mining the amount of borax to be added to the bath in the case of articles with teeth having a 55° angle and heated to 900°C for 20 min is shown by the dotted line in Fig. 3. Similar graphs can be drawn for different typical shapes of machine parts.

**LITERATURE CITED**

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**RAPID HEAT TREATMENT OF Mn-Si PIPE STEEL**

B. P. Kolesnik

Ukrainian Scientific Research Pipe Institute

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The purpose of this investigation was to determine the relationship between the temperature and rate of double heat treatment and the mechanical properties of Mn-Si steel so as to find the optimum treatment conditions.

We investigated 36G2S steel (0.37% C, 1.56% Mn, 0.61% Si, 0.026% P, 0.018% S, Ac1 = 740°C, Ac3 = 798°C), which is used for manufacturing pipe for oil pipelines.

![Fig. 1. Effect of quenching temperature on the strength and ductility of tempered steel. The heating rates are: 1) 8 deg/sec; 2) 4 deg/sec; 3) 1.8 deg/sec; 4) kept at the quenching and tempering temperatures 30 min.](image-url)
Fig. 2. Effect of tempering temperature on the mechanical properties of quenched steel. Rates of heating to tempering temperature, deg C: 1) 10 deg/sec; 2) 4 deg/sec; 3) 1.5 deg/sec; 4) kept at the quenching and tempering temperatures 30 min.

Samples 11 x 14 x 70 mm were cut from hot rolled pipes 299 x 11 mm. The samples were heated in an electric furnace with a special attachment; the samples were quenched in water, but cooled in air after tempering. The first series of samples was heated to 740-1000°C at the rate of 1.8-8 deg/sec. After quenching, all the samples were heated to 600°C at the rate of 4 deg/sec.

Samples of the second group were heated to 870°C at the rate of 4 deg/sec, quenched, and then tempered at 350-680°C.

For comparison, we prepared another series of samples which were treated at the same temperatures but were kept at these temperatures for 30 min [3].

Samples for measuring tensile strength (6 mm in diameter) and impact strength (6 x 10 x 55 mm with Menage notches) were prepared from the heat treated metal. The hardness was measured on the impact strength samples.

The variation of the mechanical properties of tempered steel with the quenching parameters (heating rate and temperature) is shown in Fig. 1.

The strength of the steel heated to a quenching temperature of 740-770°C at the rate of 1.8 and 4 deg/sec increases and the ductility decreases with increasing temperature. At the same time, the amount of ferrite in the structure decreases.

Thus, the properties of the steel change in the same way after ordinary heat treatment (where the samples are kept for 30 min at the quenching temperature) and after rapid quenching (where the samples are heated at the rate of 1.8 and 4 deg/sec and quenched from critical temperatures).

Quenching from 740-800°C after heating at the rate of 8 deg/sec does not increase the strength of 36G2S steel. Higher quenching temperatures (840-870°C) induce a sharp decrease of relative reduction of the section and the impact strength. Quenching from 900°C (the heating rate being the same) eliminates the free ferrite from the structure.