

LSR History

The first example of silicone rubber was produced as early as 1872. The substance was very viscous oil, developed by reacting diethoxydiethylsilane with water and trace amounts of acids. The first commercial grades were produced in 1943, only high-consistency rubbers (HCRs), by the Dow Chemical Company, with many other companies following shortly after. It was not until the late 1970's that a "pumpable" silicone rubber was developed and available to fabricators. Since then, LSR's have continued to evolve and have surpassed use of HCRs for injection molding. Liquid Silicone Rubber has come a long way and today, is utilized by a variety of industries- from automotive to medical.

When someone mentions using a silicone product, one or more of several varied products could come to mind. Although all trace themselves back to the common element silica, their forms and end uses are as varied as their processes. Thermoset Elastomers can basically be broken out into two types:

HCR/HCE

- HCR/HCE -HCR Heat Cured Rubber and HCE Heat Cured Elastomers are very high viscosity (greater than 50,000,000 centipoises-cps), non-flowing rubber compounds typically compression or transfer molded or extruded.

LSR/LIM

- LSR/LIM -LIM® Liquid Injection Molded or LSR Liquid Silicone Rubbers are lower viscosity two component flowable pastes in the typical viscosities from 10,000 to 1,000,000 cps.

NPI Medical's use of LSR

- NPI Medical has broad experience in using LSR
- NPI has a custom heated master frame and insert system.
- Vacuum venting is standard, "plaque molds"
- Prototype to Production LSR core capabilities

Silicone Terminology & Description

Silicone Elastomers (Methyl-Silicone, Vinyl-Methyl-Silicone, Fluoro-Vinyl-Methyl-Silicone, and Phenyl-Vinyl- Methyl-Silicone) are formulated from the second most abundant element on earth, Silica. Silica is a major component of many clays, sand, rocks and quartz. If modified by adding oxygen, silica becomes silicon, another gray, rocklike substance. Perhaps most famous for revolutionizing the electronics industry (Silicon Valley, telecommunications, computers, electronics), silica is the base component that is processed, catalyzed and chemically processed into the components of what will become flexible LSR (Liquid Silicone Rubber). Additionally, LSR's readily accept a number of fillers to provide selected physical properties, improve strength, and increase viscosity. Some are self-extinguishing or flame resistant while others are not. Following are brief descriptions of the five families of Silicone products.

1. **R.T.V.'s** (Room Temperature Vulcanizing) are two component silicones that when mixed together begin to catalyze- set but have a reasonable pot life to enable them to be cast or poured into a variety of end use products. They are used in the mold-making industry to make rapid tooling for prototype parts, in the electronics industry for potting or encapsulating components for environmental protection of sensitive materials, or in the entertainment industry to make special effects and life-like characters.
2. **Silanes and Coatings** are single component products that can be used to promote adhesion to substrates, to crosslink plastic polymers to improve their performance properties, to scavenge water to prevent premature curing of compounds and improve stability, and as coupling agent to bind organic polymers to mineral or siliceous fillers for improved bonding and strength.
3. **Silicone Fluids** are commonly used in high performance lubricating applications involving

extreme high or low temperatures. They also can be used as an additive to enhance the performance of greases, pastes and other lubricants.

4. **Silicone Sealants** come in one or two-component form. The two component form requires the end user to measure and mix the two parts together just prior to using and is a bit tricky to use. The more common one component form starts to cure as soon as it is exposed to air (actually the moisture in the air) must be applied fairly quickly. They are commonly used as automotive sealants or gaskets, moisture barriers for kitchen or bathroom fixtures, and for sealing windows and doors.
5. **Silicone Elastomers** (LIM® or LSR) are castable or moldable thermoset polymers with a broad range of characteristics and end uses. They are two component resins (Commonly called “A” and “B” component) that are stable for long periods of time when kept separate and sealed. They too begin to catalyze (set or harden) when mixed, but can have extended pot lives (time they can be applied, formed or used) of up to several days at room temperatures, even longer if kept cool or cold, but set quickly at elevated temperatures (seconds at 150°-180°C). They exhibit an extended range of qualities, characteristics and appearance and are used for a wide range of products from baby bottle nipples, oven bake ware non-stick liners, healthcare or medical products, valves, and as high friction grips on tools and appliances.

Processing & Production

Process: High consistency compounds are typically compression or transfer molded, thus largely limiting the design of products to shallow/simple or no details perpendicular to the parting line. High consistency rubber injection molding is possible; however this is a limited, niche technology. Processing LSR Elastomers, on the other hand, require only three steps: meter-mixing, molding, and finishing. LSR Elastomers have excellent flow qualities, and are rugged and pliable after curing in the mold, which permit extraordinary details and undercuts virtually impossible in other injection molding materials such as plastics or Thermoplastic Elastomers. LSR's are most commonly injection molded using Injection Molding Machines similar to but not the same as thermoplastics. The “A” and “B” LSR components are most commonly packed and handled in 19.9 kg (about 5 gallon) pails or 204.1 kg (about 55 gallon) drums. The drum kits or pail kits are placed in high pressure pumps fitted with precise follower plates to push the viscous components from the drum through a precision, high pressure control pump that can be either a fixed 1:1 ratio or variable ratio type. Smaller pumps are available that can be fed by several sizes of cartridges that are popular for prototyping and product development.

The “A” and “B” components are fed through high pressure hoses from the drums through the pump(s) up to a mixing head where the two parts are brought together and then mixed in a static mixer into a homogenous mix in preparation on forming the final product. At the point in the system where the two components come into contact are blended together, a cooling medium such as chilled water insures the mix is maintained at a controlled, cool temperature (10° - 20°C) to inhibit the cross linking or curing reaction. Cooled LSR mix will remain stable for extended periods of up to several days.

Production: The two most common types of molding machines are reciprocation screw and several variations of screw over plunger. One uses a reciprocation screw to prepare a dose and to inject the LSR, and the other uses a feeding screw to fill an exact dosing plunger which in turn injects the LSR. Unlike a thermoplastic screw with several zones to compress and heat plastic by friction and to push the melt in front of the check ring, LSR screws rely on a combination of the screw flights and the LSR pump to push the mix in front of the check ring or into the plunger. And also unlike a thermoplastic molding machine that uses heater bands to assist in plasticizing plastic pellets into a melt for injection into mold cavities, LSR machines use water jackets to keep the machine barrels and screws cool to retard the cross linking process. If the LSR molding machine is using a shut-off nozzle to positively cut off LSR flow, it too will be cooled by a water jacket. Silicone molds look “similar” to thermoplastic injection molds but they really are quite different. In theory (and in function) LSR molds are more closely related to compression rubber molds; rubbers and LSR's can flash (escape) through gaps as small as 0.0025mm (.0001”) and mold component fits and tolerances are an order of magnitude smaller and tighter than those normally associated with thermoplastics. Additionally, unlike the majority of plastic molds that control processing temperatures (0° - 150°C) with water or fluids (such as glycol or thermal transfer fluid) to provide a suitable means

to “cool” the plastic melt into a hardened, rigid plastic product, LSR molds are heated (usually by heating cartridges” to a high temperature (150° - 200°C) to cure the LSR into a finished, resilient product. Thermoplastic molds commonly use ejector pins to push (eject) the finished parts out of mold cavities. The highflowing characteristic of LSR’s prevents the use of the same, relatively inexpensive ejector pins. Ejector pins, if used in an LSR mold are special designed to fit an application, usually with tight fitting angled mating faces to prevent the

LSR from fouling the pin shaft. Ejection is usually using automated fixtures, sweepers or robots to push, scrape or to pull the finished part from a core, cavity, and retainer plate or undercut mechanism.

Benefits of LSR

- Great thermal stability
- Ability to resist extreme temperatures of heat and cold
- Medical & Food grade compliant
- Extremely clean and free from impurities as well as any potential biological contaminants
- Does not discolor from UV light
- Superior color stability
- Cost effective; depending on volume,
- Almost no scrap
- Outstanding mechanical, electrical insulating properties
- Ability to repel water and form water tight seals
- Low chemical reactivity
- Low toxicity
- Low viscosity makes liquid silicone rubbers suitable for molding applications requiring complex, intricate molds.
- Designed to be used in highly automated closed systems with very little labor required once the system has been put into operation.

Applications

Liquid silicone rubber applications are products that require high precision performance, reliability and smooth surface. Those items include seals, sealing membranes, electric connectors, multi-pin connectors, medical applications, infant products, such as bottle nipples, pacifiers, overlay on feeding spoons, as well as kitchen utensils such as spatulas, spoons, baking pans, etc. Silicone rubber is often over-molded onto other parts made of different, less soft or flexible materials such as thermoplastics or metals. For example, a silicone soft grip handle on cooking utensils or a button face might be over-molded onto Nylon™ housing. Since silicone rubber has many positive properties, new material advances continue to be made. Most recently the healthcare industry is benefiting from the high optical transparency and excellent physical stability to produce products such as catheters, wound drains, endoscopic devices, hydrocephalic shunts, pacemaker lead coverings, replacement finger joints, and respiratory components.

Conclusion

The selection of the right type of silicone rubber Elastomers for a specific use is largely a matter of personal preference and availability of equipment. There is little observable difference between peroxide cured high consistency silicone rubbers; addition cured high consistency silicone rubbers, and liquid silicone rubbers in terms of physical property performance. However, the materials differ significantly in terms of the processing necessary to fabricate medical devices and components. High consistency or liquid silicones are acceptable for injection molding machines. For facilities already processing high consistency Elastomers, continuing with the same type of material may be the most efficient and cost-effective course of action. However, new operations entering the marketplace should give serious consideration to using liquid silicone rubber, because the capital costs and labor involved are significantly lower than those associated with the processing of high consistency material.