# Thermal treatment of H13 steel tools

*This article by Józef Olejnik and Leszek Maldzinski describes SECO/WARWICK's technology, which overcomes the problems traditionally associated with the thermal treatment of H13 steels, particularly during the complex cooling process*

H13 steel is a material frequently used to produce tools to plastic processing when hot, or for casting in metal moulds. It is characterised by significant hardenability and good ductility, as well as by its resistance to drawing, oxidation and, in particular, thermal fatigue.

The heat treatment of finished tools, particularly large ones, produced from H13 steel (as from other steels for hot working) requires both a good deal of experience and close familiarity with the phenomena that occur during the heating and cooling phases, as well as the stresses associated with them. It must ensure the acquisition in the whole structural profile of a majority of martensite or bainite saturated with alloy elements without thereby causing excessive hardening stresses.

The special requirements for heat treatment of H13 steel are covered by standards, steel manufacturers' recommendations and the general recommendations of NADCA and GM Powertrain DC-9999-1 and Ford AMTD-DC2010. These standards give the precise temperatures for particular heat treatment operations; the recommended and required heating and cooling rates; the permissible temperature differences on the surface and in the core of the tool; the method of locating thermocouples in the charge; and also the methods used for strength testing.

In the light of these requirements, it is necessary in heat treatment processing to use modern vacuum furnaces that allow programmable and controlled cooling after austenitizing at the appropriate rate. Heating to austenitization and soaking is a well-known operation in industrial practice. Cooling, on the other hand, is a most difficult operation in the heat treatment of H13 steel and to a large degree responsible for the functional qualities and the costs of the finishing process.

In industrial practice, the principle of isothermal hardening is often used, where modern vacuum furnace control equipment enables programmed, rapid cooling to temperatures of the order of 350 - 450°C to be carried out easily. Then, after holding these for an appropriate time essential for equalising the temperature on the profiles of the tool, further cooling in the transformation region is required, without being subjected to stresses from the high-temperature cooling region.

*Fig 2. Test results*

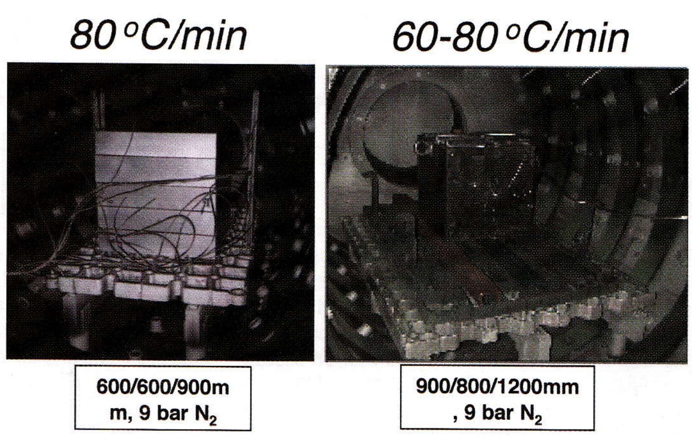
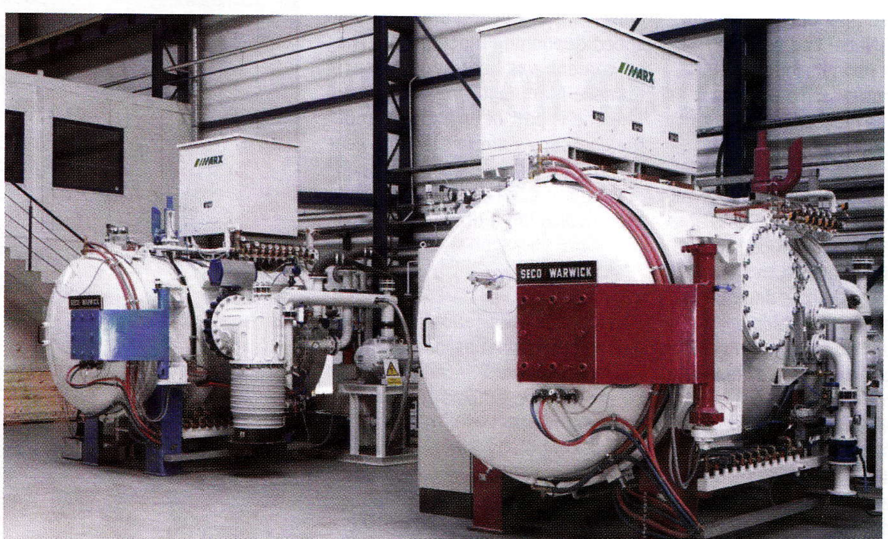



*Fig 1. Typical furnace for heat treatment of H13 steel tools*




Seco/Warwick has for many years been producing furnaces suitable to the thermal treatment of H13 steel as well as to other steels to plastic working when hot. Moreover, recent advances have made possible the introduction of a new technology. With this the performance of the system for cooling a charge is accurately programmed in the rapid cooling region to the 540°C range and in the range for isothermic maintenance. An example of a typical furnace for the heat treatment of H13 steel tools with moulds and dies is shown in fig 1.

## COOLING/STRENGTH RELATIONSHIP

The rate of cooling in the 1030°C to below 540°C range must be high enough not to allow the onset of pearlite transformation, the precipitation of carbides on grain boundaries and the formation of bainite (or at least must inhibit its precipitation). The literature describes the strict relationship between the rate of cooling and the strength of the material. The greater the rate of cooling, the greater the strength and general fatigue strength in cycles of use. The requirements of standard GM DC-9999-1 specify the test conditions for cooling an H13 block of 406 x 406 x 406mm. When cooling such a block from the austenitizing temperature of 1030°C to below 540°C, with thermocouples placed in accordance with NADCA recommendations in the centre of the lateral surfaces at a depth of 16mm, a rate of cooling higher than 28°C/min, must be obtained at a cooling pressure of not less than 9 bar (10 bar abs.).

Tests carried out on standard Seco/Warwick furnaces at a cooling pressure of 10bar abs. (9 bar overpressure) indicate a significantly higher rate of cooling than required by NADCA recommendations. The test results are shown in fig 2.

The CCT chart for H13 steel (fig 3) compares the temperature runs for the cooled block with those for the minimum rates recommended by NADCA. The findings from an analysis of the cooling tests show, on the one hand, significantly better cooling curves in comparison with the minimum NADCA requirements whilst on the other show differences in cooling with the same furnace design, depending on the size of the heating chamber. Here there occur differences in the coefficient of heat exchange (α [W/m² °K], which decrease with the growth of the size of the furnace while increasing with the rise in the linear circulation rate for a cooling gas chamber. The linear rate of flow of cooling gas across the charge has a similar effect on the magnitude of the coefficient of heat exchange, as does gas pressure.

The tests were conducted by placing just one part in the heating chamber. The furnaces were equipped with standard blast gas used by Seco/Warwick. The capacity of the motors for such blowers is, for example, 135kW for a size of 600 x 600 x 900mm and 225kW for a size of 900 x 800 x 1,200mm.

The cooling conditions at the time of these tests are approximate to the conditions obtained in a furnace charged with large moulds and dies, as shown in fig 4. In the case of smaller moulds and dies under production conditions, the furnace is charged with a larger quantity of tools, which, as is well known, improves the cooling conditions because of the increase in the density of the load and thus the rate of the cooling gas flowing through it.

The practical operational results for moulds and dies confirm the very high dependence of the number of possible working cycles on the cooling rate. Rates of cooling higher than recommended by NADCA are preferable in this case.

## HIGHER CAPACITY MOTORS

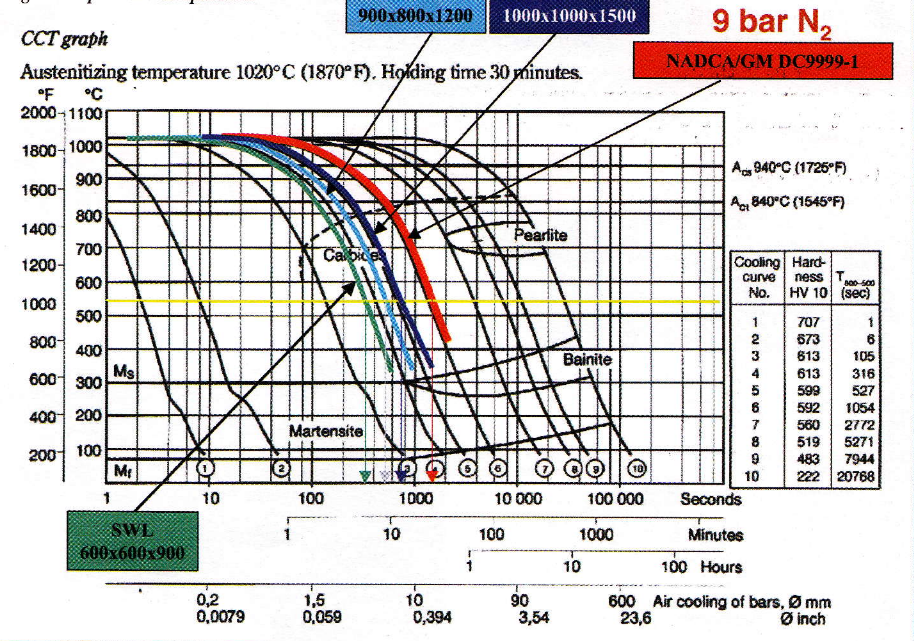
Seco/Warwick offers vacuum furnaces, having a cooling gas pressure of 12 bar abs. or 15bar abs., which proportionally increase the coefficient of heat exchange. Irrespective of this, there exists the option of fitting blowers to the furnace with higher-capacity motors per furnace; for example 160kW for a furnace of 600 x 600 x 900mm. A well-known facility in the USA with a 900 x 800 x 1200mm Seco/Warwick furnace having a 300kW power unit and a pressure of 10 bar abs. achieved a cooling rate of 120°C/min in a GM test.

This exceptional performance results from the design of Seco/Warwick furnaces, in which the gas flows over the charge via a 360° system of nozzles arranged around the charge in the plane of the door, and the heating chamber outflow is through a large hatch located on the axis of the charge[1]. The system of nozzles ensures the highest rate of cooling because it directs the flow of cooling gas across the charge from its smallest cross-section. The nozzle system is also characterised by more uniform cooling in comparison with furnaces with a rectangular heating chamber and reverse gas flow from hatches positioned, for example, above and below the charge.

Seco/Warwick produces furnaces with heating chambers both circular and rectangular in section, as shown in figs 5 and 6. Furnaces with circular sections, though a little more expensive to produce, are more suited to rapid and uniform cooling of heterogeneous charges, including moulds and dies of H13 steel for hot working.

The characteristics of Seco/Warwick furnaces also meet tests for the cooling of charges having medium and dense packings of small parts. For these tests a Seco/Warwick furnace with a heating chamber of 600 x 600 x 900mm was used. The cooling tests were conducted at a pressure of 10 bar abs. nitrogen on a charge of carbon steel bars having diameters of 25, 50 and 100mm and a net mass of approximately 400kg (about 500kg gross); see fig 7. Cooling times were obtained for temperatures of 800 to 500°C, corresponding to 70, 100 and 190sec, during which thermocouples were placed in the cores of the bars. These times correspond to coefficients (λ = 0.7, 1.0 and 1.9. For the 25mm diameter bars a cooling rate of 5.5°C/sec at the level of 700°C was achieved. A charge of less densely packed parts, for example approximately 220kg net (about 300kg gross), of 25mm diameter bars shows under the same conditions a correspondingly higher cooling rate at the level of 60sec (λ =0.6).

*Fig 3. Temperature comparisons*




## SUMMARY

The heat treatment of H13 steel tools is a difficult process that requires a number of boundary conditions to be met, among them controlled heating, austenitization and cooling. The most difficult operation technically is cooling, which requires the achievement of a specific rate greater than 28°C/min.

For such requirements the perfect solution is the use of Seco/Warwick's Type VPT furnaces which have circular-section heating chambers, as well as the most up-to-date and state-of-the-art cooling system solutions, making it possible to cool charges at rates of up to 120°C/min in accordance with GM requirements.

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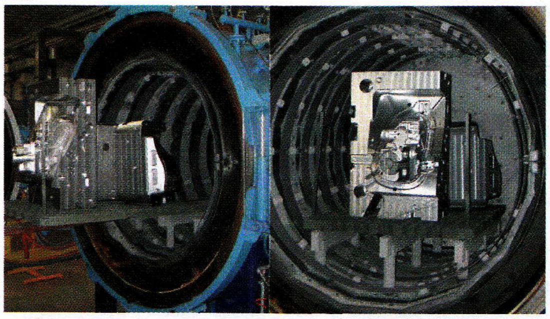

*Fig 4. Cooling conditions at the time of these tests are approximate to the conditions obtained in a furnace charged with large moulds and dies*

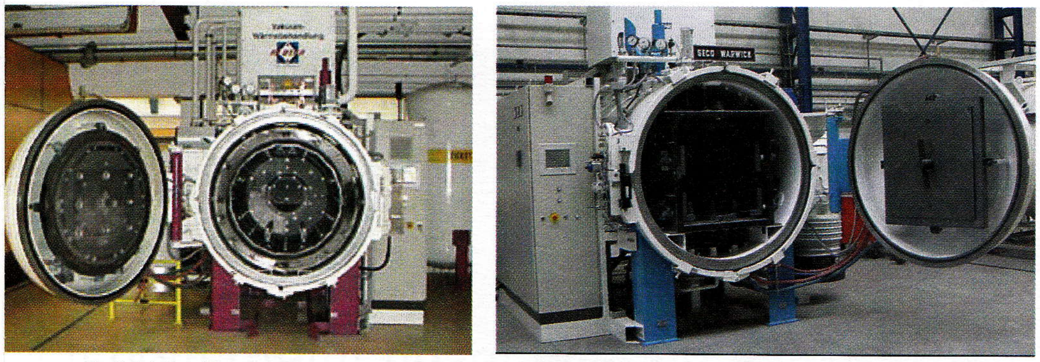

*Fig 5 & 6. Seco/Warwick produces both circular and rectangular heat chambers*

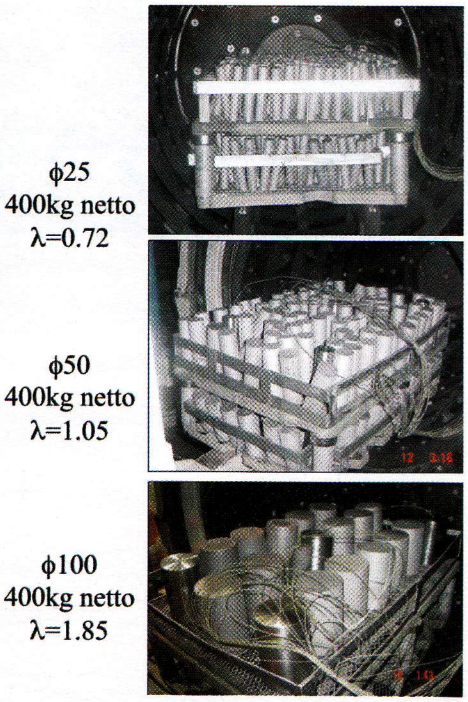


*Fig 7. The cooling tests were conducted at a pressure of 10 bar abs. nitrogen on a charge of carbon steel bars*