Trends in LSR 2017: Overview

Since its inception and ensuing growth, liquid silicone rubber (LSR) has established itself in many fields, displacing conventional materials and opening up new applications.

The material has existed since the late 1970s, and has become the material of choice for manufacturing rubber parts and products.

LSR is expanding in its use as a direct result of its versatility and unique properties. The material is non-reactive and stable. It also is resistant to extreme environments and temperatures.

Parts molded from LSR are formed through an injection-molding process similar to that of conventional plastic injection molding with one major difference — the material delivery system is cooled and the mold is heated. Final LSR parts are strong and elastic with excellent thermal, chemical and electrical resistance.

Since its high thermal stability, good rubber-like properties and resistance to aging, LSR is the material of choice by many industries including medical, military, electronics, appliance, automotive and textile industries. The material has a wide temperature range (-94 degree F to +400 degree F) with low compression set and resistance to the damaging effects of sunlight and ozone.

In designing a LSR mold, it is important to note the injection process is highly sensitive to flash, which can occur within shutoffs of only 0.0002 inches. As such, the fit between the A and B sides of the mold has to be very tight. This is some of the most challenging work a mold maker can perform, using 0.004- to 0.006-inch-diameter end mills.

LSR also blends two components. It’s not easy to master the molding, with liquid pumping and dosing controlled by precise mixing and metering. There is a cross-linking of parts A and B that takes place in the mold. The mold accelerates cross-linking typically heated above 300 degrees. Some processors will require a lower temperature.

But the result is a flexible and strong thermoset. Properties include good hardness, tensile strength and excellent compression set.

The parts maintain their physical properties at extreme temperatures and can withstand sterilization, making the material a natural fit for the medical end market.

LSR parts also are biocompatible, so they work very well for products that have skin contact. Those benefits lend themselves well to automotive, medical and food appliance industries, typically in the form of seals, gaskets, valves and cables.

LSR also is used in industries that include sporting goods and consumer products. It is used to manufacture a number of different items, including overmolded parts, filtration components and more.

Molded silicones can be used for energy-efficient LED lights, as well as secondary optics and cables and connectors.

In transportation, LSRs are good for under-hood applications in cars, he said. A new class of fluoro-LSR resists aggressive chemicals, solvents and oils. The big benefit: reduced emissions in cars and trucks.

However, silicone in general is not compatible with petroleum; therefore, it is mostly used in electrical components for automotive. The design flexibility, in part, gives LSR its allure.

As a result, LSR is a paradigm-shifting material. Engineers who are used to dealing with thermoplastics or other thermosets have to be trained to accept the differences and to design for the material.

Silicones are projected to grow at 4.5 percent per year through 2020, becoming a more than $4 billion industry in the U.S., according to the Freedonia Group.
“With liquid you basically open the two vessels and put the dosing system on. The raw material is never exposed to the open air. Your potential to get a contaminant in there is significantly reduced compared to an HCR or a heat cured silicone. On those you’re going to put them in the mixer, put them in an open mill, to get the material prepared. LSR has a very clear advantage in cleanliness.”

— Randy Ross, CEO, Q Holding Co.

Overall, the U.S. silicones market is back in growth mode having recovered from the great recession,” said Kent Furst, an industry analyst with the Freedonia Group. “Over the next decade we are expecting overall demand in silicones to rise in line with the U.S. economy.”

Further, health care spending in Asia is increasing by more than 10 percent per year.

“LSR technology is not as widespread in Asia as it is in the U.S., which is both a challenge and an opportunity,” Furst said.

Production of liquid silicone rubber stood at 46,647 tons in 2011 and is expected to exceed 63,000 tons in 2017. China continues to dominate the liquid silicone rubber market as the largest producer, as well as the largest global exporter.

In 2017, trends point to LSR continuing to displace one material after another. Not only that, new applications are unfolding which owe their existence to LSR.

Applications and benefits

Injection molding is the primary process in the production of LSR parts and the segment is evolving as new materials are introduced.

LSRs are typically used when a customer has biocompatible or temperature application requirements, said Jim Ritzema, Rogan’s director of new product development. For silicones, he said Rogan only processes LSRs.

When manufacturers reach out to Rogan for help with product development, Ritzema said they first ask them if their application requires LSR because it’s a material that gives manufacturers options. For example, it’s a transparent material with the option to add color if needed.

“It keeps its properties at high and low temperatures,” Ritzema added.

Luis Tissone, life sciences director for Trelleborg Sealing Solutions in America, said the main advantage is LSR can be processed in a closed loop system, greatly decreasing the risk of contamination.

The material’s excellent properties and overall performance allow it to achieve many shapes in demanding environments while meeting many rigorous regulatory requirements.

“Liquid silicone has an inherit advantage over the heat cured or gum based silicones,” said Randy Ross, CEO of Q Holding Co., the parent company of LSR manufacturer Qure Medical.

“With liquid you basically open the two vessels and put the dosing system on. The raw material is never exposed to the open air. Your potential to get a contaminant in there is significantly reduced compared to an HCR or a heat cured silicone. On those you’re going to put them in the mixer, put them in an open mill, to get the material prepared. LSR has a very clear advantage in cleanliness.”

LSR also is beneficial because it can be a medical grade that contains the following attributes: thermal stability; low compression set; excellent mold flow; minimal flash; autoclavable; and implantable.

Bob Waitt, medical market manager for Bluestar Silicones, said LSR is perfect for molding high volume parts or requiring precise and specific parts thanks to the injection molding process, which allows producers to automate the process much like in thermoplastics — efficient and repeatable.

In a molding project involving LSR, it is critical that the molder, the mold builder and the molding press manufacturer communicate with one another clearly and cooperate to meet customer requirements. Failure to do so can dramatically affect the success of the project.

Beyond material characteristics, manufacturers also should pay attention to both ma-
material price and the overall cost of a project. Adding new materials to production also may require additional tooling costs. Consulting experts, from the molder to the material supplier, will help guide a manufacturer to select the correct soft material to meet their needs.

Each soft material has its own attributes and is best suited for different applications. When needing a biocompatible option, manufacturers should look at LSR, HCR or soft PVC, Ritzema said.

For a material with chemical resistant properties, LSRs and RTVs are suitable. They both also have excellent mold flow properties with a low compression set.

Medical continues to emerge as a leading application for LSR. The growing demand for LSR-based products in the healthcare industry will positively impact the global LSR market. The market is expected to gain from the rising demand for disposable medical devices and implants.

Medical is an obvious — and large — market for LSRs. There are a number of opportunities for LSR in the medical market and 2017 should be another busy year for contract manufacturers, according to Mark Bonifacio, president, Bonifacio Consulting Services.

“There is more processing on both sides of the compression molding and injection molding environments that have opened up a slew of applications,” he said.

Bonifacio said LSR has a number of positive properties and a proven track record inside the body.

“It is gaining in the medical device sector and we could see a growth rate of more than 10 percent in this area,” he said. “It is outpacing the thermoplastic growth rate.”

**Technology advances**

Since the advent of LSR, molding technology has moved forward at a rapid pace, expanding the capabilities of the process in many industries. The integration of soft materials has changed the game for manufacturers and end users alike.

Many soft materials can bond to both other soft materials and hard materials. Their bonding abilities give designers an expanded freedom to create a different form of molded product.

Some of the most common uses of LSR are for handling and the operation of products, such as grips for everything from surgical instruments to hand-held electronic devices.

Utilizing this material can save manufacturers both time and money, but device makers must determine when LSR is preferable to other soft materials.

Miramar, Fla.-based Simtec Silicone Parts LLC is starting a production process that integrates parts made of three materials – a metal, liquid silicone rubber and a thermoplastic – into one component within one manufacturing cell.

A breakthrough in LSR tooling technology enables the combination of multiple materials in a single production cell and the company is about to use it for a new application, Simtec President Enrique Camacho said.

“A revolutionary approach for the integration of functions and materials is starting production at Simtec. It is the first of its kind in the world for this particular application,” Camacho said.

While he couldn’t identify the product or customer due to a confidentiality agreement, he could talk about the technology that is moving the company beyond overmolding LSR onto a thermoplastic substrate to also incorporating a metal part.

“We are redefining the LSR two-shot manufacturing process to LSR multi shot,” Camacho said. “The key for us is how we combine all the elements together in such a way that it’s an efficient operation with innovative solutions that push the boundaries of technology.”
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— Enrique Camacho, President, Simtec

Camacho noted that previously, components of a similar nature would have to go through an assembly process using extensive manual labor, necessitating multiple tools, assembly lines and large capital investments - all of which have been mitigated.

Processors are advancing secondary processes in molding LSR. As a result, the material is becoming more marketable and customers are seeking parts that are more complex, personalized and customized.

In 2017, LSR molders are being required by customers to provide more value-added services, including multiple colors, adhesives, and small holes and slits.

A key trend, fueled by overseas competition, is a belief that molders can do almost anything and do it at a low cost. As a result, molders are increasingly finding themselves in a position of coming up with creative ways to produce parts as economically as possible.

Some things that can be done during secondary processes include punching, slitting, painting, screen printing, pad printing and applying adhesives. This will allow companies to offer custom parts featuring a printed logo.

**Automation**

Like most plastics processes, molders who are doing LSR molding are seeking efficiencies in their operations and are increasingly turning to automation.

One example is New Albany, Ind.-based PTG Silicones Inc.

The firm, approaching its 10-year anniversary, remains small in size with just 12 employees. But that's because of a core philosophy to focus on highly automated processes to produce LSR parts.

“It drives consistency,” said PTG President Brendan Cahill. “When you look at a cycle time with automation and having a molding cell that’s varying by plus or minus a hundredth of a second, when you have that kind of capability your stability is very good.”

Cahill said the end result is very little variability in part quality.

“The challenge with a manual process is no matter how diligent people are, you’re always going to have that variability in the cycle time. With automation and having that kind of a manufacturing style, you don’t have that,” he explained.

The firm operates one facility spanning 5,100 square feet in New Albany. This includes about 3,000 square feet of manufacturing space with five LSR molding machines and 12 employees, a 1,000-square-foot Class 100,000 clean room, and 1,100 square feet of office space.
When Cahill formed the company in 2007, he focused on products like LSR as he saw an opportunity to stand out in the market.

“There are so many good thermoplastic molders out there that I didn’t feel we could differentiate ourselves in that market,” Cahill said. “When I looked at what we wanted to do, I wanted to be able to run high automation. I thought there would be a better opportunity to do that in liquid silicone rather than doing it in traditional thermoplastic molding.”

PTG operates primarily in the food packaging market, but also does work in the automotive, medical, dental, large appliance, consumer and personal care industries. The company does not release annual sales, though Cahill noted PTG’s focus is solely on LSR.

A lot has changed in the 10 years since PTG’s founding. The executive said the firm has evolved its ability to automate and really refined its lights-out manufacturing. It’s also entered into secondary operations, such as slitting, in-process machining inspection and post-curing.

But what really sets PTG apart in the industry is its highly automated process. Cahill said it’s been a learning process, one that’s been refined over the years.

Cahill said that PTG has turned down business that would have required the company to run a program manually. “That’s not for us. We’re not resourced for that,” he explained.

“There’s a way we have to design the molds and look at how the parts are designed as well,” Cahill said.

“And the part has to be conducive to running like that. If a customer comes to us and we don’t feel we can run it with automation the way that we want to, then we will decline it.”

Going into 2017, Cahill said PTG will continue to refine its manufacturing process with a goal to become more involved in upfront design and development than it is currently, and begin to develop some of its own valves for food packaging with an aim to increase efficiency for its customers.

Megatends and LSR

LSR is taking a leading role in major megatrends facing the world, such as climate change, growing demand for energy, water management, health care and transportation, according to Hans Peter Wolf, Dow Corning’s manager of global research and development for silicone rubber.

Wolf points out that agriculture also is becoming a key end market for LSR. He estimated that 50 percent of the population will not have access to fresh water by 2050.

“LSR is the material of choice to prevent losses and provide higher harvests,” Wolf said. “LSR and other rubbers still are used in dripper irrigation systems, which contain an elastomeric membrane.”

These trends are interconnected. He said growing population leads to more energy and water consumption, which in turn leads to more people demanding vehicles, increased vehicle production and greater need for energy efficient products.

“Most if not all megatrends are linked to each other,” Wolf said. “This again causes a demand for LSR. In general the demand is increasing for all markets because of this megatrend driven needs for solutions. The major leading market I would say is medical, where LSR has a really unique position of process, performance and regulatory compliance versus ordinary elastomers.”

With new types of fuels being developed for vehicles, he said these new chemicals also demand new types of materials that have different resistance properties. He identified fluorosilicones as an ideal class of material to help with emission reduction because of their resistance to aggressive fluids in harsh environments.

Electrification also is an opportunity for silicone. Electrical vehicle systems are projected to grow 16 percent annually, Wolf said. Hybrids are projected to occupy 33 percent of car production by 2025.
Wolf pointed out that the total length of cables in cars had increased 20-fold, and there were about 47 times more connectors in vehicles through 2011, estimating that both likely only increased further over the last five years.

“Not all of these need silicone rubber, but the demand is increasing here because of the demand in temperature and making high quality parts,” Wolf said. “If we go to electrical vehicles, we need to change the infrastructure to be capable of being run on direct current instead of alternative current. There is definitely also opportunity in the more mature countries like the U.S. and Europe.”

LED technology is another opportunity for silicone. The technology uses less energy and provides higher life output. Wolf said LSR helps enable this kind of innovation because its properties provide flexible design possibilities and are easy to process compared to other optically clear thermoplastics.

Wolf said LSR is a key component in insulation applications for high voltage because it lasts longer, performs better than other counterpart materials, reduces power outage, and reduces maintenance and service costs.

“This development is only a few years old,” he said. “We see new projects starting in automotive and industrial lighting. Some of them already have been taken up by special design companies for consumers, but this is still more fashion than for real mass usage.”

**Growth drivers**

The LSR market will gain from the high growth in the electrical and electronics segments in addition to the rising demand in medical applications.

Medical has high growth potential for silicone. Wolf said a number of new medical devices are emerging because of LSR’s biocompatibility. It is light on the skin, easily removable and lends itself to regulatory standards because of its high purity.

Growth rates for silicones in the U.S. medical industry have bounced around in the last 15 years, but Freedonia’s Furst said demand remained strong over that time period. Contrary to every other major market, silicones serving the medical industry scarcely were affected by the recession because medical product shipments remained consistent throughout the downturn. Re-approval of silicone breast implants in 2005 also helped boost demand.

Furst said growth is projected to outpace medical products overall and continue to take share from rubber and plastic materials. These factors should lead to medical being the fastest growing silicone market in the next five years.

“Silicones have numerous benefits in medical applications, including biocompatibility, optical clarity, soft touch, moldability and ease of sterilization,” he said.

Moreover, growth witnessed in the demand for medical grade LSRs will also boost the global LSR market.

Tissone listed a number of key global megatrends that are driving the strong demand for new medical devices worldwide, and thus driving demand for LSR. More Asia-Pacific countries are starting to adopt more advanced Western medical technology.

Ross said China and India have ideal demographics for growth.

“These are markets that formerly didn’t have this kind of technology 10 years ago,” Ross said. “Today you put a big hospital in, you teach and the demand is altered just by offering the services and full Western medicine technology centers. There are enormous population centers that now have access to these treatments that use these high-end medical devices.”

According to Lynn Momrow-Zielinski, co-founder of Watervliet, N.Y.-based Extreme Molding, the growing affordability of the material is having an impact on the LSR molding segment in 2017.

“We are seeing parts that are becoming larger as silicone becomes a more affordable

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**LSR properties:**

LSR molding offers a number of valuable properties, including:

- Anti-Microbial
- Extreme Temperature Range
- Flexible
- Durable
- Superior Chemical Resistance
- Transparent
- Ease of Sterilization
- Superior Dielectric Insulation
material,” she explained. “We are now down in the $4 range for silicone, which you never used to see.”

Momrow-Zielinski noted that when the company got into LSR molding in 1992, its focus was on parts that could be held in the palm of your hand. Their first press dedicated to LSR molding was 48 tons. Today, the process includes two-shot and overmolding.

“Today, we wouldn’t think of buying anything less than 110 tons and we are actually thinking of buying a machine in the 300-ton range,” she said.

Robert Pelletier, an expert on dispensing of liquid silicone rubber, said current trends in the medical industry include using LSR in the production of medical equipment parts that require high precision such as seals, sealing membranes, electric connectors, multi-pin connectors, infant products where smooth surfaces are desired, such as bottle nipples and multiple medical applications.

“It is prevalent in the production of materials that are implanted in the body, such as covers for leads on a pacemaker,” he explained.

Pelletier noted that LSR often is over-molded onto other parts made of different plastics. For example, a silicone button face might be over-molded onto a Nylon 6,6 housing injection molding process.

LSRs can provide a seal into medical device products or cases. LSRs also can be sterilized, so products that previously were disposable do not need to be anymore, saving the end user money.

Because of its sterilization capabilities, there are huge growth opportunities for LSRs in medical products, such as grips, handles and soft-touch buttons.
The medical end market, including healthcare, uses LSR in the applications like textile coatings, instruments, anesthetic masks, membranes, medical cables and tubing.

Strong R&D investment trends across the healthcare space in 2017 can continue to translate into potential growth for the LSR market. O-rings and gaskets are another avenue offering strong growth potential for manufacturers.

Medical grade LSR is biocompatible, hypoallergenic and hygienic, which gives it an especially critical advantage over other molding materials in the manufacture of disposable medical devices and self-diagnostic devices.

As the requirement for devices designed for home use continues to grow, the demand for LSR will also continue to grow.

The wearable device industry is one emerging market that LSR is advancing, ranging from patches to monitor vitals and possibly evolving to other types of patches used for drug delivery.

Rogan’s Ritzema noted that there are potential opportunities in the automotive and technology markets.

While automotive is typically an HCR market, he said, there are some applications that warrant LSR. The company has not yet embarked into automotive, but he knows there are suitable applications.

Additionally, while Rogen has not yet produced molds for the technology market, Ritzema has seen LSR used in cell phone and speaker covers because of its good UV protection and abrasion resistance.

LSR is extensively used as an adhesive in the electrical & electronics industry. The rise in the demand of electronic gadgets and devices especially cellular phones and other portable electrical products is anticipated to boost global silicone elastomers market consumption.

Proto Labs recently debuted liquid silicone rubber for LED optics designs. LED technology is providing another opportunity for LSR in 2017. Photo courtesy of Proto Labs

**LSR Advantage:**

**Biocompatibility is key**

After extensive testing, LSR has demonstrated superior compatibility with human tissue and body fluids. In comparison to other elastomers, liquid silicone rubber is resistant to bacteria growth and will not stain or corrode other materials. LSR is also tasteless and odorless and can be formulated to comply with stringent FDA requirements. The material can be sterilized via a variety of methods, including steam autoclaving, ethylene oxide (ETO), gamma, e-beam and numerous other techniques.
Challenges for LSR

Despite ongoing reshoring trends, Momrow-Zielinski said overseas competition remains a challenge for LSR molders in 2017.

“I still think the biggest hurdle to compete with China and Taiwan is getting our mold costs down,” she explained. “Most domestic molders want to source our molds domestically. We have tried to source our mold work to China and having them shipped over. We have never been successful with that. We can do that on the plastic side.”

Momrow-Zielinski noted that when it comes to LSR molds, the complexity and other issues make it virtually impossible to source from overseas, particularly Asia.

“There are translation issues and you never get quite what you ordered,” she said. “As a result, making lower-cost good quality molds is a hurdle to overcome for this segment.”

Finding skilled workers also is a major challenge for U.S. manufacturing. LSR is so different that Victor Morando, chief technology officer at Ellington, Vt.-based Dymotek Corp., Plastics News’ 2016 Processor of the Year, said people and training are even more important for the company.

The goal, Morando said, “is to have all the people in your company at that skill level. It’s easy to have one or two technical people, or engineers that are knowledgeable, but when you’re running around the clock, every single shift you have technical coverage to keep these molds running. So it’s tough to get everybody up to speed. But it’s been a big commitment of ours, and we’ve done it. We took the time to train everybody so they are very knowledgeable about the process and the equipment.”

CEO Norm Forest said Dymotek does in-house training and employee development, coupled with outside education. How else can you build a strong workforce?

“Let’s face it, they’re not gonna show up at the door,” he said. “Or if we steal them, we’re going to have to pay top dollar. And sometimes, the baggage that comes along with that isn’t worth the effort.”

Plante Moran’s Mengel agreed that skilled labor is a growing challenge for the plastics industry in general, and LSR molders in particular.

Reshoring trends: Hurdles to overseas production

Reshoring has the potential to have an impact on plastics processors in 2017 and beyond. When it comes to processing LSR or any plastic product abroad, processors face a lot of long-distance obstacles. Some of these include:

• Communication issues. When manufacturers work with people in other countries, they have to deal with time differences, language barriers and cultural norms — all which make it harder to effectively communicate. Reshoring eliminates this hurdle, with business conducted in one country.

• Different laws. Most LSR processors today are familiar with American business laws, but outsourcing production into another country means complying with a whole different set of rules and regulations. It also makes it harder to protect valuable intellectual property, since those laws are difficult to navigate abroad. Bringing production back to the U.S. leaves everyone on the same page.

• Unnecessary costs. A lot of issues can arise when shipping products globally — so it becomes a lot less complicated when the product has to travel shorter distances. Shipment delays aren’t as frequent, goods have less opportunities to be damaged and production managers avoid costly trips overseas.

Medical devices made from LSR by Rogan. Photo courtesy of Rogan
“As a niche segment, this requires a very specific set of skills,” he said. “You just don’t go out and find people with these skills. You have to train them in-house. That requires an investment of time and money, but it is an investment that will pay off in the long run.”

When it comes to the learning curve required for processing LSR, Engel’s Broadbent contends that a company should either hire people that are experienced in LSR or hire someone with no experience at all.

“I would recommend against trying to convert plastics people into silicone,” he said. “Molders are likely to be better off if they hire a new engineer with no experience.”

The UV curing method is a new process and many molders are still trying to determine how it fits into production.

It can be used with some commodity grades that are going to be over-molded. It can be over-molded onto polypropylenes and some of the olefin-based materials as it doesn’t use heat as a catalyst, instead relying on UV to cure.

There currently are no bondable grades, so a mechanical bond is required.

In terms of the learning curve required for processing LSR, Engel’s Broadbent maintains that a company should hire people that are experienced in LSR or hire someone with no experience at all.

“Do not try to convert plastics people into silicone,” he said. “As a molder, you are almost better off hiring a new engineer with no experience.”
**Liquid silicone rubbers (LSRs) are molecules formed from a basic silicone oxide backbone. They do not contain any plasticizers, stabilizers, or promoters and exhibit exceptional flex characteristics that are due to their unique chemistry.**

Since LSR is comprised of silicon, the second most common element in the earth’s crust, it is not only versatile in its uses, but it is also derived from a highly sustainable resource and doesn’t have the pricing volatility of commodity resins.

There are many special grades and forms of silicone rubber, including: steam resistant, metal detectable, low smoke emitting, high tear strength, extreme high/low temperature, electrically conductive, chemical/oil/acid/gas resistant, and flame-retardant.

As a crosslinked material, LSR will withstand extreme temperatures with no heat aging and will maintain its mechanical properties and resilience over time. The material is cured through a process that contains non-hazardous substances; therefore, even in an under cured part, there is no threat of hazardous chemicals being released.

Due to the thermosetting nature of the material, LSR injection molding requires special treatment, such as intensive distributive mixing, while maintaining the material at a low temperature before it is pushed into the heated cavity and vulcanized.

Liquid silicone rubbers are supplied in a variety of containers, from tubes to 55 gallon drums. Because of its viscous nature, LSR is pumped at high pressures, from 500 psi to 5,000 psi, based on the durometer of the material.

The LSR itself is typically shipped in separate containers with two compounds, generally dubbed “A” and “B.” The two compounds must be mixed in a 1 to 1 ratio, usually by way of a static mixer.

Once the two components come together the curing process begins immediately. A chiller supplying cold water to jacketed fittings is typically used to retard the curing process prior to the materials introduction to the mold.

When examining growth trends, the easiest measurement is to examine trends in pounds being produced.

Eric Bishop, North America Marketing Manager for Shin-Etsu Silicones of America, noted that production is trending upward in 2017.

“Generally speaking, if you look at announcements from the major manufacturers, everyone is expanding their capacity,” he explained. “On a global basis, we continue to see the growth of LSR in volume.”

Six key players combine for a 90 percent market share — Dow Corning Corp., Momentive Inc., Wacker A.G., Shin-Etsu Chemical Co. Ltd., Bluestar Silicones and Evonik A.G.

Pricing has remained flat in recent years, which has been good news for LSR processors.

Lynn Momrow-Zielinski, co-founder of Watervliet, N.Y.-based Extreme Molding, noted that LSR doesn’t have the same volatility as typical thermoset plastic resins.

“Pricing is more stable,” she said. “Typically, the availability has been very good. The lead times are not too long.”

The key suppliers are in competition, but the price isn’t dependent on the oil industry.

“You can sign longer term contracts to lock in prices,” Momrow-Zielinski added. “There aren’t a lot of challenges on the pricing side.”

Bishop added that the fact LSR is not based on petroleum is a key factor in many respects and contributes to its unique properties.

“We don’t have the fluctuations you see with the materials that are petroleum-based,”
Properties of LSR

LSR’s specific properties are a result of its unique chemical structure. Its backbone is formed by a series of siloxane bonds which, compared to carbon bonds, are stronger and more stable.

This provides liquid silicone rubber products with:

**Superior temperature range performance.** Liquid silicone products won’t elongate at high temperatures. They also remain flexible at temperatures as low as -40°C. High thermal stability makes LSR parts suitable for heavy-duty applications.

**Chemical stability.** Liquid silicone rubber parts are chemically inert, hypoallergenic and resistant to bacteria growth. They also feature high biocompatibility, which makes them suitable for healthcare applications. However, they can degrade when exposed to certain organic compounds, or to highly acidic or basic environments.

**Electrical resistance.** On its own, LSR offers high resistance to corona discharge, making it a good choice for use as an insulator in high-voltage applications. However, it is also possible to add conductive materials without compromising the other properties of an LSR component, so that it can be used to make keyboard contact points and other electrical parts.

he said. “When you talk about availability, the manufacturers have invested in capacity increases so we haven’t really seen any shortages.”

**Low variation**

According to Steve Broadbent, LSR/ELAST Project Engineer at Engel Machinery North America, LSR provides very low variation.

LSR also offers a better material mix for micromolding in color dispersion and other areas, according to Broadbent. The material is expandable and requires higher mold temperatures than typical plastics. Plastic mold temperatures typically range from 70 degrees to 150 degrees, while typical LSR ranges are 320-450 degree range.

There are many different LSR grades available. Some examples include: electrically conductive, medical grade, FDA compliant, self-adhesive, self-lubricating, and various combinations of these.

Silicone rubber is available in a range of hardness levels, expressed as Shore A or IRHD between 10 and 100, the higher number being the harder compound. It is also available in virtually any color and can be color matched. Suppliers offer a wide range of grades of silicone. While new materials are always in development, standard product offerings haven’t changed all that much.

Electrically conductive grades are usually carbon filled to the desired conductivity. Medical grade materials are prepared under rigorous testing and regulations to assure superior quality and adherence to safety standards. There are many different kinds of self-adhesive LSRs.

In general, LSRs have outstanding compatibility with thermoplastics, but many formulations are available so as to fit many different applications. The most general formulations provide direct strong bonds onto most thermoplastic surfaces and metals including aluminum, magnesium and steel.

Silicone rubbers also are highly resilient materials. Cured during processing to create a strong intermolecular cross-linked structure, this structure will provide extreme elongation of the material with no permanent deformation and a higher tear resistance.

LSR also is resilient in elongation and compression. When the material is compressed it will create an equal opposing force that will not change over time, making it great for seals and gaskets. LSR materials are cross-linked, which will prevent any creep or stress relaxation problems.

“All of this control equipment can now be realized because of these measurement and electronic systems,” said Hans Peter Wolf, Dow Corning’s manager of global research and development for silicone rubber. “You need a material that provides a good coating, good processability and can come in contact with the skin. Liquid silicone rubbers are absolutely fully approved for skin contact in this kind of way, and we have options to embed electronic equipment into the material in some way.”

Companies serving the medical end market are offering multi-shot liquid silicone rubber capabilities that can enhance design and assembly feasibility and reduce part count.

Multi-shot LSR can be applied to combine either two different types of LSR or LSR and a thermoplastic in one molded part.
Shin-Etsu’s Bishop noted that manufacturers today are developing LSR materials that are known as low volatile.

“In any silicone rubber part that has been molded, there is some level of volatile residuals that are in the silicone,” he said. “The easiest way to get rid of those is to post-cure the parts.”

In general, an LSR post-cure can be 4 hours at 400 degrees. Bishop noted that the low volatile parts would contain less volatiles from the plant and may eliminate the need for post-curing processes.

“We continue to see self-bonding silicones,” he added. “They typically will mold to thermoplastics to make a multi-component part. Shin-Etsu has a family of products that bond very well to polycarbonate.”

As consumers express concerns about BPA, some customers are moving away from polycarbonates to Tritan from Eastman or some nylons. As manufacturers, we have to develop materials that will stick chemically to those materials just as they did to polycarbonate.

UV curing

Extreme Molding’s Lynn Momrow-Zielinski noted that UV curing remains a trend as companies like Momentive create products that offer the properties that molders are looking for.

This cure technology is a photochemical process where UV radiation is used only to initiate the catalytic curing reaction, thereby reducing energy consumption.

According to Momentive, its Silopren UV LSRs and Addisil UV EX extrudable solid silicone rubbers are two-part formulations that contain a UV-activated platinum catalyst. The company noted that the materials can be cured using a common UV lams that emits light in the wavelength range of 315 to 430 nm.

However, UV curing of LSR requires transparent molds or cavity inserts. For extrusion, the UV light is provided externally using a modified lamp fixture, while molding requires transparent molds or cavity inserts.

There are many advantages of the UV-cure process. One such advantage is that there is no need for a water-cooled injection barrel or cold deck on the mold; this can reduce tooling costs. Since mold filling is accomplished at room temperature, there is virtually no risk of scorching. Low-temperature curing also means no pressure buildup in the mold and lower post-mold shrinkage.

Momentive’s Silopren liquid silicone rubber family is a new self-bonding material that addresses the rising demands for hard-soft designs. According to the company, it helps to achieve the bonding between silicone and thermoplastics, reduces assembly steps and meets various complex design requirements.

Momentive’s self-bonding LSR technology offers a primerless solution that enables the combination of two materials via a two-shot over-molding process for a hard-soft design as well as cost-efficient manufacturing of high part-quantities in one integrated molding process.

“Momentive continues to lead the market in developing silicone elastomer solutions that enable design complexity and manufacturing efficiency,” said Holger Albrecht, Vice President, Elastomers. “Our newest offering advances adhesion technology for molded parts that have been previously unavailable in the market.”

The company also has developed LSR RSH, a line of LSR that features reduced self-healing of valve slits in molded parts.

Silopren LSR RSH offers benefits for valve and fluid-flow products in the food, medical, and infant-care industries. The FDA-approved, RSH version of the Silopren LSR 2040 series comes in Shore A hardness of 42-26.

UV Curing: Advantages

UV technology is a fast, versatile and extremely cost-effective means of curing silicone elastomers.

The low-temperature, UV curing process can allow:

- The combining of silicone rubbers with temperature-sensitive plastics
- The incorporating of thermally-sensitive ingredients into silicone rubber
- The encapsulations of electronic parts
- The UV curing elastomers decreases the need for costly heat-resistant materials and offers a variety of advantages for both LSRs and high consistency rubbers.
Silicone trade favors U.S.

According to Kent Furst — an industry analyst with the Freedonia Group — the U.S. exports silicones to a wide range of countries. He said the largest trade partners have been Belgium, Mexico, China and the Netherlands; however 18 other countries bought at least $12 million of U.S.-made silicones.

While both imports and exports rose steadily from 2001-15, export levels increased substantially more, and net exports more than tripled over the last 15 years because demand has been stronger in foreign markets than it’s been in the U.S.

A rebound in the domestic market combined with overseas capacity has served to limit silicone exports from the U.S. while boosting imports, Furst said.

Through 2020, imports and exports of silicones are projected to rise, boosted by the quality and technology advantages of U.S.-based silicone producers.

Furst said that while China imports have increased 20 fold over the past 10 years, the country still only accounts for about 5 percent of total imports, while Germany and Japan — high income countries with higher quality standards — combine to account for 60 percent of imports. He added that Canada and other Western European countries also hold a significant share of the import market.

“This is evidence that product quality is more important to silicone customers than price, and China is not quite ready to compete on that front right now,” he said.

Opportunities

Momrow-Zielinski said there seems to be limited amount of innovation in new materials, but the work that is occurring represents potential advances in high-opportunity areas.

“You don’t hear too many concerns about silicone,” she said. “I think people are going to design products more often using silicone.”

One area of opportunity for LSR is optically clear applications for LED lighting. Several companies, including Shin-Etsu Silicones, have introduced materials to get ahead of the curve in this opportunity. With a transparency of 95 percent, optical materials are uniquely engineered and ideal for expanding LED applications in street lighting, automotive and exterior illumination.

Bishop said LSR offers improved high temperature resistance compared to thermoplastic resins. This allows molded silicone optics to be positioned in close proximity to the LED light source without yellowing or cracking over time.

“Next-generation LED systems are getting hotter as light output continues to increase,” he said. “The advanced engineering properties of our material delivers unparalleled heat resistance and clarity at these higher operating temperatures.”

Looking forward, Bishop said he sees a steady but positive future for LSR. “There are a number of end markets that will continue to be strong,” he said. “We’ve seen a pretty decent economy and that has been beneficial for our customers.”
hen it comes to processing liquid silicone rubber, choosing the correct injection technology is an integral first-step toward a successful process, particularly when molding with directly gated components (no sprue).

In 2017, injection molding of liquid silicone rubber remains on a growth trajectory. However, processors working with the thermoset find that it has unique characteristics that make the molding of the material tricky and that requires a mindset change for those accustomed to molding thermoplastics.

Selecting a LSR injection molding machine is not all that different from selecting a machine for thermostatic injection molding. However, there are some key differences as a result of the heat-curing thermoset nature of LSR, its very low viscosity and its tendency to expand during cure.

As a result, machinery manufacturers continue to boost their efforts to ensure that molders can work with this niche material and enhance the benefits it brings to products.

Mass production of LSR parts uses specialized injection molding machines that meter, mix and inject LSR into a heated mold.

The quality of injection molding solutions for LSR processing is improving all the time. Molders are seeing fully electric machines and automated production cells. They are looking for increased precision, energy consumption and emissions, as well as increasing unit volumes and the associated multi-cavity molds.

The process

According to Steve Broadbent, Engel Machinery Inc.’s project engineer for LSR and elastomers processing machinery, selecting the right injection technology for LSR molding is key to a successful part.

LSR is a thermoset that cures when it is heated. The injection unit has a water-cooled barrel to maintain consistent temperature of the material during metering and injection and to retard reaction of the material before molding. The screw is a zero-compression feed screw equipped with a plate-style, spring-loaded check assembly.

The check assembly is designed for positive shutoff of low-viscosity LSR materials and the spring ensures the plates are in the closed position when static. This means the forward movement of the screw is not required to seat the check assembly, as is necessary with the standard check ring used in thermoplastic molding.

Today’s evolutionary trend has been nearly two decades in the making, dating to the 1990s, when LSR molding machines were no different than standard plastic injection molding machines.

There are many factors involved in selecting the correct injection unit, such as injection pressure limits, shot capacity and performance requirements.

The two most popular systems involve open nozzle systems and valve gates.

There is an increasing demand for fully electric machines, particularly for medical molding of LSR. However, technology is helping machinery manufacturers produce hybrid systems that work well in the molding of LSR, which has led to the molding of larger parts.

Eric Bishop, North America Marketing Manager for Shin-Etsu Silicones of America, said the industry is seeing more all-electric servo-driven machinery, particularly for the injection units.

“Because the material can flash very easily, it is very important to have precise control of your shot size,” he said. “If your shot size is too large, it has to go somewhere.”

Bishop said he has seen customers who are using servo-driven injection units.
“Some companies have gone to servo-driven plunger systems as opposed to reciprocating screw systems,” he added.

**Markets drive growth**

Broadbent added that a number of markets are leading the LSR charge.

“The biggest growth, based on market, is medical,” he said. “It still is not the same volume as in automotive, but it is where the growth is. Automotive is high volume, but it is a mature market.”

Engel also is seeing growth in consumer goods.

But when it comes to machinery, medical has some key parameters for processors to consider.

“For most of the medical parts, an injection molding machine has to run extremely short cycles at the highest level of repeatability to allow mass production of medical technology products with long and thin cores. Engel develops injection molding machines that meet these ever-increasing requirements,” Broadbent noted.

According to Lynn Momrow-Zielinski, co-founder of Watervliet, N.Y.-based Extreme Molding, said the LSR segment is starting to trend toward larger machines.

A decade ago, the typical machine would have been in the 50-ton to 120-ton range. Broadbent noted that today that has increased with the ability to mold larger parts.

“In the past, a 200-ton machine was rare for LSR,” he said. “Today, I would say that 19 percent of everything we do is in that 200-ton to 250-ton range.”

And molders who want a machine set up specifically for LSR may pay a little more for the added options included on the machine.

“I would say there is probably a 15 percent to 20 percent increase for LSR because of the additional options,” Broadbent said. “When you are purchasing an LSR machine, you are essentially taking a thermoplastic machine and adding several options to it. As a result, there is going to be a cost premium because there are options added to a standard injection molding machine.”

Technology also is more advanced on today’s LSR machines, according to Momrow-Zielinski.

“The newer machines also have smart phone interfaces so that we can know what is going on with our machines and we can have direct access to tech service,” she said. “They also have interactive screens that are very user friendly.”

And there are some options and key differences between standard injection molding machines and those molding LSR.

“The plasticizing assembly – the screw and the barrel are the biggest differences that everyone recognizes,” Broadbent said. “There is a zero-compression screw and water-cooled barrel and non-return valve. Those are the biggest things from the machine mechanically to ensure that you are getting an accurate shot compared to thermoplastic. It is because of the viscosity of the material.”

LSR molding machines also feature a special check-ring design and a spring-loaded check that is required at the beginning of the screw instead of the standard plastic check-ring.

According to Broadbent, other factors important for consistent LSR processing are sufficient mold heating zones and temperature control, a cooling-water manifold and flow control, vacuum pump and vacuum monitoring software, interface for an integrated demolding device, and programmable sequence control.

LSR molders who use a standard plastic check discover that there is not enough surface area on the screw face to cause it to close. Because of its viscosity, LSR tends to want to run over the system and the molds.
For larger parts that weigh more than 200 grams, a valve gate system offers the advantage of a clean gate area. With high cavitation molds (16 cavities or more) the valve gates tend to have greater imbalance during the injection process due to the friction of the many moving parts.

In order for the liquid injection molding process to fully occur, several mechanical components must be in place. Typically, a molding machine requires a metered pumping device in conjunction with an injection unit—a dynamic or static mixer is attached. An integrated system can aid in precision and process efficiency. The critical components of a liquid injection molding machine include injectors, metering units, supply drums, mixers, nozzles and mold clamps.

An LSR molding cell is capped off by its dosing system, and there are a number of options, including systems that are fed by small reusable plastic cartridges to ones fed by 55-gallon drums. Pump operations range from electric servo-control to hydraulic and pneumatic operation.

**Choices**

According to Paul Caprio, CEO of KraussMaffei, the criteria for selecting a liquid silicone rubber injection molding machine are very similar to selecting a machine for standard thermoplastic injection molding.

“The biggest differences are tied to the heat-curing thermoset nature of LSR and its low viscosity," he said. “It also has a tendency to expand during cure.”

Caprio noted that KraussMaffei has been involved in the niche LSR market during the 25 years he’s been with the company and it is looking to expand its presence going forward.

The field currently is led by Arburg and Engel. Companies like KrausMaffei are looking to gain a bigger piece of the pie.

Selecting the right clamp is key. The two most common clamping systems to choose from are hydraulic ram and electric toggle. Sizing the clamp also is key.

Caprio also noted that while very similar to typical injection molding, LSR molding requires different injection units, including injection pressure limits, shot capacity, and performance requirements.
Caprio added that the biggest change between an LSR molding machine and standard thermoplastic injection molding machine focuses on the screw and barrel assembly.

“AT KM, we make our own screws,” he said. “LSR cures when it is heated and this requires a water-cooled barrel to maintain consistent temperature of the material during metering and injection and to retard reaction of the material prior to molding.”

The screw is a zero-compression feed screw equipped with a plate-style, spring-loaded check assembly.

The check assembly is designed for positive shutoff of low-viscosity LSR materials, and the spring ensures the plates are in the closed position when static. This means the forward movement of the screw is not required to seat the check assembly, as is necessary with the standard check ring used in thermoplastic molding.

The trend today in LSR injection molding machines is a reciprocating screw to help mix the two-component resin system.

Caprio added that LSR injection molding machines also require flexibility in shot capacity.

“For the most part, you are looking at smaller shots, with an LSR screw injection unit fitted with a zero-compression screw,” he said.

As a result, there are no feeding, melting, or compression zones.

To gain consistency when processing LSR, primary considerations must be given to mold heating zones and temperature control, a cooling-water manifold and flow control, vacuum pump and vacuum monitoring software, interface for an integrated demolding device and programmable sequence control.

Lastly, a final piece of the LSR molding cell puzzle is the dosing system and there are many options, including systems that are fed by small reusable plastic cartridges to ones fed by 55-gallon drums.

Most of the growth will be for high-end producers in the United States, Europe and Mexico and now the material is coming up more and more in China for high-tech production for each kind of application and industry. China also is moving faster and faster for medical parts for LSR.

Another trend, according to Momrow-Zielinski, is more options directly from the machinery suppliers.

“There are some machinery manufacturers, such as Engel, that actually have some LSR machines ready to ship,” she said. “It used to be that we would have lead times of up to a year to get an LSR machine. That isn’t the case anymore.”

**Retrofitting vs. new**

In the early days of molding LSR, retrofitting was more prevalent. Molders would change their Engel presses to accommodate the new process.

Broadbent said it isn’t all that challenging to retrofit a machine, though it is typically done by a company just entering the LSR fray. He noted the principals of the machine remain the same, whether you are molding LSR or a thermoplastic.

“There are some software differences for the dosing equipment and vacuum systems that are an absolute requirement for LSR,” he said. “We are seeing people ordering machines that can be changed back and forth. They want to have the thermoplastic option still on the machine.”

Retrofitting is often of interest in particular to those who are new to LSR technology. Each case has to be judged individually, subject to the age and configuration of the available injection molding machine and the mold technology required.

First and foremost, the plasticizing unit must be adapted and a dosing system as well as further peripherals added. A challenge that affects older machines in particular is up-
grading the software and integrating the required interfaces.

LSR molding machines also feature a special check-ring design and a spring-loaded check that is required at the beginning of the screw instead of the standard plastic check-ring.

For larger parts that weigh more than 200 grams, a valve gate system offers the advantage of a clean gate area. With high cavitation molds (16 cavities or more) the valve gates tend to have greater imbalance during the injection process due to the friction of the many moving parts.

Extreme’s Momrow-Zielinski said conversion of a thermoplastic injection molding machine to mold LSR does occur, but it isn’t a perfect situation.

“It isn’t as easy as it sounds,” she said. “You want a lot more precision for silicone. The trends are toward electric.”

Momrow-Zielinski noted that Extreme does have one machine that it can convert between general injection molding and LSR processing.

“I would say that most people buy the LSR machine exactly the way they want it,” she added. “You want to specify your needs up front.”

While retrofitting is an option, Broadbent noted that more and more companies are opting for dedicated machinery.

“When it comes down to it, this is a very precise process,” he said. “You have to maintain exact control in all aspects of the molding sequence, particularly in heat. This is critical.”

In recent years, several machinery manufacturers have come out and provided a turn-key LIM system. That includes a water-jacketed screw, barrel and throat as well as heating elements to heat the molds. They have LIM- and gum-specific screws and barrels.

Entering the fray

Ellington, Conn.-based Dymotek got involved with the use of LSR 11 years ago when a customer asked if the company could do it.

Chief Technology Officer Victor Morando said that he had previous experience with it through a prior employer, and knew that it took different skills than its thermoplastics operations.

Dymotek officials turned to machinery maker Arburg to learn as much as they could. This led them to the local Arburg Days as well as a trip to the main plant in Germany.

“We had one customer and one application when we first got involved,” he said.

“What we saw was that the level of silicone production had come so far,” he explained. “In the 1990s it was not scientific and its beginnings were crude. But when we saw the new technology we really approached it two ways. First, what can we do for the customer? Second, we looked at it as an opportunity to invest in silicone.”

Dymotek had a relationship with Arburg, which had provided the company’s plastics injection molding machinery. By working with them on LSR, Morando said they were able to gather new information. It also saw that Europe was ahead in the use of silicone.

“To make the jump to silicone everything has to be better,” he said, noting that requirements were quite different vs. thermoplastics.

Morando said that ordering an LSR machine is a highly detailed process and that everything is designed to better control what is happening on the machine. Factors such as mold time, air pressure and temperature are all crucial elements during the process.

The company works on components usually where air or fluid is involved. It does a variety of work for the medical, commercial/industrial and food and beverage industries.

When Molded Rubber & Plastic Corp. needed to expand its capacity with the addition
of another liquid silicone rubber machine at its Butler, Wis., plant, it ordered a 150-ton Engel rotary injection press to add to its integrated manufacturing cell in a Class 8 clean room.

MRPC has a long history of liquid silicone molding, originally using silicone rubber in tooling and bonding agents. It has evolved into a LSR specialist that also has expertise in thermoplastic injection molding.

The latest project for an undisclosed customer needs an injection press with impressive credentials.

“This project requires a process with extremely tight tolerances and exceptionally accurate shot control, explained MRPC Process Engineering Manager Brunson Parish.

“Their [Engel’s] machinery provides the level of precision required for our core business, allowing us to meet the quality standards required by our customers,” he explained. “That, along with the flexibility provided by their machine design, made them our supplier of choice.”

Brunson said Engel’s expertise in liquid silicone molding from tooling through to process set-up made it the choice for MRPC.

“Their knowledge in all things LSR helps us tremendously when developing new production systems.”

Engel’s range of machine models and sizes include features such as tie-bar-less platens and insertion equipment that save cost and floor space. Engel also retrofits injection units and plasticizing assemblies.

“MRPC is the perfect model of a production company,” Broadbent noted, because the company looks for cost competitiveness while focusing on the best technology for each project to support its rapid growth in the medical device market.

Getting in on the action

In an effort to expand its product base and diversity into new markets, Toyo Machinery & Metal has started to expand in recent years into LSR.

Toyo had offered dedicated thermoset molding presses over the years, but the key difference with its current line of machines, is that it is based on a standard thermoplastic injection machine.

The potential for growth in the LSR market has caught the attention of other Japanese machinery manufacturers as well. While European manufacturers like Arburg have been the dominant players, Fanuc, Nissei and Sodick in recent years have been demonstrating LSR molding machines.

A European manufacturer eyeing LSR as a growth opportunity is Fernthal, Germany-based Dr. Boy GmbH, a company that has focused on small-tonnage machines with a clamping force that maxes out at 100 tons.

The company has a U.S. subsidiary – Boy Machines Inc. – based in Exton, Pa.

According to Alfred Schiffer, the company’s managing partner, LSR is a part of the company’s growing stable of technology and a growing market.

“In the future, LSR will become more of a share of the cake,” he said. “Especially in the technical area. It will be strong and growing in the medical area.”

Stepping up

One company investing in its LSR capability is M.R. Mold & Engineering Corp., which recently took delivery of its seventh injection molding press at its Brea facility as the tooling maker ventures further into the world of LSR processing.

KraussMaffei installed a 55-ton two-platen hydraulic 50-180 CX-model LSR machine that
was manufactured in Munich.

M.R. Mold is permitting the use of its Brea site as KraussMaffei’s first training facility on the West Coast, Caprio noted, as the machinery manufacturer expands its LSR presence.

M.R. Mold also collaborated with Wittmann Battenfeld Inc. in an LSR demonstration during the recent UBM Advanced Manufacturing Expo in Anaheim, Calif. M.R. Mold is inviting attendees to visit its Brea facility, which is a short distance from the expo.

A Wittmann Battenfeld 16.53-ton standard MicroPower machine equipped for LSR will mold a punctal plug using Silopren LSR 2030 from Momentive Performance Materials Inc. in a four-cavity tool from M.R. Mold. The small medical device is inserted into the tear duct, or puncta of an eye, to block the duct.

Wittmann Battenfeld offers a patented system that lets the plunger travel all the way into the split line of the mold. That creates a thin disc rather than a cold runner sprue.

“This disc has much less volume of material and cools down much faster,” said Markus Klaus, Wittmann Battenfeld U.S. division manager for injection molding machines. “This saves the customer a lot of material and reduces cycle time dramatically. Some of those medical-grade bio-absorbable materials cost up to $2,500 per pound, and most cannot be recycled.”

Looking forward, Broadbent said the LSR market continues to be an area of opportunity for machinery manufacturers, and it is becoming less and less of a niche market limited to a select few custom silicone molders.

“Today, you are seeing more and more established thermoplastic molders taking the leap and getting into LSR molding,” Broadbent said. “More OEMs on the medical side are bringing LSR technology in-house. We will continue to see that.”

Over the last decade, Broadbent said Engel has seen consistent growth of 3 percent to 5 percent each year in LSR machinery sales, even during the recession.

“I don’t see that slowing down,” he noted. “The easiest way to track LSR is to follow the increased use of the material. That follows what I see in machine sales. It isn’t skyrocketing, but it has been consistent over the last decade.”

KraussMaffei’s Caprio said he sees LSR as an opportunity for his company going forward.

“We are seeing innovation in the developments of materials and there will be more uses for LSR and more demand for machinery,” he said. “It is a niche and it won’t be a key driver for a machine manufacturer. It is a nice specialty and if you have experience, that is what the customers want.”

The company said the new investment was part of its strategy to proactively expand its silicones business, which is one of its main business segments. The plant will produce functional silane and will be able to carry out various kinds of small-quantity production.

The facility is scheduled to be completed by March 2018 and is being built on the site of Shin-Etsu’s Naoetsu plant in Niigata Prefecture.
Working with LSR is a challenge, and building the molds to create myriad products made from the material today can be an equally daunting task.

Building molds for LSR processing requires a totally different approach than mold making for traditional thermoset injection molding.

LSR is a free-flowing, shear thinning thermoset material that injects easily into a mold and is less prone to many defects like sink as compared to typical thermoplastic materials. However, LSR flashes extremely easily and into gaps as small as 0.0002 inch.

Molds for LSR require precision throughout the mold building process. Detailed designs, proper material selection, state of the art machinery utilizing the latest machining techniques and highly skilled mold makers are keys to success for every mold produced.

Overall the design and manufacturing of molds for LSR is different, from tolerances, venting and part ejection to the installation of a vacuum system.

While the tooling design is different, optimizing processing variables such as temperature, pressure and time are essential in both thermoplastic molding and silicone molding.

In 2017, companies doing LSR injection molding typically outsource the mold making for the process. As a result, success can hinge on the communication between the molder, the mold builder and even the molding press manufacturer to meet customer requirements.

There are a lot of tool makers out there that may claim to have a robust valve-gated cold runner system. The companies who excel in this market have an R&D program to be able to come up with a system that is better than what is out there.

According to Jeff Mengel, Plante Moran’s national practice leader for plastics and the food processing/packaging industries, there are benefits to having in-house tooling, especially when you have unique structures, but it isn’t always best to do the work internally.

“In this case, you would think LSR would fit into this,” he said. “There are tooling companies that know how to work it better. The expertise seems to be with a handful of companies.”

According to Lynn Momrow-Zielinski, co-founder of Watervliet, N.Y.-based Extreme Molding, in-house mold-building remains a rarity today.

“Part of it is the complexity,” she said. “It also is a very different skillset. Buying the equipment to make molds is one part of it. You need the people who have the experience to be machinists and that is a different skillset.”

As a result, this is an area where many companies are looking to outsource the tooling.

“It is such a small part in most instances and the tooling ships very easy,” Mengel said. “You want to make sure the tool is right. The vendors will tell you when it is going to be done. Most LSR molding is done by smaller molders and they just don’t have the capability in house.”

For nearly three decades, Brea, Calif.-based M.R. Mold and Engineering Co. has been making waste-free LSR molds. These molds, coupled with various types of automation devices, such as the company’s cold runner system, provide the opportunity for lights-out molding.

According to Rick Finnie, president of M.R. Mold & Engineering, there are few similarities between LSR molds and plastic injection molds. He said that they are actually complete opposites.

“Plastic injection molds are water cooled, silicone molds are heated,” he noted. “There is also a significant difference in viscosity between LSR and plastic.”
Mengel also pointed out that OEMs that are used to buying tools for TPE parts or thermoplastic parts find that the tools for LSR tend to be more expensive due to the increased accuracy that is needed.

Many silicone molders don’t have in-house tool room capabilities because it’s such a specialized field. They also go to those tool and mold makers who have experience building a tool for LSR. There can be challenges for companies making molds for LSR injection molding.

“LSR molds have extremely tight tolerances and customers expect flashless tools,” Finnie said. “The mold is heated. The challenge of automation also is important.”

Steve Broadbent, an elastomer/LSR process engineer for Engel North America, agreed that mold building is more outsourced in the LSR segment.

“I only have a couple of customers who build their own molds for LSR,” he said. “It is a real challenge. In 10 years, it may be more the norm. I would say 98 percent of LSR molds are outsourced to a mold builder who specializes in LSR molding. In an LSR mold, the cavities are heated. They use a cold runner system, which is the direct opposite of a thermoplastic hot runner system.”

According to Brian Geisel, operations manager at M.R. Mold & Engineering, demolding can be a challenge for mold makers.

“Silicone parts can have undercuts that leave the part in the mold and sometimes need to be removed manually,” he explained. “At times, this presents challenges when saddled with the task to automate part removal for high volume parts.”

Flash also remains a challenge.

“Because of silicone’s low viscosity and its compressibility, processing without flash can be a challenge. The craftsmanship of the tool plays an important role in how a mold will perform,” Geisel said.

**Building the molds**

According to Finnie, when it comes to making molds for LSR it is completely different from molds for thermoset injection molding.

“With thermosets, you melt the material, inject it into a cold mold and it shrinks,” he explained. “LSR is a 2 part thermoset. The material is kept cold, it is injected into a heated mold and the material expands then shrinks. When silicone is injected it flows like water and it flashes at .0001. Because of this, the manufacturing of an LSR mold requires more precision than thermoset molds. Ejector pins and venting pins cannot be used and plates must be flat and parallel within tenths.”

The difference between thermoplastic injection molds and LSR molds are significant and start at the design stage.

One difference is ejector pins. Straight wall ejector pins cannot be used in LSR molds. While ejector pins are used in LSR molding, they must have a valve fit to assure no leakage or flash during the LSR molding process. LSR will flash in gaps that are less than .0001, meaning these fits must be very tight. This is in comparison to some plastic materials that allow gaps in mold lands of .0010” or greater without flashing.

Even the most experienced thermoplastic toolmaker or molder will find that certain strategies just don’t translate to LSR, which is processed very differently, according to Broadbent.

Momrow-Zielinski added that aluminum isn’t easy to use when it comes to making molds for LSR processing. The high temperatures for LSR molding tend to warp the aluminum.

Steel is the primary material used to build the molds.

“We see P20 and stainless steels dominating in LSR molds because of the temperatures,” she said.
LSR molds

There are key differences between typical injection molds and molds used to process LSR. From the design of the tool through part ejection, the differences include:

• Cold manifolds with water-cooled channels rather than the heaters employed by plastic injection mold hot runners.

• Closer fits. Plates must be parallel and flat, fits and clearances are critical, and only the highest levels of precision will do.

• Vacuum sealing. LSR undergoes a gas-creating chemical reaction when two components are mixed and as a result, require vacuum pumps to help clear cavities of all gases immediately prior to injection. It is important to properly utilize a vacuum pump that requires an air-tight seal around the entire parting line.

• Tighter gating. Typically, an LSR gate may measure just 0.0001 or 0.002 inch deep. With a smaller gate, smaller runners should be completely round to avoid breakage. Injection molding sprue bushings often are too large to ensure efficient cycle times in LSR molding.

• Tighter venting. If you are using a vacuum pump, you still will need dedicated vents. With a propensity to flash, vents usually are smaller and tougher to machine compared to plastic molds. Average measurements are 0.0001 or 0.002 inch deep.

• Fewer moving parts. Ejector pins aren’t the only common mold component missing from most LSR tools. These molds don’t usually incorporate slides, lifters or other moving actions.

• Challenging ejection scenarios. Although the material’s high elasticity can simplify mold designs, LSR presents its own challenges for part ejection.

Geisel said that determining the parting lines and gate locations remain an integral part of designing and building a mold for LSR.

“Determining where the part will stay once the mold is open and how to get the part out of the mold are key to a successful design process,” he noted. “In thermoplastics, the part shrinks and stays on the core. That is not the case with LSR. The mold design has to be approached with the intent to keep the part in the mold whether it be on the stationary or moving side as well as in a center plate.”

Another challenge, according to Geisel, is the fact that LSR adheres to shiny surfaces which can cause demolding issues.

“A textured or EDM finish is the best for LSR because it allows the material to release from its cavity or core more easily,” he said. “High-polish finishes are for some products, i.e. baby bottle nipples. In these cases, specific coatings are used to allow the silicone to release from the mold.”

Moreover, when selecting a soft material like LSR for molding, Jim Ritzema, Rogan Corp.’s director for new product development, said he advises manufacturers to work closely with molders and mold builders for optimal results because they have the knowledge of how each material performs.

Momrow-Zielinski noted that simulation can be used by toolmakers to identify molding problems that otherwise wouldn’t be found until production.

“When you stop production to fix problems and retool, it can be very expensive,” she said.

Simulation can be used for gate location and to help eliminate premature curing during filling. It also can detect high shear rates and pressure drops and identify air traps in the mold design.

Another part of the process can be cycle time, which is an important parameter for LSR molders.

The longer the cure time, the lower the profits are for a molder. Cure time is the longest part of the cycle time in molding LSR and it is influenced by material properties, part thickness and gate location.

Over the last several years, simulation technology has improved to allow toolmakers to pinpoint the cure time and cycle time by running a filling and curing analysis on the part.

If the estimated cycle time is longer than the target cycle time, then the toolmaker can make changes to the part and tool design and then analyze the effects of the changes, to lower the cycle time without affecting part quality.

Ultimately, simulation helps the toolmaker optimize the tool design and identify potential problems before cutting the steel and can help reduce or even eliminate some of these problems.

In recent years, the software products have also become simple to use, fast and affordable. When paired with material characterization, this should encourage toolmakers to take advantage of simulation in the design process.

Automation

The growing trend toward automation in the rubber industry has caused Roembke Manufacturing & Design to search for ways to be more efficient and cost-effective, especially because its customers in Asia are adding automation solutions, President Greg Roembke said.

Roembke Manufacturing, based in Ossian, Ind., serves the medical, health care, automotive, lifestyle, aerospace and consumer markets, and the majority of its business is in the medical and health care industries. Liquid silicone rubber molding within the medical segment is a big business Roembke Manufacturing has developed since it began branching out into medical in the late 1990s.
According to Roembke, his company has a capacity advantage over smaller ones, which must subcontract work out to other shops.

The company has taken on more turnkey projects in recent years, and those projects “are getting more complicated,” Roembke said. Hence, expanding the company’s automation capabilities help ensure consistency across product lines.

“The molds we build are typically purchased for higher-end products with tight tolerances,” he said.

To stay ahead of the curve, Roembke recently acquired the assets of Design Facts Inc., an automation company in Fort Wayne, Ind., for an undisclosed price.

The new equipment will help Roembke control the quality of the products it supplies to all of its customers, as well as manage the timing of production so that product delivery times meet customer requirements, Roembke said.

“Increasing our capability to design and integrate automation solutions will allow Roembke to service our customers with higher quality products,” Roembke said. “We can provide a complete molding cell with automation, as well as all necessary automation after molding.”

Momrow-Zielinski said a hurdle for mold makers seeking to compete with Asia remains mold costs.

“Making lower-cost good quality molds is a hurdle to overcome,” she said.

**Economic outlook for mold builders**

Finnie said silicone is growing at a rate of about 7 percent annually and TPEs are being replaced by silicone components because of the material properties of LSR.

“More molders are getting into molding silicone because of the demand,” he said. “Because of the unique differences between thermoplastic and thermoset, this is not an easy transition for most molders.”

The U.S. manufacturing sector is doing well overall, but it could be facing some challenges in the near future.

“Manufacturing has been doing well coming out of the recession, but it’s now flattened out,” said Laurie Harbour, president and CEO of the Harbour Results Inc. consulting firm in Southfield, Mich.

Harbour concluded that markets for toolmaking are expected to be strong for the next 2 to 3 years. But she also added that planning for the future “is critical.”

“Companies need to develop robust sales processes to grow their business,” she said. “And they need to go after operational efficiencies.”

Overall, business conditions for mold makers are moderately good at the present time, and my forecast calls for these conditions to continue through at least the end of 2017.

“This outlook is based on the assumption that the growth rate for the U.S. economy will stay close to 2 percent in 2017, which is just about the same rate of growth the economy has exhibited for the past six years,” said Plastics News Economics Editor Bill Wood.

Wood said the level of output will accelerate in the medical industry in 2017.

“Overall, this has been a very strong market for mold makers during the past 10 years, but the pace of growth in the output of these products does exhibit some cyclicality,” he concluded.

**Micromolding challenges**

Micromolding of LSR parts is a challenge for many injection molders, according to officials from Kipe Molds Inc. and Starlim North America Corp.

Both companies are making inroads in the molding of LSR.

Starlim, a major LSR molder, uses heavily modified Engel LSR injection presses for its molding, according to John Timmerman, vice president of marketing and sales at Starlim North America in London, Ontario.

For micromolding, the company uses an all-electric press with a clamping force of 10 tons. The machine was designed for micromolding of LSR including two-component molding of thermoplastics and LSR, or two LSR materials. The maximum pellet size is 2 to 4 millimeters, which qualify as micropellets.

Most of Starlim’s existing molds are made by EDM, but the company had to come up with a new way to cut the micromold. The mold base was the only thing that did not change.

Starlim uses CT scan technology to see the interior of the parts.

Dana King, director of business development for Kipe Molds in Placentia, Calif., said LSR micromolding magnifies issues like material compressibility, mixing and changes in viscosity and flow rate from shear. Pot life is an issue for very small parts, because you will have more material waiting to be molded than with regular-sized parts.

King said that Kipe Molds and a customer developed the MicroDeck, and Kipe Molds holds a license to manufacture it. The goal: create micro parts, weighing a thousandth of a gram, without having a substantial runner, and with no flash.
PolyJet technology for LSR molds

The molds used to produce LSR parts generally are very expensive for the low-volume production that many parts offer. As a result, manufacturers often resort to labor-intensive manual casting methods that can result in molds that stick or deform.

One alternative is 3-D printing with PolyJet technology.

Using this process, Stratasys offers reliable, low-volume molds that can be ready for use in as little as one day.

LSR is a widely used material due to its versatility and unique properties. It is non-reactive and stable, as well as resistant to extreme environments and temperatures. LSR is used in industries that span automotive, defense, sporting goods, medical devices and consumer products.

Mass production of LSR parts uses specialized injection molding machines that mix, meter and inject LSR into a heated mold. Due to the time and expense of this process, low-volume production and prototyping is often done with manual casting methods that use molds made of modeling board, RTV rubber or soft metal.

However, although they are easier, faster and cheaper to produce, prototype molds have their own challenges. Making LSR parts with RTV molds is a multi-stage process requiring time and labor to produce the patterns and molds. Care is also needed to ensure the soft rubber RTV mold does not deform or stick to LSR parts. Machined molds overcome these challenges, but they can be much more expensive, time-consuming and labor intensive than RTV molds. Additionally, machining may have limitations with respect to the complexity of a part's design.

Value of using PolyJet

PolyJet technology provides an alternative method for producing molds for LSR parts with dramatic time and cost savings. This 3-D printing process (additive manufacturing) builds objects layer by layer, using data from computer aided design (CAD) files. With an inkjet-like process, PolyJet technology delivers extremely high-resolution molds with smooth surfaces.

Using 3-D printed molds, LSR parts can be produced in just one or two days. After designing the mold in CAD, it is printed, often overnight, without operator attendance or added time for complex designs. PolyJet molds preserve fine details and deliver smooth surface finishes. With only a few minutes of labor for cleaning and assembly, the mold is ready to make LSR parts.

Liquid silicone rubber is usually made from low-viscosity, two-component materials. After mixing the two components, the LSR is injected into a pre-heated PolyJet mold. The LSR part is removed from the mold after curing, and the process is repeated to create the required number of parts.

LSR parts created with PolyJet molds have all the characteristics of mass-production, molded parts. They exhibit subtle details, excellent accuracy and exceptional aesthetics, combined with the desirable mechanical and thermal properties of production-grade LSR material. This makes both functional testing and low-volume production a practical alternative to conventional LSR molding techniques.

If the mold needs to change, simply revise the design and print a new mold, which will be ready for testing within a day or two. ■
EXECUTIVE SPOTLIGHT
Q: What are some of the current trends we are seeing in the use of LSR today?

A: We are seeing a number of trends from a product and use standpoint. We are seeing more use of LSR in new applications and new fields. The primary one we are experiencing a lot of growth is in the field of optics. They are being used to make lenses for LED applications. LEDs are becoming brighter and hotter. There is actually a fair amount of heat generated by an LED and there is a lens that disperses the light. They have been made from polycarbonate or a thermoplastic that isn’t as high temperature. They also tend to yellow or degrade. Silicone has a higher thermal resistance compared to thermoplastics. We are seeing a lot of people starting to use optically clear LSRs as a replacement for those thermoplastics.

Q: How is LSR different from typical plastic resins that we see today?

A: It is a completely different material. It is a thermoset material, as opposed to a thermoplastic material. You don’t melt it and form it. You inject it into the mold and you heat it to have the materials cross-link and become a rubber. This gives it certain properties that are unique to silicones. These include heat resistance and chemical resistance.

Q: How has production of LSR trended over the last five years? The pounds produced each year?

A: I won’t speak in specifics, but generally speaking, if you look at announcements from the major manufacturers, everyone is expanding their capacity. On a global basis, we continue to see the growth of LSR in volume. I have seen reports by some of the market research firms that indicate growth is in the high single digits, between 5 percent and 8 percent year-over-year. In some geographies, like China, that may be higher. We are seeing growth in a variety of segments.

Q: When it comes to molding LSR, what are some of the biggest areas of opportunity in 2017 and beyond?

A: Medical continues to be a large area of growth for silicones. As more and more procedures become out-patient procedures and as demand increases for disposable single-use devices, silicone use increases. It is used in these applications. With an aging demographic, more of these procedures are being done. This drives demand for silicone in general and LSR in particular. On the retail side, you go into a store and see more and more applications for LSR, including seals in bottles and lunch boxes. It is becoming the elastomer of choice for consumer applications.

Q: What are the fastest growing end markets for the use of LSR?

A: Optical is one of the fastest growing. In infant care, we see a lot of growth, too. It is an explosion of silicone in those areas. Electronics also is certainly an area where silicone is used widely. It can be on the exterior as a soft-touch material or inside for sealing.

Q: What properties make LSR a great option for specific end markets?

A: It is inert. It is safe, from a biocompatibility standpoint. You can put it in the dishwasher. It doesn’t crack or fade. Silicone, as opposed to a thermoplastic elastomer, has much better physical properties. This includes compression set. Gaskets, even at room temperature or higher, silicone is going to perform better than even some of the TPEs on the market. It also is readily sterilizable. This makes it indispensable in the medical market.

Q: What are some of the challenges in molding LSR, compared to traditional injection molding?

A: It flows like water. It is a much lower viscosity material than most thermoplastic molders are used to running. Mold manufacturers and processors who have spent a lifetime making thermoplastic molds generally do not have success right away with LSR. A common mistake is to go back to the known supply chain. We encourage customers to go
with reputable silicone mold makers to learn the process. The venting is smaller and parting lines are much more important. Containing flash is a big problem.

Q: What new innovations are we seeing with regard to the development of new LSR materials?

A: We are seeing some manufacturers coming out with materials that we call low volatile. In any silicone rubber part that has been molded, there is some level of volatile residuals that are in the silicone. The easiest way to get rid of those is to post-cure the parts. A typical industry post-cure can be 4 hours at 400 degrees. These materials, as the name would imply, would have less volatiles from the plant and can eliminate the need for post-curing. We continue to see self-bonding silicones. They typically will mold to thermoplastics to make a multi-component part. Shin-Etsu has a family of products that bond very well to polycarbonate. It has been a great material of choice for health care. With concerns about BPA, some customers are moving away from polycarbonate to Tritan from Eastman or some nylons. As manufacturers, we have to develop materials that will stick chemically to those materials just as they did to polycarbonate.

Q: What can be done to improve the sustainability of LSR products?

A: First, silicone rubber is derived from silica, which is one of the most abundant materials on the surface of the Earth. Unlike thermoplastics that are petroleum based, we don’t need oil to make silicone. It is immediately more sustainable in that manner. We are looking at ways to break silicone down to its original feedstocks that can be used to make different silicones. We also look at grinding it down to make something polymeric. It is a challenge, particularly when you have two component materials and the silicone is bonded to another material. It is almost impossible to separate the two so you can recycle the thermoplastic.

Q: What sort of challenges do molders face when it comes to LSR, such as flexibility in price and availability?

A: LSR pricing has been stable over the last several years. I have been involved in the industry for two decades and it has remained stable. If anything, the pricing has trended down ever so slightly. It is pretty flat. You go back to the fact that is it not based on petroleum. We don’t have the fluctuations you see with the materials that are petroleum-based. When you talk about availability, the manufacturers have invested in capacity increases so we haven’t really seen any shortages. We haven’t seen times where materials were being allocated. There has been ample supply to meet the needs of our customers.

Q: Are release agents needed during the molding process?

A: Generally speaking, no. Most any of the general purpose LSRs have internal mold release or there is enough of the silicone oil, they tend to release pretty easily from steel. Some molders may use spray-on release agents for a couple of shots. It can be like seasoning a pan as the silicone permeates the mold. In generally, there is no need for release agents.

Q: How is LSR evolving and what are some of the improvements we’ve seen in materials in recent years?

A: One area that we see some improvements in is the speed of the cure and the viscosity of the materials. This has a goal of molding more complicated geometries. Shorter cure times can reduce cycle times. Just about every manufacturer has a general purpose material that offers lower cure times. When it comes to cure time, it is based on the cross-sectional thickness of the part, as well as the mold temperature and the reaction speed of the material.

Q: Dusting off the crystal ball, what is your outlook for LSR in 2017 and beyond?

A: I don’t expect a lot of change. We expect to see continued growth in a lot of applications. The economy has been pretty strong and a lot of our customers are benefitting. In the world of silicone, we are growing organically with our existing customers and existing applications. Innovation is driving new growth. I am pretty bullish for LSR over the next decade.
Executive Spotlight | Paul Caprio

President, Krauss Maffei Corp.

Q: When it comes to machinery, what are some of the current trends we are seeing in the use of LSR today?

A: It is definitely a niche that we are in and we would like to be more involved in that market in North America. We are not in the market share position that we are in with the rest of our equipment and there is no reason that we shouldn’t be. We would like to put a little emphasis on the LSR market. It is something we see being filled by other vendors and there is no reason we shouldn’t be stronger. We have always had thermoset machines and we have always had a niche in polyester and standard thermoset. We have always offered the technology to mold LSR. There is nothing different than on a standard thermoset in controlling temperatures and the barrel. We have always had the technology, but we have never actively marketed it.

Overall, it is not all that different than a standard machine. You want accuracy on the injection unit side of the machine. Anyone who has closed-loop control and so many people do today, can consider this. You have to have your know-how on the screw technology. Since we make our own screws and we have our own screw development group in Munich, it gives you a leg up in the marketplace.

Q: How long has KM offered machines specific for LSR molding?

A: We’ve really been doing this for the 25 years I have been here.

Q: What are some of the critical components of an LSR molding machine?

A: Because you are dealing with smaller shot sizes, it more of a control issue. It would be your check valves and process control from the computer running the machine to your switch-over points. It can be pressure or position. It emphasizes the control side of the process. Anyone who is in very precision molding is suited to this process. It is everything from the valving to the computer control. We have demonstrated our electric machines at events. I do think when you have servo controls, you get that much control on the injection unit side as well. It is a natural fit. Since a lot of the LSR is in medical, the electric technology is desired. On our electric machine, we do build an encapsulated lubricated system that is protective of the environment in the clean room.

Q: Are companies still retrofitting injection molding machines to do LSR molding? How challenging can this be?

A: I don’t see that a lot. People more or less dedicate the equipment. It is absolutely possible and you can retrofit a thermoplastic machine to run thermoset. What we find is that you are either in LSR or you are not. We are seeing more multi-component molding. You can be limited to the more advanced machinery that is doing multi-component.

Q: How different is a machine for LSR when compared to a typical injection molding machine?

A: It is mainly around the injection unit and around that unit it is around the plasticizing.

Q: How do these machines compare in price?

A: There are options that you have to get, but it is in the same range. You do have to have auxiliary equipment that is feeding the material. This is not provided by any OEM. You have to go to a third party and it is usually the customer that is purchasing this separately. It is generally fed from a drum.

Q: What are some of the challenges that are unique to molding LSR?

A: I believe it is just unique to the feeding of the material. Your setups are not different in how you are controlling or setting up your shot size. If you can mold thermoplastic, you can mold LSR. I don’t think the knowledge is different. However, mold making for LSR is a specialty.
Q: What new innovations are we seeing with regard to the development of new LSR materials?

A: It is the traditional changes that we’ve developed in standard machines for thermoplastics. Everyone wants faster computers and more intuitive controls.

Q: What sort of additional controls and auxiliary equipment are LSR molders seeking?

They want robots integrated into the machine. It doesn’t matter if they are a thermoplastic molder or a liquid silicone molder. They all want the same automation. We integrate our robots into the machine so that the setups are on one control and you can run the machine remotely if necessary.

Q: When it comes to areas of opportunity, what end markets are growing for this process?

A: I still think that medical is the biggest growth area. We are seeing highly transparent LSRs for optical applications and lens technology for things like street lighting. You see some housings under the hood in automotive. That has more to do with the development of the material than the machinery.

Q: Dusting off the crystal ball, what is your outlook for LSR molding in 2017 and beyond?

A: I see it as an opportunity for the KM Group. In general, because of the development on the materials side, there will be more uses for LSR and more demand for machinery. It is a niche and it won’t be a key driver for a machine manufacturer. It is a niche specialty and if you have experience, that is what the customers want.
Executive Spotlight | Tristin Hatch

Associate Product Manager, Liquid Silicone Rubber Injection Molding, Proto Labs

Q: What are some of the current trends we are seeing in the use of LSR today?

A: Optical LSR, due to the durability, heat resistance, and non-yellowing properties, optical LSR is a great option for lenses, outdoor and indoor lighting, and many more lighting applications. Another trend is overmolding with LSR. It is a popular material used for overmolding. Material compatibility is a key consideration if bonding is critical to the application. It is often beneficial to design in a mechanical interlock as a back-up to the chemical bond between the two materials.

Q: What are the fastest growing end markets for the use of LSR?

A: Lighting, with the increased availability of optical LSR, the lighting industry is able to replace traditionally used glass and thermoplastics with a material that has more durability, is lighter weight, and has similar heat resistance properties. Medical, with the large range of temperatures that LSR can withstand, it is an ideal material that can stand up to heat for sterilization as well as the extreme cold for certain procedures. The anti-yellowing properties and ability to remain virtually unaffected by environmental factors are also desirable for the medical industry as cosmetics of a tool may be linked to perceived quality. Lastly, automotive. LSR injection molding is a great option for a variety of automotive parts including gaskets, O-rings, and other components. Certain LSR materials such as fluorosilicone also have oil and fuel resistant properties.

Q: Does injection molding remain the leading process for LSR?

A: Yes, injection molding is currently the leading process for LSR. Proto Labs has recently started to offer Polyjet, which is a 3-D printing process that uses photopolymers with elastomeric properties to mimic silicone but it does not have the same material properties as silicone.

Q: What are some of the challenges in molding LSR, compared to traditional injection molding?

A: First would be flash, which is a much bigger issue with LSR injection molding than with plastic injection molding because silicone materials flow much more easily than most thermoplastics. Molds must be designed to take this into account. Molding of LSR also requires heating of the material in the mold to cure it while plastic injection molding requires cooling of the material in the mold to cure it. While this may not necessarily be a challenge, it is a difference in the molding process that takes additional expertise.

Q: Are molders producing tooling in house for the molding of LSR?

A: Proto Labs creates the tooling for LSR molding in-house. A customer uploads their part CAD files on our website and our technical team reviews the files and provides an interactive quote complete with DFM feedback to ensure that the part is optimized for molding. We then make the mold and parts in our Minnesota manufacturing facility.

Q: What are some of the key developments in molds used for the processing of LSR?

The flexibility of LSR allows for more complex geometries than plastic injection molding including undercuts and potentially less draft. The use of ejector pins is also not needed to get the part out of the mold which helps improve the cosmetic appearance.

Q: What developments are we seeing in machinery to be used to process LSR?

A: We are seeing increased competition in the pumping manufacturers which could help reduce the price of the pumping units going forward. Smaller pumping units which are much easier to break down and clean have been increasing in availability and usage. This not only shortens the maintenance time and cost but also allows cartridges to be filled and then attached directly to the throat of the injection molding machine for processing smaller batch sizes.
Q: Is it better to convert an injection molding machine to mold LSR or dedicate a new machine to the process?

A: LSR requires a specific injection molding machine to create the parts. With plastic injection molding, the material is fed into the machine in a pellet form where it is heated so that it melts and then the hot liquid is injected into the mold and cooled. LSR material comes already in a liquid form and then is heated and cured in the mold to create the part.

Q: On the materials front, what sort of challenges do molders face when it comes to LSR, such as price, availability and flexibility?

A: LSR is a more expensive material than plastic therefore resulting in more expensive parts. However, there are certain properties such as flexibility and heat resistance that are hard to replicate with plastic so depending on the end use of the part, the added cost can be warranted. Material shelf life is another challenge that molders face with LSR. While plastic is able to be used for years after it is purchased, LSR has a shelf life of only 6 to 12 months. This makes it difficult to stock all material options for customers without potentially having to throw large amounts away. Proto Labs has recently started offering customer supplied material for LSR so that the customer can send in the exact materials and amount of material needed for their parts allowing additional flexibility beyond our stocked materials.

Q: Who are some of the leading suppliers of LSR today?

A: Wacker, Dow Corning, Shin-Etsu, and Momentive are a few, but many large material suppliers are expanding their offerings to include LSR.

Q: How much innovation is going on with LSR today?

A: There is quite a bit of innovation especially around material options. Suppliers are continuing to refine their selection and specialization of materials for certain applications and industries.

Q: Dusting off the crystal ball, what is your outlook for LSR molding in 2017 and beyond?

A: LSR continues to be a growing business for Proto Labs and we foresee this to continue over the next few years. Materials will continue to be developed and created for specialized applications.

Proto Labs has expanded its selection of LSR materials, which have some distinct elastic and optical advantages over certain thermoplastics. Photo courtesy of Proto Labs.
Executive Spotlight | Jeff Mengel
National Practice Leader for Plastics, Plante Moran

Q: What are some of the current trends we are seeing in the use of LSR today?

A: LSR is an interesting material. You just have to look at injection molding rankings in Plastics News. Only two of the Top 100 say they do LSR. I am guessing it is really six or seven. And they are smaller companies. You don’t get volume with LSR. It is very niche. It almost always is combined with another material. It is two-shot or it is joined in some way. It allows you to differentiate yourself. Your product has a seal or something that differentiates itself. It is a unique product and it almost always has a higher gross profit margin. It has more risk associated with it.

Even though the LSR component of a product being produced is very small, it is a unique component. It is a very nice way of differentiating yourself in the marketplace and you are only competing with six percent of the population compared to 100 percent overall.

Q: When it comes to molding LSR, what are some of the biggest areas of opportunity in 2017 and beyond?

A: You see a lot in medical and food service. It is something that can be sanitized in the thermoset. You can put it into a high-heat environment. It also has other applications where a need for a constant seal is needed. This could be used in industrial products or defense. You are not going to see it widely used. It is expensive. If this were not the case, you’d see more than 6 percent of the industry. It also has a skill set that is unique. It is the opposite of injection molding. In injection molding, you heat something and inject it into a mold and cool it down. In LSR, you cool it, inject it into the mold and heat it up. The skill sets in tool building and processing are unique and you have to train people in these skills.

Q: Are molders producing tooling in house for the molding of LSR?

A: There is a benefit of having in-house tooling, especially when you have unique structures. In this case, you would think LSR would fit into this. There are tooling companies that know how to work it better. The expertise seems to be with a handful of companies. This is an area where you would be looking to outsource the tooling. It is such a small part in most instances and the tooling ships very easy. You want to make sure the tool is right. The vendors will tell you when it is going to be done. Most LSR molding is done by smaller molders and they just don’t have the capability in house.

Q: Does injection molding remain the key process for LSR?

A: Yes, and we are seeing some extrusion as well. Particularly in medical we are seeing extrusion for tubing. In injection molding, we are seeing more complexity and freedom of form. That is why injection molding is so helpful.

Q: What are some of the challenges in molding LSR, compared to traditional injection molding?

A: Think of the three components. You have materials that need to be metered just right to make sure they work. You have unique presses to support this and you have unique tools. All of these need to be working perfectly. Unless you have some problem with your metering, it does tend to be pretty repeatable. It is a lot like injection molding in that regard.

Q: What developments are we seeing in machinery to be used to process LSR?

A: I do think LSR has a home and each of the machinery manufacturers is probably looking to get a share of the niche stuff. There is another component, too. A lot of times the joining can be mechanical or it can be chemical. In the chemical one, you do a two-shot and that can be done in the press. You have another level of complexity. If you take it out of the press and join it mechanically, you have some processes and equipment to do that. The metering also is an important component of the process and the materials are different. It is a critical aspect to getting this process to work correctly. Press performance,
pump performance and mold performance are also important to producing good parts.

Q: On the materials front, what sort of challenges do molders face when it comes to LSR, such as price, availability and flexibility?

A: The commodity resins tend to move a lot more than engineered resins. I think of LSR as engineered. The price doesn’t move as much, but it is more expensive.

Q: Who are some of the leading suppliers of LSR today?

A: Wacker and Dow are some of the leaders. There aren’t a bunch of players. If you look at the amount of material produced in pounds, it is miniscule.

Q: How much innovation is going on with LSR today?

A: Most of what we are seeing is in the dispensing, the tooling and the press. There isn’t as much focus on the materials. There are a lot of companies that focus on that side and I think this helps them maintain their position in the industry.

Q: What are the biggest challenges that molders of LSR face in 2017?

A: Key challenges are planning, design and launch. Early on, it is modeling and having the tool process. I don’t want to discount the tool process. They have taken a lot of the variability out of the mix. When you get to higher volume and you are dealing with keeping things moving, there are challenges with automation. There also are environmental variables. Other challenges also include whether it molds the same in the winter as the summer. You also have to deal with the higher machinery costs. You can convert a press and move back and forth, but is it going to be as good as a dedicated machine? You also need the dosing system. And finally, you need the knowledge. You don’t find that knowledge. You have to develop it. You have to grow them. This is why you see smaller companies doing this. They have key people who manage the process and control it in a very closed environment.

Q: Dusting off the crystal ball, what is your outlook for LSR molding in 2017 and beyond?

A: It is growing. I don’t know to what extent it is growing. The easiest way to determine growth is to look at the number of pounds being produced. The material manufacturers could tell us a lot about growth. When the product designers understand the properties and the ability to use LSR and when its operations become more sophisticated, you will see more products made with it. You may see some more in packaging and in things that need a seal. You also may see more in medical and food service. All of the dispensing machines have LSR in there because it is a good product for seals. You also can clean it. The repeatability of the seal component lends itself to an LSR product.
Bluestar Silicones USA Corp.

Bluestar Silicones has been active in the silicone industry for over 60 years – serving diverse markets, from energy to cosmetics, aerospace, automotive manufacturing, construction, healthcare, mold-making, paper and textile coating, personal care and others.

The company’s North American operations are based in East Brunswick, N.J., offering silicone products for release coatings, engineering elastomers, fabric coating, resins, and emulsions.

The company offers its products through agencies and distributors in France and internationally. The company was formerly known as Rhodia Silicones SAS and changed its name to Bluestar Silicones France SAS in February 2007.

The company was incorporated in 1999 and is based in Lyon, France with additional offices in Latin and North America, Europe, and the Asia Pacific.

In June 2015, Bluestar Silicones International was acquired by Elkem. Elkem is one of the world’s leading companies for environmentally friendly production of materials. The company has four business areas; Silicon Materials, Silicones (BSI), Foundry Products and Carbon. The principal products are silicon, silicones, ferrosilicon, foundry alloys, carbon materials and microsilica.

Elkem is headquartered in Oslo, Norway with a presence in over 40 countries worldwide. This company employs about 3,600 people.

The company recently launched its line of Bluesil silicone moldmaking products for rapid prototyping applications. It also announced the launch of a new self-bonding soft skin adhesive for wound, scar, transdermal and wearable device applications. The company’s Silbione RT Gel 4645 offers high bond strength to achieve adhesion.

Bob Waitt, market manager for Healthcare in North America, said the company continues to expand its capabilities in the healthcare arena and demonstrate its ability to meet the evolving needs of its customers.

“We take pride in working collaboratively with our customers to provide next generation solutions with the personal touch, raising the bar as to what customers should expect from a silicone partner in the healthcare arena,” he said.

Bluestar Silicones has moved its production facilities from Santo André, Sao Paulo, to Joinville, Santa Catarina in Brazil, according to its parent company China National Bluestar Group. The new Joinville unit started operation in September 2016 at the Perini Business Park, the company said in a news release.

According to the company, services, logistics, and transport infrastructure; as well as skilled labor were the main reasons behind the move.
Dow Corning is a supplier of silicones, silicon-based technology and more than 7,000 products and services via the company’s Dow Corning and Xiameter brands.

Dow Corning also is approaching its first year anniversary of officially being a subsidiary of Dow Chemical Co., which bought out its joint venture partner Corning Inc. in a $4.8 billion deal announced December 2015. The move became official June 1, 2016.

The move brings two different technology portfolios together: Dow Corning’s silicone-based compounds and Dow’s carbon-based technology.

Its global operations adhere to the American Chemistry Council’s Responsible Care initiative, a stringent set of standards designed to advance the safe and secure management of chemical products and processes.

Dow Corning was established in 1943 specifically to explore and develop the potential of silicones.

With headquarters in Midland, Mich., Dow Corning has a worldwide distributor network and nearly 12,000 employees globally.

Dow Corning is working on LSRs for insulation of high-voltage electrical lines, reducing the amount of electricity lost over long-distance power transmission.

As part of its growth strategy, Dow Corning is investing in state-of-the-art capabilities and new product technologies, and in particular is expanding its North American Healthcare Application Center in Midland, Mich.

The center will be modernized with additional capabilities to characterize material performance for advanced application development.

Roger Hendrick, technical service and development for food, pharma and medical, said the center established a set of core competencies in injection molding. Investment details were not disclosed, but the company described it as “significant.”

“We continue to make investments in areas of interest and growth, and medical materials are still maintaining that appeal to Dow Corning,” Hendrick said. “We have had for a long time a very comprehensive technical capability in regions around the world to help our customers. This is a further expansion of our capabilities specific to Midland and most importantly specific to health care and medical applications.”

Gary Lord, global strategic marketing director for health care, said the U.S. is the largest market, so it needs to be the best equipped.

“It’s always been the largest, most well-advanced area for Dow Corning for the medical area. Because the U.S. market is one where there is a lot of growth potential still and a lot of innovation that happens, we’re constantly increasing the capabilities of the center here in Midland,” he said.

Dow recently took the wraps off two new silicones, including Silastic Q7-78XX, a new series of elastomers designed for Class 3 biomedical devices. The product comes in Shore A harnesses of 40, 50 and 70.

It also launched C6-7XX, a liquid silicone rubber for short-term or non-implant applications—or Class 2 devices.

Lord, said the two new silicones combined with the firm’s QP1 silicone designed for Class 1 devices give Dow Corning a bundle of products designed for all classes of medical devices.
Momentive Performance Materials Inc. is a global leader in silicones and advanced materials, with a 75-year heritage of being first to market with performance applications for major industries that support and improve everyday life.

The company delivers science-based solutions by linking custom technology platforms to opportunities for customers. Momentive Performance Materials Inc. is an indirect wholly-owned subsidiary of MPM Holdings Inc. The company itself was formed in October 2010 from the combination of Momentive Performance Materials and Momentive Specialty Chemicals Inc. (formerly known as Hexion Specialty Chemicals Inc.).

Momentive Performance Materials is the product of a $3.8 billion buyout of General Electric Co.’s silicone plants in 2006.

Momentive scientists invented one of the world’s first plastics, better known as Bakelite, the first epoxy resins, and the first silicones for commercial use. Today, it continues to develop a multitude of resins, silicones and other advanced materials to meet the specific end-use and manufacturing requirements of our customers.

It also is known for its low-viscosity, pumpable LSR family of materials, which can help promote easier injection molding of complex articles.

The company had 2016 sales of $2.2 billion. It has more than 10,000 employees at about 85 manufacturing facilities worldwide.

“In 2016, our results reflected meaningful product mix improvement,” said CEO and President Jack Boss. “While overall volume was lower due to intentional declines in our basics business, specialty volume was up 5 percent year-over-year, as we achieved gains in key portions of the specialty silicones portfolio driving EBITDA margin accretion.”

New and innovative products drive growth at the company, including its self-lubricating Silopren LSR 3186/50 liquid silicone rubber, which is broadly used in the automotive industry for connector seals.

Silopren LSR 2670 liquid silicone rubber highlights a 20 year success story. Launched in 1996 as the hardest (70 Shore A) version of the new LSR 26xx series – and optimized for high tear-resistance and fast curing – Silopren liquid silicone rubber’s well-balanced properties led to a fast adoption in critical high temperature applications.

Additionally, the ability of Silopren LSR 2760 liquid silicone rubber to be considered for specific applications in contact with human skin or food became the basis for broader applications in food processing and wearable devices.

The company’s Silopren LSR 4655 SL is a two-component, self-lubricating liquid silicone rubber for injection molding processes that provides a lubricious surface on the molded part after vulcanization.

“We are proud to showcase the processing benefits of our LSR in close cooperation with our industry network of leading suppliers,” said Holger Albrecht, Vice President, Elastomers at Momentive.

Momentive’s family of liquid silicone rubber materials (LSR) enable health care device designers and equipment manufacturers to introduce improved material features for critical applications such as needle-free access valves, O-rings, stoppers, seals and assembled parts.
Shin-Etsu Silicones of America

Shin-Etsu Silicones of America is the U.S. subsidiary of Shin-Etsu Chemical Co. It has been producing silicones for more than 40 years.

Parent company Shin-Etsu Chemical produces and distributes synthetic resins and other chemical products such as fertilizers. The company also manufactures electronic materials such as semiconductor silicon, synthetic and rare earth quartz. Shin-Etsu Chemical operates in Japan and overseas. It has more than 17,000 employees globally.

To meet the increasing demands and to supply its products efficiently and economically, Shin-Etsu Silicones has now established worldwide production/sales networks in Japan, the U.S., Holland, Taiwan, Korea, Singapore and Shanghai.

As part of its business strategy, Shin-Etsu Silicones has adopted the policy of “market in.” With applications of silicone being versatile, it is necessary to do close marketing with customers. In response to the trends and needs of its customers, the company’s sales department offers the best solution and supports the development of value added products for their customers.

The company’s silicone rubber products are available in three forms. Many of its grades are compliant with USP Class VI and ISO 10993 standards.

Shin-Etsu’s liquid injection molding system products can be used to mold silicone components in high-speed, automated equipment.

According to Eric Bishop, North American marketing manager at Shin-Etsu Silicones of America, the company’s LSR’s are getting a lot of play in lenses and optics, LED drivers, light engines, and high-power COB (chip-on-board) electronics. Its KE-2062 series of optically clear LIMS (liquid injection molding system) with hardnesses ranging from Shore A 30 to 70, offer the clarity of the thermoplastic contenders with significantly higher heat resistance up to 200 C (392 F).

Shin-Etsu’s newest LIMS is X-34-1972-3, developed to meet increasing demands for higher heat/brightness characteristics of cutting-edge LED technologies.

With a transparency of 95 percent, this 70 Shore A LIMS is said to be well suited to LEDs in street lighting, automotive, and exterior illumination. Its superior high-temperature resistance allows molded silicone optics to be positioned in close proximity to the LED light source.

As part of its global growth strategy, parent company Shin-Etsu Chemical Co. Ltd. is planning to establish a new silicones production plant in Japan and expand its technical center in a $21.9 million investment.

Shin-Etsu expanded silicones production capacity in Thailand and Japan last year, investing a combined $380 million in the projects.
Wacker Chemie AG is a worldwide operating company in the chemical business, founded 1914. It is a public company with the Wacker family holding more than 50 percent of the shares.

The company’s silicone division, Wacker Silicones, ranks among the world’s largest manufacturers of silanes and silicones. It also is a market leader in key sub-segments.

The division’s product portfolio ranges from silanes through silicone fluids, emulsions, elastomers, sealants and resins to pyrogenic silicas.

In 2016, silicone sales surpassed the €2 billion sales level for the first time in history. The specialty company announced that a 3 percent rise volume growth helped offset “some-what” lower price conditions. The company has 17,205 employees globally.

Wacker’s U.S. activities began in 1965, when the Munich-based chemical company established Wacker Chemicals Corporation in New York. This move provided Wacker with direct access to North American markets. In the U.S., the company now operates six production sites, six sales offices and has fifteen distributors, thus ensuring close proximity to its customers.

In the United States, Wacker has production facilities in Adrian, Mich.; Chino, Calif.; and North Canton, Ohio. It also has facilities in Germany, Brazil, China, South Korea, Norway and the Czech Republic.

The company’s growth strategy includes a focus on long-term and continual corporate growth. It focuses on products and regions with above-average growth. Top priority is given to expanding its presence in dynamic regions and gaining new customers.

According to company officials, Wacker wants most of its growth to be organic. Nevertheless, acquisition options are reviewed if they suit the group’s long-term strategy and offer prospects for tapping additional success potential.

Wacker’s foundation is formed by its technological and entrepreneurial strengths. This is why the company enjoys a leading competitive position in most of its business fields. The company’s portfolio includes about 1,000 different silicone products.

Wacker Chemie expects earnings to stagnate in 2017 as the spiraling cost of raw materials eats into its profit.

“We are ... facing headwinds from raw-material prices. At present, they are rising significantly and this could impact earnings,” Chief Executive Rudolf Staudigl said in a statement.

“We see some challenges going forward, but our course is clearly set,” Staudigl added. As part of its business strategy, Wacker announced it will sell a 21 percent stake in Siltronic, a German company that makes silicon wafers for mobile phones and computers. Staudigl said the company’s plan is to “reduce our stake to go to a minority position and yes, that’s certainly the next step, which we will follow at the right time.”

Overall, Staudigl said he expects volumes to increase at every decision.

“In the industry sectors relevant to our business, the trend will be broadly positive in 2017,” he said. “That is why we are confident of increasing sales by a slightly higher percentage than last year.”

At Wacker Silicones and Wacker Polymers, sales are expected to grow by a mid-single-digit percentage, with all business units contributing.
Evonik Corp. is the North American subsidiary of Evonik Industries, one of the world’s leading specialty chemicals companies. The central elements of its strategy for sustained value creation are profitable growth, efficiency and values.

Around 80 percent of sales come from market-leading positions, which we are systematically expanding. The company concentrates on high-growth megatrends, especially health, nutrition, resource efficiency and globalization.

Evonik has more than thirty major production sites in the United States, Canada and Mexico, as well as numerous offices, labs, warehouses and distribution centers in North America, employing about 4,660 people in the region.

The company focuses on specialty chemicals that find application in diverse products and industries, from automotive to pharmaceuticals.

Evonik Industries is active in more than 100 countries all over the world, with more than 35,000 employees and €12.7 billion in sales in 2016.

As part of its business strategy, Evonik recently entered an agreement to acquire J.M. Huber Corp.’s silica business for $630 million, which will enhance Evonik’s position in both North America and Asia.

In a separate move, the Germany-based specialty chemicals company disclosed that it will invest about $120 million to build a precipitated silica plant near Charleston, S.C., close to the production facilities of many large tire manufacturers. The project is forecast to be complete in 2018 and create 55 jobs.

In May 2015, Evonik disclosed plans for a double-digit million Euro investment in the U.S. — its largest in North America during the past five years—for a new precipitated silica production plant, but did not provide specifics. Evonik said at the time that completion was scheduled for late 2017 and that basic engineering on the facility had already begun.

Evonik will produce its Ultrasil-brand of rubber silica products at the new facility—which are reinforcing fillers for the rubber industry. In addition to the tire industry, the product line is used in hoses, belts and rollers.

The firm said manufacturers using a silica-silane combination are able to produce tires that allow for fuel savings up to 8 percent because of significantly reduced rolling resistance compared to conventional passenger car tires.

Evonik said it had increased its global capacity for precipitated silica by about 30 percent between 2010 and 2014, expanding its precipitated silica production plant in Chester, Pa., by about 20,000 metric tons in September 2014.

The firm operates a colloidal silica plant in Portland, Ore., and it produces fumed silica in Waterford, N.J., and Mobile, Ala.

As part of its business strategy, Evonik recently named Christian Kullmann its new CEO, replacing Klaus Engel.
APPENDIX
### NORTH AMERICAN PROCESSORS AND MOLD MAKERS IN LIQUID SILICONE RUBBER SECTOR

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>LSR Volume</th>
<th>Products manufactured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albright Technologies</td>
<td>Leominster, MA</td>
<td>N/A</td>
<td>Custom silicone prototypes and volume production</td>
</tr>
<tr>
<td>All Formed Products LLC</td>
<td>Medota Heights, MN</td>
<td>0.001</td>
<td>“Skirting mates”</td>
</tr>
<tr>
<td>Apple Rubber Products Inc.</td>
<td>Lancaster, NY</td>
<td>0.05</td>
<td>Seals and sealing devices</td>
</tr>
<tr>
<td>Bekmar Corp.</td>
<td>Broomfield, CO</td>
<td>0.001</td>
<td>In-place gaskets</td>
</tr>
<tr>
<td>Bryant Rubber Corp.</td>
<td>Harbor City, CA</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Cikautxo S. Coop</td>
<td>Berriatua, Bizkia, MN</td>
<td>0</td>
<td>Medical devices</td>
</tr>
<tr>
<td>Custom Manufacturing and Engineering Inc.</td>
<td>Lino Lakes, MN</td>
<td>0</td>
<td>Custom injection molder</td>
</tr>
<tr>
<td>Dymotek Corp.</td>
<td>Ellington, CT</td>
<td>0.156</td>
<td>Custom</td>
</tr>
<tr>
<td>Freudenberg Medical LLC</td>
<td>Carpinteria, CA</td>
<td>N/A</td>
<td>Medical</td>
</tr>
<tr>
<td>GW Silicons</td>
<td>Royalton, VT</td>
<td>0.55</td>
<td>Custom molder, manufacturer of components, assemblies</td>
</tr>
<tr>
<td>IRP Medical</td>
<td>San Clemente, CA</td>
<td>0.1</td>
<td>Custom medical devices and biotech components</td>
</tr>
<tr>
<td>Jamak Fabrication Inc.</td>
<td>Weatherford, TX</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Lauren Manufacturing Co.</td>
<td>New Philadelphia, OH</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>M.R. Mold &amp; Engineering Corp.</td>
<td>Brea, CA</td>
<td>N/A</td>
<td>injection molds</td>
</tr>
<tr>
<td>MDS Manufacturing LLC</td>
<td>St. Louis, MO</td>
<td>0.25</td>
<td>Custom; infant care items, recreation, retail display market, toys</td>
</tr>
<tr>
<td>MedPlast Inc.</td>
<td>Tempe, AZ</td>
<td>N/A</td>
<td>Contract</td>
</tr>
<tr>
<td>Medron Inc.</td>
<td>Salt Lake City, UT</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Merit Medical Systems Inc.</td>
<td>South Jordan, UT</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Midwest Rubber Co.</td>
<td>Deckerville, MI</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Minnesota Rubber &amp; Plastics</td>
<td>Minneapolis, MN</td>
<td>N/A</td>
<td>Contract manufacturing</td>
</tr>
<tr>
<td>Molded Rubber &amp; Plastics Corp.</td>
<td>Butler, WI</td>
<td>0.08</td>
<td>Medical device components, assemblies, clean room molding</td>
</tr>
<tr>
<td>Namso Plastics Industries Inc.</td>
<td>New Kensington, PA</td>
<td>0</td>
<td>Custom injection molder</td>
</tr>
<tr>
<td>NewAge Industries Inc.</td>
<td>Southampton, PA</td>
<td>N/A</td>
<td>Flexible tubing and hose</td>
</tr>
<tr>
<td>NPI Medical</td>
<td>Ansonia, CT</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>OEM/Miller</td>
<td>Aurora, OH</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Parker Hannifin Corp.</td>
<td>San Diego, CA</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Phillips-Medisize Corp.</td>
<td>Hudson, WI</td>
<td>N/A</td>
<td>Contract, top medical</td>
</tr>
<tr>
<td>Polymer Conversions Inc.</td>
<td>Orchard Park, NY</td>
<td>N/A</td>
<td>Contract manufacturing</td>
</tr>
<tr>
<td>Proto Labs Inc.</td>
<td>Maple Plain, MN</td>
<td>N/A</td>
<td>Custom with automated tooling</td>
</tr>
<tr>
<td>PTG Silicones Inc.</td>
<td>New Albany, IN</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>QPharma AB</td>
<td>Malmö</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Qure Medical</td>
<td>Twinsburg, OH</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Raumedic Inc.</td>
<td>Mills River, NC</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Rogan Corp.</td>
<td>Northbrook, OH</td>
<td>0.01</td>
<td>Custom molding and contract manufacturing</td>
</tr>
<tr>
<td>Saint-Gobain Performance Plastics Corp.</td>
<td>Solon, OH</td>
<td>N/A</td>
<td>Tubing - top medical/automotive</td>
</tr>
<tr>
<td>Scientific Specialties Inc.</td>
<td>Lodi, CA</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Silicotech North America Inc.</td>
<td>Bolton, ONT</td>
<td>0</td>
<td>large volume liquid injection molding</td>
</tr>
<tr>
<td>Silikids Inc.</td>
<td>Traverse City, MI</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Simtec Silicone Parts LLC</td>
<td>Miramar, FL</td>
<td>1.25¹</td>
<td>High-volume injection molding</td>
</tr>
<tr>
<td>Sinicon Plastics Inc.</td>
<td>Dalton, MA</td>
<td>N/A</td>
<td>Custom</td>
</tr>
<tr>
<td>Specialty Silicone Products Inc.</td>
<td>Ballston Spa, NY</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>St. Jude Medical Inc.</td>
<td>St. Paul, MN</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Starlim N.A. Corp.</td>
<td>London, ONT</td>
<td>2¹</td>
<td>N/A</td>
</tr>
<tr>
<td>Trelleborg Sealing Solutions</td>
<td>Fort Wayne, IN</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Vesta Inc.</td>
<td>Franklin, WI</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Source: Plastics News rankings; Based on injection molders from the Plastics News rankings that reported processing liquid silicone rubber; E - Estimate; LSR volume in millions of pounds
LSR: The molding process

Source: SimTec

LSR: Light transmission

<table>
<thead>
<tr>
<th></th>
<th>Silicone</th>
<th>PC</th>
<th>PMMA</th>
<th>Glass</th>
</tr>
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<tbody>
<tr>
<td>Light Transmission</td>
<td>94%</td>
<td>88-90%</td>
<td>93%</td>
<td>95%</td>
</tr>
<tr>
<td>Refractive Index</td>
<td>1.42</td>
<td>1.58</td>
<td>1.49</td>
<td>1.52</td>
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<tr>
<td>UV Resistance</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Chemical Resistance</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Temperature</td>
<td>&gt;150°C</td>
<td>120°C</td>
<td>90°C</td>
<td>&gt;200°C</td>
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<tr>
<td>Yellowing</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Micro Detail</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Thick Part</td>
<td>Yes &gt;1 in.</td>
<td>No</td>
<td>&gt;PC</td>
<td>Yes</td>
</tr>
<tr>
<td>Minimum Part Thickness</td>
<td>&lt;0.020 in.</td>
<td>0.040 in.</td>
<td>0.040 in.</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: Proto Labs
MOLECULAR STRUCTURE OF SILICONE RUBBER

Source: SimTec

LSR: Extrusion

Feed hopper

Crosshead

Conveying screw

Extrusion die

Source: Wacker