Chapter 1 - WHY PLASTIC OPTICS?

The many reasons why product designers decide to use plastic optics essentially fall into two categories: relative low cost and the opportunity to use unique element configuration.

Plastic optics have a number of advantages over glass. Foremost of these are lower cost, higher impact resistance, lighter weight and more configuration possibilities for simplifying system assembly. Configuration flexibility is especially useful in systems that can use aspherical lenses to simplify system design and reduce pats count, weight and cost. Moreover, light transmittance is comparable to that of high-grade crown glasses. Finally, the plastics that can break generally do not splinter like glass. The fragments are larger and tend to be more obtuse and less hazardous.

The chief disadvantages of plastic optics are comparative intolerance to severe temperature fluctuation in some systems and low resistance to scratching. These disadvantages, however, are far outweighed by the advantages plastic brings to the majority of optical applications. Although plastic has less temperature tolerance than glass, most optical systems do not operate in ambient, temperatures beyond the thermal limits of plastic elements. For that matter, glass optical systems often will not withstand much more physical abuse than their plastic counterparts and still function properly.

The variety of available glass optical raw materials is much greater than that for plastic. This abundance of glass options translates to greater design freedom because of the wide selection of dispersions and indices of refraction. However, creative use of plastic aspherics often compensates for the narrower choice of materials.

Low Cost: The injection molding process, Fig. 1.1, is ideal for producing large volumes of parts economically. Multicavity molds allow a low-cost manufacturing process

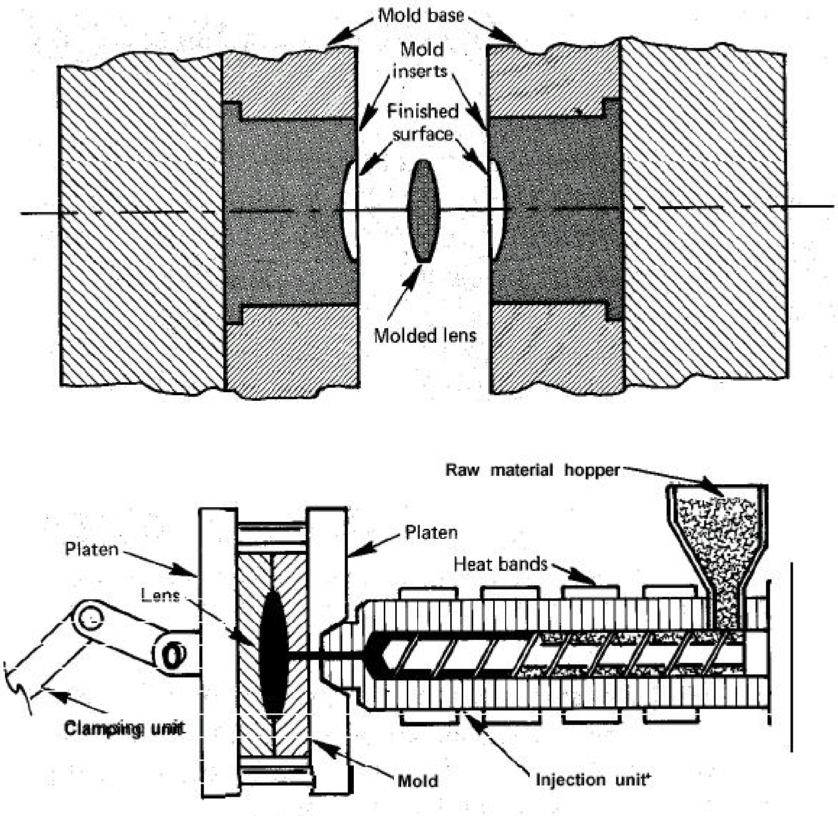

Fig 1.1 - Injection-molded optical elements are formed in steel molds that contain machined cavities with surfaces polished to an optical quality (top). The molten raw material is forced under pressure into the temperature-controlled mold (bottom). After cooling, the parts are removed from the gates and runners and require no further finishing process.

to be combined with comparatively inexpensive raw materials to create a powerful economic advantage for large production volumes. By carefully sizing the mold for required production volume, the break-even cost, compared to the glass alternative, can be surprisingly low, Fig. 1.2.

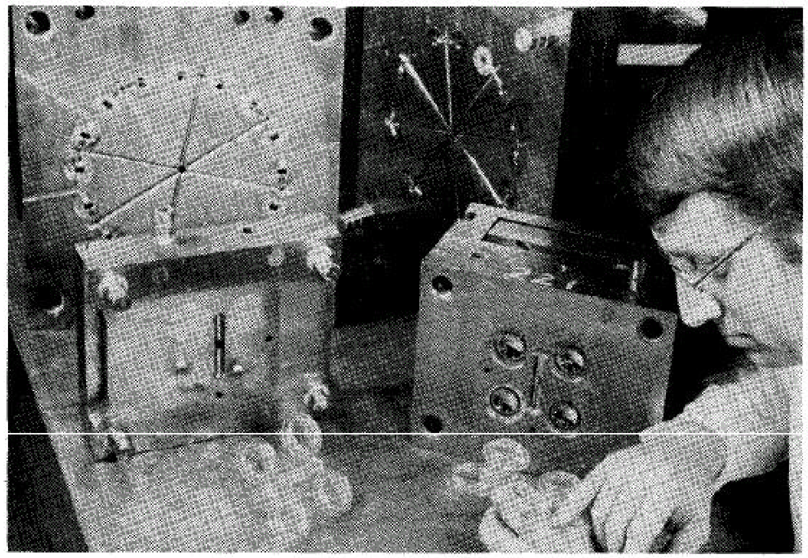

Fig. 1.2 - Multicavity injection molds can be sized for specific production-volume requirements to optimize break-even cost.

Integral Mounting: The molding process permits mounting and assembly features such as mounting brackets, holes, slots and flanges to be integral with the optical element. The result is a single-piece design that eliminates mounting hardware and simplifies assembly and alignment. Assembly costs often are more than that of the optic itself, so the benefits of using imaginative configurations are obvious.

Furthermore, multiple elements can be combined in unique optical configurations such as transceiver lenses for transmitting and receiving simultaneously. Figures 1.3, 1.4, 1.5, 1.6 and 1.7 demonstrate special designs incorporating both multiple elements and integral mounting.
Fig. 1.8 is a multielement lens with a special edge configuration that aligns and centers the elements; this design is economically beneficial for high production volume applications.

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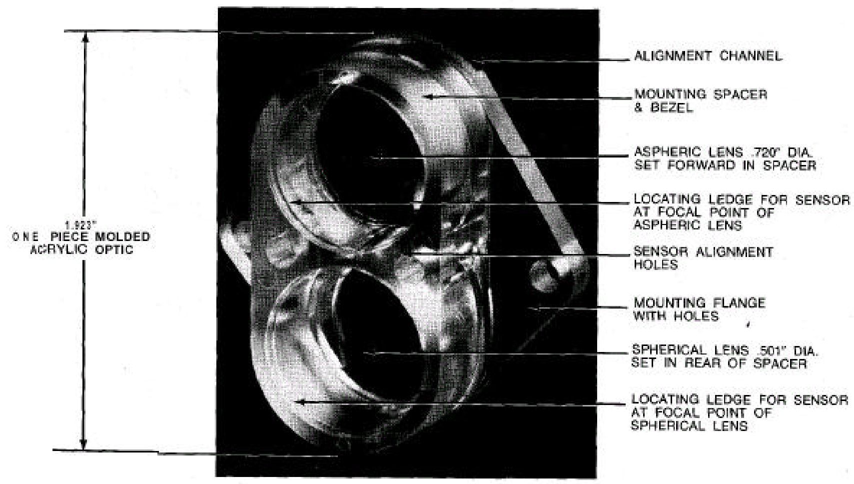


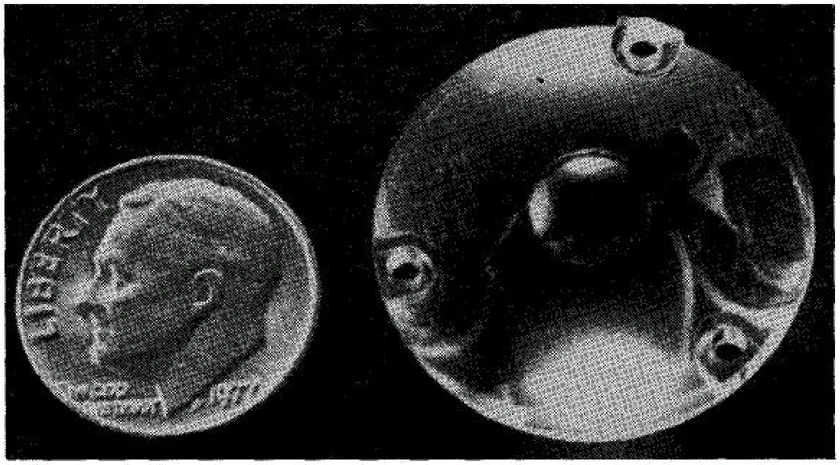


FIG. 1.4 - Coaxial lens design, combining a dual lens function with mounting pads, simultaneously sends and receives light.

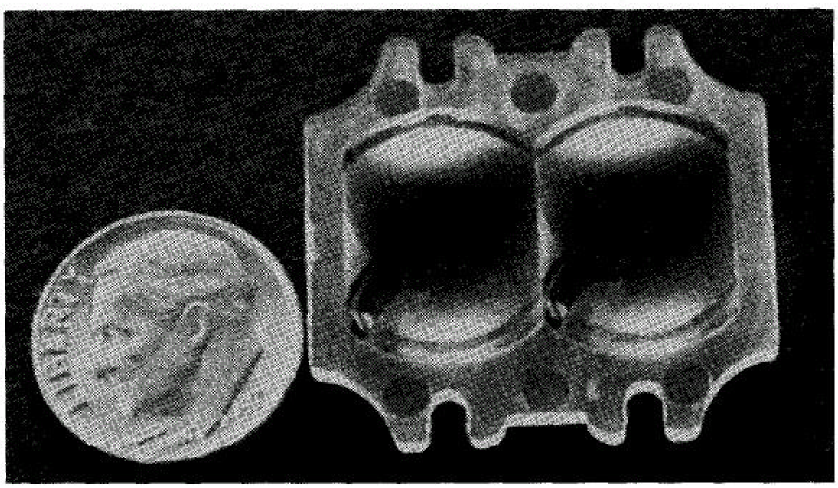


FIG. 1.5 - Mounting flange of this dual lens also prevents dust from entering the optical system.

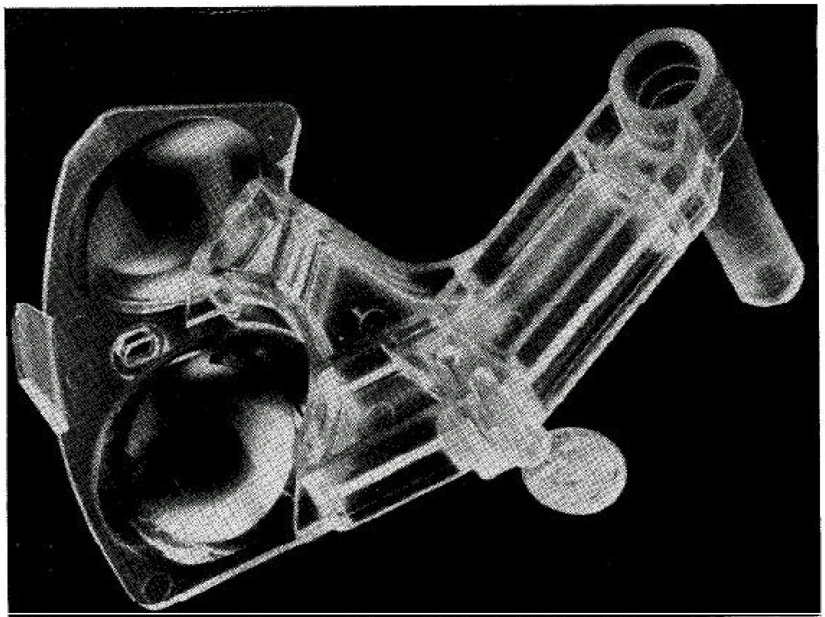


Fig. 1.6 - Integral post allows condenser lenses to be swung into the optical path of a dual-function projection system as required.

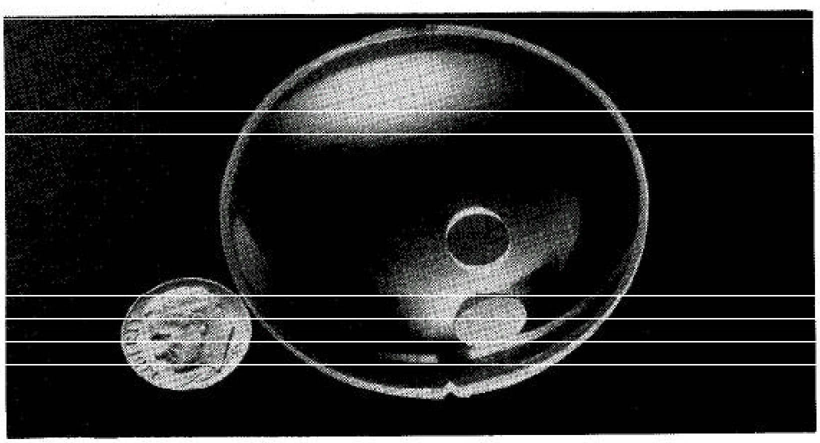


Fig. 1.7 - Transceiver lens has alignment notches to facilitate assembly. The off-axis optic focuses a laser beam in a product code-reading system.

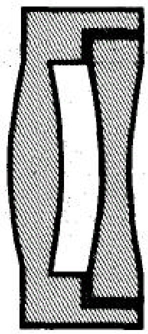


Fig. 1.8 - This optical doublet has an integral flange that provides proper airspace and centering. The assembly can be snapped, glued, ultrasonically welded or heat-staked, depending on size, required tolerance and available tooling.

Lens arrays that are economically impractical in glass are comparatively easy to manufacture in plastic, even though the moldmaking process is usually complex and expensive. Fig. 1.9 and 1.10 are examples of such arrays.

Aspheres: Virtually all glass optic grinding and polishing equipment employs mechanisms that utilize mechanical movements for contouring spherical surfaces. Traditionally, finishing the optical inserts of a mold for injection and compression-molding has been performed with a similar

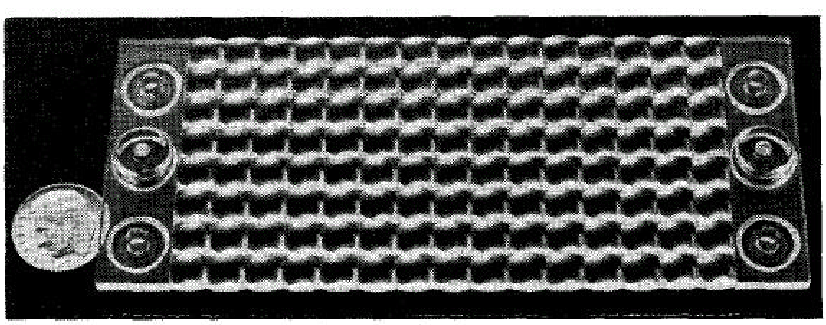
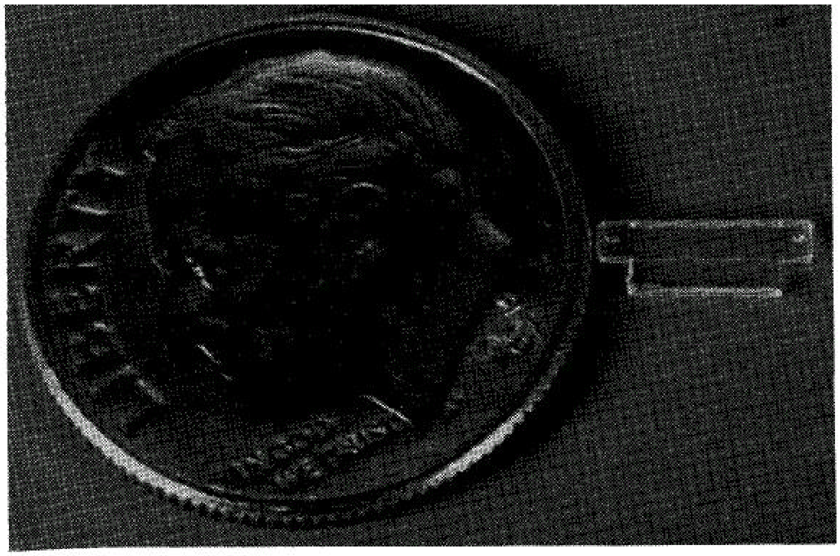


Fig. 1.9 - Lens array with 120 lens elements has integral mounting pads and alignment pins for accurate positioning in a card reader..



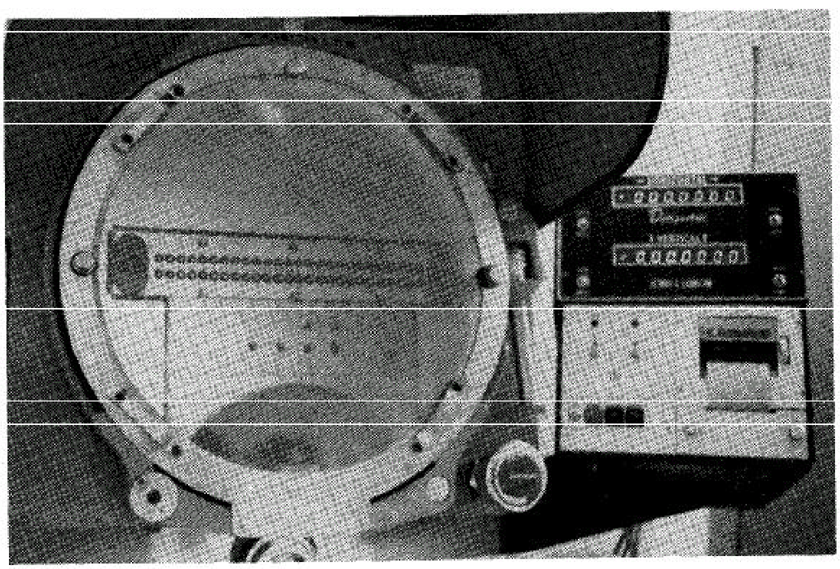


FIG. 1.10 - Micro-lens array is 0.2-in. long, 0.06-in. wide, and contains 52 0.007-in. diameter lenses. Part of an automatic focusing device, the array has pads at the ends and alignment posts for mounting an aperture. The bottom view shows the part magnified 50 x.

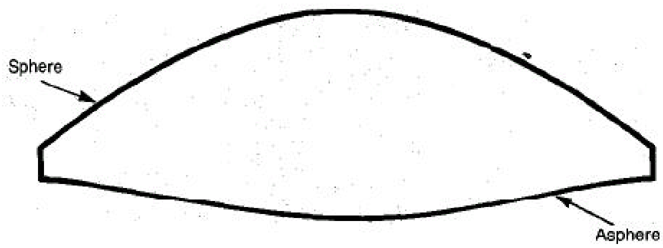


Fig. 1.11 - Aspheric curves often allow optical system correction using fewer elements.

process. Hence, most optics produced have been spherical. Aspheric lenses (nonspherical surfaces) are highly desired by optical designers, Fig. 1.11.

Designs using aspheres often contain fewer elements and cannot be configured in the same way if only spherical surfaces are used. The complex process of producing a precise aspherical mold cavity surface is required only once for each cavity. Consequently, the injection molding process is an economical means for exploiting the advantages of aspheres. Optical designers are using aspheres increasingly to reduce costs or to obtain performance un-available by any other means. Fig. 1.12, 1.13, and 1.14 are examples of aspheric lens designs.

Repeatability: The molding process can yield high lens-to-lens repeatability, which is often a significant advantage of plastic over glass. This repeatability can reduce system assembly and alignment time, with minimal impact on the system tolerance budget.

Where extremely critical tolerances are required, plastic optic makers apply process control techniques for even tighter regulation of process variables. Production tolerances for diameter and thickness are +O.OOl in. or less for lenses up to 1 inch in diameter. In contrast, high-volume, low-cost glass has a +0.002-in. tolerance for thickness. Lens-to-lens focal length variation is typically 1 to 2%, but

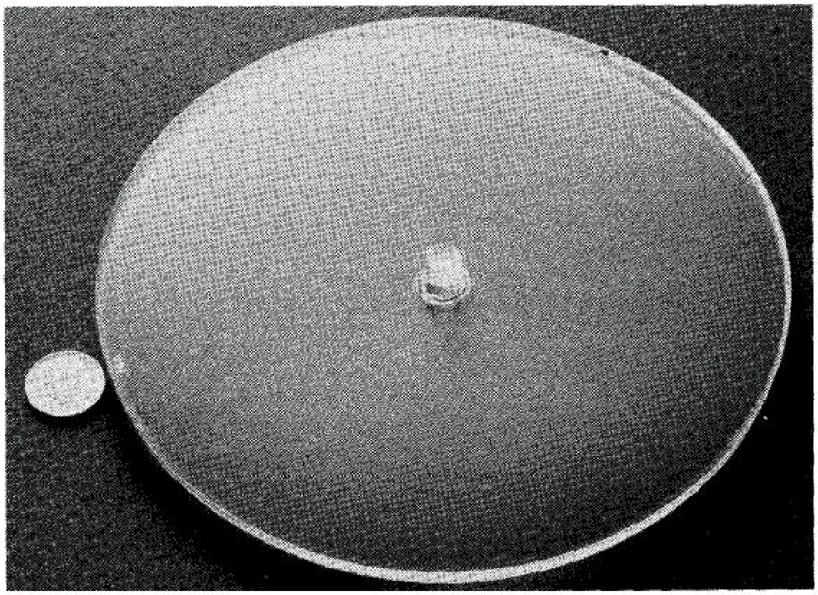


Fig. 1.12 - Aspheric corrector cancels spherical aberration produced by the primary mirror in a Schmidt optical system used in a projection television set.

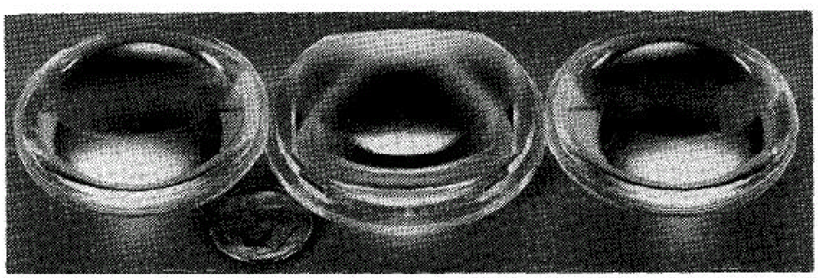


Fig. 1.13 - Using aspheres in condensing systems results in more uniform light distribution. Three examples of aspheric condensers are shown here.

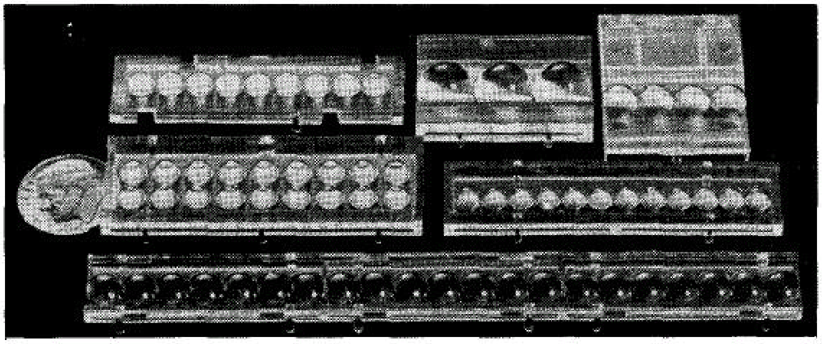


Fig. 1.14 - Aspheric lens arrays or “bubble” lenses are often used to magnify light-emitting diodes. Aspheric surfaces are necessary to optimize magnification and viewing angle.

can be held to 0.1% for higher quality lenses. This precision is a significant advantage over glass.

Weight: For a given volume, optical glasses weigh approximately 2.3 to 4.9 times as much as plastic. In small lens systems, this weight difference generally is not important. But where larger elements are used, the lighter weight of plastic may be the overriding selection factor, Fig. 1.15.

Breakage: Breakage, like scratching, is seldom a problem in glass. However, the use of glass generally is ruled out in special applications requiring high impact resistance. For example, Fig. 1.16 and 1.17 illustrate military applications where glass was unsatisfactory because of resistance-to-breakage requirements. Both products are made of polycarbonate because of its high impact resistance. The facemask lens of the helicopter pilot’s helmet was designed to withstand the impact of a 22-caliber bullet..

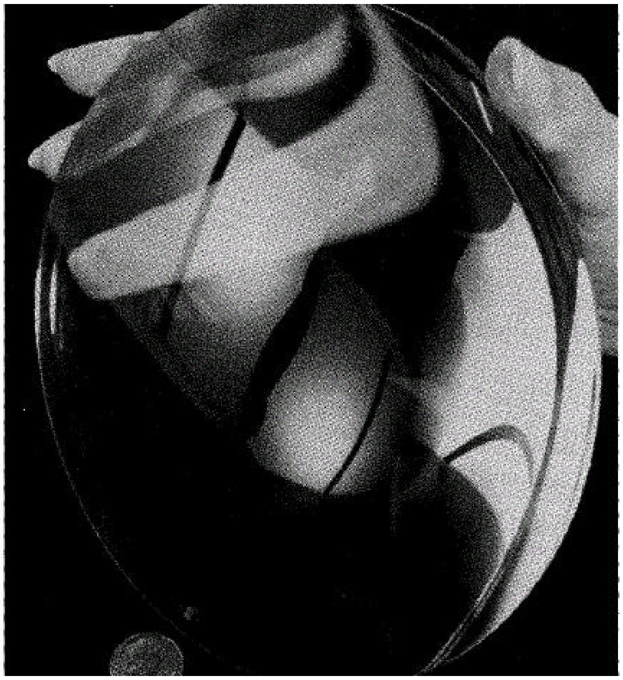


Fig. 1.15 - This 6-in. diameter lens is 1.5in. thick at the center. In plastic, it weighs 0.85 lb; a typical glass version would weigh 2.2 lb.

Surface Texturing: To disperse light or create a contrasting appearance without using special decorative hardware, designers occasionally specify a surface texture. This feature can be applied by etching, controlled abrasion or some other mechanical means. However, for mass-.

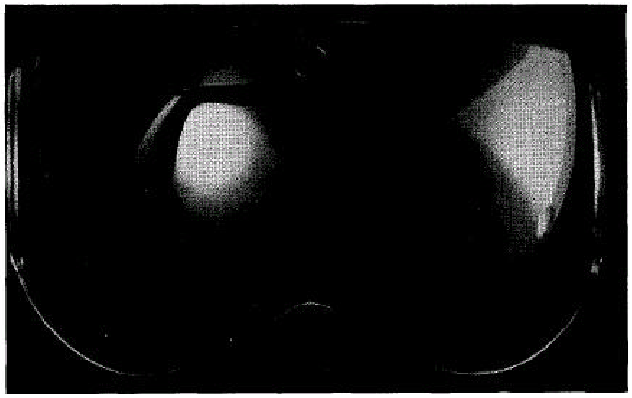


Fig. 1.16 - This face mask is made of polycarbonate to withstand severe impact tests.

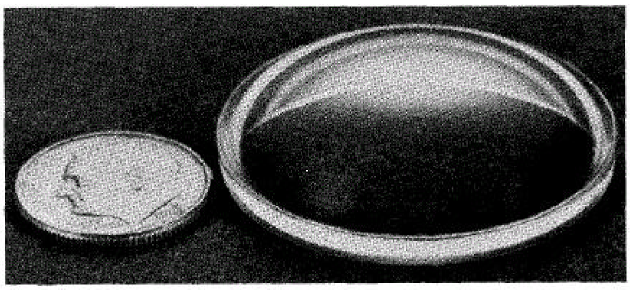


Fig. 1.17 - Polycarbonate rocket nose lens must withstand severe temperature and impact tests.

produced parts, surface texturing is more economically obtained by incorporating the feature into the mold cavity surface. Fig. 1.18 and 1.19 demonstrate the use of this technique to diffuse light and to create a light barrier.

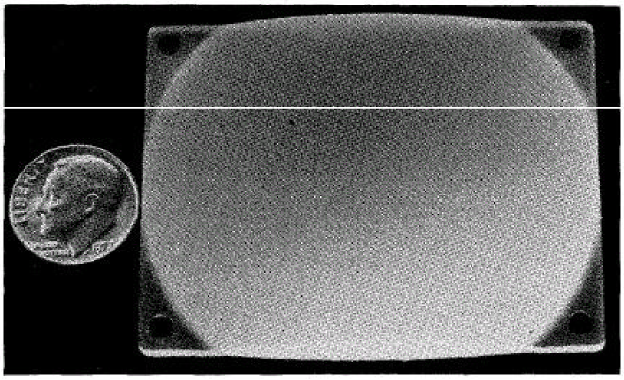


Fig. 1.18 - Condensing lens has controlled etching for even light diffusion.

Light Transmission: Light transmittance of quality optical plastics covers a wide range. The transmittance of acrylic is higher than most optical glasses throughout the visible spectrum. Other optical plastics have a transmittance typical of many optical glasses, which is slightly lower than that of acrylic. This lower transmission is not a factor in most applications.

The transmittance of optical plastics is better than most glasses in the ultraviolet and near infrared wavelengths. The ultraviolet end of the spectrum is usually restricted by absorbing additives used to protect UV-sensitive materials. Spectral response can be tailored to specific requirements by adjusting the composition of the additives. Fig. 1.20 and Fig. 1.21 show two parts with additives providing a specific spectral response.

In most cases the determining factor for using plastic optics is cost. It is in the best interest of the supplier to be as frank about tradeoffs as possible, because profit results.

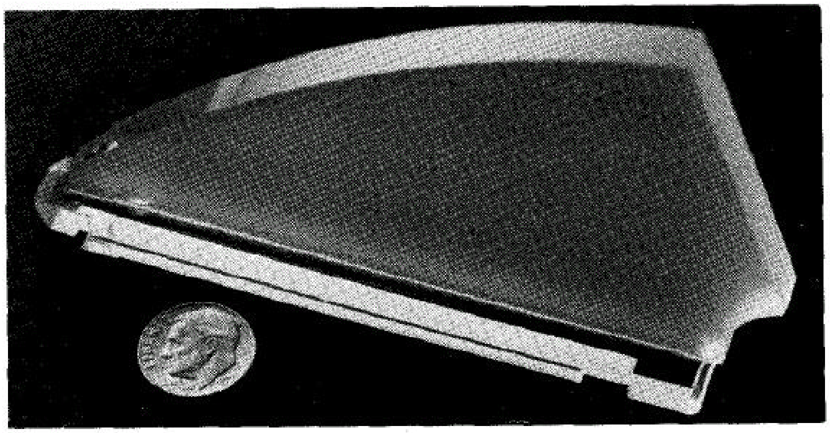


Fig. 1.19 - Parabolic reflector has etched surfaces on the side-walls for good paint adhesion and maximum stray-light absorption.

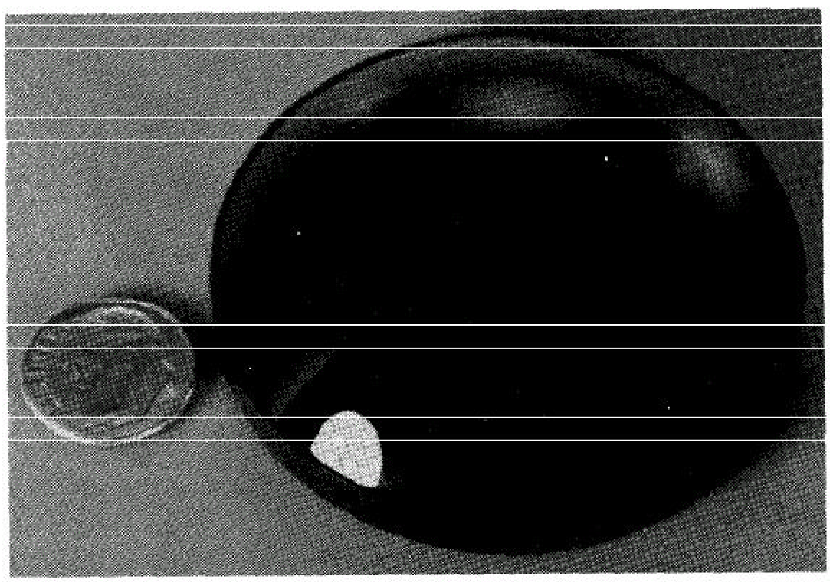


Fig. 1.20 - Detector lens, using dyed material, restricts transmission in the lower visible wavelengths, but allows maximum transmission in the region where the detector is sensitive.

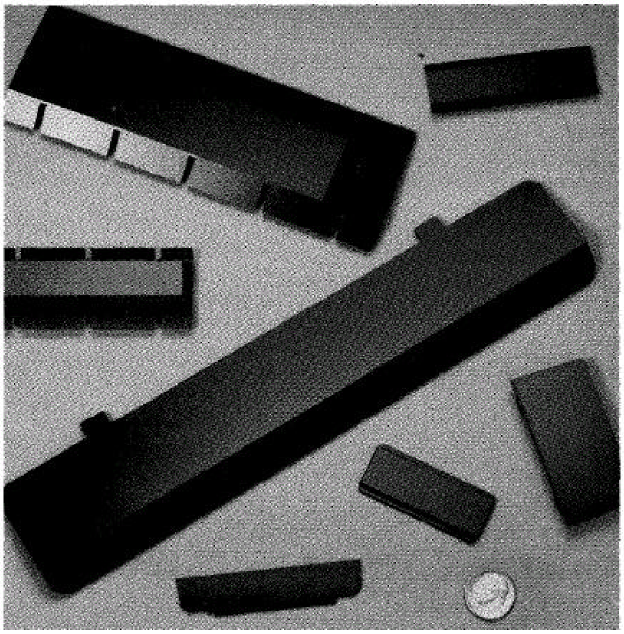


Fig. 1.21 - Colored windows are used to absorb background light in illuminated display applications.

from providing parts - not tooling. Therefore, the supplier is motivated to use engineering and tooling time in a manner that makes long-term sense to everyone involved. A plastic lensmaker needs a good estimate of production quantity requirements in order to bring the advantages of plastic optic technology to the buyer. This factor will be discussed in more detail because the balance between tooling cost and part cost is a critical requirement for realizing minimum total cost.