculate the soak from the section thickness, compare the cooling gases, and list the published vacuum cycles for thirteen tool and mould steel grades, from the carbon and low alloy tool steels through to the high speed grades.

**Reference only.** This sheet is a reference summary of published handbook practice, not an Aobo Steel specification. Confirm the cycle against the mill certificate and the governing drawing before an order or a production run is set against it. Values are printed as they appear in the source table.

## Furnace and cooling gas

| Cooling gas                | Relative cooling time |
|----------------------------|-----------------------|
| Hydrogen (H <sub>2</sub> ) | 1.0                   |
| Helium (He)                | 1.2                   |
| Nitrogen (N <sub>2</sub> ) | 1.5                   |
| Argon (Ar)                 | 1.75                  |

Source, section 8.2.6, printed page 477. Cooling time relative to hydrogen, taken as 1. The handbook notes that a mixture of 60 to 70 volume per cent helium with 30 to 40 volume per cent nitrogen is regarded abroad as the best compromise.

## Vacuum level against heating temperature

| Heating temperature, °C | Vacuum level, Pa |
|-------------------------|------------------|
| Up to 900               | ≥ 0.133          |
| Over 900 to 1100        | 13.3 to 1.33     |
| Over 1100 to 1300       | 13.3 to 666.0    |

Source, Table 8-17, printed page 476. The level is allowed to rise as the load temperature rises, to hold back the evaporation of alloying elements.

## Soak time from the section thickness

| Steel group           | Soak coefficient K, min/mm | Time allowance T, min | Preheat noted                         |
|-----------------------|----------------------------|-----------------------|---------------------------------------|
| Carbon tool steel     | 1.9                        | 5 to 10               | One preheat at 560 °C                 |
| Low alloy tool steel  | 2.0                        | 10 to 20              | One preheat at 560 °C                 |
| High alloy tool steel | 0.48                       | 20 to 40              | Preheat at 560 °C and again at 800 °C |
| High speed tool steel | 0.33                       | 15 to 25              | Preheat at 560 °C and again at 850 °C |

Source, Table 8-18, printed page 477. Soak time  $C = K D + T$ , where C is the soak in minutes, K the coefficient above, D the effective thickness of the part in millimetres and T the allowance in minutes. The prepared tables differ from a general soak chart and replace it for a vacuum cycle.

## Vacuum heat treatment schedules by grade

| Grade      | Preheat, °C                 | Preheat vacuum, Pa | Austenitising, °C          | Quench vacuum, Pa | Cooling                           | Temper, °C             | Hardness, HRC      |
|------------|-----------------------------|--------------------|----------------------------|-------------------|-----------------------------------|------------------------|--------------------|
| 9SiCr      | 500 to 600                  | 0.1                | 850 to 870                 | 0.1               | Oil, above 40 °C                  | 170 to 190             | 61 to 63           |
| CrWMn      | 500 to 600                  | 0.1                | 820 to 840                 | 0.1               | Oil, above 40 °C                  | 170 to 185             | 62 to 63           |
| 9Mn2V      | 500 to 600                  | 0.1                | 780 to 820                 | 0.1               | Oil                               | 180 to 200             | 60 to 62           |
| 5CrNiMo    | 500 to 600                  | 0.1                | 840 to 860                 | 0.1               | Oil or high purity N <sub>2</sub> | 480 to 500             | 39 to 44           |
| Cr6WV      | 500 to 550, then 800 to 850 | 0.1                | 970 to 1000                | 10 to 1           | Oil or high purity N <sub>2</sub> | 160 to 200             | 60 to 62           |
| 3Cr2W8V    | 480 to 520, then 800 to 850 | 0.1                | 1050 to 1100               | 10 to 1           | Oil or high purity N <sub>2</sub> | 560 to 580, 600 to 640 | 42 to 47, 39 to 44 |
| 4Cr5W2VSi  | 480 to 520, then 800 to 850 | 0.1                | 1050 to 1100               | 10 to 1           | Oil or high purity N <sub>2</sub> | 600 to 650             | 38 to 44           |
| 7CrSiMnMoV | 500 to 600                  | 0.1                | 880 to 900                 | 0.1               | Oil or high purity N <sub>2</sub> | 450, 200               | 52 to 54, 60 to 62 |
| 4Cr5MoSiV1 | 500 to 550, then 800 to 820 | 0.1                | 1020 to 1050               | 10 to 1           | Oil or high purity N <sub>2</sub> | 560 to 620             | 45 to 50           |
| Cr12       | 500 to 550                  | 0.1                | 960 to 980                 | 10 to 1           | Oil or high purity N <sub>2</sub> | 180 to 240             | 60 to 64           |
| Cr12MoV    | 500 to 550, then 800 to 850 | 0.1                | 980 to 1050, 1080 to 1120  | 10 to 1           | Oil or high purity N <sub>2</sub> | 180 to 240, 500 to 540 | 60 to 64, 58 to 60 |
| W6Mo5Cr4V2 | 500 to 600, then 800 to 850 | 0.1                | 1100 to 1150, 1150 to 1250 | 10                | Oil or high purity N <sub>2</sub> | 200 to 300, 540 to 600 | 58 to 62, 62 to 66 |
| W18Cr4V    | 500 to 600, then 800 to 850 | 0.1                | 1000 to 1100, 1240 to 1300 | 10                | Oil or high purity N <sub>2</sub> | 180 to 220, 540 to 600 | 58 to 62, 62 to 66 |

Source, Table 8-19, printed page 478. Read from the page image at 300 dpi. A cell with two values carries the first and the second preheat, or the two austenitising temperatures, or the two tempering temperatures, in the order the source gives them. Vacuum levels below 1 Pa are a gauge pressure inside the chamber, and 10 to 1 Pa is the working level used once the quench begins.

### Notes on the data

The schedule table is the published reference cycle from a Chinese mould and tool steel handbook, and the page numbers are the printed page numbers of that handbook rather than the sample numbers of this site. The grade names are the Chinese GB designations, so 4Cr5MoSiV1 is the H13 family, Cr12MoV is the D2 family and W6Mo5Cr4V2 is the M2 family, and the equivalents are set out on the grade pages rather than assumed here. The vacuum levels are chamber gauge readings, and a furnace's own pump-down curve and leak rate will shift the practical figure. The soak coefficients are paired with one manufacturer's preheat practice, so an operator using a different preheat count should take the coefficient and leave the allowance.

## Aobo Steel, tool steel supplier

We supply forged and rolled tool steel from Huangshi, China, in D2, D3, O1, A2, H10, H11, H13, 420, 440C and related grades, in round bar and plate, annealed and ready to machine. Reference data for the grades and the heat treatment cycles of tool and die steels is collected for the buyers and process engineers who work with us.

Source, vacuum heat treatment, section 8.2.6 and Tables 8-17 to 8-19, printed pages 476 to 478. Page, [aobosteel.com/tool-steel-vacuum-heat-treatment/](http://aobosteel.com/tool-steel-vacuum-heat-treatment/)

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