

### Nickel-copper alloys

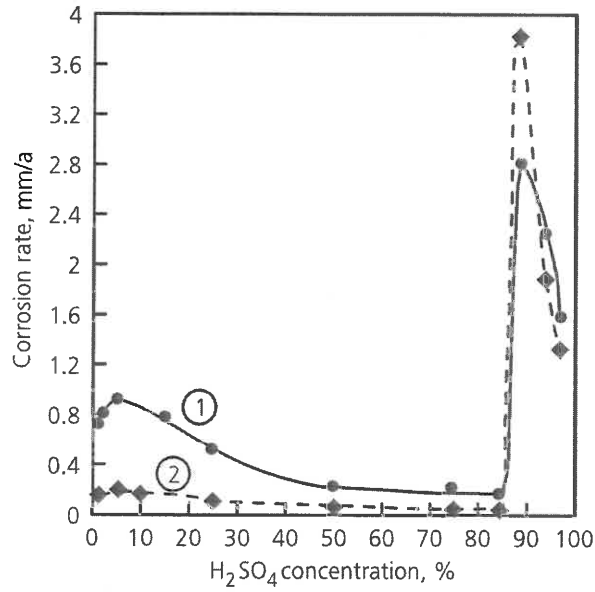
Monel<sup>®</sup> 400, an alloy containing about 66% Ni and 32% Cu (NiCu 30 Fe, 2.4360), is one of the chief materials used in the chemical industry.

This alloy is even more important when dealing with sulfuric acid than pure nickel; although they are both similar in their chemical resistance to sulfuric acid.

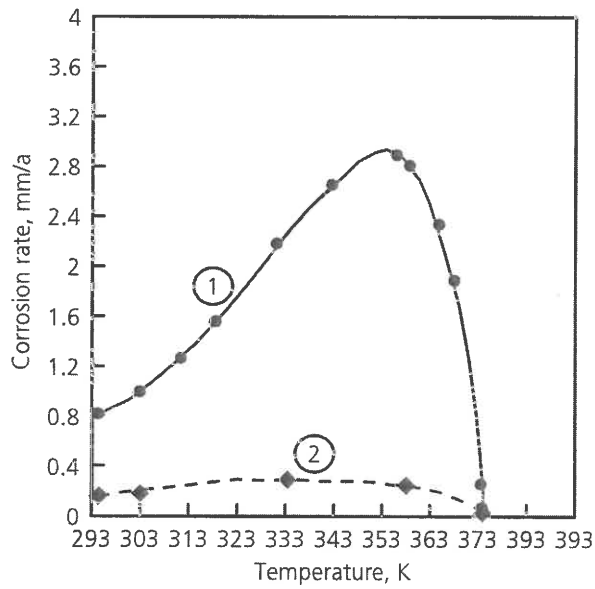
As with nickel, the corrosion of Monel<sup>®</sup> 400 is increased by the presence of oxygen in sulfuric acid and by iron salts. Its corrosion resistance to all acids, with the exception of highly oxidizing acids, can be described as good [395, 397, 398, 401, 402, 405, 406, 422, 425, 438, 461].

In non-oxidizing acids, the corrosion potentials of Monel<sup>®</sup> 400 in most cases lie in regions where evolution of hydrogen is avoided. Corrosion can occur, therefore, only if dissolved air or other oxidizing substances are present. Thus the degree of aeration of sulfuric acid is an important factor in the corrosion of NiCu-alloys. For the corrosion behavior of Monel<sup>®</sup> 400 in sulfuric acid and media containing sulfuric acid see also Figure 90. Figures 126 and 127 show the influence of the oxygen content on the corrosion rates in sulfuric acid at room temperature. Figure 126 shows that hardly any corrosion occurs in air-free sulfuric acid at room temperature, corrosion rates in up to 80% H<sub>2</sub>SO<sub>4</sub> with a maximum of 0.3 mm/a prevailing. The corrosion passes through a maximum in air-free H<sub>2</sub>SO<sub>4</sub> of approximately 5%. In air-saturated sulfuric acid under the same conditions, the maximum corrosion rate is still 1 mm/a in approximately 5% H<sub>2</sub>SO<sub>4</sub>. On this basis, Monel<sup>®</sup> 400 can be used for storage and transportation of sulfuric acid in the concentration range up to 80% H<sub>2</sub>SO<sub>4</sub>, and is the material used the most for this purpose [395]. Above 80% H<sub>2</sub>SO<sub>4</sub> increased attack occurs as a consequence of the oxidizing acid. In the concentration range from 15 to 80%, the corrosion rate falls almost linearly, as a consequence of the decrease in the hydrogen ion concentration and oxygen solubility. Above a concentration of 80%, the sulfuric acid has an oxidizing action and hence causes a higher corrosion rate on Monel<sup>®</sup> 400 which is then evidently less influenced by the aeration. In very aggressive 5 to 6% sulfuric acid at room temperature, an increase in the temperature has no significant effect on the corrosion rate of Monel<sup>®</sup> 400 if the acid is air-free. In air-saturated sulfuric acid, in contrast, the corrosion rate increases very sharply and reaches a maximum at 80°C of about 3 mm/a (Figure 127). The weight losses are about 3 times higher in oxygen-saturated acid than in air-saturated acid [461]. The corrosion on NiCu-alloys is intensified as the flow rate increases. As well as fresh acid, the flowing acid also brings dissolved oxygen and oxidizing constituents to the surface of the metal and corrodes this away. Figure 128 shows the conditions for 5% sulfuric acid saturated with air as the flow rate increases.

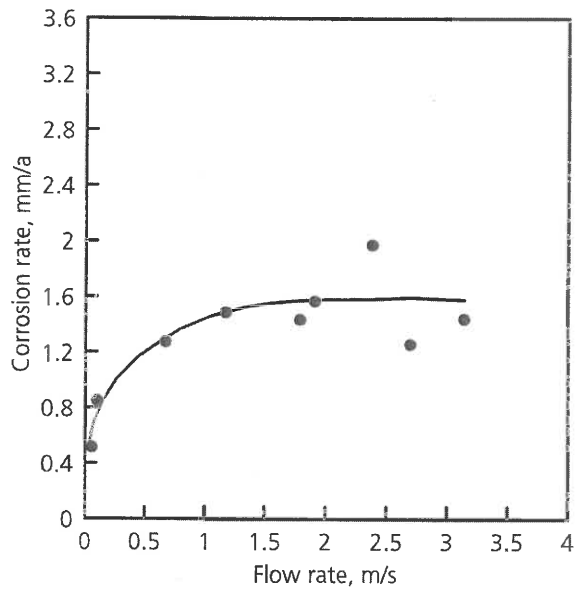
Figure 129 shows an overview of isocorrosion curves of Monel<sup>®</sup> 400 in sulfuric acid solutions. Since no further information is available, this graph applies to non-aerated acid. Higher corrosion rates can be expected with aeration, additional agitation of the acid and an increase in temperature, as can be seen from Figure 130 [396, 404, 454, 462].



**Figure 126:** Corrosion behavior of Monel® 400 (2.4360) in sulfuric acid at room temperature as a function of aeration (test duration 48 h) [395, 396, 401, 406, 461, 463]  
 ① saturated with air  
 ② saturated with nitrogen, air-free

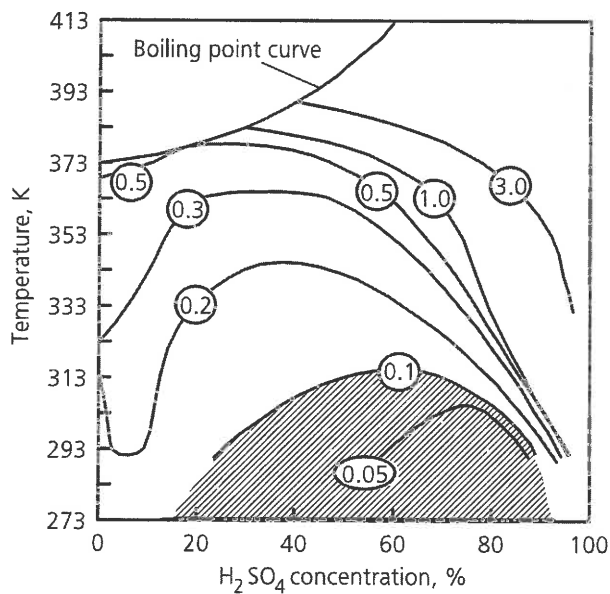


**Figure 127:** Corrosion behavior of Monel® 400 (2.4360) in 5 to 6% sulfuric acid as a function of aeration and temperature (test duration, 48 h) [395, 396, 401, 406, 461, 462]  
 ① saturated with air  
 ② saturated with nitrogen, air-free



**Figure 128:** Influence of flow rate on the corrosion rate of Monel<sup>®</sup> 400 in air-saturated 5% sulfuric acid at room temperature (test duration 28 h) [396]

In comparison with lead materials, for example, Monel<sup>®</sup> 400 can be used in the concentration range between about 25 and 85% H<sub>2</sub>SO<sub>4</sub> [464] with a corrosion rate of not more than 0.1 mm/a up to 40°C, in agreement with [404] (Figure 129 and Figure 131).



**Figure 129:** Isocorrosion curves (mm/a) for Monel<sup>®</sup> 400 ((%) 67Ni-30Cu-1.4Fe-0.15C) in sulfuric acid [404]