Historical Perspective

OPTICAL BLANKS...
Eyeglasses to Satellites

Microscopes, Camera Projectors, Periscopes, Range Finders, Telescopes, Fire Control Devices, Aerial Cameras, Bomb Sights, Guidance Systems

Glass, once thought of as an age-old material with commonplace uses, is today an indispensable component in many fields, some of which did not exist as recently as 20, or even 10 years ago. In optics alone glass is opening new vistas of exploration, especially in space, which is quite dramatically illustrated by the variety of lens blanks molded by United Lens Co., Southbridge, MA - lens blanks for the manufacture of microscopes, camera projectors, telescopes, periscopes, range finders, gun sights, fire control devices, tracking cameras, aerial cameras, bomb sights, guidance systems, and now, satellite components. Other blanks, of course, are widely used in the making of single vision, bifocal, trifocal, and sunglass spectacle lenses.

The company stocks more than 120 different types of glass. Optical glasses run from 446-673* to 786-256, and rare earth, from 652-585 to 880-411. Rare earth glasses are used in sophisticated lens systems, where low dispersion is required, or where either high index or high V value, or both, are required. These are for expensive cameras, or where true color definition is needed. Heat absorption glasses protect the film in projectors; Kovar sealing glasses are used in face plates for cathode ray, and other electronic tubes; and filter glasses serve a need in various transmission uses, such as infrared or ultraviolet.

United Lens stores these glasses by categories in 12-ft. high steel racks, each section holding 6 tons. The raw glass is purchased in several forms - gobs, strips or extrusions, and sheets or blocks - principally from Corning Glass Works, Pittsburgh Plate Glass Co., Bausch & Lomb Inc., Hayward Scientific Glass Corp., and Schott & Gen., West Germany.

Gobs, stocked in hundreds of sizes (larger gobs are called slugs), various diameters, and in many types of glass, range from 3 to 500 gms. These are the preferred source of lens blanks, since they require only heating and pressing, but this method is less flexible than the other two because the weight of the gob must be quite exact so as to keep the thickness tolerance within limits.

Strips, or extrusions, run from 6 mm. thick by 4 in. wide by 24 in. long up to 2-1/2 in. by 6-1/2 in. by 24 in. These can be cut with a glass cutter into predetermined weights and sizes. Blocks (large pieces produced by Pot method) weigh from 30 to 40 lbs. and are the least desirable form of glass because their thickness dictates that they be cut with a diamond saw. They are used for flexibility since they can be cut to specified sizes, when gobs are not available, especially for short runs.

Sheets, also 30 to 40 lbs. each, are usually 18 in. by 36 in. and range in thickness from 6 to 22 mm.

The Cutting Process

Before the operator cuts sheets and strips to fit the specifications of the molded blank, he computes the size square that will produce the exact finished blank. Four cutting methods are used.

(1) Original cuts are made with a glass cutter (Figure 1), using pressed wood sticks as guides, ranging in width from 8 to 50 mm, in 1-mm increments. These can be used in combination for any size to be molded. Originally, the sticks were made of maple, but it was found that pressed wood was more stable and did not warp.

(2) The operator places the scored sheet over a thin strip of rawhide and presses the glass on both sides of the scratch mark so that it will break evenly. This is repeated until the entire sheet is broken into the maximum number of squares laid out.

(3) When breaking thicker sheets or strips, the operator taps the score line with a steel ball on a handle, and in another method he places a thick fiber block - resembling an inverted "U" - on top of the glass which, as before, is positioned over a rawhide strand. Each leg of the "U" is parallel to the score and applies equal pressure to both halves of the glass when the block is struck with a hammer.

(4) With strips more than 2 in. thick, United Lens uses various sizes (Figure 2) of diamond wheels** ranging from 10 to 16 in. in diameter and 0.050 in. thick. Specifications are D46 N25 M-1/8, the standard marking system for diamond products (Table 1).

TABLE 1 - Marking System for Diamond Products

Abrasive Type	Grit Size	Grade	Concentration	Bond	Depth of Diamond Section
D (Diamond)	46 (30 to 600)	N	25 - Low	B - Resinoid	1/16
		A to Z	50 - Medium	M - Metal	1/8
		(Soft to Hard)	100 - High	V -Vitrified	1/4
					Absence of depth symbol indicates solid diamond

Life expectancy per wheel, according to Richard DiGregorio, plant manager, is about one week of steady use. This particular specification for the wheel makes rapid cutting possible and also provides smooth surfaces that require no additional preparation prior to pressing. On selecting the appropriate grit and bond, the wheels are dressed by the constant cutting.

After they have been cut to size for molding, the lens blanks are weighed to insure that they are within the prescribed tolerances - overweight pieces can be ground down to meet specifications; underweight ones are rejected.

Molding

The raw blanks are then transferred to the molding room where 20 gas-heated ovens (Figure 3) turn out thousands of pressings a day. These ovens were built entirely by United Lens' engineers and labor, from the ground up, in accordance with their own specifications. Within the past few years, capacity of the furnaces has been increased from a maximum size lens blank of 3 lbs. to 22 lbs. because of the need for special lenses required in space technology, as well as for beam splitters, fire control, guidance systems, and new, larger lens systems.

Depending on the pressing cycle, each blank is placed in a pre-heating compartment of the furnace for varying periods in order to prevent thermal shock when subjected to the normal processing temperatures between 1600° and 2000°F. At these higher temperatures, the glass is heated to the softening point (Figure 4), then transferred to the specified hand-held mold, and placed in the air press equipped with a machined steel plunger cut to the precise curvature desired. Following a brief cooling period, the molds are inverted to remove the blanks which then enter temporary annealing ovens, built into the furnaces, where they remain overnight. The furnaces are turned off at 4:15 PM, but the annealing ovens retain the proper heat until the blanks are removed at 3 AM, when the fires are again lit for the next day's operations.

A special forced-air system, designed by United Lens, maintains a comfortable climate in the molding room both winter and summer, despite the extreme temperatures generated by the furnaces. Each molder is cooled by two streams of air, directed at him from the back and side; in addition, he views his work through a tinted glass heat shield.

The intake air from the blower system passes through a cooling tower with a 2-stage spray bank, and this air is used as the screen between the molder and the fire. The air is completely saturated with water - to 100 percent humidity - which is drawn at 55°F from the firm's artesian wells. As it discharges from blower nozzles, a second cooling takes place as a result of evaporation, so that the air hitting the molder is relatively dry and cool. The room itself is ventilated by a bank of large exhaust fans above and behind the furnaces which change the air completely 2-1/2 times per min., drawing in outside air from opposite sides of the room. This air, for additional cooling, passes through water discharged from a third spray bank originating from cooling towers mounted on the roof. This water comes from the original cooling of the molder's air.

Final Annealing

After removal from the temporary annealing ovens, the blanks are submitted to the inspection department where all flash is removed, and they are inspected for contamination, fire cracks, and flaws. They are then placed in stainless steel trays with wire-mesh bottoms, to allow even circulation of heat, and inserted in the annealing ovens.

Since glass is manufactured below the predetermined limit of index, the final annealing is a critical science which compacts the molecules, making the glass more dense and raising the index within the predetermined limits. It must, of necessity, provide the maximum stress relief, while maintaining the index tolerance.

This process is performed in electric furnaces† (Figure 5) whose controls (Figure 6) were developed for United Lens and incorporate features added by the company's engineers. Final annealing normally takes anywhere from 3 to 35 days. The automatic control programmers establish the initial heating rate, initial soak period, initial cooling rate, 2nd soak period, and the final and accelerated cooling rates, extending over varying periods, according to the sizes of the lens blanks.

Cycles are infinitely interchangeable, with entire cycles recorded automatically so that each can be reproduced at any time. All records of the 16 annealing furnaces are kept in *permanent* files. The controls, both cam-type and motor operated front-setter type, permit heating and cooling rates as low as 0.3°F per hour. With the annealing temperatures running about 1020°F, a typical cycle would consist of:

1. An 80°F per hour rise in temperature.
2. First soak period at 1020°F.
3. Cooling at 2° per hour.
4. Second soak period at a lower temperature.
5. Second cooling at 4° per hour.
6. Cooling to room temperature at 50° per hour.

With furnace loads varying between 200 and 300 lbs., any of 50 to 60 annealing cycles may be used, depending on the type of blank involved. Usually the annealing cycles are supplied by the glass maker, up to a given thickness, with 0 to 40 mm considered standard; other cycles are calculated by United Lens.

All cycles are calculated in accordance with Government Specification Jan-G-174, considered the industrial standard in instrument manufacture. The optical glass standard is specifically stated in paragraph E-4a:

"The distribution of permanent strain in each fine annealed plate or formed blank of optical glass shall be symmetrical. The birefringence resulting from the permanent strain shall not produce a relative retardation or path difference of over 10 mµ per cm. of transmitted path for sodium light."

United Lens has recently been working on blanks whose annealing required even more critical results than those called for in Jan-G-174. These demanded a difference of less than 5 mµ and have applications in precise lens systems such as guidance or fire control. While environmental conditions, to which the finished lenses will be subjected, are considered the problem of the lens designer and the glass manufacturer, it is United Lens's concern, according to Albert DiGregorio, general manager, that the proper annealing relieves the stress, assures the optical resolution of the final lens by raising the index within tolerance, and maintains the homegeneity of the glass.

After the fine annealing, the lens blanks are transported in their steel baskets back to the inspection department for final observation (Figure 7) in regard to dimensional, index and strain tolerances; then they are packed for shipment to the customer.

A Bright Future

From its small start 46 years ago as a producer of blanks for the optical industry, United Lens Co. has advanced with the technology of the times. Today, its production of instrument components for industry far outweighs the spectacle blanks portion of its business. Operation of the company is entirely a family affair. President and founder is Fileno DiGregorio who, at 77, is still the active head of the firm. Three sons, Albert, Richard, and Ronald are general manager, plant manager, and assistant plant manager, respectively. A son-in-law, Anthony Detarando, is executive vice-president.

The firm now produces thousands of blanks for devices that weren't even thought of when Fileno DiGregorio opened his little shop in Southbridge, and it is quite possible that when an American satellite lands on the moon, the pictures will come back through a lens made from one of his own blanks.

* Trade shorthand for the index (nD) and Dispersion (V Value) of each type of glass; e.g., 446-673 means: 1.446 nD ± 0.0001 and 67.3, ± 0.5 V. Value.

** The Carborundum Co.

† Made by Leeds & Northrup Co.