The principal requirements which must be satisfied by a production process for the preparation of sponge iron from scale by the reduction technique are that it should be characterized by maximum reducibility and high reproducibility. In view of this, considerable scientific and practical interest attaches to the problem of reduction kinetics. In the literature, very few research data have been published on the kinetics of the composite iron oxide reduction process, which is the main method by which iron powder is produced in industry.

The overall rate of reduction is made up of the rates of the individual stages. However, like all metallurgical processes, this process cannot be divided into strictly consecutive stages, because these are superimposed upon one another in both time and reaction space. It is therefore necessary to examine the rates of the individual stages to discover the stage exhibiting the least rate, which will of course characterize the rate of the whole process.

The rate of composite reduction depends on the rate of chemical reactions, rate of diffusion of the reducing gases into the powder particles and reverse diffusion of reaction products, rate of circulation (diffusion) of the reducing gases and gaseous reaction products through the layer of reduced iron, and rate of reaction of these gases with the carbon in the charge, and also on the rate of diffusion of iron and oxygen ions within the crystals of the solid reaction products.

According to Esin and Gel’d [1], the reduction of oxides may be effected by three – kinetic, diffusion, and intermediate – mechanisms.

In the case of the diffusion mechanism, the reduction time is related to the thickness of the reduced layer by the parabolic expression:

$$\delta^2 = kt,$$

where $\delta$ is the thickness of the reduced layer, $t$ the reduction time, and $k$ the rate constant.

In the kinetic mechanism, the intensity of the process is governed by the rate of a crystallochemical act and is expressed by the formula $\delta = kt$.

In the case of the intermediate mechanism, the kinetics of the process is determined by the rates of both diffusion and chemical reaction.

The authors investigated the kinetics of the composite reduction process of powder and briquetted charges, the object of the investigation being to determine the relationship between the reduction time and the weight of the charge material in a tray. The magnitude employed in our experiments was not the weight of the charge or height of the charge layer in the tray, but the specific weight, i.e., the weight of the charge per unit surface area of the tray bottom. For such a case, the following expressions relating the reduction time to the specific weight may be employed:

$$T = a_1b^2$$

and

$$T_1 = a_2b,$$

where $T$ is the process time, min; $b$ is the specific weight, $g/cm^2$; $a_1$ and $a_2$ are coefficients.
Specific weights of 2, 4, 6, 8, and 10 g/cm² were chosen for investigation. Experiments were carried out in an electric muffle furnace with Silit (silicon carbide – Transl.) heating elements at temperatures of 1100 and 1150°C. The temperature was measured with a Pt/Pt-Rh thermocouple located in the center of the charge pan. Another thermocouple was used to measure the temperature in the heating zone of the furnace. The charge material was poured into a nickel pan 21.5 × 21.5 cm in size (wall thickness 1.5 mm), which was lined with sheet asbestos and held in a 1Kh18N9 stainless steel tray. The whole assembly was placed in the furnace muffle, which was provided with a nickel endpiece enabling converted gas to be fed into the reaction space.

In the first series of experiments, the time required for heating the tray assembly was determined. For greater accuracy, the heating was performed in an argon atmosphere (the time for heating the gas was taken into account). As a result of these experiments, it was found that the tray assembly heating time was 27-37 min.

Subsequent experiments, concerned with the determination of the heating time of the tray assembly with a charge and study of iron powder reduction, were carried out on a Brovary Factory charge material having the following composition: TGMZZ carbon black 9.5%, scrap iron powder 10%, balance scale. The scale was obtained from the Il'ich Zhdanovsk Factory and had the following composition: undetermined components 0.3, Mn 0.35, S 0.05, P 0.02, Si 0.15, and Fe not less than 72%. The particle size distribution of the scale (in wt. %) was as follows:

\[+025 \quad +016 \quad +0071 \quad +0056 \quad +0056\]

\[4-5 \quad 20-25 \quad 60-70 \quad 5\ \max. \quad 5\ \max.\]

Table 1 presents the results of experiments on the reduction of charges with different specific weights. It will be seen that, at a temperature of 1100°C and a specific weight of 2 g/cm², in 90 min it is possible to obtain an iron powder containing 0.35% oxygen; a reduction time of 75 min is too short for obtaining iron powder with less than 1% oxygen (1.08% O₂). At a specific weight of 4 g/cm², a reduction time of 240 min is required to reach an oxygen content of 0.25%, while at 6 g/cm² an oxygen content of 0.35% is attained in 640 min. Raising the temperature to 1150°C decreased the reduction time. At a specific weight of 2 g/cm² and a holding time of 60 min, the amount of oxygen in the powder was 0.32%.

Reduction experiments similar to those involving loose charge materials were conducted also on briquetted charges. The Brovary Factory briquetting charge material, consisting of scale, carbon black, and pitch and containing 12.65% total C and 23.3% O₂, was used for pressing, under a pressure of 10 tons, briquets 50 × 25 mm in size. The briquet thickness was 10, 20, and 30 mm for specific weights of 2, 4, and 6 g/cm², respectively. Table 2 presents the results of the briquet reduction experiments.

It will be seen from this table that, at a specific weight of 2 g/cm², the briquetted charge was reduced in 40 min to iron containing 0.27% O₂. At a specific weight of 4 g/cm², powder with 0.36% O₂ was obtained.