Fig. 2. Deformations associated with twinning:
- - along the (130) plane; - - - along a crystallographically equivalent plane.

From the standpoint of the physical processes which occur in the region of a fission spike, it is doubtful whether the arguments of the authors are correct. The time for formation and growth of a thermal spike ($r \sim 10^{-11}$ sec) is much too short to expect the appearance of large-scale twins whose formation requires a considerable time.

Assuming that twin formation proceeds with the speed of sound, $c$, we obtain its maximum diameter, approximately equal to $r c = 10^{-6}$ cm. It is doubtful that such twins would be stable. Theories based on the processes of atomic displacement and "agitation" which take place in the region of a fission spike seem more perspicuous.

LITERATURE CITED


Materials which contain nickel, molybdenum, boron and other elements have a wide practical application. In particular, steels which contain approximately one percent by weight of boron can be used for the production of shielding; and if there is more than two percent by weight of boron, they can be used for the production of control rods. Thus the phase composition of alloys which contain significant quantities of boron is of interest.

The results of an investigation of nickel-base alloys containing up to 22-33 at.\% of molybdenum and up to 25-33 at.\% of boron are reported in this paper.

For the melt, the charge materials described in reference [1] were used plus molybdenum in powdered form containing 99.7 wt.\% of molybdenum, 0.2 wt.\% of oxygen, 0.002 wt.\% of nickel, and 0.01 wt.\% of iron. All alloys were melted in aluminum oxide crucibles in an argon atmosphere. Burn-up of nickel, molybdenum, and boron is slight for a melt under pure argon; thus, the composition of the alloys was that of the charge.

The alloys studied were subjected to annealing for 100 hr at 1000°C with subsequent cooling in air. An increase in annealing time did not lead to a change in phase composition, as was determined by studies of microstructure and measurements of microhardness and by x-ray analysis.

Electrolytic etching and thermal coloration by heating with a high-frequency current were used to bring out microstructure [2].

Measurement of microhardness was carried out on a PMT-3 apparatus. Using cobalt $K_\alpha$ radiation, qualitative x-ray powder analysis was done. Powders from high-boron-content alloys were prepared by grinding castings; in low-boron-content alloys, the boride phase was separated electrochemically by the method described in [3].
It is possible to divide the alloys in the region studied into four groups according to phase composition. To the first group belong alloys with the structure of a homogeneous solid solution having a nickel base and containing not more than 0.02-0.03 at.% of boron. Alloys containing no more than 10 at.% of molybdenum, in whose structure there is the compound Ni₃B in addition to the solid solution, belong to the second group. For alloys of this group, the two-phase structure is characteristic (Fig. 1). X-ray analysis of the precipitate electrochemically separated from this alloy confirms the judgement concerning the presence of only one boride phase — Ni₃B. An increase in boron content of the alloys, with molybdenum content kept fixed, leads to an increase in the solid-solution lattice period, since, in this situation, boron binds nickel and molybdenum is forced into the solid solution. To alloys of the third group belong the three-phase alloys in which, besides the solid solution and Ni₃B, there is a third phase which we call phase M. The typical structure of these alloys is shown in Fig. 2. In the case of electrochemical precipitation from alloys of this group in electrolytes, which usually are used for the separation of carbides from nickel alloys [3], Ni₃B is dissolved to a significant degree, and lines characteristic of phase M are seen mainly in radiographs of the precipitates. In radiographs of the precipitates which are obtained by precipitation from alloys of the third group in an electrolyte, reflections from the planes of the rhombic Ni₃B lattice are observed. The structure of alloys of the fourth group containing more than 10 at.% of molybdenum consists of two phases: nickel-base solid solution and phase M.

For low boron content, phase M is seen as a dispersed component, but large inclusions of phase M are developed in the case of a significant boron content in the alloy structure (Fig. 3).

Phase M is a ternary nickel-molybdenum-boron compound, as was shown by the results of qualitative x-ray analysis of the phase (separated from the alloys and synthesized).

As a result of the determination of the composition of phase M and the investigated alloys, it seems possible to present an isothermal section of the nickel corner of the nickel-molybdenum-boron ternary system at 1000°C (Fig. 4).