It is considered that the stable intracystalline segregation of phosphorus is due to its low diffusion mobility. However, in [1] and elsewhere it has been shown that intracystalline segregation of phosphorus in carbon steel can be induced as well as eliminated by heat treatment.

The influence of phosphorus on processes occurring during heat treatment of steel can be determined from its diffusion mobility. The diffusion of phosphorus in ferrite and austenite alloyed to various degrees was investigated in [2]. It was found that the diffusion mobility of phosphorus is below that of carbon and above those of the alloying elements. The bulk diffusion coefficient of phosphorus at the usual heat treatment temperatures for steel is two to three orders higher than those of alloying elements and selfdiffusion of iron.

The development of reversible temper brittleness is associated with the diffusion of phosphorus. To prevent reversible temper brittleness it was recommended in [3] that steel be tempered a long time at temperatures near Ac1. The steel subjected to such treatment is insensitive to rapid cooling after tempering. The effect of such prolonged tempering on the properties of the steel is explained by the diffusion of phosphorus.

It was noted in [4] that the degree of homogenizing of phosphorus in steels of the pearlitic class is the same for the homogenizing annealing time at 700 and 1100°C. This could result from the higher diffusion mobility of phosphorus in ferrite than in austenite. However, comparison of the phosphorus diffusion coefficients in ferrite and austenite at 700 and 1100°C (respectively 2.7·10^{-12} and 1.2·10^{-9} cm^2/sec) shows that the phosphorus diffusion coefficient in ferrite at 700°C is approximately three orders lower than in austenite at 1100°C. Consequently, the effect of equal homogenization of phosphorus at 700 and 1100°C is not due to the higher diffusion mobility of phosphorus in ferrite.

In low-alloy carbon steels the elements diffuse into the single-phase system of recrystallized austenite at 1100°C; at 700°C they diffuse into the ferrite-pearlite structure, characterized by a branching system of boundaries between the coexisting ferrite and cementite phases. Consequently, as in unrecrystallized austenite, the diffusion of phosphorus and other elements forming substitution solid solutions with iron must be accelerated. Apparently this also explains the equal homogenization of the steel in phosphorus at 700 and 1100°C [4].

To check this assumption we investigated steels KhG2, 10KhG2, and 40Kh, which have different structures at 700°C. The samples were heat treated to produce an equilibrium structure: heated to 1100°C, soaked 2 h, cooled slowly. In KhG2 steel this treatment produced a ferrite structure with small inclusions of secondary phase in the grain boundaries, and in steels 10KhG2 and 40Kh a ferrite-pearlite structure. Radioactive phosphorus was then applied and the samples subjected to homogenizing annealing at 700°C. Figure 1 shows the microstructure after homogenizing annealing.

Sectioning and radiometric analysis showed that the depth of diffusion in steels 10KhG2 and 40Kh is approximately double that in steel KhG2. Figure 2 shows the variation of radioactivity (phosphorus concentration) with depth in steels 10KhG2 and KhG2.
The diffusion curves for KhG2 steel, characterized by coarse ferrite grains, were treated by a method allowing separate studies of boundary and bulk diffusion [5]. These studies showed that boundary diffusion has little effect on overall diffusion. The bulk diffusion coefficient for KhG2 steel at 700°C was $5.6 \times 10^{-12}$ cm$^2$/sec.

The diffusion curves for steels 10KhG2 and 40Kh, with a ferrite-pearlite structure, were treated by a method allowing one to obtain the effective diffusion coefficients [6] - the total of bulk diffusion in the coexisting phases and diffusion along phase boundaries. The effective diffusion coefficient characterizes the transfer rate of phosphorus in the steel under heterophase conditions. From this one can judge the redistribution rate of phosphorus during heat treatment of the steel.

The average values for the effective diffusion coefficient of phosphorus in steels 10KhG2 and 40Kh are respectively $3.0 \times 10^{-11}$ and $2.16 \times 10^{-11}$ cm$^2$/sec. By comparing the depth of diffusion and the diffusion coefficient one can see that diffusion is accelerated in steels with a pearlite structure at temperatures near $A_C$, as in unrecrystallized austenite. The diffusion coefficient at 700°C is approximately one order higher in steels than in single-phase alloys.

Thus, the effect of identical homogenizing at 700 and 1100°C can be explained by the additional acceleration of diffusion in pearlitic and ferritic-pearlitic steels. The more complete equalizing of the phosphorus concentration in the steel by diffusion is also promoted by the higher solubility of phosphorus in ferrite. In the austenite region at 1100°C the equalizing of the composition results primarily from bulk diffusion, the rate of which is somewhat below that of boundary diffusion. The solubility of phosphorus in austenite at 1100°C is less than in ferrite at 700°C.

Prolonged heating of steels in the two-phase $\alpha-\gamma$ region is usually avoided during heat treatment. This is due to the fact that heating in the two-phase region induces redistribution of elements between the $\alpha$ and $\gamma$ phases in conformity with their solubility in the two phases, which induces chemical heterogeneity in microvolumes of the metal. Nevertheless, such heat treatment is used to improve the properties of steels. It was shown in [7] that heat treatment in the two-phase region reduces the cold brittleness threshold of phosphorus carbon steel because of the more favorable distribution of phosphorus. The effect of repeated quenching from the two-phase region on the susceptibility of structural steels to reversible temper brittleness was investigated in [8]. The authors concluded that after normal and repeated quenching from the critical temperature range structural steels become insusceptible to reversible temper brittleness. This is explained by the fact that previously quenched steel quenched from the critical temperature range develops a structure consisting of fine acicular ferrite interbedded with high-carbon martensite. Apparently the formation of such a structure and its effect on the properties of the steel are due to the unusual distribution of carbon and phosphorus during heating in the two-phase $\alpha-\gamma$ region [1, 7].

Heat treatment in the two-phase region is used to improve the mechanical properties and cold brittleness of high-manganese low-carbon steels [9, 10] and to improve the quality of carbon steel casting [11].

We investigated the effect of phosphorus on the processes occurring during heat treatment of different steels in critical temperature range.