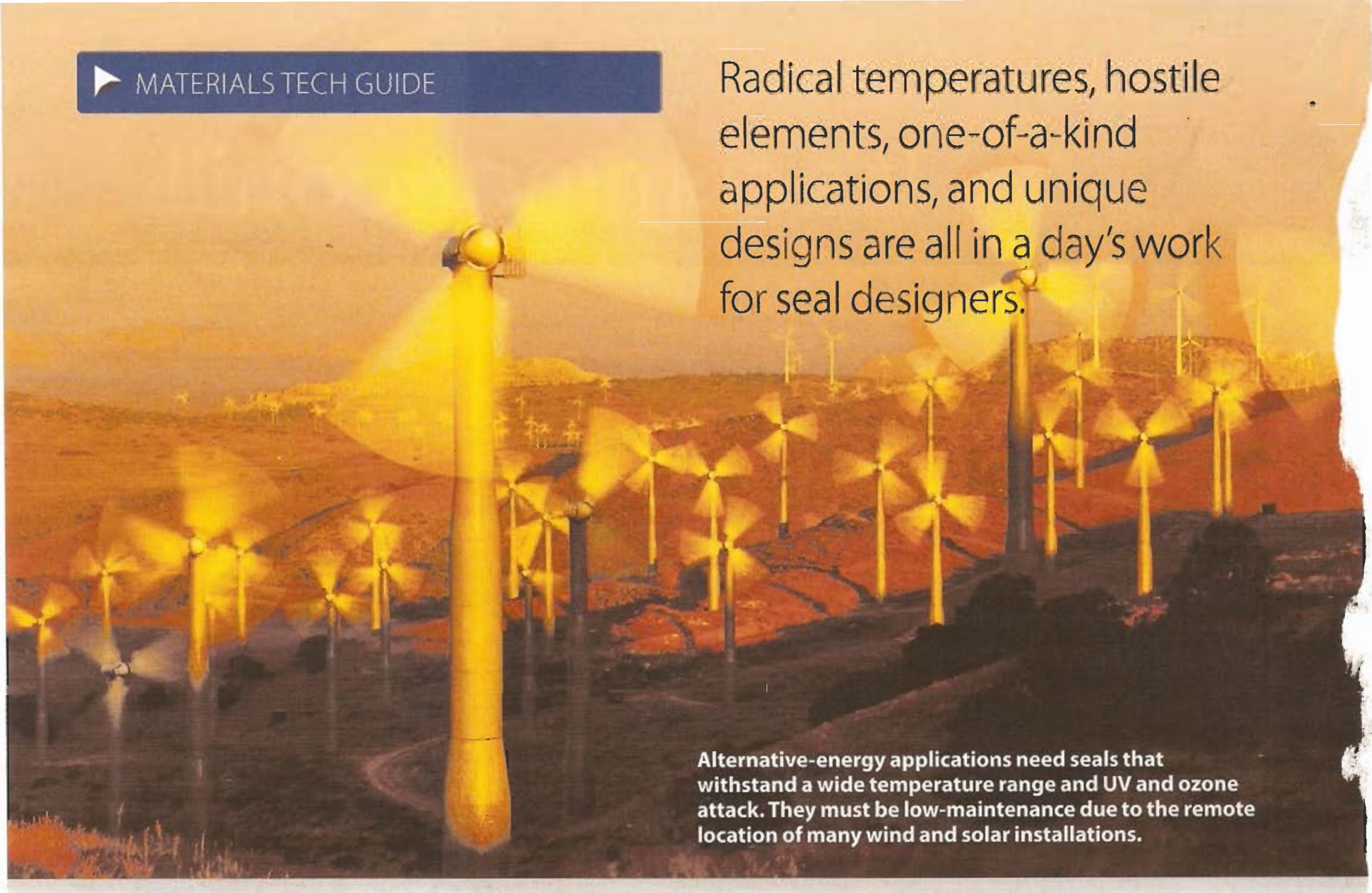

Radical temperatures, hostile elements, one-of-a-kind applications, and unique designs are all in a day's work for seal designers.

Alternative-energy applications need seals that withstand a wide temperature range and UV and ozone attack. They must be low-maintenance due to the remote location of many wind and solar installations.

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Key points:

- Aerospace applications may call for seals that are fireproof, resist fluids, and work over a large temperature range.
- Viscoelastic properties help elastomeric seals work in subfreezing temperatures.
- Semiconductor and alternative energy applications require low-maintenance seals that resist chemicals and weather.

Resources:

Simrit Div. of Freudenberg-NOK, *www.simritna.com* **RS# 621**

"New sealing systems take the heat," Machine Design, June 5, 2008, *tinyurl.com/ykjktju*
"Tips to improve energy efficiency," Machine Design, Nov. 17, 2009, *tinyurl.com/yf6mbxj*

What do an Antarctic loading crane, a jet engine, and a solar array have in common? Sealing is a critical component that keeps these devices working.

To address these applications' requirements, designers continually advance sealing materials and designs. Sealing engineers need a deep appreciation of how critical even the smallest component – such as an O-ring – is to an application.

So, what are some of the material and application trends emerging within the sealing industry for extreme applications? Four industries driving the latest sealing devices are aerospace, fluid power, semiconductors, and renewable energy.

Up, up, and away

Aircraft depend on their seals. So it is critical for aircraft engineers to use materials and designs that provide resilience in demanding elements. Extreme heat and cold and radical temperature fluctuations are just some of the hostile conditions of special concern in the aerospace market.

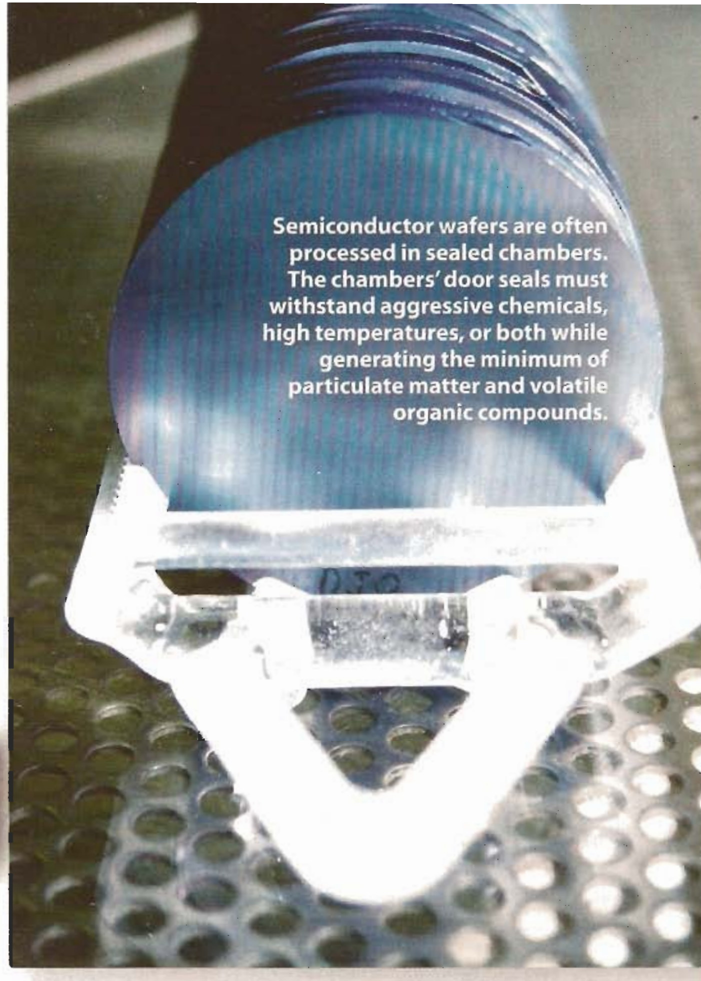
To combat these challenges, many sealing manufacturers develop custom components and systems to address a given application's unique design requirements. For example, modern jet engines are expected to go more than 10,000 flight-hr at extreme exhaust-gas temperatures before a major overhaul. Consequently, designers expect the surrounding components to endure high temperatures for extended time frames as well.

Perfluoroelastomer (FFKM) compounds are among the few materials that meet the challenge. Their resilience makes them an excellent choice for demanding aerospace environments that not only need protection against extreme temperatures but must also seal tightly and resist aggressive chemicals. The high level of fluorine in FFKMs provides resistance to heat and a broad range of chemicals.

One such material is Simriz 498 from **Simrit.** The black compound's proprietary cross-linking system gives it long-term resiliency and resistance to compression set in addition to its resistance to both aggressive chemicals, including nitric acid and amines, and temperatures above 300°C.

A major regional jet manufacturer recently switched to Simriz 498 to reduce sealing-related warranty issues. A combination of aggressive fluids such as long-

The extreme side of sealing



Semiconductor wafers are often processed in sealed chambers. The chambers' door seals must withstand aggressive chemicals, high temperatures, or both while generating the minimum of particulate matter and volatile organic compounds.

life jet turbine lubricants and long-term exposure to high temperatures caused the original seals to fail before their 30,000-hr expected life. Lab testing duplicating the service conditions confirmed that Simriz 498 would meet or exceed the 30,000-hr requirement.

For seals away from fuel sources, many aircraft designers turn to ethylene-propylene-diene, Class M rubber (EPDM). It is especially noted for its resistance to aviation hydraulic fluids, although most grades are not recommended for contact with kerosene and other fuels.

Materials that meet specifications like NAS 1613 Revision 5 have good low-temperature capabilities and meet maximum compression-set requirements. Compression set occurs when a rubber compound loses some of its elasticity after prolonged constant or repetitive compressive stress. Simrit's E454 and E458 EDPM compounds have been used by major aircraft-component manufacturers.

Given all the flammable fluids that keep aircraft flying, many aerospace applications require fireproof materials. In such cases, like the design of firewalls, engineers may turn to special silicones.

According to the FAA, a firewall material is fireproof if it can withstand 2,000°F for 15 min without any ignition away from the heat source. A North American very-light-jet (VLJ) manufacturer wanted a single material — as opposed to the industry-standard silicone-ceramic fabric composite — that could provide fireproof seals for its aircrafts' engine firewalls.

Simrit engineers developed AU 9250, a fireproof silicone that saved the company about $150,000/yr. The physical properties of the silicone's surface change when burned to form a rigid barrier that protects the flexible polymer below. The new material met the requirements of FAA Circulatory AC20-135 which called for compliance with 14 CFR Part 23, §23.1191, 23.1301, and 23.1309.

Both the material and the product are FAA and EASA approved for use as fireproof and fluid-susceptible materials in aircraft. The material also handles temperatures as low as –55°C, so it works at any altitude the VLJ flies.

Repeated changes in altitude and weather mean that aerospace seals must operate in temperatures that fluctuate between extreme hot and cold. A major aircraft-engine supplier using general-purpose silicone seals found it was frequently rebuilding its engines' compressor sections after they failed prematurely in the field.

Newer extreme high-temperature silicone works in the engines' gas path at temperatures from –60 to 260°C. General-purpose silicones, in contrast, work up to 200°C on average. As an added benefit, the material had 10% higher tensile elongation and tear strength for longer service life.

Hot and cold

While some new innovations are generated from specific customer needs, seal engineers must also anticipate

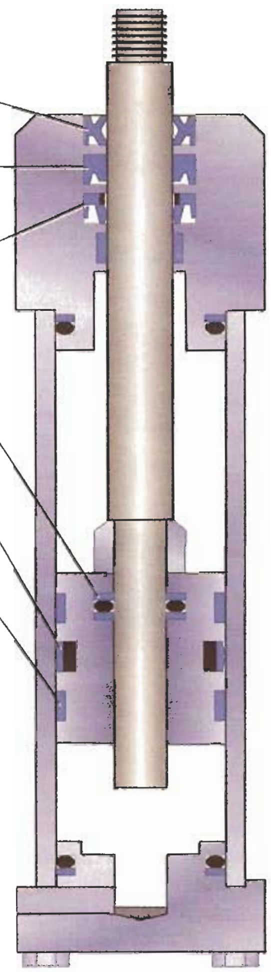
WHAT'S THIS?

When you see a code like this, take a photo of it with your smart phone (iPhone 3G-S gives best results) and, using software from *www.neoreader.com*, you will be connected to relevant content on *machinedesign.com* industry trends. One up-and-coming trend is the drive toward smaller hydraulic packages that see greater pressures and hotter temperatures, often due to new environmental standards. Such systems demand better seals, and one way hydraulics designers address future sealing challenges is to use a single seal that meets a range of geometric and operational requirements.

One such example comes from Simrit's modular rod-sealing system. By using standardized configurations to mount the sealing system and mix-and-match design and material combinations, Simrit engineers ensured seals could withstand temperatures of 100, 110, or 120°C, pressures up to 42 MPa, and resist fluid and chemical contact. Seal materials include Disogrin 9250 urethane, AU U641 urethane, A505 nitrile butadiene rubber, and Nok UH05 combined with G928 hydrogenated nitrile butadiene rubber. The modular design helps engineers meet current and future industry needs while staying within price-performance requirements.

While many hydraulic systems are running hotter, that's not the case for all applications. Cold temperatures can cause sealing problems, too, especially at extreme temperatures like those near the South Pole.

A loading crane in the Antarctic was experiencing oil leaks in hydraulic cylinders for the boom and extension arm. Although operators only use the crane during the summer, its operating temperature is between -20 and -40°C. It stands frozen under ice and snow for the remainder of the year.



Engineers at Simrit developed a modular rod-sealing system that lets users mix and match materials and configurations depending on their application. The seals work in high-pressure, high-temperature environments with fluid and chemical contact.

A new low-temperature polyurethane stops the oil leak and boosts the crane's productivity. The material, called 92 AU 21100, has viscoelastic behavior that lets it stay flexible over a wide range of temperatures. It has elastic behavior at temperatures as low as -50°C but resists extrusion at high pressures and temperatures up to 100°C. Operators have reported no leaks after seal installation in 2006.

Semiconductor seals

Instead of meteorologic concerns, economics and quality are driving the semiconductor industry. For seal engineers, the challenge is maintaining the precision and consistency semiconductors require in the face of extreme fab environments that include plasmas, acids, and solvents.

Each stage of the semiconductor chip-fabrication process has its own temperature and chemical requirements. At the same time, the precise nature of semiconductor work means any components must not generate particulates or volatile gases.

The most-severe processing regimes require sealing materials like FFKM that can resist both high temperatures and noxious chemicals. Fluorocarbons may be suitable for less-aggressive chemical environments, while perfluoroelastomers resist chemical attack at lower temperatures.

During semiconductor manufacturing, wafers often enter processing chambers, undergo an operation, and then exit. The chamber doors open and close using slit valves sealed with bonded gates. Through a customized manufacturing process, Simrit bonds FFKM, fluorocarbons, perfluoroelastomers, and other materials directly to process chamber gates. The seals' engineered profiles allow for less movement, ensure position, reduce installation problems, and extend service life.

The seals' unique cross sections cushion metal-to-metal contact and eliminate rolling, twisting, and abrasion that can lead to substrate-metal particle contamination. The bonded-seal gates also prevent seal "pop-out" when the gate is actuated to transfer product.

In another example of extreme semiconductor sealing, magnetic-fluid vacuum seals use magnetic force to keep a fluid in a specific position around a shaft. The suspended fluid acts as a high-performance, low-friction, rotary seal for fluids and gasses that resists high temperatures and minimizes contamination.

Sealing up energy

While semiconductors were considered the wave of the future 20 years ago, today's innovations often center

TYPICAL PHYSICAL PROPERTIES	SIMRIZ 498	E454	E458	AU 9250	AU U641	AU UH05	G928 HNBR	92 AU 21100
Specific gravity	1.95	1.2	1.2	1.17	1.18	1.14	1.33	1.18
Hardness (Shore A)	78	83	82	92	94	95	85	92
Modulus (elongation), psi	1,520 (100%)	1,378 (100%)	2,153 (100%)	2,000 (100%) 3,500 (300%)	1,885 (100%) 2,850 (300%)	2,567 (100%), 4,351 (300%)	1,930 (100%)	1,261 (50%) 2,277 (300%)
Tensile strength, psi	2,650	2,775	3,344	6,500	6,450	6,816	2,940	7,832
Elongation at break, %	161	151	151	420	350	440	197	770
Compression set, (duration @ temperature, % squeeze), %	19.5 (70 hr @ 230°C) 40 (70 hr @ 316°C, 25%)	4.4 (22 hr @ 121°C)	4.4 (22 hr @ 121°C)	22 70 hr @ 80°C) 54 (70 hr @ 100°C) 74 (70 hr @ 110°C) 99 70 hr @ 120°C)	31 (70 hr @ 80°C) 43 (70 hr @ 100°C) 53 (70 hr @ 110°C) 94 (70 hr @ 120°C)	30 (70 hr @ 80°C) 42 (70 hr @ 100°C) 50 (70 hr @ 110°C) 69 (70 hr @ 120°C)	6 (70 hr @ 100°C) 19 70 hr @ 120°C)	25 (22 hr @ 80°C) 43 70 hr @ 100°C)
Low-temperature retraction stretch (% stretch, % retract), °C	0 (75%, 10%)	-55 (75%, 10%), -30 75%, 70%)	-55 75%, 10%) -30 (75%, 70%)	-29 (75%, 10%)	-18 (75%, 10%)	-27 (75%, 10%)	-22 (75%, 10%)	-57 75%, 10%)

Sealing engineers choose different materials based on design requirements. Here are some commonly used sealing materials that work in applications from aerospace to hydraulics to alternative energy.

around alternative energy capture and use. Seals keep systems from wind turbines to photovoltaics to solar-to-steam modules running.

In addition to sealing some of the largest mechanical components currently manufactured — such as the giant rotating blades of wind-power plants — seals for the drive systems, bearings, and hydraulic braking and pitch-adjustment systems have to work over a wide temperature range and resist ozone, humidity, salt spray, and hydraulic oils. Additionally, the proprietary elastomeric seals need uncompromising functional reliability to prevent difficult and costly unplanned maintenance at isolated turbine sites.

In another extreme arena, sealing components play a critical role in solar "smart" energy-conversion systems, such as thermal collectors and photovoltaic modules. These applications demand tough sealing components that resist exposure to weather and extreme temperatures.

Thermal energy boxes at the heart of heat-collection systems usually have a lid with a seal and a lower enclosure that houses connections. The seal must keep out moisture, dust, and other undesirable elements, while also meeting production tolerances for the lid and enclosure. Compensating for the minimum and maximum tolerance with O-rings would lead to high insertion forces, and to best use the available space, designers have had to use smaller-dimension seals.

Simrit engineers designed a custom, multilip, radial seal using liquid silicone rubber that resists the elements, is thermally stable, and is slow to age. The unique seal shape was optimized via finite-element-analysis computer simulations.

Thermal-energy-box customers had the option to injection mold the silicone seal onto the thermoplastic lid material in a single production step, joining the parts permanently. In addition to meeting the needs of the application, the final one-part seal design simplified customers' assembly, logistics, and installation.

Although photovoltaics often come to mind when solar power is mentioned, solar water heating may make better use of the sun's energy. One renewable-energy company's solar water heater uses evacuated-tube collectors. The design has a vacuum space inside an evacuated tube to improve energy efficiency with higher operating temperatures and pressures.

Sealing the connection between the round tubes and the connector housing proved to be technically challenging. The project called for a new sealing design that could keep out water at temperatures over 200°C and pressures of up to 8 bar while being easy to install.

The circumferential seal had to keep air from the heat-transfer medium. Simrit's material and seal specialists, along with customer engineers, developed a patent-pending sealing system using Simrit 70 EPDM 291 elastomer material. The material has very-low relaxation even after thousands of hours in water at 200°C, good thermal stability, low long-term compression set, and resists high-pressure, ozone, and UV attack.**MD**