The effect of residual elements on the heat resistance of steels has not been studied in sufficient detail. The literature contains data [1] concerning the effect of impurities (Sn, Zn, Pb, etc.) on the properties of austenitic Cr–Ni steels and nickel-base alloys, but there are no data concerning the effect of these impurities on the properties of low-alloy steels based on iron. By analogy with austenitic steels and alloys, it is considered that these impurities will not lower the long-term strength or the hot plasticity. The concentrations of these elements are not controlled in steels, although the quantity of filings is limited in boiler steels, which is one of the main sources of impurities. However, impurities may also come from ferroalloys, slag materials, and some iron ores with Cu, Zn, As, and Ni [2].

This work concerns the effect of Pb, Sn, Zn, Cu, Ni, N, and other elements on the properties of widely used Cr–Mo–V steel 12Kh1MF. According to MRTU 14–4–21–67 specifications, the quantity of Cu and Ni in steel 12Kh1MF should not exceed 0.3%. Laboratory heats (see Table 1) were melted in a 30 kg induction furnace.

Fig. 1. Results of torsion tests for steel 12Kh1MF (1) with additions of 0.36% Cu (2), 0.008% Zn (3); 0.003% Pb (4); 0.03% N (5); 0.014% Sn (6); 0.072% P (7); 0.08% S (8).
sulfur and phosphorus were added in the form of alloys with iron (35% Fe–S and 16% Fe–P). Carbonyl iron, ferrochromium, and nickel were added with the charge, and molybdenum after melting. After melting, the surface was treated with a slag mixture and calcium boride, followed by deoxidation with silicon, manganese, and drawing off the slag. Fe–V was added 8 min before teeming; Zn, Sn, and Pb were added to the ladle under the stream, and nitrided manganese and copper were added to the ladle before the metal was poured. The metal was top cast in ingots weighing 25 kg and forged to a diameter of 18 mm. The forging temperature did not exceed 1160–1170°C, and the final forging temperature was 800–900°C.

The plasticity and resistance to deformation of the steels were determined by torsion tests at hot deformation temperature (950–1200°C). Additions of Zn, Cu, Pb, and P do not impair the plasticity of steel 12Kh1MF (Fig. 1). For the steel with zinc the number of twists is larger than for the steel without zinc. However, the addition of tin and sulfur lowers the plasticity of the steel at all temperatures investigated. The additions investigated have no effect on the resistance to plastic deformation. The lower number of twists or plasticity at high temperatures is usually associated with the fact that low-melting compounds or eutectics form in the grain boundaries. Analysis of binary systems of iron (the base of low-alloy steels) with Sn, S, P, Bi, and Zn indicated that these elements form low-melting eutectics. Microscopic examination in a light microscope (×1000) of samples subjected to torsion tests showed no changes of any kind in the grain boundaries.

Mechanical tests at 20, 540, 570, and 610°C after normalization at 950°C and tempering at 730°C for 3 h showed that these additions have almost no effect on the strength or plasticity of steel 12Kh1MF.

Long-term strength tests at 570°C under stresses of 18, 16, and 14 kg/mm² showed that the additions have no effect on the