The determination of a metal's hardness by pressing a diamond cone, diamond prism, steel ball, etc. on different devices—Rockwell, Vickers, Brinell, and other types—is one of the basic and objective methods of determining the quality of heat treatment for articles.

The operational reliability of the devices is determined using calibrated hardness standards. These standards are only manufactured in a large-scale series-produced variant at the Ivanovo Production Union "Tochpribor."

The high requirements set forth for the quality of the calibrated standards make it necessary to refine their technology in various production operations. The basic and most critical operation is the heat treatment, which should be carried out in strict conformity with all temperature and time parameters. The development of automated continuous chains in various stages of heat treatment, which are united into a single system, is most promising in this respect.

MTR-type specimen-hardness standards are produced from tool steel U10A, and their basic requirements are as follows: uniformity of hardness over the surface, increased wear resistance, and in-service parameter stability.

It is necessary to note that the HRC surface hardness for standards (60 ± 5) should have a spread of no more than 0.5 units. The percentage output of suitable articles may be increased only after careful analysis of all factors affecting the quality of heat treatment during all of its stages (heating, quenching, and low tempering) with observances of the identification of heat-treatment conditions for large batches of articles, which can be achieved only on automated, or semiautomated lines. A semiautomated line for the heat treatment of specimen hardness standards has been developed and implemented for the Ivanovo Union "Tochpribor." (see Fig. 1).

Steel U10A specimens measuring 0.01 × 0.04 × 0.06 m were heated in a three-zone electric muffle furnace while in continuous motion; the zone temperature were 450-680-780°C. The specimens were heated by radiation from the muffle, which was constructed of steel 12Kh18N9T; the latter was also heated, in turn, by radiation from silicon carbide heaters and the furnace brickwork. This indirect method of heating makes it possible to increase the temperature of a moving blank evenly. Use of silicon carbide heaters ensures the sufficiently reliable operation of the furnace over a prolonged operating period. To reduce decarburization of the surface layers, the dimensions of the muffle were selected with minimum gaps between its walls and the blanks, and a hydraulic gate is also used in transferring the blanks from the furnace to the quenching bath. The temperatures are automatically maintained with an error of ±3°C by the method of proportional-differential regulation in combination with a thyristor circuit for controlling the electric parameters. With a minimum time interval of 5 sec, the blank is delivered from the furnace into a vertical quenching pipe with a water trap, which is a system of opposing jets. The vertical pipe is immersed 1 m into a 0.5-m³ bath of an aqueous solution containing 10% of NaCl and 2% of NaOH. A centrifugal pump circulates the solution in the bath and develops the jets in the pipe. The temperature of the quenching medium is maintained at a level of 20°C using the automated inclusion of a "tube-in-tube"-type "refrigerator" that operates on running water.
Fig. 1. Schematic diagram of automated line for heat treatment of hardness standards: 1) muffle; 2) heating elements; 3) brickwork; 4) magazine; 5) pusher; 6) lever; 7) conveyer; 8) pump; 9) pipe; 10) jet system; 11) trap.

For a furnace productivity of 60 pieces/h, i.e., with a rhythmic output of 1 piece per minute, the actual dimensions of the quenching bath cannot ensure that the blank is cooled in the bath in the descending state to the temperature of the coolant. A system of opposing jets and a highly turbulent flow of solution in the vertical pipe provides for cooling of the blank to 170-180°C.

Structurally, the problems involving the cooling and discharge of the blank from the quenching bath (one piece/min) were solved by the use of a perforated copper gate in the lower part of the vertical pipe, onto which the blank falls and is cooled for a period of 40 sec to the temperature of the quenching medium; it then drops onto the discharge conveyer when the gate is automatically tilted; thereafter, it is directed into the furnace for low tempering. On passing a system of orienting devices, the blank falls into a partitioned disk feeder, and then into a circular six-shelf furnace. The blanks move in the furnace from top to bottom along a spiral during the 3-h period required for low tempering at 170 ± 5°C. This construction makes it possible to reduce the clearance dimensions of the furnace as much as possible; this exerts a positive influence on the maintenance of the required temperature of the heat-transfer medium and energy expenditures. Hot air, which is fed through four nozzles onto each of the six furnace shelves, is employed as the heat-transfer medium. This medium is circulated by a centrifugal fan, and its preliminary heating is accomplished by a miniature three-stage air heater. Under the given conditions, two stages of the air heater are automatically switched off at the furnace outlet, and the temperature is maintained by a single heating stage.

The following factors affecting the output of suitable blanks were revealed in the process of adjusting the production conditions for operation of the semi-automated line:

1. The cooling rate in the period of the martensitic transformation (below the point $M_n$) (given as a percentage of the output of suitable blanks):
   a) cooling on a perforated shelf formed from corrosion-resistant steel 12KhlSNgT: a 40% rejection with a spread to 1.5 HRC, and a thermal conductivity $\lambda = 20 \text{ W/(m} \cdot \text{°K)}$ for the 12KhlSNgT steel;
   b) cooling on a perforated copper shelf with $\lambda = 280 \text{ W/(m} \cdot \text{°K)}$: a 35% rejection with a spread to 0.8 HRC; and,
   c) cooling on a perforated copper shelf with the insertion of an active jet of quenching medium below the shelf: a 25% rejection with a spread to 0.8 HRC.

2. Surface roughness after machining. For an adjusted cooling regime: a 20% rejection with a spread of 0.8 HRC.

3. The presence of contaminating substances on the surface (oil, dirt, etc.); washing in kerosene: a 15% rejection with a spread to 0.7 HRC using the optimal variants of the two above-enumerated factors.