REBUILDING THE SECONDARY COOLING SYSTEM
ON THE CONTINUOUS SLAB CASTER AT THE
KAMASTAL’ METALLURGICAL PLANT

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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 Motovilikhinskie 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The water-type secondary cooling system on continuous slab caster No. 4 has been replaced by a water-air system.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-trans-
fer 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-

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tinctive characteristics. It is necessary to provide for low-intensity cooling by a water-air mist in order to avoid local overcooling 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]:

$$\rho c_{\text{eff}} \frac{\partial T}{\partial t} = \text{div}(\lambda \text{grad} T),$$  \hspace{1cm} (1)

where $c_{\text{eff}}(T) = \begin{cases} c_L(T), & T > T_L; \\ (1-f_L)c_S + f_Lc_L + L\frac{df_L}{dT}, & T_S \leq T \leq T_L; \\ c_S(T), & T < T_S; \end{cases}$ $T_S$ and $T_L$ are the solidus and liquidus temperatures of the given alloy, respectively.

Fig. 1. Distribution of the temperature of the surface of a slab across its width (low-alloy steel).

Fig. 2. Distribution of the temperature of the surface of a slab along the working axis (low-alloy steel; ingot width 1020 mm, ingot thickness 175 mm; casting speed 0.7 m/min): 1) center of slab; 2) 1/4 of the width from the center of the slab.