The first group of studies is concerned with products made by injection moulding. In this chapter we start with an outline description of the process itself, and this is followed by three sections on features of polymers as materials which are particularly important in the design and processing of polymers by this route.

1.1 INJECTION MOULDING

1.1.1 The basic process

The basic principle of injection moulding is to inject molten polymer into a closed, cooled mould, where it solidifies to give the product. The moulding is recovered by opening the mould to release it. An injection-moulding machine has two principal parts: the injection unit; the clamp unit, or press. This is illustrated in Fig. 1.1.
1.1.2 The injection unit

The injection unit is essentially a plastics extruder. It comprises an Archimedean screw rotating within a barrel, with minimum clearance between barrel wall and screw flight. The screw can reciprocate within the barrel, piston-like, during the injection part of the production-cycle. The barrel has electric cuff heaters on it. The screw channel depth decreases from the feed end to the output end, to allow compression of the contents. Cold polymer granules are introduced at the feed end and molten polymer emerges from the output end. Heating is partly from the barrel heating and partly from viscous dissipation (work) as the polymer melt is pumped along the screw. During the plasticizing phase of the production cycle the output end is sealed by a valve, and the screw accumulates a reservoir ('shot') of melt in front of itself, by moving backwards against the head pressure. When this phase is complete the screw stops rotating, the sealing valve opens, pressure is applied hydraulically to the screw and it becomes a ram or piston and forces the accumulated melt through the connecting nozzle into the mould, or tool, which is contained in the clamp unit: this is the injection phase.

1.1.3 The clamp unit

This is essentially a press, closed by a hydraulic or mechanical toggle system. The clamping force available to it must be great enough to resist the force generated by the melt as it is injected. The pressure of this melt can be around 138 MPa (20 000 psi), so that, for mouldings with a large projected area, the force required can be considerable - in the largest machines, several thousand tonnes.

1.1.4 The mould or tool

The mould is mechanically fastened (e.g. bolted) in the clamp unit, but is interchangeable to allow different products to be moulded. The essential features of a mould are listed below.

(a) The cavity, or impression, in which the moulded product forms.
(b) The channels along which the melt flows as it is injected. These are the 'sprue' channel, which is the channel from the nozzle, and the 'runners' which run from the sprue to the individual cavities. In a single impression mould no runners are needed. The runner constricts to a narrow 'gate' where the melt enters the cavity. The constriction at the gate serves three main purposes.

(i) It allows rapid freezing of the polymer at the conclusion of injection. This isolates the cavity and allows withdrawal of the screw.
(ii) The narrow solid section allows the moulding to be sheared off easily when the moulding is discharged, eliminating finishing trimming.
(iii) It increases the shear rate as the melt flows through. Polymer melts are pseudo plastic, or shear thinning, i.e. apparent viscosity decreases with increased shear rate. The lowered apparent viscosity at the gate assists easy filling of complex shapes.