Depending upon its properties the failure of a material in the ductile-to-brittle transition range may be accompanied either by the formation on the surface of the fracture of a concentrated ductile area (zone of stable crack growth $\ell_s$ [1]) or the transition from ductile to brittle failure occurs as a result of an increase in the relative area occupied by shiny facets [2, 3] (dispersed failure).

This work is devoted to an investigation of the features of dispersed failure in the ductile-to-brittle transition temperature range.

The investigation was made on 45 steel, the microstructure of which after annealing at $900^\circ$C consisted of alternating areas of ferrite and pearlite (Fig. 1a), which, apparently, were the reason for its dispersed failure. The average ferritic grain size in the annealed steel was 70-80 $\mu$m.

The impact tests of $15 \times 15 \times 55$ mm prismatic specimens with a V-shaped stress raiser were made on a KM-30 pendulum impact tester at temperatures from $180^\circ$C to $-196^\circ$C, the quantitative macrofractographic analysis on an optical microscope and a comparator, and the microfractographic analysis on a JSM-U3 scanning electron microscope.

The x-ray diffraction analysis of the condition of the material close to the surface of the fractures in the center portion of them was made on a DRON-1.5 diffractometer in cobalt $K_\alpha$ radiation. The presence of plastic deformation of the material was judged from the width of the (220) $K_\alpha$ diffraction line. To determine the depth of the zones of plastic deformation under the fracture surface, the surface of the fracture was etched off layer-by-layer [4] with subsequent x-ray micrography of it. Then the graphic relationship of the change in the width of the (220)$K_\alpha$ diffraction line to the thickness of the layer etched from the fracture surface was drawn. The depth of the zones of plastic deformation were determined from the thickness of the etched-off layer of material corresponding to the start of the horizontal portion of the curve [5].

Macrofractographic analysis of the fractures obtained showed that at all of the test temperatures other than $-196^\circ$C the fractures have a relatively flat center portion, shear lips, and a peripheral ductile area in the zone of contact of the striker with the specimen. A reduction in test temperature leads to an increase in the size of the flat center portion of the fracture. On the fractures obtained at $-196^\circ$C there were practically no shear lips or peripheral ductile portion.

After tests at $130-180^\circ$C the whole fracture, including the flat center portion, has a fibrous structure characteristic of ductile failure. After tests at $130^\circ$C in the center portion of the fracture there appear the first shiny facets, indicating the presence in the fracture of a brittle constituent. The average size of the shiny facets is $300-600 \mu$m, about equal to the size of the pearlite areas. With a further reduction in test temperature the area occupied by shiny facets increases. The shiny facets are located uniformly over the whole center portion of the fracture. After tests at temperatures of $90^\circ$C and lower the shiny facets occupy the whole center portion of the fracture, forming a brittle square. On the surface of the fractures it was not possible to reveal the zone of stable crack growth $\ell_s$ by the macrofractographic method.

Microfractograms of impact specimens of 45 steel obtained at different temperatures are shown in Fig. 1b-h. Close to the notch at all test temperatures it is possible to observe the initial shear zone $\ell$ (Fig. 1c, e-h) located at a certain angle to the surface of the fracture. At temperatures of 20 and $-5^\circ$C at the mouth of the notch there appears a ductile zone of stable crack growth $\ell_s$, the maximum length of which is $100-150 \mu$m (Fig. 1c, e). This zone...
Fig. 1. The microstructure of 45 steel (a) and microfractograms of impact failure (b-h) at 100 (b), 20 (c, d), -5 (e, f) and -196°C (g, h): a) 50x; b) 600x; c-f) 300x; g, h) 1000x.

follows after the zone θ and is oriented perpendicular to the surface of the fracture. After tests at -196°C the ιs zone is not observed and beyond the zone θ (Fig. 1g, h) is located the area of brittle fracture covered with cleavage facets.

Microfractograms of the area following after the zones θ and ιs are shown in Fig. 1b, d, f. After tests at 100°C the facets of brittle fracture are surrounded by areas with a pitted relief (Fig. 1b). At 20 and -5°C, despite the fact that the center portion of the fracture has a macrobrittle structure, areas with a pitted microrelief may be seen on the microfractograms (Fig. 1d, f). However, the share of ductile constituent is small and does not exceed 1-5%. The size of the cleavage facets increases with an increase in crack length. At a short distance from the notch the size of the cleavage facets corresponds approximately to the grain size, and with an increase in distance from the notch the cleavage facets join several grains (Fig. 1c, f). After tests at -196°C the pitted microrelief in the center portion of the fractures is not observed (Fig. 1g, h). A clearly expressed tendency toward an increase in the extent of the cleavage facets with a reduction in test temperature may be seen (Fig. 1d, f, h).

Figure 2a presents the temperature relationships of the relative area occupied by shear lips λ and of the percent of fibrous constituent in the whole surface of the fracture (F*) and in the center portion of them (F) where the x-ray diffraction investigations were made.