system. The machine can be programmed for gradual pressure changes, instead of the sudden changes found in conventional circuits; this process reduces or eliminates shock in the hydraulic system. Many times reed switches (which are not solid state but are highly reliable) are used to interface with solid state circuits.

Trouble shooting is aided by having lights show which part of the circuit is operating. When the malfunction is located, the defective electronic circuit board or plug-in unit can be replaced. The use of solid state controls is relatively new, with each machine manufacturer using his own system. General discussions of solid state circuits are found in Ref. 18 to 24.
CHAPTER 8

Examples of Molded Parts

A number of parts, most of which were injection molded by the author, have been selected to illustrate some of the principles and ideas previously discussed.

Filter Disk

Figure 8-1 shows a 12-in.-diameter filter grid molded in high impact polystyrene, over which is later sewn a polypropylene fiber filter bag. A number of these are stacked on a center tube and enclosed in the filter container. The filtering media, usually clay, is put in the container outside of the fiber bag. Dirty water flows through the filtering media, through the bags, on to the grids. This filtered water is carried off through the center hollow tube. A significant number broke radially while in operation. More broke when the user dismantled and cleaned the unit.

The original end user and molder must have decided to economize. The thickness was minimal. The part being center gated was oriented in the direction of flow. The strength was therefore much stronger radially than circumferentially. Since the ribs (which were used to keep the polypropylene bag off the surface of the filter grid) were in the direction of flow, they did not contribute to the strength of the piece.

A second supplier decided to build a disk engineered to overcome these faults (Figure 8-2). The part is much thicker and reinforced circumferentially with ribs where it is weakest. The radial slots permit the water to run into the center tube. The other side of the piece is identical except that the slots have been moved to the midpoint of the ribs on the other side. Therefore there is always at least one rib supporting the flat part of the filter disk. The part was overdesigned because
of consumer resistance caused by the "cheaper" unit. After consumer acceptance was established another unit was made (Figure 8-3), which was sufficiently strong and considerably less expensive.

Four Way Valve

One of the advantages of injection molding is that parts can be produced requiring little or no finishing. An inherent advantage of plastic is its corrosion resistance, particularly for water applications. Both these properties were used to replace a four way valve for swimming pool applications originally made in an aluminum die casting (Figure 8-4). The diameter of the valve body is 4 3/8-in. and its height 2½-in. The rough casting had to be machined and the valve assembled. After one season's use the chemicals in the pool began to corrode the valve causing it to jam. When leverage was used on the handle, the "freeze" was so severe that the metal handle bent or broke.

The part was converted into polycarbonate (Figure 8-5). The design chosen was very close to the die cast part for two reasons. Die casting is similar to injection molding and there were a large number of valves in the field so that the outside dimensions had to be similar. There were also many internal parts that would be obsolete if they could not be used in the polycarbonate version.

The main problem was the mold design. There were four parts — the valve...
body, the valve cover, the spool body, and the spool cover. For economic reasons they had to be molded in one shot. For engineering reasons the body had to be center gated. This required a three plate mold with seven cams and four irregular seal-offs for the four parts of the valve body.

Complicating the decision was that at that time the raw material supplier did not know of any three plate molds with pin point gates for parts of this complexity molded in polycarbonate. Nonetheless the mold was built. All parts were of air-hardening tool steel, highly polished. The hardened cams moved on hardened ways. The mold base was of a superior grade steel. Precision fitting and excellent workmanship were required. Since the cams and molds would be smashed if the mold closed when they were not in place, electrical interlocks were designed, so that the machine could not close unless the cams were in the correct position.

The valve's cover was attached to the valve body by a combination of solvent cementing and ultrasonic welding. The only machining required was to tap the eight holes that hold the cover on to the body, tap the one body hole for a pipe
connection, and tap the spool cover for the handle. The cost of the valve was reduced by the approximately two-thirds. The tooling cost for the plastic part was approximately double that of the die cast part. Rejection in the field because of corrosion was eliminated.

Mortar Training Device

Figure 8-6 shows a mortar training device used by the Armed Forces. Instead of using live shells, a special tubular device is inserted in the mortar. The plastic projectile is dropped into the tube and is ejected by an air-blast. When it hits the ground, an inertial device in the body explodes a “22” blank cartridge. Special air gauges and tables simulate the calculations and aiming, as if live ammunition were fired. The performance specifications are close, requiring the missile to hit a target about the size of a garbage can cover, one half a city block away.

Many nonplastic materials were tried un成功fully. Their main problem, aside from cost, was that they were nicked when they fell on pebbles or rocks. The nicks had to be removed so that the projectile would slide through the tube. Plastic was tried as a last resort and ABS proved to be satisfactory. Usually the indentations did not interfere with the reusability. If they did, rubbing them on
Figure 8-4  Aluminum die cast four way valve. The body is 4-3/8 in. in diameter and 2½ in. deep. (Courtesy of American Machine Products, Inc.)

a rock or using a pen knife or bayonet would solve the problem.

Prototypes were made and it became evident that the exploding blank cartridge would eventually affect the plastic. It was decided to mold a steel insert A into the plastic body F. The firing pin E, which is held in its back position by the spring D, is retained in the molded insert by metal ring C and snap fastener B. The firing pin has its bearing surface on the plastic. There are four rings on the outside which act as a seal between the projectile and the barrel. The compressed air expands, imparting velocity to the projectile. The fit had to be very close and consistent. A slight oversize would cause binding and an undersize permit too much air to escape. The required accuracy could not be maintained by molding but was achieved by centerless grinding. The tail section had to be molded without significant voids. If not, it caused an irregular trajectory which was too inaccurate.

The main problem was caused by the design limitations of the piece. The part was 4 3/8— in. long and 1—in. in diameter. The internal parts did not permit a
Figure 8-5  Aluminum valve of Figure 8-4 molded in polycarbonate (Courtesy of American Machine Products, Inc.).

thick enough wall around the steel insert A. Inspection of the piece will show that it must be gated into the center of the fin section. The part above the fin is cammed. The greatest strength of the plastic would be in the direction of flow. This is longitudinal in relation to the insert rather than circumferential which would be desired. Since this is an orientation effect it was felt that it might work if the bushings were kept very hot. This would permit relaxation of the plastic around the bushing and increase its hoop strength. It was subsequently shown that those parts molded with a cold insert failed in the field and those with hot inserts were satisfactory. Today the problem would not be so severe, as stronger materials are available.

Lamp Housing

A lamp part, 8 in. high and 5 in. in diameter, molded out of general purpose heat resistant polystyrene, is shown in Figure 8-7. The bottom cap is solvent
cemented after molding. The material was selected for low cost, beauty, and ease of molding. The main problem was the tool design. To achieve esthetically pleasing triangular cutouts, four cams were required. The cutout effect could have been achieved with two cams, but the triangles close to the parting line would be severely distorted. The cam blocks were massive and held together by a large ring which acted as a cam lock. To prevent tearing, the cams move at right angles to the core. The cams are on the ejection side and are activated by the pins that are attached to the injection side. The cores must be maintained accurately in their position when the machine closes. If not, the core pins will not locate. If one visualizes the mold in a horizontal press one can see that the top cam must be supported against the pull of gravity. This is done with springs and detents. The cams and knockout plate are electrically interlocked. If the
knock-out plate is not completely back, the cams would hit the knockout pins, damaging the mold.

**Skimmer**

Figure 8-8 is the front view of a stationary skimmer that removes surface debris from a swimming pool. It is 10 in. long by 8 in. wide by 7 in. high. The top and bottom housings are molded in ABS and the hinged weir (flap) is made of polypropylene. The hinge is kept at water level by a styrofoam panel which is attached to the underside of the flap, with three stainless steel clips that snap on over three tits molded on the polypropylene (Figure 8-9). The debris is caught in a polypropylene strainer (Figure 8-10).
Figure 8-8 Stationary skimmer for removing debris from the surface of swimming pools. It is 10 in. long, 8 in. wide, and 7 in. deep. The housing is molded of ABS and the hinged weir of polypropylene (Courtesy of American Machine Products, Inc.).

Figure 8-9 Underside view of the skimmer cover, showing the foamed polystyrene pad held on to the weir by stainless steel clips.
There are some interesting applications of plastic in this part. The cover has a 3/4-in.-long undercut hook on each side molded with a "jiggler" pin. They snap into the corresponding slots in the base (Figure 8-8). To separate the cover, the flexible property of the ABS is used. The sides are pushed in to relieve the undercut hooks.

The hinged weir makes use of the orienting characteristics of polypropylene. Its size is 7 3/4 in. long by 5 1/2 in. wide by 0.075 in. thick. The part is molded so that all the plastic must flow through the hinge section. Because of the direction of flow and the thinness of the section the molecules are oriented in the direction of flow. As soon as the flow stops, they freeze. The hinge must be flexed right after molding. This further orients the molecules by stretching them. It probably also freezes them in place. The hinge works because the C-C linkages are strong and flexible. Such hinges have been experimentally flexed over a million times without failure. If the hinge section is made thicker, 0.030 in. for example, the hinge will not work. The extra thickness will make it impossible to orient sufficiently the molecules.

The strainer appears to have a large cross hatched design. Its purpose is not esthetic. The hinged weir and the strainer are molded on the same mold. It was impossible to fill the strainer without packing the hinge. Therefore, the hatched design was added as additional runners to provide more flow to fill the part easily. They also provide mechanical reinforcement. It is multigated on the
a parting line along the long side. This gives no distortion. However, if the part is packed and too much material is forced in at the gate sections, the side by the gate will subsequently bow, as the excess material must go somewhere when it cools.

Vacuum Metallized Lamp Parts

Figure 8-11 shows vacuum metalized lamp parts molded in general purpose or heat resistant polystyrene. The part on the left is 5 1/2 in. long and 1 1/4 in. in diameter. It is slipped over a pipe separating other components of the lamp. The finial (lamp top) in the upper right is 3 1/2 in. long and 1 1/8 in. in diameter, and the other finial 1 1/4 in. long by 1 in. in diameter. Both finials have metal threads inserted after molding. Plastic threads were unsatisfactory because of the high heat developed by the incandescent bulb.

With the start of the Korean war, it became evident that the nonmilitary use of brass would be restricted. At this time vacuum metallizing of plastic was beginning to become commercially available. Molds were built and an extensive molding and metallizing experimental program undertaken. The main problems were adhesion and quality. If the part had the slightest flaw, the housewife would attempt to polish it off with brass polish, removing the metalized finish. Although the parts were less expensive than brass, weighed less, and had a surface that did not tarnish, their acceptance by lamp buyers in stores was poor. The attitude of the lamp buyers was why try something new, even if better, when the old item was accepted. When brass was no longer available they accepted vacuum metallized parts which today are the standard of the industry. This was one of the first large scale commercial uses of metallizing. Fortunately, the attitude toward plastic today is one of acceptance for its own merits and it is no longer considered a substitute.

The parts are produced in large multicavity cammed molds. The spindle is cammed from both sides to reduce part weight. The large finial uses an air operated cam and the small one a mechanical cam. Since these parts were copies of brass turnings with large smooth surfaces, quality metallizing is difficult. Exceptional attention is paid to molding clean shiny surfaces which are protected from mold release, oil, and dust. Special spinning and filtering techniques are used in the lacquering operations of the metallizing.

Venturi Tube

Figure 8-12 shows a venturi tube used in a swimming pool skimmer system. It is 9 1/2 in. long and 1 3/8 in. diameter, with a 1-in. molded pipe thread on the outside. An adjustable plastic flap controls the flow of water and is held with a brass knurled screw threaded into a brass knurled nut.
Figure 8-11 Vacuum metalized polystyrene lamp parts. The spindle on the left is 5 ½ in. long and 1 ¼ in. in diameter. It has a ½ in. hole. The finial on the top right is 3 ½ in. long and 1 1/8 in. in diameter. The finial on the bottom right is 1 ¼ in. long and 1 in. in diameter. Both finials have a metal thread inserted after molding (Courtesy of Robinson Plastics Corp.).

Molding the part in one piece would require a complicated mold with three cams, one having a pull of 10 in. The wall thickness would be uneven, reducing the water flow, and an expensive brass turning would have to be inserted.

The part was made in two halves with a tongue and groove joint. It was solvent cemented using a specially devised jig with four clamps. This was necessary for the mechanical strength of the bond. An inexpensive brass nut was
Figure 8-12 Venturi tube molded in high impact polystyrene. It is 9\(\frac{3}{8}\) in. long and 1 3/8 in. in diameter. The tab is held in place by a brass knurled screw which is tightened against a brass nut held in place by the two cemented halves (Courtesy of American Machine Products, Inc.).

inserted in an hexagonal recess and held in place by the cementing of the part. The total cost for mold and part for the quantities contemplated was considerably less this way.

**Tissue Box**

Figure 8-13 shows a tissue dispenser molded in general purpose crystal styrene. It is 10 in. long, 5 1/2 in. wide and 2 1/2 in. high with an average wall thickness of 0.200 in. The box was designed to simulate the quality and brilliance of hand carved and polished acrylic. The design of the carvings was based on the angle of refraction of polystyrene, and selected to give maximum brilliance.

For economic reasons the base plate and body had to be run together. The box was assembled and packed at the molding machine. The major problem was designing a cam for the 3/16-in. deep slots, in which the base plate slid. Pulling a 10-in. core, with a minimum of draft, would require that the base plate go in in one way only. This was not acceptable. Two internal cams, one for each side, were designed. The total movement was small, 1/4 in. Even though the internal
Figure 8-13 A tissue dispenser molded in crystal polystyrene. A schematic drawing of the internal cam is laid upon the base plate (Courtesy of Rialto Products Corp.).

cam looked perfectly feasible on paper the author looked for "moral" support before starting the mold. At that time (1952) neither he nor the many people asked were able to discover a similarly built mold. Nonetheless the mold was built and ran over 750,000 shots without replacement or repair of the cams. They were lubricated externally once every 8 hr shift with a silicone mold release spray. Today, of course, complexity or novelty of a mold construction is no longer a bar to the production of a plastic part.

Flashlight Head Assembly

Figure 8-14 shows the head assembly for a rechargeable flashlight. The assembled part is 2 1/2 in. long, 1 1/2 in. wide, and 1 1/2 in. deep. It consists of a vacuum metallized reflector into which is eyeletted two metal parts, which serve as the bulb holder and contact. The bezel is molded in polystyrene with a protrusion on each side that snaps the unit into the main housing. These
protusions are molded with jiggler pins. The lens protector is stamped out of clear polycarbonate sheet. This was the only material which had the clarity, scratch resistance, and strength in the thin section needed for the assembly. The back of the bezel has two round tits which correspond to the holes at the ends of the reflector and the cutouts in the polycarbonate shield. They are assembled together and the tits are smeared over with a hot punch, holding the assembly together. This method was chosen because there was not enough room for a metallic fastener. It is not possible to cement vacuum metallized polystyrene to polycarbonate. The beryllium molds presented no problem. Beryllium pressure castings were used because of the ease in duplicating the irregularly contoured elliptical surface of the bezel and the optical requirements of the curvature of the reflector. The product illustrates the use of different materials — polystyrene, polycarbonate, steel, and beryllium stamping — and different processes — injection molding, vacuum metalizing, plastic stamping, metal stamping, and assembly — to produce an economical, well engineered unit.
Combs

Figure 8-15 shows part of a shot for an eight cavity standard comb 8 1/4 in. long by 1 1/4 in. high by 0.200 in. thick. What makes this unusual is that it is molded in polycarbonate. It is inserted in a gold plated holder and is part of a very expensive boudoir set. The previously used polystyrene comb broke readily which was not acceptable for this high cost item.

Molding combs is not simple. The slightest short shot immediately shows by a curvature on the line of teeth. A packed shot causes minute flash which will cut the scalp. There was real question whether the viscosity of polycarbonate would permit proper filling of the teeth. The material supplier suggested borrowing a comb mold and trying it. With the customer's acquiescence it was decided to build the mold.

Since no one was sure whether to gate at the thin tooth end, thick tooth end, or center, the mold was designed to gate in all locations. The initial attempt was made at the thick tooth end.

The mold filled very nicely except there were severe blemishes along the root of the comb. Because the mold was designed for easy runner changes, it was

Figure 8-15 Gate section of eight cavity polycarbonate 8 in. comb mold (Courtesy of Globe Silver Co., Inc.).
decided to attempt to eliminate this even though it was covered by the gold plated holder. Several different types of runners, including an H runner, had no effect on the blemish. Initially a restricted gate was used which was very satisfactory from the point of view of mold filling. Many different gates were tried. The final solution was a tab gate, with the tab being the width and height of the root.

Car Tray

Figure 8-16 shows a car tray of low density polyethylene for holding 12 MATCHBOX® miniature cars. It is 9 3/8 in. long by 6 in. wide by 1 3/8 in. high with an average wall thickness of 0.050 in. It was originally a one cavity mold. Production estimates were very large. For this reason and the cost of the part it was decided to attempt a four cavity, three plate, back gated mold.

The mold was large, 19 in. by 31 in. and had to run automatically. Great rigidity was required for any shifting would thin out one wall preventing filling. Each cavity and core had its individual water channels. The sprue was brought right up to the secondary runner. To obtain even flow, minimize packing (which would cause sticking) and prevent orientation warping, it was decided to gate at six different places (1-6).

The mold filled and ran beautifully. One problem developed. The separating ribs or dividers above gates 3 and 4 warped. This was shown to be caused by packing too much material in the gate area, similar to what happened in Figure 3-29. Investigation showed that ribs over gates 1, 2, 5, and 6 were also packed. Since they had one end terminating on the outside they stretched the rim (which was not esthetically visible) and looked straight. The dividers over gates 3 and 4 were constrained by the structure and therefore warped. The solution was simple. Gates 3 and 4 were blocked from the back at the secondary sprue bushing. After this was done, one looking at the part would be “sure” that there were six gates. If he decided to copy exactly the mold he might wonder how the original part was molded with a straight divider.

Subsequently three other molds were built. The runner system weighed almost as much as the parts. Its handling and regrinding were difficult and costly. It was decided to build one of the molds using an insulated runner, with heated nozzle tips. The runner ran very well unless a nozzle plugged up. When that happened the insulated runner plate opened, plastic covering the whole plate. This gave an effect of projected area of about 400 in. square which was too much for the 425-ton clamp. This would blow the plate causing one-half hour loss in production. For a long time this was a rare occurrence, happening perhaps once or twice a week. Suddenly it became intermittent, happening three or four times a day and then not appearing for a week. It was eventually traced to very fine particles of Texas sand which plugged up the nozzles and which was introduced in the bagging operation of the raw material supplier.
Figure 8-16 12 compartment low density polyethylene tray to hold MATCHBOX® miniature cars. The tray is 9 3/8 in. long, 6 in. wide, and 1 3/8 in. deep, with an average wall thickness of 0.050 in. (Courtesy of Lesney Products Corp.)

Apollo Bust

It is fitting to end this book with the first custom molded product in which the author was the "engineer." Figure 8-17 shows the bust of Apollo, molded in acrylic, 4 in. high, 2 1/2 in. across the shoulders, and 1 in. thick, and molded in 1940. Incidentally, the parts still retain their original clarity and brilliance. The part was put on an alabaster base, lighted from underneath by a battery operated bulb and used as bookends. The customer was having them hand carved from blocks of acrylic. He could not turn them out fast enough to satisfy his demand.

He was sent to my employer who asked me (on the basis of my 4 months' experience) if the part could be molded. I suggested that if the customer could engrave the reverse of the part in steel I would build a mold around it and try it. The customer asked for the steel. Knowing nothing about steel, I bought two pieces of boiler plate about the right size from the local junk yard.

Some weeks later he returned with the steel, a mold was built around it, and the part was molded. Initially there was considerable flash which was eliminated by hand fitting in the machine. The customer was exceptionally well pleased; he took the parts, buffed the seam, and gave the bust the appearance of a handmade part.
There was an interesting sequel. Some months later a very knowledgeable and experienced person in the plastic business saw the polished sample on my employer's desk and suggested that it could be molded if the undercuts were removed. My employer, who had a fine sense of humor, called me in and repeated this suggestion. I asked him what I should do with the 20,000 parts already molded. After duly chastising me for being disrespectful to an older person, he suggested that I learn something. I then found out what an undercut was. It tied in with an observation about the part that, until then, was not clear.

If one waited too long to open the machine, it was relatively difficult to
get Apollo out of the mold. The longer one waited, the harder it got. This new knowledge of "undercuts" explained why. The parts were molded with a 1-minute cycle and ejected relatively soft. As it knocked out, the head bent forward, because of the undercut, to clear it from the cavity. This did cause a small tear on the shoulder, but fortunately the tear looked like muscles. Obviously the longer one waited, the harder Apollo became and the more difficult it was to eject.