In the pressing of articles of complex shape, an important part is played by nonuniform porosity distribution, which frequently leads to layering and cracking. It should be noted that cracks of this kind are a result of a steep density gradient, which must be evaluated by porosity changes on a basis one order of magnitude greater than the mean particle size. The most widely used method of porosity determination, involving hydrostatic weighing, has low resolving power, and can therefore be used only for analyzing relatively gradual density variations along the coordinates. An alternative is provided by microscopic methods, and these were used in the present work for porosity field determinations in parts with internal voids.

Studies were made of the porosity field in the median cross section of prismatic specimens of varying densities, pressed from PZh3M iron powder.* The specimens were 20 mm wide, 80 mm long, and 14 mm high. The ratio of the internal void height to the compact height was chosen so as to obtain a critical density distribution, i.e., a distribution preceding the initiation and propagation of layering cracks. After being pressed, the specimens were impregnated twice with epoxy resin in a vacuum-and-pressure treatment cycle. Since the specimens had a symmetrical shape and microsections were prepared on both specimen halves, it was possible to obtain a good averaging of results with a single specimen. Before the measurements, grids with 1- and 2-mm meshes were applied to the microsection surface, as shown in Fig. 1. Subsequent determinations were performed separately for each mesh.

Porosity distribution measurements were performed by Glagolev's individual point method [1] and with a quantitative television microscope (QTM), known as quantimeter [2]. Glagolev's individual point method, which is widely used in metallographic analysis for determining percentage amounts of phases, involves counting the number of points lying on the phase being investigated in the microscope field. In the present investigation, there were two phases, particles and pores. The latter were visible in the microscope field as dark mat spots (epoxy resin in microsections). In each specimen field, density was determined from a number of units equal to approximately 7000 points. The accuracy of such measurements is given by the formula \( e = \sigma \cdot t \), where \( e \) is the absolute error, \( t \) the standard deviation, and \( \sigma \) the root-mean-square deviation of the arithmetic mean, obtained with the formula \( \sigma(\bar{F}) = \sqrt{F(100-F)/x} \) (\( F \) is the percentage content of the phase being measured and \( x \) is the number of points). At an error determination confidence of 0.9, which did not exceed the value of \( \sigma \) found for a mean specimen density of 80%, the absolute measurement error in our case was \( e \approx 0.82\% \). The results of these measurements are presented in Fig. 1.

Although this method does in fact yield the required information and ensures adequate accuracy, it is extremely time-consuming and can only be recommended for research investigations. Microscopic studies may be made less laborious by the employment of a scanning technique. Here the investigator's eye is replaced by an electron-optical system, which partly assumes also the function of the brain. Scanning techniques may be of two kinds, statistical and specific. The former implies a certain spatial distribution of objects and calls for very careful specimen preparation to prevent particle dispersion or agglomeration.

*Reduced fine iron powder of 98.0% purity - Publisher.
and is therefore suited only to studies of dispersed objects. In the majority of statistical methods, scanning is performed by moving a long slit along the specimen, which gives rise to a number of statistical errors. This technique is inappropriate in those cases where the distribution of objects in the field is the parameter being measured.

The specific method of scanning calls for much more complex electronic and logical apparatus, but are free from the disadvantages mentioned above. These techniques are based on scanning not with a slit but with a spot and a group of spots. In our work, density field determinations were carried out with a Type B quantimeter, in which, in addition to the usual television scanning of the image plane, rough scanning is performed also in the object plane, as a result of which the surface area of large specimens can be rapidly measured. A block diagram of the apparatus is shown in Fig. 2.

The optical image is obtained either from the microscope or a special epidiascope when photographs or transparent specimens are employed. The picture is projected onto the screen of a transmitting camera. The electric signal from this camera is transmitted by cable to a monitor, which gives a magnified picture of the field. The signal passes also to an analyzing device, which may eliminate such unwanted objects as contaminant particles, retaining only those which are to be measured. The output signal from this device, containing pulses from the essential objects, can be superimposed on the monitor screen to enable the operator to be in full command of the observation operation. The same signal is fed into the computer, which is capable of measuring the total surface area of particles in the field, the total length of the particle perimeters, and the particle and chord size determinations. As a result, measurements are possible yielding the following data: information upon the number of inclusions in metals, with size and shape classification; surface area or volume of fractions; mean shape factor; mean size of objects; surface area of each phase in a multiphase system; density of dislocations; particle-size distribution of powders; fiber diameter in fibrous structures. With information of this kind, it is possible to perform a number of additional calculations (for example, determination of the specific surface area of particles, pores, etc.) [3, 4]. A simple variant of the apparatus is available provided with a counter, and also an automatic model in which information is delivered to a printing device or a perforator for subsequent data processing in a computer.

The epidiascope and microscope give various fields of vision increasing in $\sqrt{2}$ steps, with diagonal lengths ranging from 30 µ to 125 mm at a frame side ratio of 4 : 3. The television system gives 300 lines in the field of vision, and the horizontal resolving power is greater than $10^5$ bits per frame. Three analyzing circuits permit three separation operations: 1) the main control, for the setting of an illumination threshold, which permits separation of objects with illuminations below a critical value; 2) separation according to the "sign" of illumination, permitting segregation of objects with illuminations above or below a threshold. By using both these techniques and performing two or three successive measurements, it is possible to analyze objects with different shades of illumination; 3) variation of the resolving power of the apparatus, enabling the operator to lower this power in order to cut out unwanted small objects such as contaminant particles and scratches on polished metal surfaces.

In the determination of the surface area occupied by pores, the signals passing from the analyzing circuits to the computer consist of a series of television line signals quantized so as to yield a series of rectangular pulses. The height of all pulses is constant, while their widths correspond to the lengths of chords formed by the intersection of object images by the television lines. For measuring the total surface area of objects, these pulses are summated, giving a magnitude which is directly proportional to the duration of registration of objects by the television scanning beam. This magnitude is, of course, directly proportional to the true surface area of objects, because the distance between the lines is automatically allowed for as a constant factor.