In Part I [1] it was shown that the friction and wear properties of a rubbing pair are linked with the presence of working films on the rubbing surfaces and that the changes occurring in them in the course of time have a periodic character. It is reasonable to assume that the wear of such a pair takes place in two stages (successive or parallel): 1) formation of a working layer; 2) buildup of irreversible changes and destruction of the layer. During steady-state wear the processes corresponding to these two stages are in dynamic equilibrium.

The present work was undertaken with the aim of identifying the working films and determining the mechanism involved in the operation of a rubbing pair. Identification of the composition of the working films consisted in subjecting the films themselves and the wear products to standard metallographic analysis and also to layer-by-layer spectral [2], petrographic [3], and electron microprobe [4] analyses.

Examinations of transverse microsections of the surface and subsurface layers of a specimen and a mating part (Fig. 1), made with a metallographic microscope, indicated that the material, the matrix of which was untexturized (for ferrite the microhardness \( H^\mu_{20} = 320 \text{ kg/mm}^2 \)), was covered with a 3- to 12-µ thick film of high microhardness (\( H^\mu_{20} = 850 \text{ kg/mm}^2 \)). Below this working layer there was a softer (\( H^\mu_{20} = 380 \text{ kg/mm}^2 \)) undercoat up to 5-6 µ thick. On the mating part there were similar layers, of the same thickness and hardness, but the work-hardening of the subsurface layers in this case was more marked than on the specimen (Fig. 1b). Judging from its structure and microhardness, the working layer consisted of localized fields of oxides of the matrix metals or of a mixture of these oxides.

To verify this hypothesis, petrographic analyses were made of the wear products of the rubbing pair and of the material itself. Comparison with the starting condition of the material showed that asbestos, silica, and the phosphide eutectic had passed unchanged into the wear products. In addition, the wear products and hence the working layer contained two kinds of oxides — magnetite (\( \text{Fe}_3\text{O}_4 \)), in the form of dentrites, and cuprite (\( \text{Cu}_2\text{O} \)), in the form of elongated isotropic crystals.

To connect these oxides with local regions of the working specimen surface, the two types of films discovered in the rubbing zone (white and blue) were subjected to electron microprobe analysis. As a result, it was found that the white film was a work-hardened layer of the
starting metals (copper and iron) "raised" to the surface, while the blue film was a mixture of oxides of these metals (Fe₃O₄ and Cu₂O). This finding fully explains the coexistence and mutual transitions of the working layers observed in [1].

Comparing our data on the composition of the working layers and the phenomenology of the process [1], we can conclude that the following mechanism, a general outline of which has already been given by Lancaster [5], is operative in the wear of such a rubbing pair. During an early period of the running-in of the pair, when comparatively pure metallic surfaces of the specimen and mating part are in contact, material transport takes place from the softer (Brinell hardness of the specimen HB₅₂₅₀ = 50 kg/mm²) to the harder (Brinell hardness of the mating part HB₅₂₅₀ = 155 kg/mm²) element, mainly through plowing of the surface of the former. This is a period of intense running-in wear of the specimen and increase in the thickness of the mating part, whose actual duration depends on the operating conditions. In the case under consideration this period lasted 10 cycles (Fig. 2).

That material is in fact transferred from the specimen to the mating part during the running-in and subsequent (steady-state wear) periods is confirmed by results of layer-by-layer spectral analysis (Fig. 3), which indicate a marked enrichment of thin surface layers of the cast iron mating part in copper from the specimen (the copper content varying from 0.5% of the starting content at a distance of more than 10-20 μ from the surface to 2.0-2.2% on the surface).

The transfer of specimen material to the mating part is accompanied by processes of oxidation of the working specimen surface and of the material transferred to the mating part and also by cold-working of the surface layers of the specimen. Thus, the specimen surface is strengthened as a result of both reworking and embedding in it of oxides. All these phenomena hinder the subsequent transfer of material to the mating part, and may actually initiate a reverse flow to the specimen. Evidence in support of this contention is provided by the ratio of the wear rates of the specimen and mating part and the change in the coefficients of friction between the 20th and the 30th cycle, and also by the appearance, revealed by qualitative spectral analysis, in the surface layers of the specimen of a line of chromium, which is present only in the mating part.

This period is characterized by a decrease in the thickness of the mating part, brought about by reverse transfer (and wear) of material from the layers deposited on it in the earlier stage, and moderate wear of the specimen (between the 10th and the 20th cycle). The process of running-in continues a little longer, up to the 40th cycle. During this time dynamic equilibrium establishes itself between the rubbing surfaces — an oxide layer of a certain thickness, with a characteristic working relief, builds up (while the coefficient of friction steadily falls).