A new system has been developed for the water-air cooling of ingots. The system functions in the automatic regime, including during transients in the casting operation. It increases casting speed and improves the quality of both the surface and the macrostructure of the slab. The cooling system developed for low-speed continuous casters provides for low-intensity cooling of the slab by a water-air mist, which prevents local overcooling of the part of the ingot surface that first comes into contact with the coolant water. The system has passed factory tests and has been adopted for use on all of the grades of steel made in the shop.

The Motovilikhinskoe Zavody Company was one of the main creators of continuous steel casting. At the end of the 1950s and beginning of the 1960s, the plant independently designed and built continuous-casting machines and a technology for the continuous casting of steel into slabs, blooms, and other types of semifinished products. The units were installed in the open-hearth shop of the plant. The casters were continually modernized during this period and a new technology was successfully introduced for making a wide range of special high-strength steels. These efforts allowed the facility to keep the technical sophistication of the production equipment up to par until the end of the Twentieth Century. Then the plant began a wholesale reconstruction, replacing the open-hearth furnaces by a powerful 65-ton arc stage furnace and a ladle-furnace and further modernizing the continuous casters.

The water-type secondary cooling system on continuous slab caster No. 4 has been replaced by a water-air system. This vertical caster is used to obtain slabs with cross sections of 175 × 1020 and 168 × 630 mm. Slab withdrawal speed is 0.65–0.70 m/min. The secondary cooling system used to consist of an inlet zone and three cooling zones with water nozzles. Control of flow rate was manual. A preliminary analysis of the technology and equipment showed that the cooling zones were too short, causing the water to flow underneath them. That in turn resulted in secondary heating of the surface of the slab and the formation of a low-density structure in its axial region. The high temperature of the slab surface also led to the formation of a deep, loose layer of scale on top of it. The water nozzles were characterized by a nonuniform heat-transfer distribution across the jets, and water would accumulate between the rollers and the slab surface. Also, the corners of the slab underwent excessive cooling, and bulges sometimes developed on its sides.

It was decided to design a water-air system for ingot-cooling that would operate in the automatic regime, including during transient operating periods. The new system was also to make it possible to increase casting speed and improve the quality of the slab’s surface and macrostructure. Cooling systems that are designed for low-speed casters have certain dis-
tinctive characteristics. It is necessary to provide for low-intensity cooling by a water-air mist in order to avoid local over-cooling of the ingot surface in the region where the water first comes into contact with the surface. Also, the cooling nozzles must be characterized by a uniform distribution of the heat-transfer coefficient across the stream, since slabs that are cast at low speeds are susceptible to the formation of bands of metal on the surface that have undergone excessive cooling.

A mathematical model of slab-cooling was developed during the design process. To calculate the temperature field in the cross section of the slab, we used a computational method based on an equilibrium model of solidification of alloys [1–3] and a finite-element procedure for solving the heat-conduction equation [4]:

\[
\rho c_{\text{eff}} \frac{dT}{dt} = \text{div}(\lambda \text{grad} T),
\]

where

\[
c_{\text{eff}}(T) = \begin{cases} 
    c_L(T), & T > T_L; \\
    (1-f_L)c_S + f_L c_L + L \frac{df}{dT}, & T_S \leq T \leq T_L; \\
    c_S(T), & T < T_S;
\end{cases}
\]

613