Growth in the manufacture of man-made fibres has passed through several stages, which have differed both in type of starting polymer and also in methods of spinning. In the first stage, natural fibres were used exclusively, primarily cellulose and its derivatives. These polymers are characterized by high melting points and cannot be processed via the melt; therefore the only way of transforming them into fibres was spinning from solutions.

From the moment of appearance of synthetic polymers, which had relatively low melting points, lying below the region of intense thermal decomposition, manufacture of fibres from these polymers from the melt began to develop briskly. The advantage of melt spinning is obvious: The problem of manufacturing and regenerating solvents and auxiliary chemicals is not present, and energy outlays are considerably reduced. The idea developed that the only promising type of fibre was synthetic fibres which were spinnable from the melt. But this idea cannot be considered justified, for two reasons.

First, up until now it has not been possible to find ways for an economically acceptable synthesis of polymers which have a reasonably high hydrophilicity, which inherently ensure clothing comfort. In this respect, cellulose (hydrocellulose fibre) has proved to be free of competition as a polymer which is easily wetted by water and ensures evaporation of moisture from the space under the clothing, thanks to which the temperature is reduced, and, correspondingly, comfort is created.

Second, at present man-made fibres have ceased to serve only as materials for household needs (for fabrics), but are being used in ever-increasing scale for purely technical purposes. Here, one of the important requirements placed on fibres is strength retention at elevated temperatures. Such synthetic fibres as poly-caproamide, polyester, and polypropylene, which have relatively low glass points (and melting points), do not meet this requirement.

A new class of synthetic fibres has appeared, with a high melting point, which is above the thermal decomposition temperature, and the problem of processing them into fibres from solutions has arisen again. Thus, one may consider that a new stage has arisen in spinning technology, where, to fibres based on cellulose, which have retained their importance, there has been added a new group of fibres from synthetic polymers, which can be processed only via solutions.

This circumstance has brought about a need to continue and develop further theoretical and practical developments in the area of spinning man-made fibres from polymer solutions. Here, as in any region of theory and technology, there is a large number of independent problems. It is advisable to dwell on some of them, mainly in the theoretical aspect.

One of the most complex problems is selecting a solvent for a specific polymer which is to be processed into a fibre. Polymers with high melting points are characterized, as a rule, by an elevated stiffness of the macromolecular chains. In distinction from flexible-chain polymers, solution of rigid-chain polymers is achieved, not due to the entropy factor, but due to the enthalpy factor, that is, due to a high energy of interaction of the solvent molecules with active groups in the polymer chain, which greatly restricts the selection of solvents suitable for this purpose.

It is well known that cellulose is soluble only in a very small set of solvents, this group being restricted still more if one considers that to accomplish the technological process it is also necessary to take into account economic and ecological factors. This is why, if we are speaking of cellulose, dissolving it has proved to be economically and technologically acceptable only by preliminarily converting it into such derivatives as the xanthatate or acetate. Attempts to find and use practically direct solvents for cellulose, and also the difficulties associated with this, have been discussed repeatedly in the literature, including this journal.
The situation is similar in the case of fibre-forming polymers which are intended for the preparation of thermally stable and high-strength fibres. These polymers are soluble principally in aprotic solvents containing added lithium chloride, or in concentrated sulfuric acid. The other possible solvents are less acceptable economically and ecologically.

The limited selection of solvents for semi-rigid and rigid-chain polymers leads to the situation that the solutions obtained, as a rule, are at the border of thermodynamic stability. Because of this, even upon small fluctuations in properties the polymer does not completely dissolve; this shows up in gelation of the solution with time, or in the presence of heterogeneous inclinations of the gel particle type in it. Removal of these is extremely difficult. In viscose manufacture, to prevent instability it is necessary to use an excess (as compared with the theoretical) amount of carbon disulfide in the xanthation of the cellulose. In the case of synthetic polymers, this shows up in the strength properties of the fibres, due to incomplete conversion of the polymer into an ordered and oriented state. For some rigid-chain polymers the presence of a solubility limit with respect to concentration is even observed.

Thus, in preparing fibres from polymer solutions, even in the stage of preparing the spinning solution a large number of complex theoretical and technological problems arises. Let us proceed directly to the process of spinning fibres from a solution.

The meaning of converting the polymer into a solution is this: The system is made to flow, and by forcing it through the spinneret holes the polymer is given the form of a filament (fibre). Then it is necessary to go over again to the pure polymer, not in a liquid-flowing state, but in the solid state. For melt spinning, this is easily achieved by cooling the spun fibre to normal temperature, as a result of which the polymer hardens. In the case of solutions, the situation is more complicated. Here, two routes are possible: evaporation of the solvent to obtain the pure polymer, or precipitation of the polymer, converted into yarn, from the solution. By the first route, acetate fibres are prepared by evaporating the volatile acetone or methylene chloride from the yarn while it is passed through a spinning tower. A major defect in this method is the formation of a monolithic, nonfibrillar fibre structure. In this respect they are similar, both formally and in nature, to glass fibres. Their distinctive feature is elevated brittleness. In this connection, we must dwell briefly on the phenomenon of brittle failure. If the fibre has a monolithic structure, then a random defect (crack) which has formed on its surface is readily propagated over the entire fibre section. A different situation arises for fibres which consist of a system of fibrils. A defect which has appeared in any one site, as a rule, terminates in that component part (fibril) where it arose. Here a graphic analogy with the brittle failure of a continuous (monolithic) glass rod and a bundle of fine glass fibres which have the same overall cross section is correct.

One of the unsolved problems in the field of acetate fibre preparation is precisely reducing their brittleness (reduced elasticity). Attempts to reduce this brittleness by introducing plasticizers have not given any marked effect, since thereupon the glass point is reduced and irreversible deformation under prolonged loads is increased.

For such solvents as sulfuric acid or the aprotic solvents, the dry spinning method is inapplicable, due to the essential involatility of the sulfuric acid and the low volatility of the aprotic solvents which are used for synthetic polymers in the preparation of high-strength, thermally resistant fibres. Therefore the basic method of fibre spinning from solution of such polymers has remained the method of polymer precipitation.

The basis of the mechanism of polymer precipitation from solution is breakdown of a homogeneous one-phase solution into phases. For polymers, one of the phases formed is a concentrated precipitate having a polymer content of 50 to 80% by wt. and the other phase is a mixture of solvent and precipitant which is practically free of polymer. The concentrated polymer phase is the gel-form framework of the fibre being spun. The mixture of solvent and precipitant is partially separated from the fibre formed in the initial stage of spinning, but the main part of it is retained in the gel-fibre in the form of a relatively fine dispersion, included in the polymer phase. The liquid phase gradually separates from the fibre as a result of shrinkage of the polymer phase and during final drying of the spun fibre.

The decisive effect on fibre properties is exerted by such factors as the rate of formation and physical form of the separating polymer phase, the equilibrium concentration of this phase, the orientation of the polymer macromolecules under the influence of mechanical stretching, and the hydrodynamic resistance of the precipitation bath during the process of passing the spun fibre through it, secondary phase transitions in the polymer phase, drying conditions, and additional heat treatment of the spun fibre, plus a number of other factors.

Let us examine these factors separately, in sequence, for the viscose process and for fibre spinning from solutions of synthetic polymers. The separate examination is brought about by the fact that, in spite of certain