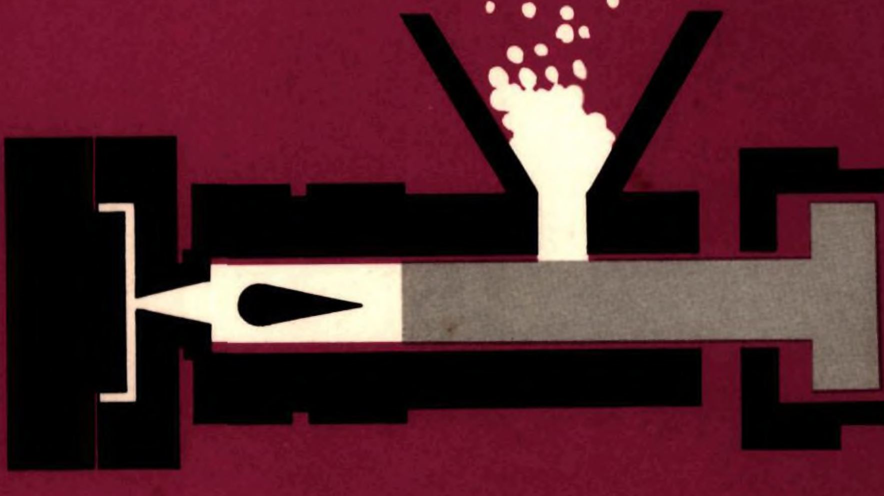
UNION CARBIDE

PLASTICS

INJECTION MOLDING OF BAKELITE® POLYPROPYLENE



INTRODUCTION

BAKELITE Brand polypropylene—newest addition to our sales line of plastics resins and compounds—exhibits several unique properties that can enhance the sales features of injection-molded end products. These properties include:

- Complete resistance to stress cracking
- Highest temperature resistance (325 deg. F.) of any thermoplastic of comparable cost
- Outstanding flex life
- Lightest weight (.90-.91 specific gravity) of all commercial plastics, thus providing greater unit output per pound

Fabricators and product designers, by properly applying BAKELITE polypropylene to take advantage of these features, can create and participate in new markets for plastics. Also, where existing products are marginal with respect to the characteristics offered by polypropylene, use of this new material can represent a significant product improvement.

Union Carbide Plastics Company, the most experienced producer of plastics in the United States, is ready to assist in establishing the proper uses and markets for polypropylene.

This booklet serves as a practical guide for the injection molding of polypropylene. It explains how to control, and often improve, end-product quality through an understanding of fundamental resin and molding variables. It shows the effects of these variables upon the salient properties of the molded piece. Furthermore, a knowledge of the ways in which many of these variables are interrelated should lead to a wiser choice of materials and of processing conditions.

While references to specific resins and compounds are purposely omitted in this booklet, detailed product data sheets are available on BAKELITE Brand polypropylenes for injection molding.

BASIC RESIN CHARACTERISTICS

SPECIFIC GRAVITY

Having a specific gravity of 0.905, BAKELITE polypropylene is the lightest-weight plastic commercially available. Its lightness is an important advantage in that more finished pieces per unit weight of polypropylene resin are obtained when fabricating an end product. This additional yield represents a worthwhile manufacturing economy.

Coupled with its excellent strength and temperature properties, polypropylene's light weight may also be an important factor for applications in which minimum weight is desired for easy handling. Carrying cases, luggage, and housings for portable appliances are only a few of the typical applications in which this property can be used to advantage.

MELT FLOW

Another fundamental property of polypropylene, which is important to the molder, is the melt flow of the material. For example, the higher the melt flow, the lower the viscosity of the heated resin, and the faster the resin will fill out a mold. The melt flow also has a direct effect on various resin properties such as brittleness, toughness, and gloss. Thus, the selection of the proper resin for a given end use must be made carefully with particular regard for melt flow. The effects of variations in melt flow are as follows:

Effects of Melt Flow Increase

Increases	Mold Fill-Out (e.g. less pressure to mold)
Improves	Gloss
Decreases	Toughness
Increases	Brittleness

Accurate melt flow determinations are made by measuring the amount of material extruded within a prescribed period of time through a standard orifice, at a specified temperature and pressure. The test is described in ASTM Method D-1238. This is the same test procedure used for polyethylene melt index measurements with the exception of the prescribed temperature, which is 230 deg. C., for polypropylene.

MOLDING VARIABLES

BAKELITE polypropylene can be easily and economically injection molded into a vast number of functional and attractive parts and products using conventional thermoplastic molding equipment. Furthermore, the thermal stability of polypropylene is adequate to take advantage of both ram- and screw-type preplasticator injection molding equipment.

Injection-molded products have a smooth, high-gloss surface and can be produced in a wide color range. They are tough and long lasting.

Of great importance in determining molding performance and end-use characteristics are the basic molding variables among which are Material Temperature, Injection Pressure, Mold Temperature, and Molding Cycle. These variables are interrelated, and only their general effects will be discussed under the following headings. Specific information on the proper control of these variables to achieve the desired properties in the molded part is presented in the section designated "Properties of the Molded Part."

MATERIAL TEMPERATURE

The material or stock temperature is a primary factor in determining the properties of the molded item. In the case of polypropylene, this temperature should fall between 450 deg. F. and 550 deg. F. The lower portion of this range (450 deg. F. to 500 deg. F.) is best suited to high-flow resins; the upper portion, to low-flow resins. Molding at temperatures below 450 deg. F. can cause brittle end products, and the use of material temperatures beyond 550 deg. F. may lead to some deterioration of resin properties.

INJECTION PRESSURE

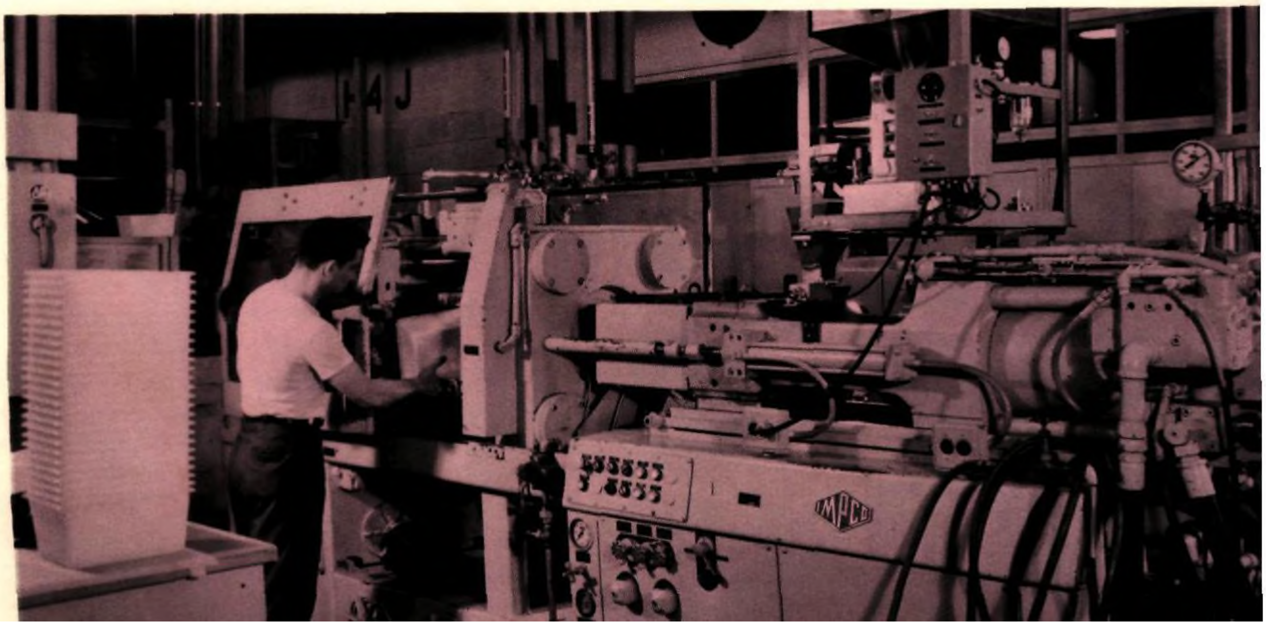
Proper pressure for injection molding polypropylene is in the range of 15,000 to 20,000 psi. and provides speedy mold filling and fast cycles. By using high pressures, the molder can take advantage of the pressure sensitivity of the resin; i.e., flow of material increases rapidly as pressure is increased. It should be remembered that injection pressures may vary depending on the area, shape, weight, and thickness of the article being molded.

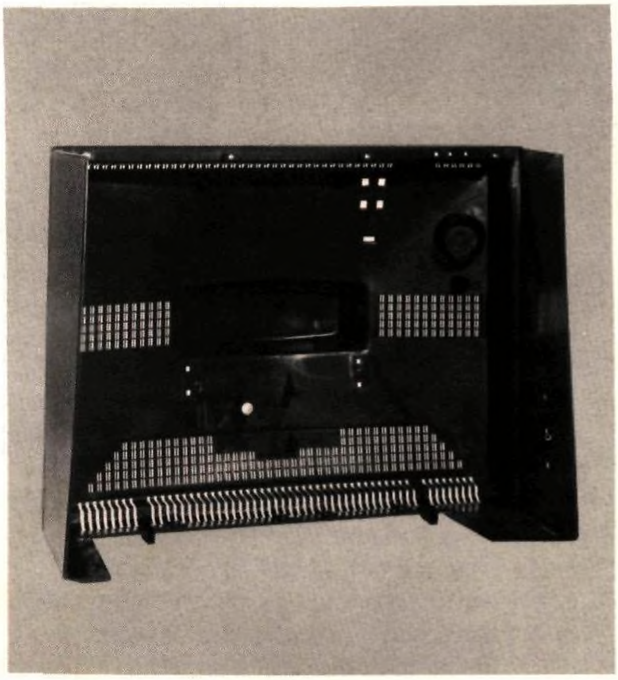
Injection pressure influences the properties of the molded part only when an increase in pressure results in mold packing or increased rate of fill. Mold packing is a condition that prevails when pressure is maintained on the material within the mold after mold filling is complete.

MOLD TEMPERATURE

Quality articles can be produced over a wide range of mold temperatures. Minimum shrinkage, faster cycles, and adequate gloss may be obtained with mold temperatures between 60 deg. F. and 100 deg. F. However, better flow and superior gloss will result at higher mold temperatures ranging from 100 deg. F. to 160 deg. F.

Injection molding machine, one of several used in Union Carbide Plastics Company Development Laboratories for evaluation of molding performance of polypropylenes.





Injection-molded portable TV back, an ideal application for polypropylene.

MOLDING CYCLES

Molding cycle time will depend on the type and size of the mold and the equipment used. It may be as rapid as feasible, however, as long as there is adequate heating and cooling of the plastic. Because of the high melting point of polypropylene, parts can be removed from the mold while still relatively warm. On the other hand, sufficient cooling before removal is recommended to avoid excessive shrinkage and warping.

SHRINKAGE

All polypropylene molded pieces undergo a certain amount of shrinkage while cooling from molding temperatures. This shrinkage (usually between 1.0 and 2.0 per cent) occurs as the result of thermal contraction of the plastic as it cools. The higher melt flow resins exhibit the least shrinkage, because these resins are more fluid and susceptible to mold packing while being cooled in the mold. The effect of this packing is to force additional material into the mold, which fills the space formed by the initial contraction.

It is possible to minimize shrinkage by lowering the cylinder temperature, raising injection pressure, lengthening the pressure cycle, or lowering the mold temperature. There is only a very minor difference between shrinkage in the flow and transverse directions.

WARPAGE

Warpage is dimensional distortion caused by strains of varying intensity within the molded piece. Polypropylene is not as prone to warp as other polyolefins because of its greater rigidity and more uniform shrinkage. Rapid and uniform cooling of the mold and proper part design will usually prevent warpage.

Should warpage occur, it probably will be caused by any one or a combination of several factors including: non-uniform mold temperatures, non-uniform section thickness, and center-gating of pieces of flat design.

Stresses and strains that cause warpage are "molded into" the piece during two distinct steps of the molding cycle: (1) initial mold filling, (2) mold packing. During the mold-filling phase, rate-of-fill and mold temperature are the important factors. Increasing the fill speed and decreasing the mold temperature will decrease warpage. Decreasing the material temperature may also have the same effect.

Increasing the packing pressure or plunger-forward-time will increase warpage, usually, independent of the resin or molding conditions used.

Changes in molding variables to correct warpage are sometimes not easily accomplished because of the interrelationship of these variables. Ideally, increasing fill speed and decreasing packing simultaneously will minimize warpage. Unfortunately, the higher pressures necessary for faster fill also cause more packing. Minimum warpage often can be obtained by the use of maximum ram pressure to increase fill speed, in conjunction with an automatic weigh feeder to ensure the proper shot.

GLOSS

Pieces injection-molded from BAKELITE polypropylene—and manufactured under a broad range of molding conditions—are characterized by high gloss. If such good surface appearance is not obtained in highly-polished molds, increases in injection pressure and material temperature should be made to correct the situation. It should be noted that, if the mold surface is dull, the finished part also will be dull regardless of the resin used or the molding conditions employed.

MOLD DESIGN

MOLD DESIGN

Basic mold design principles employed for other thermoplastics also apply to BAKELITE polypropylene.

RUNNERS

Full-round runners tend to give the best molding results. However, hexagonal runners cut into one-half of the mold perform almost as effectively and are less expensive to make and easier to maintain.

GATING

The location of mold gates will affect the properties of the finished piece. In general, center-gated molds, such as are used for dishpans, colanders, and bowls, impart more strains to the piece than do side or end-gated molds. Center-gated parts are slightly weaker around the gate area. Nevertheless, by sound design, by use of such expedients as heavy sections about the gate, and by good molding practice, completely satisfactory center-gated parts can be produced. Center-gating is common practice in molds having the inherent symmetry of a container mold, because it simplifies the design.

In multi-cavity molds, gates should be balanced along with cavity layout. Gates should be sized adequately for fast filling, yet small enough to set-up fast and prevent back flow. Land length should be short. A maximum length of 0.040 inches is recommended.

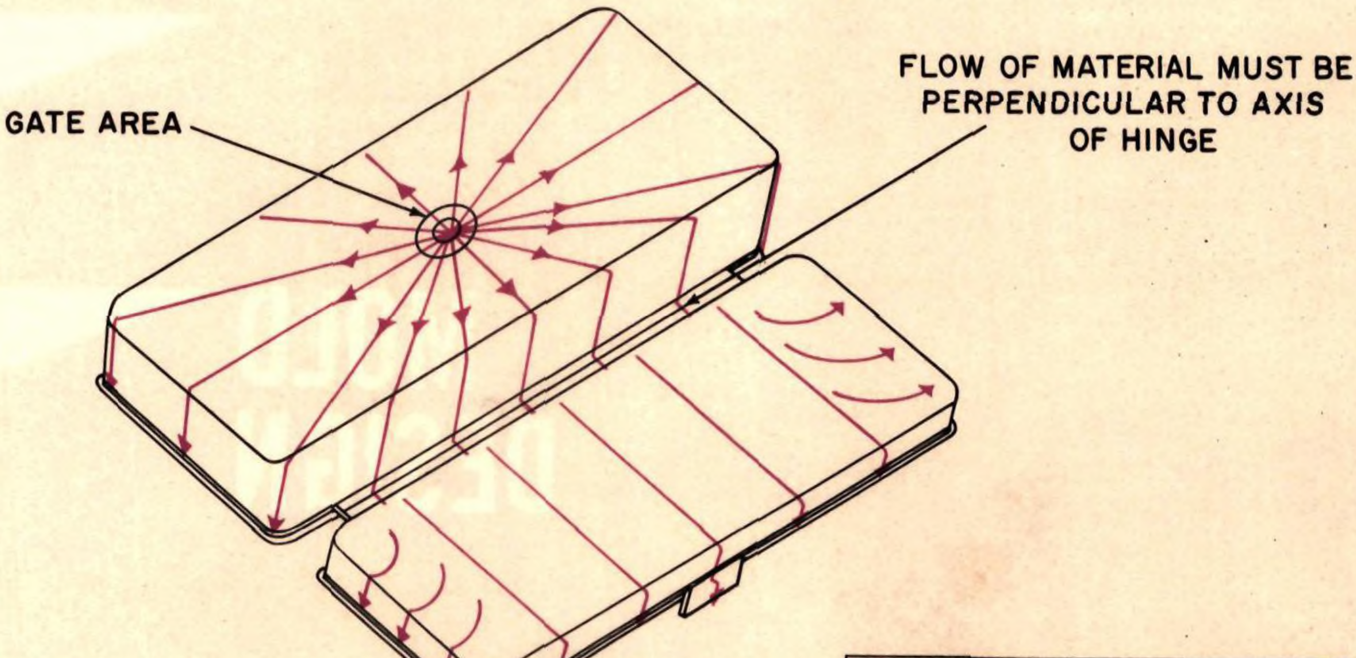
COOLING CHANNELS

Cooling channels should be designed so that the mold is cooled uniformly and rapidly. An additional cooling channel frequently is required in the gating area so as to prevent over-heating at that point.

INTEGRAL-HINGE DESIGNS

The unique flex life of polypropylene allows the practical design of products with integral hinges. In designing a mold for a hinged part, there are three important considerations:

1. The gate or gates must be located so that the weld line does not fall in the hinge.
2. The flow of the plastic must be perpendicular to the axis of fold.
3. The area around the hinge must be provided with adequate cooling because of the frictional heat built up by the flow of the material through the restricted cross-section of the hinge.



INTEGRAL HINGE DESIGN

PROPERTIES OF THE MOLDED PART

HEAT RESISTANCE

Among the outstanding properties of BAKELITE polypropylene is its exceptional heat resistance. Properly injection-molded end products are dimensionally stable up to 300 deg. F. Beyond this temperature, some distortion can be expected due to molded-in strains.

Typical Thermal Properties

Collapse Temperature, °F. (unstrained piece) no load	325	
Vicat Softening Point, °F.	311	D1525-58T
Heat Deflection Temperature @ 66 psi., °F.	210	D648-56

PROLONGED EXPOSURE AT HIGH TEMPERATURE

Where polypropylene, in fabricated form, will be exposed to elevated temperatures (250 deg. F. or above) for prolonged periods of time, it is subject to oxidative degradation unless adequately stabilized. BAKELITE polypropylene molding materials, except food-grade types, will withstand more than 700 hours in air circulatory ovens at 284 deg. F.

MECHANICAL PROPERTIES

Polypropylene is a tough thermoplastic resin with excellent rigidity and dimensional stability. Its attractive tensile and flexural properties are retained over a broad range of use temperatures. Unmodified polypropylene is adequate for most injection molding applications. However, rubber-modified grades are recommended where superior toughness is desired.

Typical Mechanical Properties

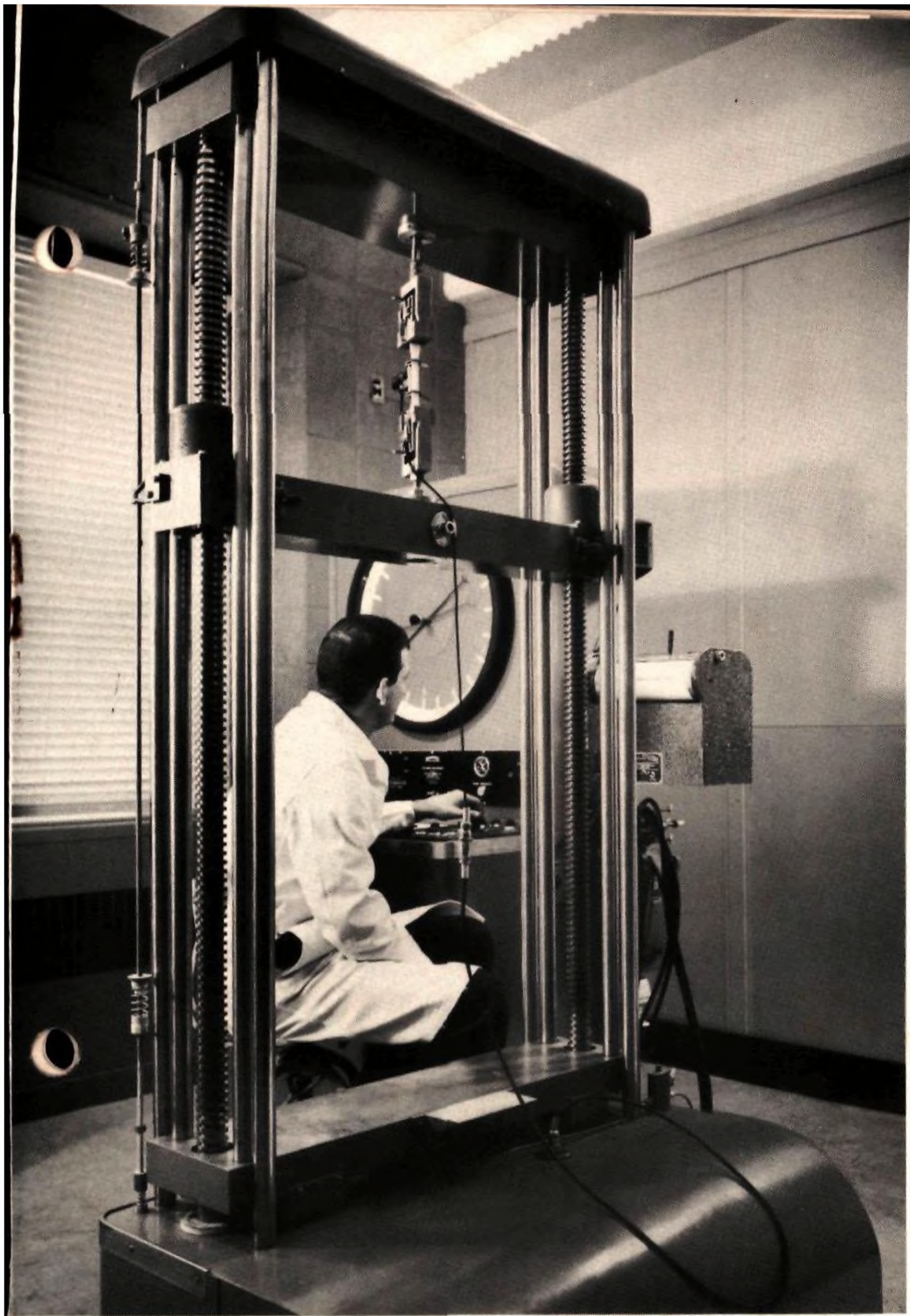
Tensile Yield Strength, psi.	5000	D638-58T
Ultimate Elongation, %	20-300	D638-58T
Flexural Modulus, psi.	180,000	D638-58T
Impact Strength, Notched Izod, ft.-lb./in.	0.8-3.0	D256-56
Hardness, Rockwell R	95	D785-51

ELECTRICAL PROPERTIES

Because of its generally excellent electrical properties, polypropylene can be used for injection molding of coil forms, fuse blocks, automotive electrical parts, and television components. In addition, the dielectric properties are constant over a wide range of temperatures and frequencies.

Typical Electrical Properties

Dielectric Constant, 60 to 10^6 cycles	2.2-2.3	D150-54T
Dissipation Factor 60 to 10^6 cycles	.0002	D150-54T
Dielectric Strength, V/mil, (short time)	500	D149-55T
Volume Resistivity, ohm-cm.	1×10^{16}	D257-58
Arc Resistance, sec.	180	D497-48T



Universal Testing Machine, used in obtaining fundamental mechanical data from injection-molded specimens.

Preparing samples for accelerated aging at high temperatures.

Accelerated weathering tests are performed upon molded polypropylene specimens. 1,000 hours equals a year of Florida sunshine.

PERMEABILITY

BAKELITE polypropylene materials have a high degree of resistance to permeation by gases and liquid vapors. Their resistance to water vapor is particularly outstanding. The permeabilities of oxygen, carbon dioxide, and water vapor (MVT) are:

O_2 (cc/mil/100 sq. in./24 hr.)	100-250
CO_2 (cc/mil/100 sq. in./24 hr.)	250-600
MVT (9/mil/100 sq. in./24 hr.)	0.4-.0.7

WEATHERING

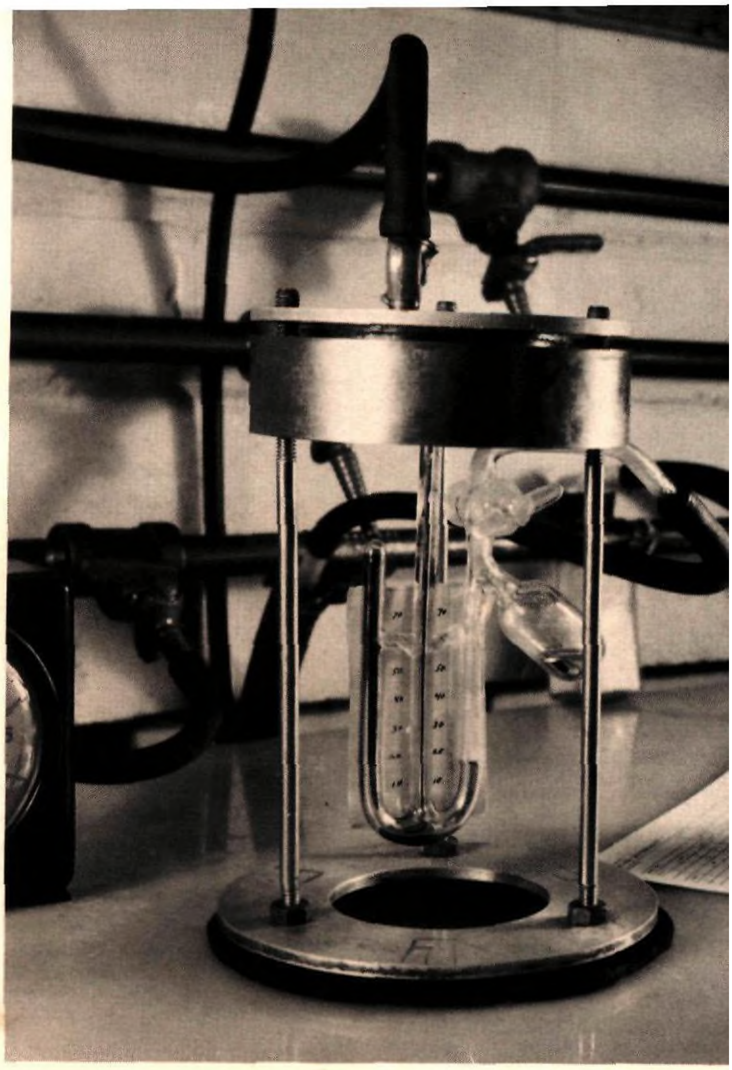
The weathering resistance ot polypropylene is almost entirely a function of the type of pigment or ultra-violet stabilizer incorporated in the compound.

Unpigmented polypropylenes, and those not containing U-V absorbers, will quickly show embrittlement, surface crazing, and a general decline in all properties from outdoor exposure.

Bright- and pastel-pigmented polymers show improvement over natural resins; while darker colors, properly dispersed, will give much better results. The addition of a U-V stabilizer will bring about even further improvement.

CHEMICAL RESISTANCE

Polypropylene, like other polyolefins, has excellent resistance to a broad variety of chemicals and solvents. It is highly resistant to greases, oils, acids, alkalies, insecticides, deodorants, detergents, and most home-use chemicals. Aromatic solvents such as toluene and benzene will attack polypropylene. This attack is limited, however, to swelling and weight gain.



Laboratory device for measuring gas permeability.

COLORING OF POLYPROPYLENE

Polypropylene is well suited to dry coloring. For critical application and where thin sections are involved, color concentrates are suggested. Colored compounds are also available.

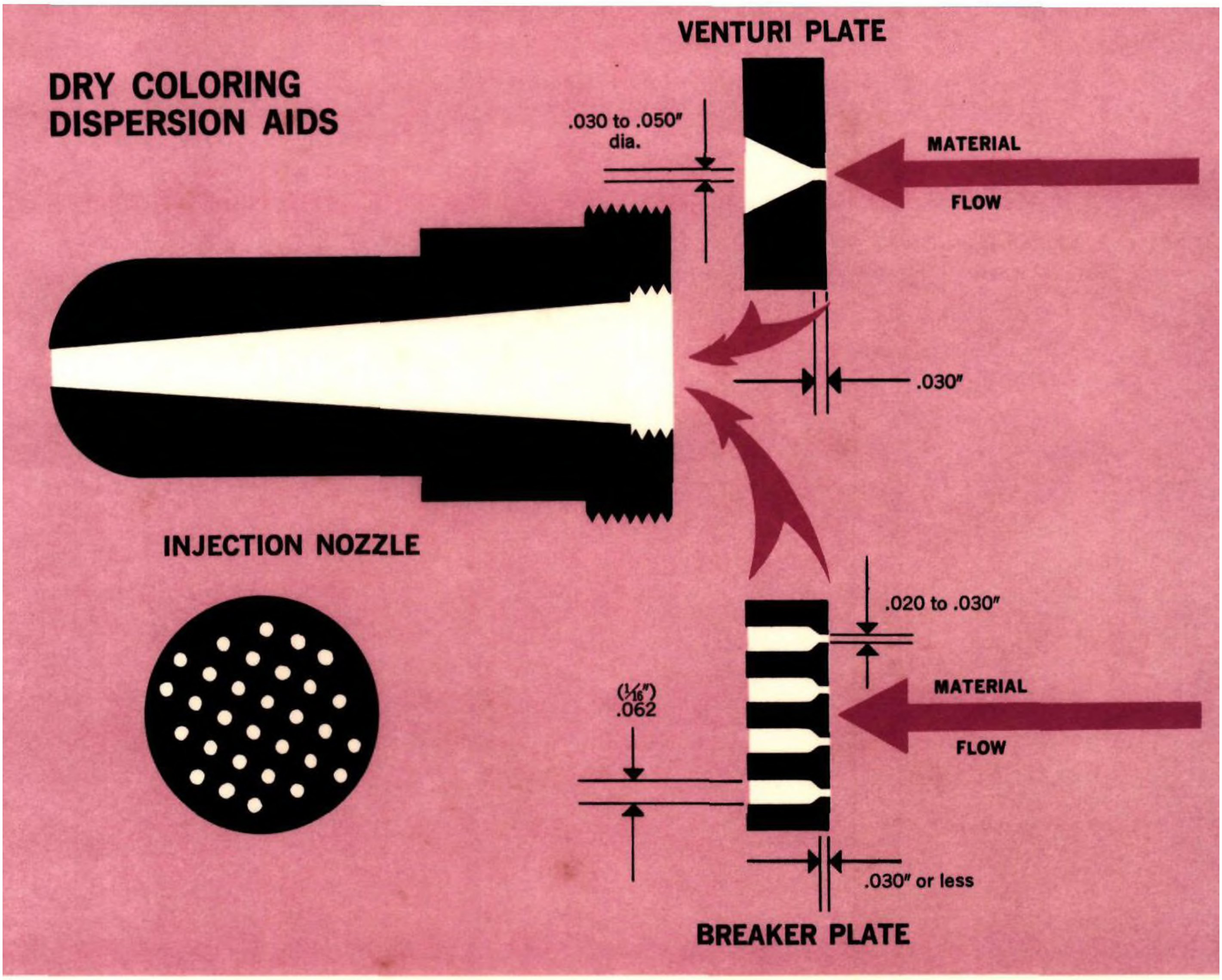
The process of dry blending consists of mixing the desired pigment and resin, usually by tumbling in a drum or blender, for sufficient time to permit the pigment to adhere to the resin pellets. The resulting blend may be fed directly to the molding machine to produce the finished colored piece.

Several factors must be taken into consideration during the initial dry-blending operation. To ensure good tumbling action, only two-thirds of the drum should be filled, and the tumbling should continue for at least fifteen minutes to blend the pigment thoroughly. Wetting agents offer no appreciable improvement in the blending; in fact, they may cause pigment agglomeration and impair coloring. The resin and pigment should be moisture free to avoid caking of the pigment and loss of the static charge on the resin. (When using color concentrates, the blending should be only for a period long enough to provide uniform mixing—about three to four minutes.)

When the dry-coloring technique is employed, proper provision should be made for maximum mixing in the plasticating cylinder of the molding press. Poor dispersion will cause color streaks and detract from the appearance of the molded article.

Little dispersion takes place in the heating cylinder except in areas of high shear. The major part of the mixing must occur as the material flows into the mold. Some molds with pinpoint gating or intricate flow patterns will provide adequate mixing to yield good coloring quality. Generally, however, a dispersion aid is required to produce sufficient mixing and shear. This principle applies both to the use of dry coloring and color concentrates.

Such dispersion aids include breaker plates and Venturi plates (see diagram), either of which may be fitted to



a modified injection molding nozzle. A breaker plate consists of a circular plate with properly placed holes of suitable design. The design is critical, and correct holes have a small diameter with short lands that taper to a slightly larger diameter. A Venturi plate is simply a single-hole breaker plate, usually having a wide angle of taper. In either type of dispersion aid, short land lengths are necessary to minimize pressure requirements. The increase in injection pressure required by the introduction of dispersion aids is the major limiting factor in their design and use. Thus, in choosing such an aid, a balance must be struck between optimum color dispersion and minimum injection pressure increase.

Comparison has indicated that a Venturi plate is superior to a breaker plate as a color dispersion aid, although the pressure requirements imposed by the Venturi plate are slightly greater. The effectiveness of the Venturi plate is due to the greater turbulence and mixing that it produces, as well as the higher shear rate it imposes.

Dispersion aids will increase the material temperature slightly due to frictional heat generated by the shearing action as the material passes through the small openings. Dispersion aids also tend to promote uniformity of material temperature.