from three points. Small overlaps occur, interrupting the smooth course of the isotherm. In this case the
smoothness of the isotherm must be established on the concentration triangle, while the curvature of the
liquidus and solidus lines, with an error, is corrected from these isotherms.

To plot similar graphs without taking into account the casting conditions it would be necessary to have
a much larger number of compositions along the parallelogram without polythermal cuts.

The correctness and the fairly high accuracy of the isotherms were confirmed as follows.

Temperatures $t_L$ and $t_S$ coincided with those found from the isotherm within a few degrees.

The isotherms were in good agreement with $t_L$ and $t_S$ of the corresponding binary alloys [1-3]. The
Ni-Al-Cr and Ni-Al-Ti systems should be noted in particular. Two liquidus lines of Ni-Cr alloys rich in
nickel were plotted in [4, 5]. In our work the isotherms of the liquidus of the Ni-Al-Cr system are in good
agreement only with the data in [4] and not with the data in [5]. The isotherms of the liquidus and solidus of
the Ni-Al-Ti system agree with the data for the Ni-Ti phase diagram given in [6] but not with the data in
[7].

The isotherms of the Ni-Al-Nb system agree with two of the polythermal cuts given in [8]. The iso-
therm of the liquidus and solidus, including the curve of maximum solubility of aluminum in nickel in relation
to the niobium content, was plotted with use of data from [8].

LITERATURE CITED

3. F. A. Shank, Constitution of Binary Alloys [in Russian], Metallurgiya, Moscow (1973), pp. 293, 543,
568, 606.

EFFECT OF BORON, CERIUM, AND ZIRCONIUM ON
THE PROPERTIES OF KhN65VBMYu CASTINGS

V. A. Polinets, L. N. Zimina, and V. K. Tsvetkova

It is possible to obtain castings of nickel-base heat-resistant alloys with niobium without using vacuum
equipment, in contrast to alloys with titanium. This greatly reduces the cost of castings and simplifies the
production technique. The introduction of modifying additions changes the structure of these alloys and has a
positive effect on the operating properties of cast machine parts.

We investigated the effect of small boron, cerium, and zirconium additions, separately and together,
on the structure and properties of heat-resistant alloy KhN65VBMYu (EP902), which is hardened by inter-
metallic phase Ni$_3$(Nb, Al) [1, 2]. Alloys containing the same quantity of the basic alloying elements (14.7%
Cr, 6.8% W, 4.0% Mo, 5.4% Nb, 0.6% Al, 0.08% C) were melted in a 50-kg induction furnace with a magnesite
 Crucible by the standard procedure. Boron as ferroboron, cerium as ferrocerium, and metallic zirconium
were added in the furnace 2-3 min before pouring. Each heat was cast in a metallic clover-leaf mold and in
a heated ceramic mold (800°).

The mechanical properties were determined with castings hardened in air from 1170° (holding 3 h) and
aged 15 h at 720°. The macrostructure was examined on longitudinal samples cut from the riser of samples

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1978.
produced by investment casting, and the microstructure on cast samples in the transverse direction.

To determine the effect of small boron, cerium, and zirconium additions on the behavior of alloy KhN65VBMYu heated to 1100° we used a thermoanalytical derivatograph (made in Hungary) permitting simultaneous recording of changes in temperature, weight, and the enthalpy of the sample. The error in the measurements was 0.1-1%, the heating rate 2.2 deg/min. We investigated shavings (0.4 mm) of castings that were not heat-treated.

The mechanical properties of the alloy were determined in tensile tests and impact bending tests at 700° and creep tests at $\sigma = 45$ kgf/mm².

Metallographic analysis showed that the addition of boron, cerium, and zirconium refines the cast structure. With the addition of 0.3% B, 0.3% Ce, or 0.3% Zr the grain size of the castings decreases by more than an order. Because of the heterogeneity of the structure through the section of the castings it was impossible to establish a direct correlation between the changes in intragranular dendritic structure and the addition of alloying elements. According to x-ray data, boron forms borides of the $M_6\text{B}_2$ type and promotes an increase in the concentration of boride phase of the $M_6\text{C}$ type. This phase constitutes ~3% in the alloy with 0.2% B.

### TABLE 1

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Fig. 1. Change in enthalpy during heating of alloy KhN65VBMYu. The heat numbers are given on the curves.

Fig. 2. Change in weight of alloy KhN65VBMYu during heating. The heat numbers are given on the curves.