Problems of deformation in amorphous, glass-like polymers are considered. The deformation and strength properties of PMMA (polymethyl methacrylate) were studied, for different temperatures and conditions of deformation. It was established that the long-term resistance to deformation of glass-like polymers subjected to forced elastic deformation, as judged by the time lapse to "neck" formation, is described by a longevity equation, allowance being made for the displacement of the origin with respect to the coordinates.

Glass-like polymers find widespread application as materials of construction, so that their serviceability has to be carefully assessed. The durability of amorphous polymers is closely connected with their deformational properties which depend on the structure and physical state of the polymer. In [1] and [2] it was shown that there are five deformational states possible, separated from each other by characteristic temperatures: the brittle point $T_b$, glass transition point $T_g$, plastic deformation point $T_p$, and yield point $T_y$. To each of these states there corresponds a certain type of specimen failure. In the low-temperature region, up to $T_b$, brittle failure is characteristic. The area of the break consists of a mirror-like region surrounded by a rough zone. This corresponds to the two stages in the rupture process. In the first stage, the breakdown proceeds by the slow intergrowth of one or more of the most dangerous fissures, with the formation of the mirror-like surface. In the second stage secondary fissures arise, causing a line pattern where they meet. The region $T_b$ to $T_p$ is the region of forced elastic deformation, characterized by forced elastic failures. This type of failure is such that until the actual separation into two pieces, the sample undergoes forced elastic deformation, the actual separation taking place in the oriented material. Forced elastic failure embraces two processes: displacement and orientation of the macromolecule chains; and the intergrowth of the fissures in the oriented material. Under prolonged stresses $\sigma < \sigma_b$, rupture of the polymers occurs, this taking place in two stages, slow growth of the fissures of the "silver" region and formation of the normal rupture fissures.

The fissures of the "silver" region constitute a wedge-shaped area, the tapering ends of which are confined by zones of highly oriented material, so-called "rods." Although the "silver" fissures attain considerable dimensions, they do not give rise to immediate breakdown, since the excess strain at their apex is less than the strain at the apex of the rupture fissures. The "silver" fissures result only in a cracking of the material, thus paving the way for its breakdown. The apex of the rupture fissures is formed by the rupture of the "rods." The rupture fissures grow after the "silver" fissures. In the temperature regions below $T_b$, the sample ruptures earlier than the formation of "rods" can take place. The molecular mechanism of rupture reduces to overcoming the intermolecular interaction and rupture of chemical bonds, with the formation of rupture fissures. Under low or medium loads, glass-like polymers characteristically show small deformations, determined only by the local mobility of the branches and different atomic groups on the main and side chains. Under large loads, appreciable, completely reversible forced elastic deformations

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*Yu. V. Mirgorod participated in the experimental part of this work.

Fig. 1. Creep curves for PMMA at different temperatures and stresses: 1) $\sigma=317 \times 10^6$ dyn/cm$^2$ and $T=16^\circ$C; 1') $590 \times 10^6$ dyn/cm$^2$ and $16^\circ$C; 2) $231 \times 10^6$ dyn/cm$^2$ and $25^\circ$C; 2') $525 \times 10^6$ dyn/cm$^2$ and $25^\circ$C; 3) $62.7 \times 10^6$ dyn/cm$^2$ and $55^\circ$C; 3') $338 \times 10^6$ dyn/cm$^2$ and $55^\circ$C.

The phenomena of crack-formation in the polymeric material and formation of "silver" fissures are closely connected with the process of forced elastic deformation [7-9]. The rate of growth of fissures in glass-like polymers depends appreciably on $\sigma$ and $T$ [10].

The aim of the present work was to study creep in linear and slightly branched polymers, as well as to predict the serviceability of polymeric materials based on these. The polymeric materials selected were technical Plexiglass ST-1 based on polymethyl methacrylate (PMMA). Before mechanical processing, the samples of PMMA were annealed at 120°C for 20 min to eliminate the influence of internal strains and nonuniform structure.

The experiments were carried out in a multipurpose apparatus of our own construction which facilitated complex studies on the creep and serviceable life of polymeric materials as well as permitting thermomechanical and thermophysical studies such as linear dilatometry. Constancy of the stress applied was maintained by an irregularly shaped lever (Zhurkov helix). Measurements of the longitudinal and transverse deformation with time were effected by observing graduation marks applied to the samples with the aid of an MBR-1 microscope. The samples were maintained at the given elevated temperature by the circulation of hot water through the heating chamber. Dilatometric curves $\Delta L=f(T)$ over the temperature range 14-85°C were measured on the same apparatus, the rate of heating of the samples being 0.6 to 1 degree/min. Calculation of the coefficient of linear expansion $\alpha_T$ was carried out taking into account the thermal expansion of the material of the apparatus. In studies of creep and length of life of PMMA and technical organic glasses based on these, the energy of activation was calculated according to the formula

$$U = 2.303 R \tan \alpha$$

where $\tan \alpha$ is the tangent of the angle of the slope of the service life curve.

Figure 1 depicts the deformation curves for PMMA at various stresses and temperatures. It should be mentioned that curves 1, 2, and 3 were obtained with formation of "silver" fissures whereas 1', 2', and 3' were without these. From the nature of the graphs it follows that curves obtained without formation of "silver" fissures differ appreciably from those obtained with samples where such fissures are present. The rate of formation and growth of "silver" fissures increase appreciably with increase in temperature and applied stress.

As criterion of the serviceable life of the PMMA samples being subjected to forced elastic deformation, the time for "necking" was taken. The point in time when the extension curve $D=f(\sigma)$ (Fig. 2) reaches a maximum corresponds to the formation of a "neck." It should be pointed out that the main reason for "necking" is that the external load lowers the relaxation time to that observed; a process analogous to lowering the glass temperature $T_g$ to an effective value $T_{ef}$. From the experiments carried out it may be concluded that "neck" formation at the time in question