The development of ordering processes in alloy N70M27 at 700-800°C lowers the corrosion resistance [1]. One method of increasing the corrosion resistance at these temperatures is alloying with vanadium or niobium [2]. However, there is no agreement on the effects of these elements [2, 3].

We investigated the effect of 1.8% V and 2% Nb on the corrosion characteristics, ordering processes, and carbide formation in alloy N70M27 at 600-800°C.

The chemical composition of the alloys is given in Table 1.

The investigation was conducted on plates 3-4 mm thick that were water quenched from 1150°C and tempered at 600, 700, and 800°C for 10 min to 500 h, and also holding for 30 min at 600-900°C. The corrosion tests were made in 21% boiling hydrochloric acid for 240 h. The corrosion rate was determined by weighing. The susceptibility to intercrystalline corrosion (ICC) was determined from bending of samples and also from measurements of the corrosion depth by the metallographic method. The kinetics of the structural transformations at 600-900°C was determined from the hardness and resistometric and dilatometric measurements, and also by means of light, electron, and field ion microscopy. The electron microscopic studies were made on carbon replicas with extracted particles of excess phases and subsequent diffraction analysis in the electron microscope. The microsections were electropolished in a 20% solution of sulfuric acid in methyl alcohol. Etching was conducted in a 10% solution of oxalic acid in alcohol, a 10% solution of ammonium persulfate, etc. The structure of Ni-Mo, Ni-Mo-V, and Ni-Mo-Nb alloys was examined in the field ion microscope by the method described in [1, 4].

Figure 1 shows the change of the corrosion rate and depth of ICC in boiling 21% HCl for Ni-Mo (heat 1), Ni-Mo-V (heat 2), and Ni-Mo-Nb alloys (heat 3) with tempering temperature (holding time 30 min). The corrosion resistance was highest in the quenched condition for all alloys investigated. The corrosion rate of binary and ternary alloys was very similar, amounting to 0.2-0.25 g/m²-h. Tempering at 600-800°C raises the dissolution rate of the alloys (Fig. 1a). The highest solution rate (1.6 g/m²-h) of the binary alloy was observed after tempering at 800°C. As the result of alloying with vanadium and niobium, the highest corrosion rate is observed at 700°C, and the corrosion losses substantially decrease, particularly after tempering at 800°C, as compared with binary alloys. After tempering at 800°C the ternary alloys dissolve four to five times more slowly than the binary alloys. After tempering at 700°C the corrosion rate of alloys with 1.8% V or 2.0% Nb is 0.4-0.45 g/m²-h, and the binary alloys dissolve twice as fast after similar treatment.

The addition of vanadium reduces the corrosion rate and eliminates ICC after tempering at 600-800°C for 30 min (Fig. 1b).

Figure 2 shows the variation of the corrosion resistance and depth of ICC for Ni-Mo and Ni-Mo-V with the holding.

### Table 1

<table>
<thead>
<tr>
<th>Heat No.</th>
<th>Mo</th>
<th>V</th>
<th>Nb</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>27.8</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>27.3</td>
<td></td>
<td>2.0</td>
</tr>
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</table>

Note. The alloys also contained 0.015-0.02% Si, 0.2-0.5% Mn, 0.003-0.005% S and P, 0.3-0.5% Fe, the remainder Ni.
time at 600, 700, and 800°C. After most of the holding times tested, the corrosion rate and depth of ICC for the alloy with vanadium are considerably lower than for the binary alloy; the difference is greatest at brief holding times.

After tempering at 600°C for times up to 100 h the variations of the corrosion rate and depth of ICC with time are similar (Fig. 2a, b). With increasing holding times the greater depth of ICC is accompanied by an increase of the corrosion rate in both alloys. For the binary alloy the peak ICC (0.12 mm) and corrosion rate (0.7 g/m²-h) occur with holding for 10 h. In the ternary alloy the maximum ICC is observed at longer holding times (Fig. 2b).

Raising the tempering temperature to 700 and 800°C changes the character of corrosion as a function of holding time. The addition of vanadium lowers the corrosion rate of the Ni-Mo alloy by a factor of two to three after tempering at 700°C but does not change the character of the time dependence – the corrosion rate increases with the holding time (Fig. 2a). The variation of the corrosion weight loss with holding time changes after tempering at 800°C. The maximum corrosion rate (1.2 g/m²-h) for the binary alloy is reached in 30-60 min; increasing the holding time to 100-500 h does not change the corrosion rate (Fig. 2a). The corrosion rate of the Ni-Mo-V alloy changes slightly after brief holding as compared with the quenched condition, and only with holding for more than 60 min does the rate increase more intensively, continuing with holding for 100 h (Fig. 2a).

The addition of vanadium to the Ni-Mo alloy also causes a sharp change in the character of the depth of ICC as a function of holding time at 700 and 800°C. The greatest depth of ICC in the binary alloy is observed after holding for 10 h at 700°C and 30 min at 800°C (Fig. 2b). In the Ni-Mo-V alloy ICC is noted