The effect of the concentration (C) of Ca$^{2+}$ impurity ions and electric fields up to 50 kV/cm on the kinetic characteristics of the expansion of edge and screw dislocation half-loops in annealed and quenched NaCl crystals is studied. It is confirmed that 1) the concentration dependence of the rate $v$ of expansion of screw half-loops takes the form $v = v^* \exp (-AC^1/2)$; 2) with increasing field strength $E$ the velocity $v$ increases linearly in pure NaCl crystals; in impure crystals for $E > 5$ kV/cm the rate of expansion of the edge half-loops increases and that of the screw half-loops diminishes as $\sim \exp (E)$. The extent of the latter effect depends on the concentration of Ca$^{2+}$ impurity ions in the crystals and also on their heat treatment. The exponential change in $v$ with field $E$ is apparently a consequence of the reorientation of the "Ca$^{2+}$ ion-cation vacancy" dipoles in the electric field. The activation energy for the reorientation of the dipoles is estimated. The linear increase in the rate of expansion of the half-loops is explained as being due to the reduction in the number of steps in the dislocation under the influence of the electric field.

When studying the velocity $v$ of the dislocations in NaCl crystals with different concentrations of Ca$^{2+}$ [1] and Sr$^{2+}$ [2] impurities as a function of applied shear stress, it was found that small quantities of impurities greatly reduced the value of $v$. This may be attributed to the presence of "M$^{2+}$-cation vacancy" dipoles and their complexes in alkali halide crystals containing divalent substitutional impurities, creating strain fields of tetragonal symmetry and preventing the movement of the dislocations [3, 4]. A calculation of the energy of elastic interaction between a dislocation and a dipole [5, 6] shows that this depends on the orientation of the dipole relative to the dislocation. Hence external actions leading to the orientation of the dipoles in one particular direction in the deformed crystal should change the velocity of the dislocations very considerably. A study of the effect of an electric field on the mobility of the edge dislocations in NaCl crystals [7-9] in fact shows that the change in the mobility of the dislocations cannot be explained simply by the action of the field on charged dislocations; it is also essential to allow for its influence on the "M$^{2+}$ ion-cation vacancy" dipoles, which are capable of becoming oriented in an electric field [10-12]. However, no detailed study of the action of an electric field on the dipoles leading to a change in the mobility of the dislocations has yet been carried out. This paper constitutes an attempt at solving this problem by studying the influence of Ca$^{2+}$ concentration and electric field on the kinetic characteristics of the expansion of edge and screw dislocation half-loops (EDH and SDH) in NaCl crystals.

We used NaCl crystals containing Ca$^{2+}$ $\geq 5 \cdot 10^{-3}$, $10^{-2}$, $3 \cdot 10^{-2}$ mol. % and also "pure" crystals with a total content of divalent impurities (chiefly Mg$^{2+}$) no greater than $10^{-3}$ mol. %. All the crystals were annealed for 48 h at 650°C and cooled at a rate of 5 deg/h in order to reduce the dislocation density in the crystals to $\sim 10^3$
Fig. 1. Rate of expansion of screw dislocation half-loops (v) as a function of the concentration C of Ca$^{2+}$ impurity ions in annealed NaCl crystals for a shear stress of $\tau = 120$ g/mm$^2$; the arrangement of the half-loops in the crystal is also shown.

Fig. 2. Rate of expansion $v$ of screw dislocation half-loops as a function of the electric field $E$ in annealed NaCl crystals containing Ca$^{2+}$ impurity ions and subject to a shear stress $\tau$: 1) "pure" crystals, $\tau = 25$ g/mm$^2$; 2) 5 \times 10^{-3}$ mol. $\%$, $\tau = 00$ g/mm$^2$; 3) $10^{-2}$ mol. $\%$, $\tau = 100$ g/mm$^2$; 4) $3 \times 10^{-2}$ mol. $\%$, $\tau = 120$ g/mm$^2$.

RESULTS AND DISCUSSION

1. Influence of Ca$^{2+}$ Impurity Content

Under the influence of an applied shear stress the screw components of the SDH move in opposite directions [001] and [100] (Fig. 1) so that the half-loop expands. The velocity of the half-loop components differ from one another, so that the average velocity of the two components is taken as the velocity $v$ of the expansion of the half-loop. The rate of expansion $v$ of the SDH in NaCl crystals in the presence of a shear stress $\tau = 120$ g/mm$^2$ is shown as a function of the Ca$^{2+}$ impurity content C in Fig. 1. Each point on the $v$($C$) curve corresponds to the mean rate of expansion of 40-50 half-loops. In coordinates of log$v$ \(-C/2\) the results of the measurements fall on a straight line, so that the $v$($C$) relationship takes the form

$$v = v^* \exp (-AC^{1/2})$$

where $v^*$ is the velocity of the dislocations in the pure crystals and $A$ is a constant. This agrees with the theoretical relationship deduced by Gilman [15] when considering the mechanism of overcoming dislocation barriers create by point defects by means of thermal fluctuations.