Porous sintered materials may be divided into two major groups:

1) Antifriction materials of up to 25% porosity;

2) Materials with a total porosity of more than 30-35%, whose porosity and permeability are utilized in service.

Such high-porosity sintered materials have found wide application in the engineering, chemical, food, electrochemical, and other industries. Sintered filters made of iron, bronze, steels, and nickel have been successfully employed for a long time in the filtration of lubricants, fuels, acids, and alkalis. For the filtration of more aggressive media (molten alkalis, dilute acids), filters of refractory compounds are used [1, 2].

The introduction of high-porosity nickel plates [3] as electrodes of sinterplate alkaline storage batteries has enabled the weight and size of the latter to be substantially reduced. In the electrochemical production of hydrogen and chlorine on smooth electrodes, substantial electrical power consumption was due to a high overvoltage. The application of porous iron electrodes enabled the overvoltage of hydrogen to be lowered by 0.25-0.3 V [4]. There is great interest in the use of porous sintered materials for electrodes in electrochemical generators (fuel cells) for the direct transformation of the chemical energy of fuel into electrical power [5].

The existence of the various manufacturing techniques is due to the diversity of applications of porous materials and the numerous requirements which these materials must meet [1, 5]. The manufacturing techniques employed may be arbitrarily arranged in the following groups.

1. Production of components without the introduction of any fillers or additions. This group includes:
   a) compaction in dies, b) hydrostatic compaction in elastic containers, c) vibratory compaction or densification, d) extrusion, e) sheet or strip rolling, f) slip casting of suspensions in molds, and g) sintering of loosely poured powders. Thus, this group incorporates all variants of compaction and molding processes (see chart).

2. The second major group comprises production processes involving the use of fillers or additions:
   a) introduction of fillers intended for the retention of pores and completely eliminated during sintering, i.e., not participating in the densification of materials; b) introduction of fillers intended both for the retention of pores and for the activation of the actual sintering process (particularly when parts are produced by sintering loosely poured powders, when the action of the fillers enables a higher strength of the finished parts to be attained); c) introduction of additions whose sole purpose is to secure strong components by strengthening interparticle contacts through the formation of a liquid phase.

3. Other methods, including the preparation of materials from fibers, metal wire, and gauze, by sintering powder loosely poured on a backing plate.

This subdivision is arbitrary, because in the group of molding processes performed without special additions (group I) the introduction of "bonding" substances (plasticizers) to the starting powders is disregarded. The relative amount of plasticizers is usually small (in die compaction, hydrostatic pressing, slip casting, and vibratory densification); however, even when they are introduced in amounts of up to a few per cent (as in extrusion), they are eliminated at a low temperature and in practice only negligibly...

assist in pore formation or preservation, since the principal requirement to be satisfied by additions or fillers is that their decomposition temperature should be close to the sintering temperature of the main component. In the compilation of the second group of processes, many variants of molding techniques were ignored, because porosity is secured in them mainly through the escape of gases forming during the decomposition of additions.

I. Methods of Production of High-Porosity Materials without the Introduction of Fillers

In the production of porous parts, practically all pressing and molding methods may be employed. The choice of a particular method must be dictated by the porosity which is to be secured in the sintered part, the shape and size of the part, and the need to achieve a uniform or predetermined porosity distribution.

Die compaction is usually employed for the manufacture of parts of simple shape and small size (disks, plates, bushings). To secure an adequate porosity, the pressures applied must be low (usually not more than 2-3 tons/cm²). In [6-8], plane and cupshaped filters (of 40-60% porosity) for the purification of molten sodium, magnesium, and titanium chloride, as well as diesel fuel, from iron powders of various particle shapes and scrap of magnesium-thermic titanium. The attainment of a relatively high porosity of parts (60%) was apparently made possible by the dendritic powder particle shape. It was established that powder rolling before compaction enables permeability to be raised by 30-55%.

The production of iron-copper (Cu contents of up to 10 wt.%). and chromium filters was investigated in [9-10]. With the latter material, compacts of adequate quality could not be produced because of the poor compactibility of pure chromium powder: to obtain green parts of some strength, it was necessary to add about 4 wt.% paraffin wax to the charge. The porosity of filters sintered at 1100-1200°C was 40-50%.

In an investigation into the effectiveness of flame localization, fire suppressors of 35-65% porosity, made from bronze, iron, and stainless steel powders, were employed [11]. As in [8], the dendritic shape of stainless steel powder particles was found to promote the attainment of high porosity. The method of powder pressing and subsequent sintering of compacts in a hydrogen atmosphere or in vacuum has been used to produce bulk-porosity anodes of tantalum electrolytic condensers [12] and materials for catalysis from copper, nickel, and tungsten and chromium carbides [13].

Hydrostatic pressing may be successfully used for the manufacture of large sintered parts with a uniform porosity distribution over their cross section owing to the absence of external friction. This process may also be recommended for the compaction of materials of low compressibility. In the Soviet Union, the hydrostatic compaction technique was developed at the Central Scientific Research Institute of Ferrous Metallurgy [14, 15]. This method is chiefly used to obtain high-density parts in a large variety of shapes (balls, crucibles, tubes, rods), weighing up to 300-500 kg each [16, 17]. It is probable that porous parts with a uniform distribution of porosity and pores of the same size could also be produced by this process, using powders of a single particle size fraction.

Jones [18] notes the possibility of producing by this method various parts, in particular oxidation resistant turbine blades with cooling passages; the latter are obtained by mounting cadmium wires in compacts and subsequently vaporizing them during sintering. The production of tubular filters up to 500 mm long from spherical powders is described in [19]. It is claimed that a relatively uniform distribution of pores in such parts is achieved.

Vibratory densification. In the Soviet Union, vibratory densification of powders of metals and their compounds was first investigated at the Institute of Physical Chemistry, Academy of Sciences of the USSR [21]. The basic processes taking place during the vibratory densification of powders and the influence of process parameters (vibration amplitude and frequency, treatment duration) has been examined by a number of authors [22-24]. In [25], it was demonstrated that parts of complex configuration can be made by the method of vibratory densification.

Densification under the influence of vibrations accompanying the compaction process (densification with the simultaneous application of pressure) is greatly intensified as a result of improved particle packing [21]. Thus, when making molybdenum parts of up to 40% porosity in an apparatus with an I-116 vibrator at a frequency of 1400 vibrations per minute and an amplitude of up to 40μ, it was possible to lower the