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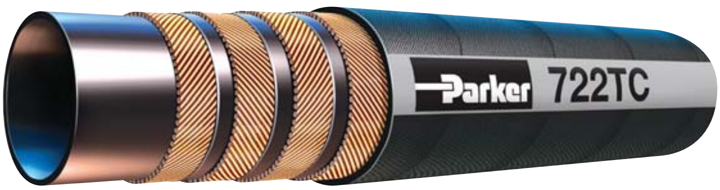
In This Issue

FEATURES


34

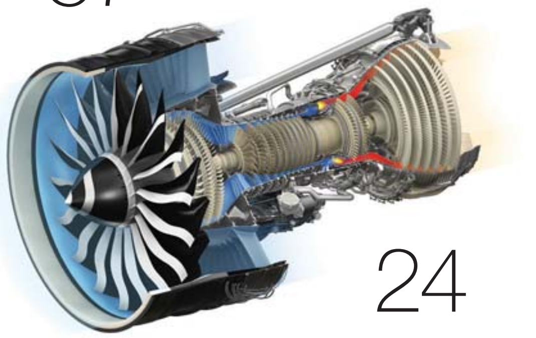


42


57

DEPARTMENTS

COLUMNS


24

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7 COMPANIES REDUCING CARBON EMISSIONS

http://machinedesign.com/manufacturing-equipment/7-manufacturers-committing-reducing-carbon-emissions

The U.S. Department of Energy (DOE) announced its second round of funding for the Technologist in Residence Program within the Clean Energy Manufacturing Initiative. Seven partnerships originated from the pilot program launched in September 2015. The DOE invested $400,000 per team to be used over the course of two years, an investment matched by its partner companies. This gallery offers a glimpse of what lies ahead with each of these partnerships.

WHAT ARE THE DIFFERENCES BETWEEN SPRUNG AND UNSPRUNG WEIGHT?

http://machinedesign.com/springs/what-are-differences-between-sprung-and-unsprung-weight

“Sprung” and “unsprung weight” are terms that are applied usually to automotive and truck suspension, though they are also applicable to any vehicle that travels on land and uses some form of suspension, such as trailers and construction equipment. Here, we look at the differences between the two.

WHERE HAS ALL THE TV SCIENCE GONE?

http://machinedesign.com/blog/where-has-all-tv-science-gone

Machine Design Tech Editor Carlos Gonzalez recalls in his latest blog how science television shows of his youth helped lead him to science-based education and, eventually, a career as an engineer. Those were the days of programming like “Bill Nye the Science Guy” (pictured above) and “Mr. Wizard.” As Carlos asks in his column, “Who are the current science role models of today and where can we turn to for science programming?”

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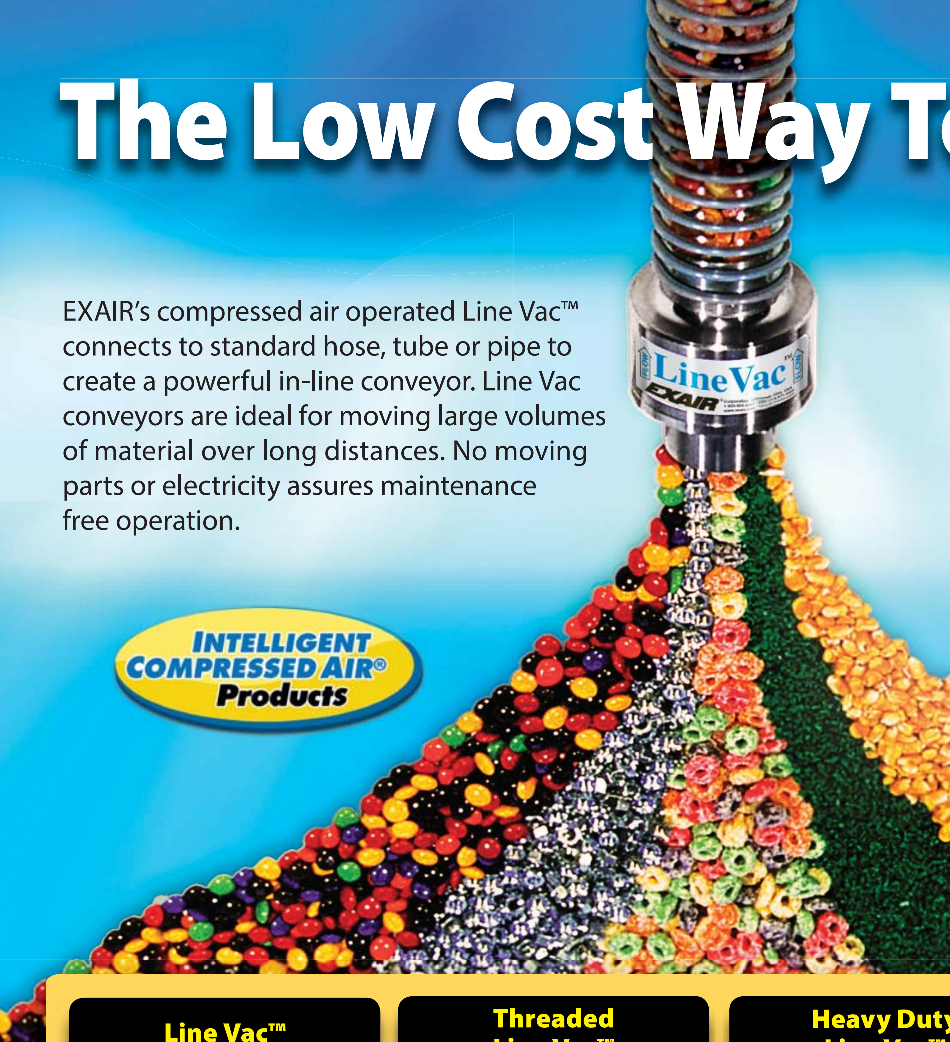
NASA EXPLORES SUPERSONIC AIRLINER—OR IS IT A SPY PLANE?

http://machinedesign.com/blog/nasa-explores-supersonic-airliner-or-will-it-be-spy-plane

NASA is making moves to start work on a new X-plane, a half-scale flying version of a supersonic airliner. Named the QueSST (for Quiet Supersonic Technology), it will be designed and built by engineers and technicians at Lockheed Martin, GE Aviation, and Tri Models Inc. While prototypes won’t begin flying until around 2020, Tech Editor Steve Mraz wonders whether the QueSST project will eventually lead to a new high-speed, manned spy plane.

The Low Cost Way To Convey!



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Editorial

STEPHEN MRAZ | Senior Editor
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Four Reasons Companies Are Bringing Manufacturing Back to the U.S.

The trend to outsource manufacturing began right after China joined the World Trade Organization at the end of 2001, and that is precisely when a large number of U.S. firms took their plants and went overseas, mostly to Asia. They told the press they were having a dickens of a time competing against China's lower labor costs when quota restrictions (aka trade restrictions) on goods entering the U.S. were phased out on certain products in 2005. Seems they couldn't hack free trade.

The overseas low-cost, no health-care labor forces had U.S. managers drooling and soon other U.S. industries—such as IT and services—jumped on the outsourcing bandwagon. They hightailed it to India and the Philippines based on the large number of English-speaking, relatively highly skilled workers there.

There was always a concern that companies would outsource engineering. And some—mostly software companies—did.

But after a decade of significant offshoring, the cost savings American firms had chased began to erode. Labor and transportation cost increased, eating into much of the savings manufacturers had previously enjoyed. And many companies uncovered the hidden costs a few consultants warned about.

Some of these hidden costs that were not always considered include the increased costs of monitoring and quality control, uncertain protection of intellectual property, and lengthy supply chains. As a result of increasing costs and other factors, some manufacturing has already begun returning to the U.S. This act of returning manufacturing, IT, and service jobs to the U.S., termed "reshoring," is due to several factors, none of which can be called patriotic or compassionate. They're just concerned about their bottom lines.

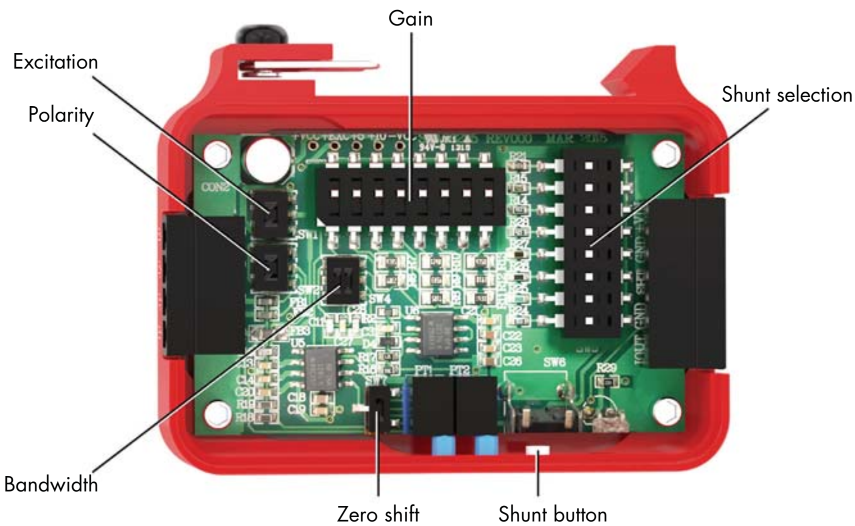
The Boston Consulting Group (BCG) studied 10 years of data (2001 to 2014) from the 25 countries that account for nearly 90% of the world's exports of manufactured goods. It wanted to understand the economics driving global sourcing decisions. The group found that manufacturing wages, exchange rates, labor productivity, and energy costs significantly affect manufacturing location decisions. These four factors also improved in terms of cost competitiveness in the U.S. over those 10 years. md

For more details on these four reasons, check out http://machinedesign.com/blog/4-reasons-companies-are-bringing-manufacturing-back-us.

What's Inside

Dual-Power-Level Amps Target Strain-Gauge Sensors

GENERAL-PURPOSE ANALOG AMPLIFIERS recently developed by FUTEK enable inline amplification for full-bridge, metal-foil, strain-gauge-based sensors. The IAA100 and IAA200 have up to a 10-millivolt per volt output (mV/V), built-in DIN-rail clips (DIN stands for the German industrial standard "Deutsche Industrie Norm"), and removable screw terminal blocks on the input and output.

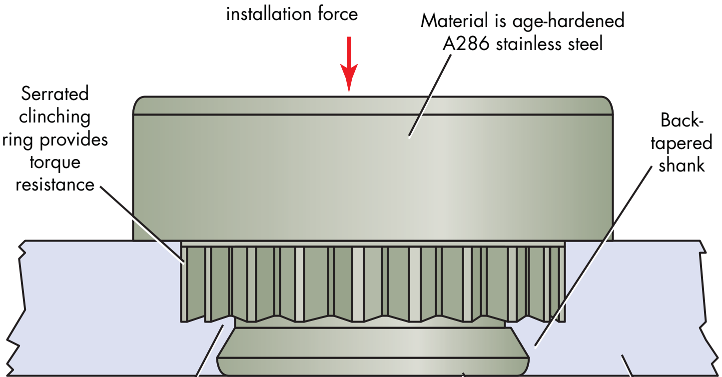


Inside the devices are eight dual-inline-package (DIP) switches for shunt selection. The DIP switches allow up to 256 different shunt values to simulate measurements at various points across a strain gauge in order to verify that the sensor meets specifications.

Bandwidth is adjustable to 1, 10, or 25 kHz for both the IAA100 and IAA200. They include two levels of power delivery to sensors; a switch can change the polarity of the output signal. The amplifiers are RoHS-compliant and Conformite Europeene (CE) approved. They meet the CE Criteria A Certification—showing no change in performance while operating as specified by the manufacturer—used in aerospace and medical-grade devices. md

Self-Clinching Nuts Leave Minimal Footprint on Ultra-Thin Stainless Steel

THE NEW SMPP self-clinching nuts from PennEngineering, which install permanently in ultra-thin stainless-steel sheets (as thin as 0.025 in.), are well-suited for stainless-steel assemblies that have limited space for attachment hardware. They can also be installed close to the edge of sheets. Once installed,



the nuts maintain a low profile (0.065 in.) and a small diameter (down to 0.22 in.). They are constructed from age-hardened A286 stainless steel and can be used in stainless-steel sheets with hardness of HRB 90 / HB 192 or less. Thread sizes accommodate mating hardware ranging from #2-56 through #6-32, and M2.5 through M3.5. md

News

Resort Makes SUSTAINABLE CHANGES to Its Daily Grind

Just how many resources does a Vegas casino and resort go through a day? Mandalay Bay puts forward its best reduce-reuse-recycle policies to improve its sustainability.

Those visiting the Waste Expo, which once again takes place in Las Vegas this month, can take advantage of a complimentary tour of the Mandalay Bay Resort and Casino, which features the second-largest solar-panel farm in the entire world and the largest in the nation. The tour also will highlight numerous changes made to the facility's waste streams, services, and infrastructure to reduce, reuse, and recycle most of its resources.

The second-largest solar farm in the world comprises 27,324 panels and spans 28 acres. It supplies 26% of the Mandalay Bay Resort and Casino's energy.

SOLAR FARM

The solar farm exploits the intense Vegas sun that shines on the roof of the resort, producing impressive energy-saving specs—but still not enough to break even. Annual power savings equate to the power of up to 1,300 standard homes, reducing its carbon footprint by up to 6,300 metric tons every year. That's equivalent to removing over 1,300 cars from the road.

Though these specs sound impressive, the panels only supply 26% of Mandalay's energy. The casino still gobbles up enough power for 3,700 homes every year, with carbon emissions remaining high. And, as pointed out by Brian Merchant in Motherboard, less advanced energy sources line the entire strip, using the limited water resources in the desert. However, Mandalay Bay claims that casinos only use 7% of the valley's water supply.

SAVING ITS RESOURCES

Meanwhile, uneaten food goes to local farms to be boiled down as feed for livestock, grease-traps are harvested for biodiesel fuel (1,089 tons per year), and 64 tons of waste are sorted for recycling. The convention's recycling rate for conventions is 80%; not including water and property recycling (like carpets and wood), it's 40.38%. Eight tons of mattresses are recycled each year, too.

Mandalay Bay also introduced a "sustainable menu" this past year. All wine is organically produced, and corks by the thousands are recycled and reused. Only glassware and china is used to serve food rather than plastic, unless it is requested;

Continued on page 15

Messy Wires?

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Continued from page 12

glassware is always recycled. The resort also made the switch to 100% craft cardboard for boxed lunches.

To reduce electricity, the resort replaced 225,000 incandescent lightbulbs with compact fluorescent LED lamps, and 281 slot machines are retrofitted with LED lighting.

Mandalay Bay also supports local charities with clothing and other unused resources. These include Three Square, Lied Animal Shelter, Big Brothers Big Sisters, Vietnam Veterans, Salvation Army, Las Vegas Rescue Mission, Greener Las Vegas, Catholic Charities, Calvary Chapel, Family Promise, Deseret Industries, Culinary Academy, Teachers Exchange, Opportunity Village, Habitat for Humanity, Humane Society, and Clark County School District. All clothing is sent to second-hand stores to be laundered and sold. Finally, old linens are reused as rags for cleaning and polishing. These "Linen Reuse" programs have reduced annual water usage by more than 100 million gallons, which is enough to fill its Shark Reef Aquarium almost 63 times. Reusing resources also reduced trash hauls by 33% last year.

Regarding the Shark Reef Aquarium, the resort uses recycled waste water to fill 90% of its 1.6-million-gallon capacity. This results in over 2.1 million gallons of reclaimed water per year. Variable-frequency drives are installed on all major water pumps to reduce their power usage by 25%. ■

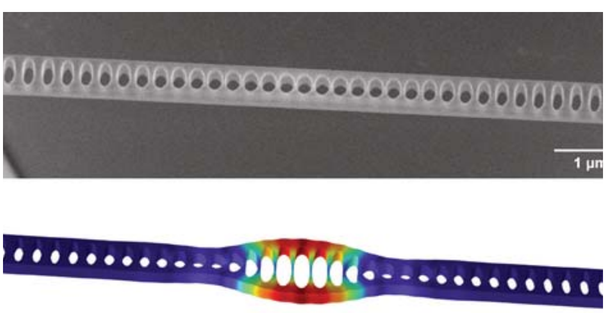
FINALLY, AN ATOMIC Standard for Temperature

In 2014, after a decade of development, the National Institute of Standards and Technology (NIST) presented the world with the most accurate clock known to science. The atomic clock measures the vibrations of cesium atoms to give our automatic time-telling gadgets, such as cell phones, a precise standard for setting the time.

Today, at an American Physical Society meeting in Baltimore, the organization presented a system that precisely measures the vibrations of silicon-nitride molecules in response to changes in temperature, ranging from cryogenic to room temperature. The effort may lead to high-accuracy temperature readings in extremely sensitive lab applications and industry procedures.

The method employs a beam of silicon nitride with small reflective cavities. The scientists directed a laser through a thin crystal beam, and measure the changes in reflected wavelength, which they could directly relate to the picometer-scale thermal vibrations.

But what makes the method so dependable is the scientists' ability to calibrate the thermal vibrations to fluctuations in electron spin, which remain constant independent of temperature. Since both vibrations are measured using the same laser, any measurements that indicate changes in quantum vibrations would also indicate an error in the readings for thermal vibration. ■



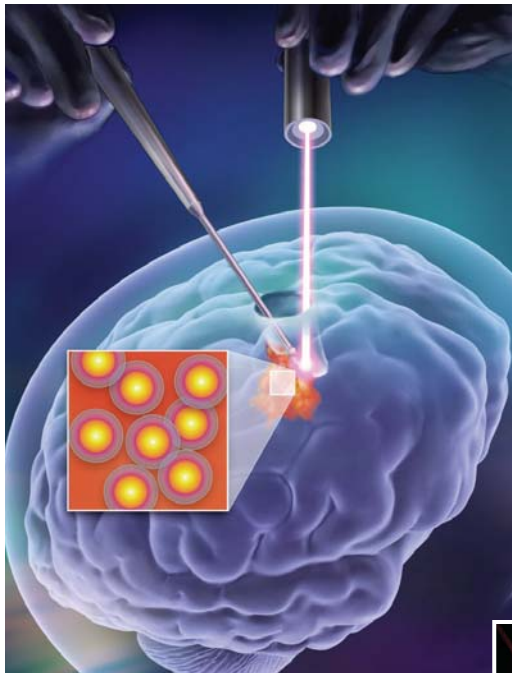
The method can produce highly accurate temperature readings by calibrating the thermal vibrations of silicon-nitride molecules against the intrinsic vibrations of electrons, which are a direct result of the uncertainty principle.

BIOMARKERS LIGHT THE Way to Detailed Brain-Tumor Images

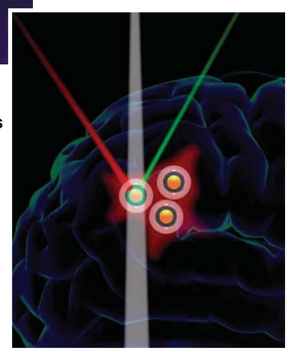
SCIENTISTS AT MEMORIAL Sloan Kettering Cancer Center's Kircher laboratory have developed a biomarker that adsorbs exclusively to the surface of cancerous cells in brain tumors. The technology is described as "theranostic" because the nanoprobes can be used for therapeutic purposes (surgery) as well as diagnostics, even in the early stages of cancer.

"We hope our technique will be helpful in showing surgeons exactly where the borders of the tumor are located," says Dr. Moritz Kircher, who heads the lab. "It may also be useful in finding cancer cells that have spread away from the primary tumor site." Kircher expects the study to lead to complete removal of brain tumors.

The nanoprobes have successfully been used in mice to generate high-resolution images of brain tumors using surface-enhanced Raman spectroscopy (SERS). The report, published in *Nature Magazine*, claims that the SERS nanoprobes enable detailed imaging down to the tumor's finger-like projections, which extend into the healthy tissue of the brain.



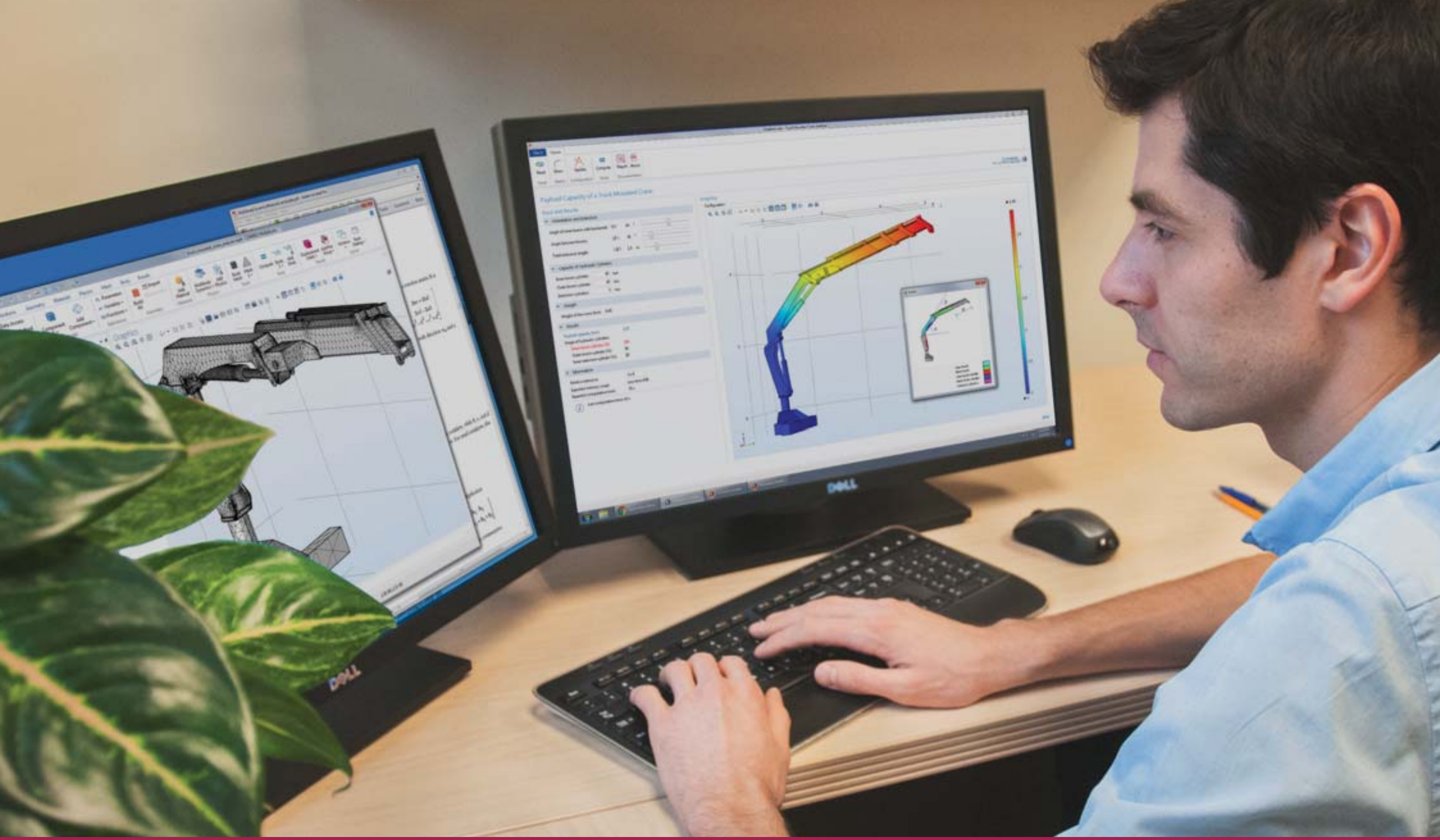
Active biomarkers adhere to individual tumor cells, and are hit with monochromatic light (red). Due to Raman scattering, energy is lost so that the reflected light has a longer wavelength (green). The active state of the biomarker determines the reflected wavelength so that a highly detailed image of the tumor can be produced.



Upon excitation by incident light, electrons jump from their ground state to higher quanta. Unlike Raleigh scattering (red), Raman scattering is inelastic; energy is lost to the system and the electrons emit of a longer-wavelength photon (smaller ΔE) as the electrons fall back to a higher energy state than ground.

The nanoprobes are injected intravenously and bind to the tumor cells for imaging. They contain a layer of Raman-active material that, when hit with monochromatic light, emits light at a photonic wavelength longer than that of the incident light. The reduction in energy is due to inelastic scattering, or the loss of energy to interatomic vibrations. An extra layer enhances the signal so that the wavelength of emitted light can be processed by a computer database. The strength and orientation of the molecular bonds can then be determined to enable extremely precise and accurate imaging of the brain tumor at the molecular level.

Since the nanoprobes remain on the cells for a few days, they can be used for imaging before and during the surgery. They also can be excited by a light source to generate heat and, in turn, destroy malignant cells that cannot be removed surgically. They do not interrupt whole-body imaging techniques like MRI, PET, or CT, and are compatible for photoacoustic imaging to enable deep-tissue localization during surgery. ■



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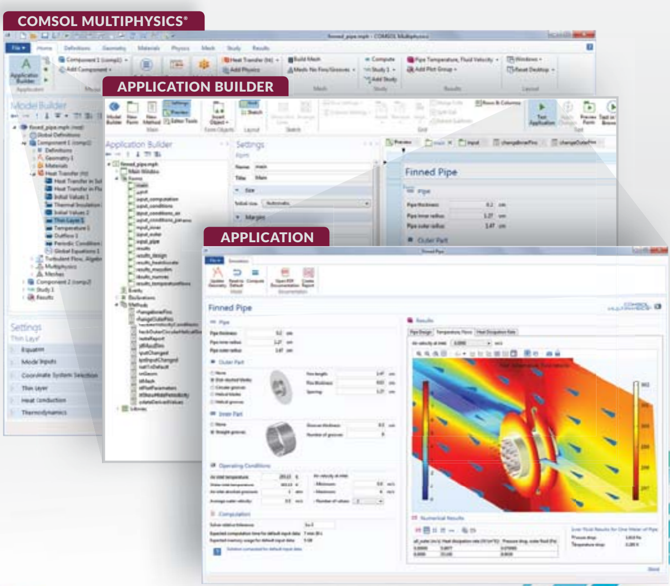

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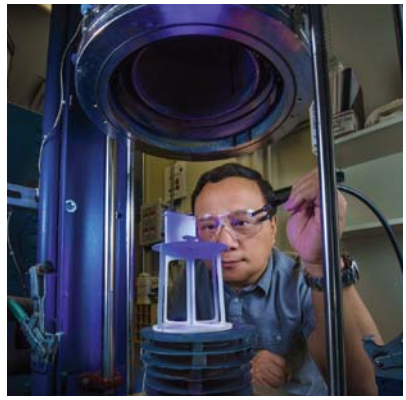
HERMETIC-SEAL RESEARCH SOLVES Glass-Ceramic/Stainless-Steel Interface Issues

STAINLESS STEEL'S RESISTANCE against corrosion makes it a popular housing material for devices that need to survive harsh environments. Although electronics may be fully insulated, usually with a glass or ceramic, it is important to hermetically seal the interface between the housing and electronics to prevent shorts caused by accidental contact. At Sandia National Laboratories, Steven Dai leads an investigation to develop a failsafe seal between stainless-steel housing and insulators made of ceramic-glass. Their final goal is to achieve a processing method that can be used in wide-scale manufacturing.



Steven Dai is leading an investigation to build a hermetic seal between glass-ceramic and stainless steel.

A range of methods may be applied to create a seal between glass-ceramic insulators and metal housing. But most (e.g., powder soldering) require heat, which is problematic because glass-ceramic and metal have inherently different coefficients of thermal expansion, and glass-ceramic is brittle. When developing a bond between the two, the relatively rapid expansion of stainless steel can stress glass-ceramic to the point of shattering. Dai's team carried out a range of experiments, manipulating the changes in processing temperatures to better match the crystalline phase changes of glass-ceramic to the metal's rate of thermal expansion.

Dai's team eschews a powder-soldering method for their own simpler method that has less intermediate steps. They doped the glass-ceramic with an oxidizing agent that, under heat, releases oxides at the interface to react with the chromium in the stainless steel (note: stainless-steel alloys may be made of iron, chromium, nickel, manganese and copper). The reaction gradually builds a strong bond at the interface.

Dai and his team tested 24 different oxidants in the glass-ceramic samples.

TV-SHOW-INSPIRED WEBSITE CULTIVATES STEM Experience

PBS'S *DESIGN SQUAD*, a television series repurposed into an interactive website, now includes *Design Squad Global* (DSG), where kids from all around the world can share engineering and STEM ideas. DSG expands cross-cultural understanding among participants and raises awareness about global issues that are solvable using available resources. Geared toward parents, educators, and kids ages 8 to 13, the redesigned site is supported by the National Science Foundation and the Lemelson Foundation.

Visiting Design Squad Global, I found myself having a lot of fun. The videos were funny, informative, and applicable. The site also provides a range of games, such as *Don't Flood the Fidgets,* a flood-prevention simulation in which players need to invent ways to use less water.

One of the most impressive features of the site is the expanding library of creative DIY projects. Those taking part in the projects use everyday items and tools to build functional end products or parts that demonstrate fundamental physics or engineering concepts. Featuring clear step-by-step instructions with pictures for easy, medium, and hard projects, the projects can also be extremely useful for STEM educators.

Furthermore, Design Squad Global has a newsletter so that parents and educators can stay up to date on new videos and projects.

The executive producer of this new online hub explains, "There is a growing awareness that technical skills alone aren't enough to compete in a global economy. The call for equipping young people with what's needed to live in today's world—defined by the digital revolution and unprecedented human migration—is dominating education today, *Design Squad Global* is meeting that call." ■

They determined the two best performers of the group and continued to test different heating processes that would linearize the thermal expansion of the glass-ceramic. Instead of step-like strain changes as the glass-ceramic changes crystalline phases, the team worked to closely match it to the expansion rate of stainless steel.

"We need to learn that part of the process to make sure that we have a good balance of all the phases, have them all crystallize in the right sequence and ideally in the right proportion," says Dai.

A provisional patent was filed in November for the interfacial bonding oxides. Finding a repeatable processing method will lead to a new generation of seals between the two highly different materials for applications ranging from fuel cells to aerospace applications. ■

Interview
JEFF KERNS | Technical Editor

A Technology Talk with Marc Tarpenning

The Co-Founder of Tesla Motors and several other technical startups provides insights both from the engineer and founder perspectives.

Can you tell me a little bit about your background?

I'm a bit of a creature from Silicon Valley. I have started several companies, but I guess the most known is Tesla Motors. I like the startup life; the high stakes can really push you to find new creative solutions. Throughout my career I moved from engineering, management, finance, to founder. That I found to be an interesting transition.

The Husky unmanned ground vehicle is a research device capable of navigating various environments, while a sensor or sensor package sits on top to collect desired data.

You recently joined the technical advisor team at Clear Path Robotics; can you tell me a little about why you made this decision?

They have a bunch of products that I kept running into, so I already knew who they were and liked what they were doing. For example, one product they make is a little four-wheel robot about the size of a lawnmower that a researcher could program to drive autonomously in an area while avoiding obstacles. The user would have a sensor package on top to collect whatever data it is they were collecting. It didn't have a specific application; it was just to send your sensor packages remotely through different environments. I thought this was interesting and, of course, they have expanded this to other products. So, as I was already interested in Clear Path's work, I was receptive when they approached me about this opportunity.

What role do you feel robotics and the industrial Internet of Things (IIoT) will play in changing manufacturing, and/or the way we do business?

The amount of labor per unit of production has been dropping over time. There was a period of brute-force automation in the 1960s through the '80s. It involved very expensive upfront cost for custom machines to make everything from detergent packets to ice cream cones. Back then, everything seemed very mechanical. There wasn't a lot of focus on electronics or software. More recently, the electronics have been allowing more flexibility, options, and quality control. For example, robot welding can make a perfect weld each time. You could even have a second machine verify that each weld meets a quality standard. The goal of using equipment or tools in general is to produce a better product—not necessarily replace workers or take jobs.

Today, the real change is the ability to make smaller-scale production lines using robots that never would have made economic sense before. You don't have to outsource or look for cheap labor because it doesn't take millions of dollars and months of labor to install and program some of the modern equipment. I think these new machines are only starting to change the way we do small-scale production, and a lot of production is small-scale.

Will the industrial Internet of Things, collaborative robots, and other innovations reduce jobs?

I believe strongly in the manufacturing capabilities of the U.S. Speaking with an entrepreneur [who] was moving production to his home state, he told me that it isn't like things were in the past. We aren't going to be starting factories with 100 workers running two shifts. He had to rely heavily on automation in order to be able to bring this production line to his home state.

Therefore, we might have fewer workers on a line, but with smarter equipment, we might start to see some products return and new products stay in the U.S. I think the smaller niche products don't matter as much, what the labor rates are...it matters where the supply chain is. Unfortunately, we managed to transfer a lot of our supply chain to Asia. It will

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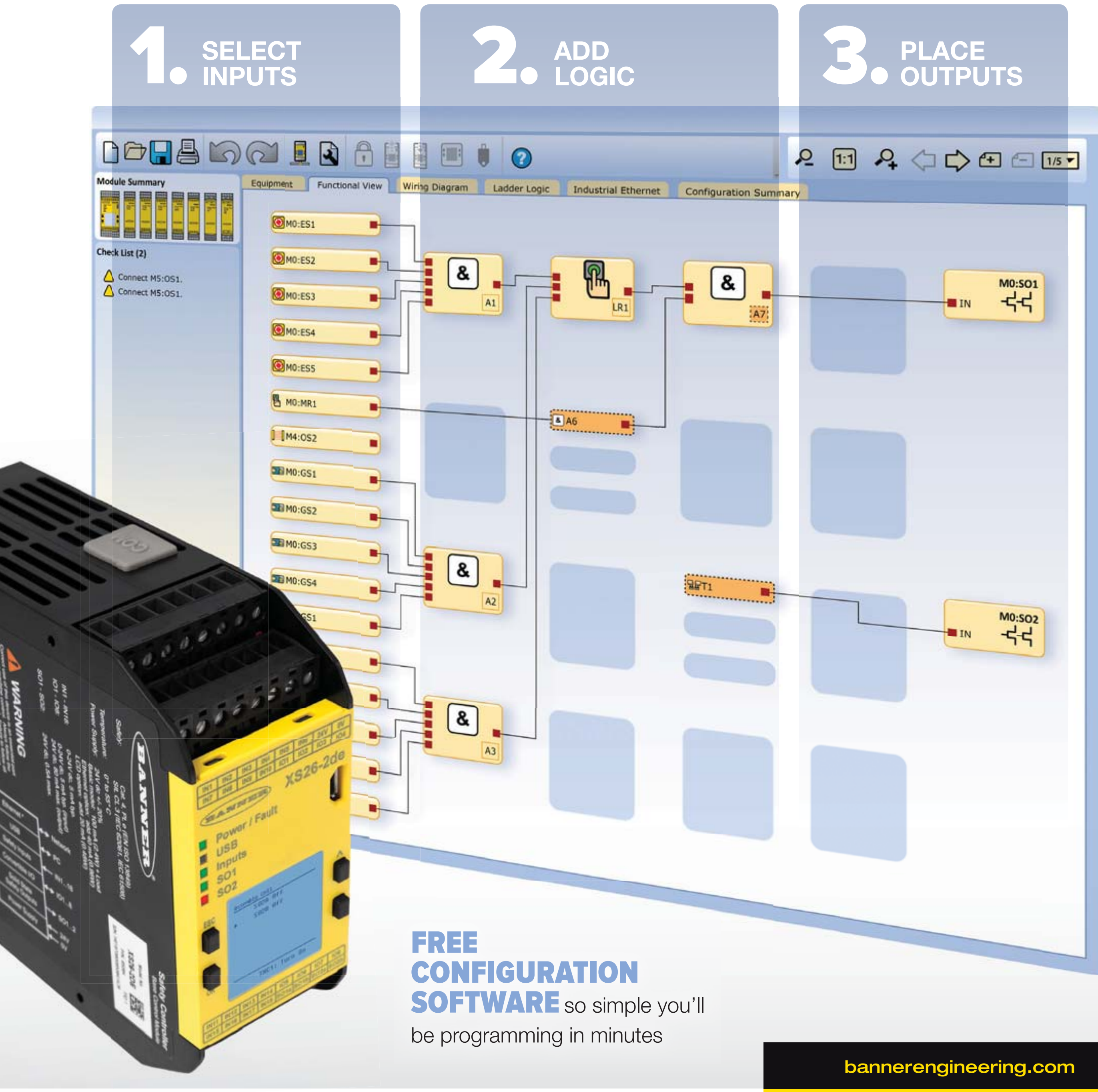

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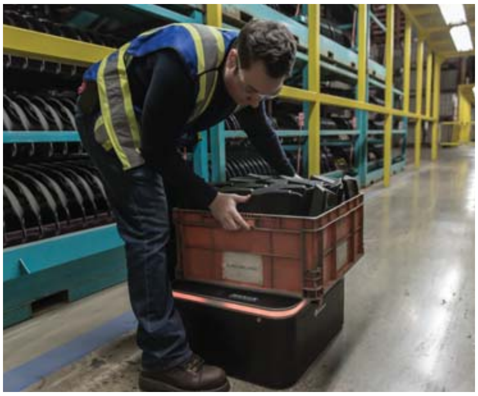
be tough to get that back, but I think that automation and robotics are the only way we can compete and keep improving our labor-to-production value. So there might be fewer people on a production line, but due to the economics, without technology that line wouldn't exist.

One example we can take from history is Luddite from the early 1800s—a band of English workers that destroyed machinery when they thought the equipment was threatening their jobs. In addition, at this time there were reports saying that it would be impossible to get more than 20% of population off the farm because you can't grow enough food for everyone. Today, the U.S. has about 1% of our workforce on the farm while producing enough food for our country and more. The only way we get richer as a society is to improve our productivity, and we have always used technology to leverage that productivity.

It seems over time we have heard these doomsday scenarios that when technology replaces workers, it's the beginning of the end. However, we have seen just the opposite. Now the individual worker might be displaced and have a hard time finding a new occupation. Unfortunately, revolutions don't necessarily affect everyone equally, but society as a whole has improved.



OTTO 100 is a smaller version of the 1500 that works well as a self-driving robot for the e-commerce and manufacturing distribution industries.

Are there specific technologies or trends you see gaining traction in robotics?

Artificial intelligence (AI) and machine vision have underdelivered for 30 years. Recently, however, we have been able to use AI and machine vision, and we will see more of this technology as time goes on. Machine vision specifically is picking up—in food-sorting devices, automated driving sensors, and other applications. A robot with the ability to observe, notice changes, etc., is a big deal and will continue to be.

In terms of sensors, the motion and orientation sensors (such as gyroscopes) have added degrees of perception that haven't existed, in an affordable way, until recently. Light detecting and ranging equipment, called LiDAR, can now be in a solid state and inexpensive. Instead of spinning mirrors, you can have a cost-effective, small widget you solder directly on the circuit board. In addition, these big changes in sensors don't rely on a computer's infrastructure. They are working at the fingertips or business end of the machines. I feel machine vision will be one of the technologies that bring robots closer to working among us.

What do you feel are the key components to focus on going forward with robotics, and what technologies will provide the foundation for smart cities?

I am not necessarily a smart city or IoT expert, but in general, the more you instrument, the more you learn about how things are working. The ability to monitor everything will lead to things becoming better, and I think it will happen in an organic way. For example, if the water company releases sensors to find water leaks, they will receive more data. Over time, they might see other patterns in the data, or that the sensors could provide more value. Perhaps it is possible to use the data to predict water demand, or electric usage. In short, there will be many interesting things happening in this area.

In addition, I think of automated driving as an attractive computer-science problem. For example, there are short trips on well-mapped roads traveling at 25 mph, and then there are long highway road trips that might have different weather and speeds. I think it will be easier to solve and implement self-driving vehicles for these shorter transportation needs where they are constantly going to similar destinations on familiar streets. Ultimately, it is going to be interesting to see this technology as it evolves.

I heard you used to play the card game Magic the Gathering. Could you tell me a little more about startup life, and if you feel Magic has helped you become a more creative problem-solver?

I haven't played Magic for a long time, other than occasionally with my kids. As for startups, you really don't have any other options but to find creative solutions. In contrast, a large company probably has many products going on at once—so if your product doesn't launch on time, you might lose your job, but to the company it isn't an existential crisis. Generally, in a startup, everyone focuses on a single product or product line. If a product is not released on time, it could be catastrophic. There is a tremendous pressure to find creative and better solutions to your problems. In a startup, time-to-market is important, so it is quite fun and entertaining when you don't have that time and must be creative.

I don't know if Magic has changed my skills in problem-solving or creativity, but it does affect my dreams. I will still play with my kids sometimes, and when I play more, my dreams are more creative. That probably has some impact to the consciousness. md

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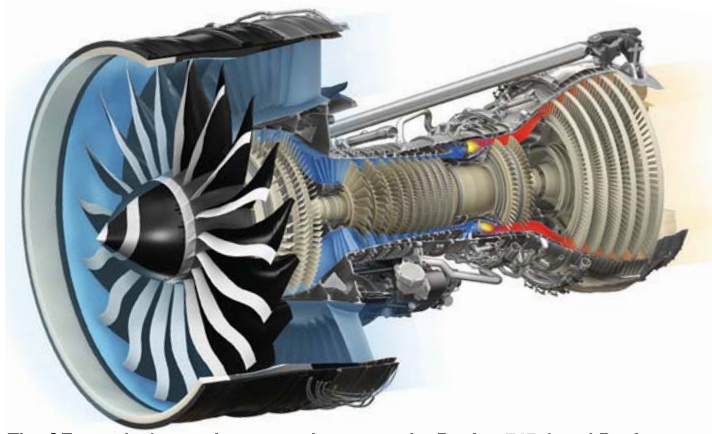
What's the Difference Between Turbine Engines?

Similarities exist in the basic composition of turbine engines ranging from turbojet to turbofan, but the differences are obviously stark in terms of delivery.

The gas turbine is one of the most widely used forms of propulsion systems for modern aircraft engines. The engine's core—defined as the compressor, burner, and turbine—is also known as the gas generator, since the output is hot exhaust gas. The compressor and turbine are defined as the turbomachinery, where the energy is added or extracted from the continuous flow by the dynamic and aerodynamic action of rotating blades.



The GEnx turbofan engine currently powers the Boeing 747-8 and Boeing 787 Dreamliner. The engine, which is 15% more fuel-efficient when compared to GE's CF6 engine, employs carbon-fiber composite fan blades and fan case for weight reduction. ***(Courtesy of GE Aviation)***

COMMON PARTS OF A TURBINE ENGINE

INLET

The inlet of the engine brings "free stream air" into the engine. The focus of an inlet is to decelerate the incoming air and convert its kinetic energy into static pressure.

- *Subsonic inlets:* Subsonic aircraft do not exceed the speed of sound. One can maximize the pressure rise by having either a longer diffuser or a higher diffuser divergence angle (diffuser area ratio).

The flow pattern for a subsonic inlet is divided into external (outside/upstream) and internal segments. External acceleration occurs for low-speed high-thrust operation (i.e., takeoff conditions), which raises the inlet velocity and lowers the inlet pressure. Hence, the inlet area is designed to minimize external acceleration during takeoff so that external deceleration occurs during cruising conditions. On a typical subsonic inlet, the surface of the inlet is a continuous smooth curve that has some thickness from inside to outside. The inlet lip or the highlight, the most upstream portion of the inlet, is relatively thick.

- *Supersonic inlets:* Supersonic aircraft are still required to slow down the flow to subsonic speeds before the air reaches the compressor. Air flow has a Mach number between 0.4-0.7 when it reaches the engine face. Flow diffusion from supersonic to subsonic flow, or "ram recovery," involves shocks. A normal shock inlet is the simplest supersonic diffuser. The shocks, which have a narrow inlet lip, are used for single normal shock (90° perpendicular to the flow) for Mach values less than 1.6.

Oblique shock inlets achieve higher total pressure recovery. Supersonic flow deceleration is achieved over a series of oblique shocks (a specific angle to the flow) followed by a weak normal shock. In an oblique shock, the supersonic flow is turned into itself; as the number of oblique shocks increase, the shock losses decrease, especially at high Mach numbers.

An axisymmetric external compression inlet is a cone-shaped diffuser that creates a conical shock. Due to the flow over the cone being inherently three-dimensional, the flow field between the shock and cone is no longer uniform. The effect results in a weaker shock wave than for a wedge of the same angle.

COMPRESSOR

Compressors are used to increase the air pressure before it enters the combustor.

- *Centrifugal compressors:* These compressors were implemented in the first jet engines, and are still used in turbojets and turboshaft engines. They turn the air flow perpendicular to the axis of rotation. The rotating impeller moves the air, which is collected in the scroll or volute. There may be a diffuser between the impeller and the volute.
- *Axial compressors:* Instead of a perpendicular flow, axial compressors flow the air parallel to the axis of rotation. The compressor consists of several rows of rotors and stators;

which are a series of air foils. The rotors are connected to the central shaft and rotate at high speeds, imparting angular momentum to the fluid. Stators, which are fixed and connect to the outer casing, increase the pressure while keeping the flow from spiraling around the axis by returning it to the parallel axis (acting as diffusers). Blade length and the annulus area decrease throughout the length of the compressor, reducing the flow area. This compensates for the increase in fluid density as it is compressed.

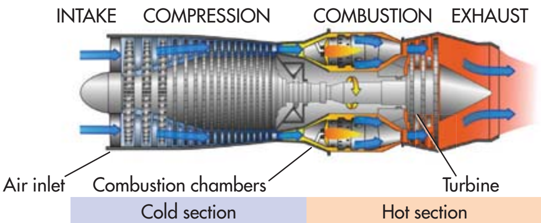
BURNER

The burner or combustion chamber sits between the compressor and turbine arranged like an annulus. Here the fuel is mixed with high-pressure air and burned to create high-temperature exhaust gas to turn the power turbine and produce thrust. A few of the desired properties of burners are complete combustion with minimum exhaust emissions, low total pressure loss, low heat loss from walls, effective cooling, proper temperature distribution exit, and operation over a wide range of mass flow rates, pressures, and temperatures. However, many of these properties compete with one another; hence, an optimal burner design is one of compromise.

• *Can-annular combustors:* Consisting of a series of cylindrical burners arranged around a common annulus, can-annular combustor chambers function independently of each other. At the entrance of each chamber is a diffuser that can reduce the velocity from a typical compressor outlet (100-150 m/s) to the bulk flow average velocity (20-30 m/s) in the combustion zone. It delivers the air to the combustion zone as a stable and uniformed flow field. This is an older design method for a burner.

• *Annular combustors:* This more modern design consists of a single burner with an annular cross-section that supplies gas to the turbine. The combustion zone itself occupies an annular space. The improved zone provides uniformity, design simplicity, reduced linear surface area, and a shorter system length.

JET ENGINE CROSS SECTION



This cross-section view of a typical jet engine shows sections divided into two areas: cold and hot. The hot section is when combustion occurs by adding fuel to the airflow provided by the intake of cold section.

TURBINE

A turbine is like a compressor in that it consists of several rows of rotors and stators. The turbine stage begins with a stationary blade row called the nozzle guide vane, which is followed by a rotating blade row. The turbine converts the thermal energy to kinetic energy by expanding through nozzles, and subsequently into rotational mechanical energy in a spinning rotor.

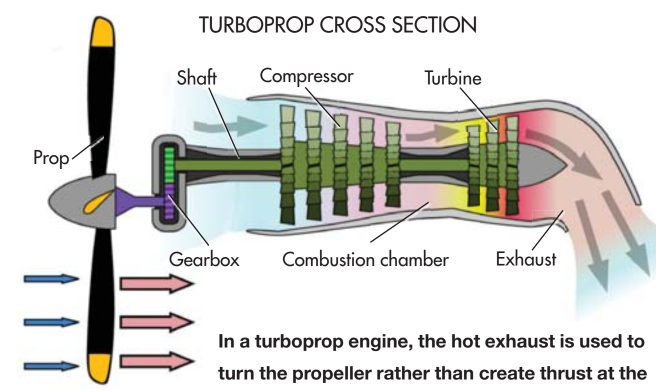
The flow in a turbine is dominated by favorable pressure gradients. Pressure changes can be quite large, and the boundary layers in a turbine are less susceptible to stall when compared to a compressor. Cooling of turbines is a major challenge; thus, they are designed to handle high temperature and corrosive environments.

NOZZLE

The function of the nozzle is to convert the thermal energy into kinetic energy in order to obtain a high exhaust velocity. The nozzle thrust, or gross thrust, is comprised of the momentum and pressure thrust. A maximized gross thrust is when the nozzle is fully expanded or the ambient pressure equals the exhaust pressure.

• *Subsonic nozzle:* To accelerate a subsonic flow, the cross-section of a duct must decrease in the stream-wise direction. When the duct ends at the smallest cross-section, the result is a converging nozzle. The pressure at the exit of the nozzle is lower than the atmospheric pressure. As a result, the flow accelerates or expands to the atmospheric or local exit pressure. The higher the aircraft flies, the more velocity increases accordingly to the lower ambient atmospheric pressure. A limit is reached when the jet discharges at sonic velocity and the nozzle is said to be choked. Once the choked condition is realized, the nozzle mass flow rate is at its maximum and the conditions remain unchanged regardless of the decreases in ambient pressure. Hence, a converging nozzle can never produce a supersonic flow.

• *Supersonic nozzle:* For high exhaust velocities required for supersonic flight, a converging-diverging (CD) nozzle is used to create supersonic exhaust velocity. The CD nozzle construction consists of a convergent duct followed by a divergent duct.



In a turboprop engine, the hot exhaust is used to turn the propeller rather than create thrust at the exit of the engine.

The cross-sectional area increase in the CD nozzle accelerates supersonic flow. A supersonic or CD nozzle requires a large pressure difference to accelerate the gas to a supersonic speed at the throat and further create supersonic flow in the diverging section of the CD. A significant pressure difference can be created by reducing the back pressure or the exit pressure of the surrounding downstream.

Adjustable nozzles allow a supersonic aircraft to match varying conditions of ambient pressure and engine power settings for supersonic flight. And altitude adaptive nozzles can change the shape of the nozzle lip angle for optimal performance.

A problem arises when the nozzle is over-expanded or under-expanded. In an under-expanded condition, the pressure falls across the expansion waves and the exhaust plume expands past the nozzle exit, reducing efficiency in high altitudes. For over-expanded nozzles, the pressure rises across the oblique shock waves and a mixture of sub/supersonic flow. The exhaust plume is pinched by high ambient-air pressure, reducing its efficiency in low altitudes. Over-expansion can produce regions of complex wave patterns in the plume, which create a white/yellow luminescent glow as the low exhaust gas pressure tries to match the high ambient pressure.

TURBOJET ENGINE

The turbojet is the simplest type of gas turbine. Large amounts of surrounding air are pulled into the engine inlet due to the compressor. At the rear of the inlet, air enters the compressor. Pressure increases as the air passes the rows of blades. At the exit of the compressor section, the air pressure is higher than the free stream. In the burner section, fuel is combined with the air and ignited.

For a typical turbojet, 100 pounds of air/sec is combined with only two pounds of fuel/sec. The hot exhaust comes mostly from the surrounding air and passes through the turbine once it leaves the burner. The turbine extracts energy from the hot airflow by making the blades spin in the flow. In a jet engine, the energy extracted by the turbine turns the compressor by linking it and the turbine to the central shaft. The rest of the hot exhaust

This image shows a Pratt & Whitney J58 on full afterburner. Shock diamonds appear in the plume of the engine. These are a formation of standing wave patterns caused by changes in density and pressure brought upon by shock waves.

is used to produce thrust by increasing its velocity through the nozzle. Since the exit velocity is greater than the free stream, thrust is created. Very little fuel is added to the stream, so the exit mass flow is nearly equal to the free-stream mass flow.

TURBOPROP ENGINE

The two main parts for a turboprop propulsion system are the core engine and the propeller. The core engine is very similar to a turbojet except for the way it handles the energy from the exhaust. Instead of expanding the hot exhaust through the nozzle to produce thrust, the turboprop uses most of the energy from the exhaust to turn the turbine. An additional turbine stage may be connected to the drive shaft, which in turn is connected to the gearbox. The propeller connects to the gearbox, which produces most of the thrust.

The thrust produced from the exhaust velocity is low because most of the energy from the core exhaust is used to turn the drive shaft. Turboprop (and turbofan) engines usually have a two-spool engine where a separate turbine and shaft powers the fan and gear box, respectively. Turboprops are used only for low-speed aircraft like cargo planes. Propellers become less efficient as aircraft speed increases.

TURBOFAN ENGINE

Modern airlines use turbofan engines to propel their airplanes through the air. This is due to their high thrust and fuel efficiency. The turbofan engine is the most modern variation of the basic gas turbine. In the turbofan, two fans surround the core engine. One fan is in the front of the core engine and the other is located in the rear. The fan and fan turbine are connected to an additional fan shaft. The fan shaft passes through the core shaft in a two-spool engine arrangement. To achieve higher efficiency, some engines have additional spools.

The turbofan operates by capturing incoming air in the inlet. Some of the air passes through the fan, into the core compressor, and then the burner. The heat exhaust passes the through the core, fan turbines, and out the nozzle. This process mirrors that of a turbojet. The rest of the incoming air is redirected around the engine after it passes the fan. The air passing through the fan has a slightly higher velocity increased from the free stream.

The ratio of the air redirected around the engine versus the air that passes through the core is known as the bypass ratio. Low-bypass-ratio turbofans are more fuel-efficient than the basic turbojet. A turbofan generates more thrust for nearly an equal amount of fuel used by the core because the fuel flow rate is changed by slightly when adding the fan. As a result, the turbofan offers high fuel efficiency.

The air passed through the core as well as the air passing around the engine comprise the thrust. The high bypass ratio of turbofans is as fuel efficient as turboprops. Due to the fact that the inlet encloses the front fan and incorporates many blades, it can operate more efficiently at higher speeds than a simple propeller. For this reason, turbofans are found on many high-speed transports.

AFTERBURNING TURBOJET ENGINE

Afterburners are used in supersonic aircraft like the Concorde, and are turned off after achieving cruising velocity. Many modern fighter planes use a low-bypass-ratio turbofan equipped with afterburners for efficient cruising conditions and to produce high thrusts for dogfights, and on turbojets to fly at supersonic speeds, overcoming the sharp rise in drag near the speed of sound. The afterburner injects fuel directly into the hot exhaust. The nozzle of the basic turbojet becomes extended and a ring of flame holders is installed after the nozzle. Additional fuel is injected through the hoops and into the stream of the hot exhaust. The burning fuel produces extra thrust, but at an inefficient rate.

The burning fuel offers a simple mechanical way to augment thrust, but at an inefficient rate. The thrust calculation is the same as a normal turbojet, except that the exit thrust value is the thrust exiting the afterburner. md

Thrust Equations

$$F_{\text{Turbojet or Afterburning Turbojet}} = \dot{m}_e \cdot V_e - \dot{m}_{FS} \cdot V_{FS}$$

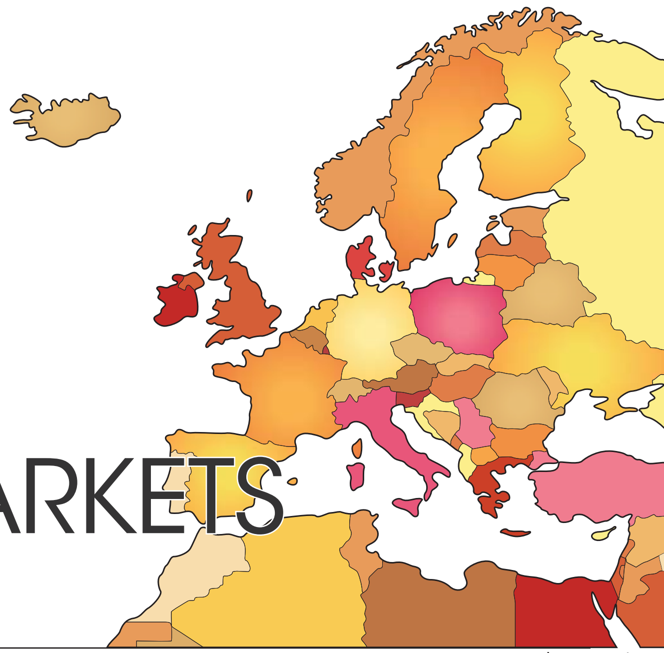
$$F_{\text{Turboprop}} = \dot{m}_{FS} \cdot (V_{Pe} - V_{FS}) + \dot{m}_e \cdot (V_e - V_{Pe})$$

$$F_{\text{Turbofan}} = \dot{m}_e \cdot V_e - \dot{m}_{FS} \cdot V_{FS} + bpr \cdot \dot{m}_c \cdot V_f$$

where:

$\dot{m}_{FS}$ = mass flow rate of the free stream of air
$\dot{m}_e$ = mass flow rate of air at the exit of the core
$\dot{m}_c$ = mass flow rate of the hot exhaust passing through the core
$\dot{m}_f$ = mass flow rate of the fan flow or bypass flow
V_f = velocity of air at the exit of the fan
V_e = velocity of air at the exit of the core
V_{Pe} = velocity of air at the exit of the propeller
V_{FS} = velocity of the free stream of air
V_e = velocity of air at the exit of the core
bpr = bypass ratio which equals $\dot{m}_f / \dot{m}_c$

VICTORIA FRAZA KICKHAM | Distribution Editor



AUTOMOTIVE, INDUSTRIAL MARKETS

Strong in Europe

Image courtesy of Thinkstock

Europe continues to drive growth in the electronics supply channel, as leading distributors of electronic components cite strong results across the region.

Electronic components distributors doing business in Europe reported strong results in 2015 that are continuing into 2016, as business investment across the region continues to pay off.

Reporting on its fiscal third quarter earlier this spring, Avnet Inc. said its electronic components business in Europe, the Middle East, and Africa (EMEA) grew for the 12th straight quarter, with strong sales in automotive and industrial business leading the way, according to Gerry Fay, global president of Avnet Electronics Marketing, the company's electronic components business unit.

"Our strategy around demand creation and automotive continues to pay off," Fay explains. "The region continues to perform quite well."

Avnet has a focus on lighting and the Internet of Things in Europe as well, Fay adds, which also contributed to strong growth early this year. Avnet EM grew 17% sequentially in Europe in the three months ended April 2, 2016, and saw more than 9% growth compared to the same period in 2015.

Fay also credits a smooth leadership transition at Avnet EM EMEA last year. Miguel Fernandez was tapped to lead the business in January 2015, taking over for Patrick Zammit, who was promoted to global president of Avnet's Technology Solutions business. "We had a solid leader running Europe, and we replaced him with another solid leader and he hasn't missed a beat," Fay says.

The industry's other mega-distributor, Arrow Electronics, is reporting strong growth in Europe this year as well. In May, the company reported global sales growth of 4% in its electronic components business, with Europe growing 9% year-over-year. Europe showed the strongest growth, although Arrow reported growth in all regions for the first three months of 2016.

Business in Europe continues to do "quite well" for Avnet Electronics Marketing, says Global President, Electronics Marketing Gerry Fay.

Growth in Europe and Asia is outpacing that of the Americas at Mouser Electronics, says Vice President of Internet Business Hayne Shumate.

"Europe has delivered six straight quarters of strong growth, and Americas returned to growth as we anticipated. In Asia, growth by our core small-to-medium-sized manufacturing customers was better than we anticipated," Arrow's chairman, president, and CEO Michal Long said in a statement announcing the results.

Long attributes the growth to the firm's investments in "customer-facing talent and resources, as well as our focus on design and value-added services" for its global components business.

The industry's two largest players are not alone in their European success stories. Distribution leaders attending the recent Electronics Distribution Show in Las Vegas also said Europe continues to lead the way in growth as tough conditions persist in the Americas and growth slows in Asia. Many distributors in attendance at the show—held May 10-13—pointed to flat conditions in the Americas offset by growth elsewhere in the world.

INVESTMENT PAYS OFF

Electronic components distributor TTI saw its strongest growth in 2015 in Europe, with sales up 6%; the company is projecting another 6% growth in the region this year, and as of early May was ahead of plan, company President Mike Morton told attendees at a TTI-sponsored meeting May 11 during EDS.

Industrial business is leading the way for TTI in Europe, and Morton says the company continues to invest in that business. As one example, the com-

pany continues to expand its sales team in Europe, with plans to add 15 people this year.

TTI's sister company Mouser Electronics experienced record sales in 2015, growing 3.3% and projecting another 8% growth this year, company President Glenn Smith reported during the same Las Vegas meeting. Like TTI, Mouser saw the most strength outside of the Americas, with business in Europe and Asia driving the company's strong performance—Smith noted that the first quarter of 2016 saw record sales as well. What's more, the company projects that sales in Europe and Asia combined are likely to eclipse sales in the Americas in the next few years—a first for this Texas-based distributor. In the first quarter of 2016, 51% of Mouser's sales came from the Americas, with 20% from Asia Pacific, and 28.5% from Europe.

"The Americas is not growing the way Europe and Asia have," Hayne Shumate, Mouser's vice president of Internet business, said in a separate interview at EDS, adding that the company is close to the Americas comprising less than 50% of global sales.

"It's already that way on the web," Shumate explains, noting that website orders comprise 53% of Mouser's business today, with the majority coming from outside the Americas.

A BRIGHT FUTURE

Another distributor that has seen positive change in Europe is Montreal-based Future Electronics. A new management team, deep technical knowledge, and a strong segmentation strategy helped drive growth in 2015 that is continuing this year, says Karim Yasmine, corporate vice president, strategic supplier development. Future hired Karim Khebere as its managing director for Future EMEA late last year, a change that also included the hiring of more sales and customer service associates and a new regional leadership team. Yasmine calls Khebere "a phenomenal addition" to Future—one that has brought balance to the corporation and helped create a hub in Europe.

"Europe was quite strong all of last year, and is driving very nice growth for us," Yasmine adds. "Asia is still the fastest-growing area for us, and the Americas is holding its own … [But] EMEA keeps on rolling, thanks to the new team we've brought in."

Future's segmentation strategy in Europe has the company focused on key areas such as lighting, display solutions, and connectivity, Yasmine adds. Looking ahead, he says the plan is to develop segment teams to deepen the company's penetration into markets such as transportation, health care, and industrial markets. ■

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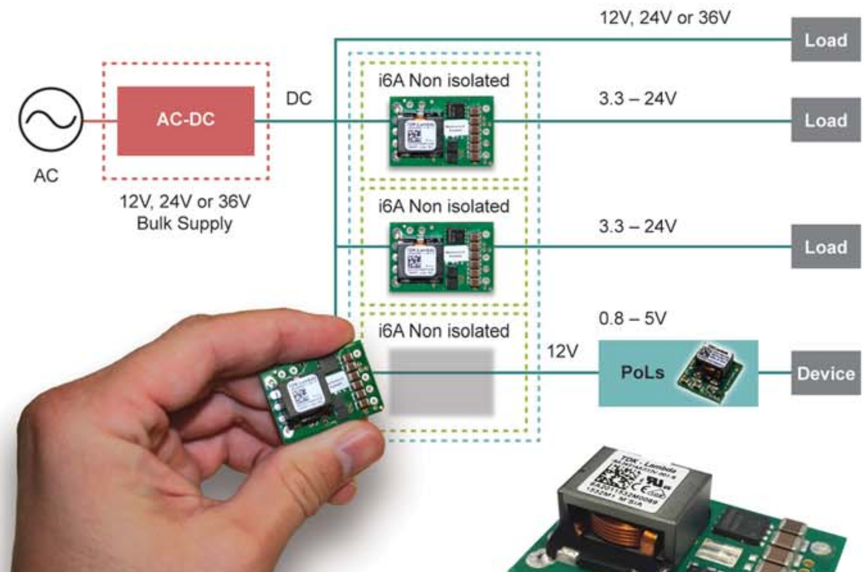

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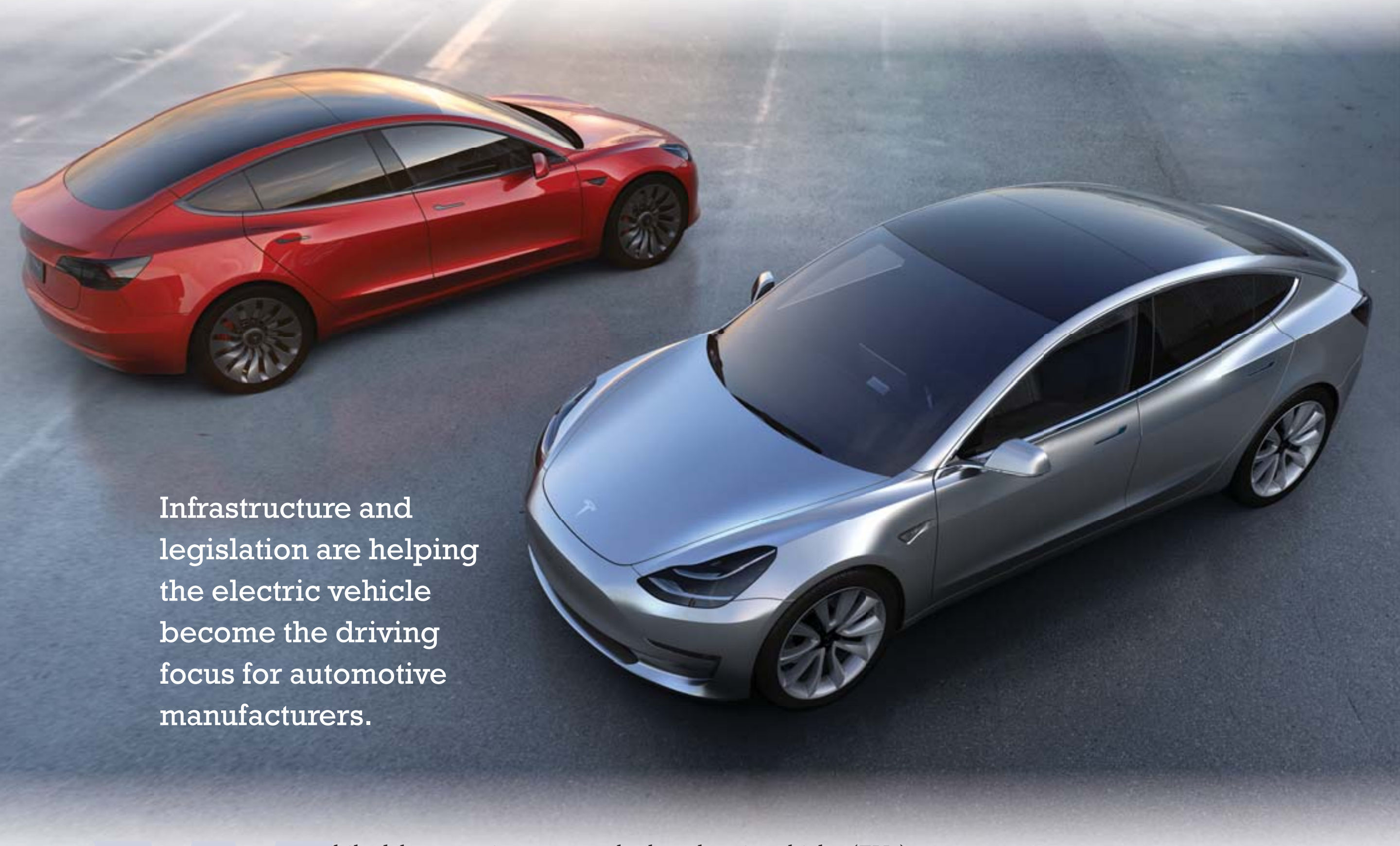
JEFF KERNS | Technology Editor

CHARGED UP:
Where Do Electric Vehicles Go from Here?



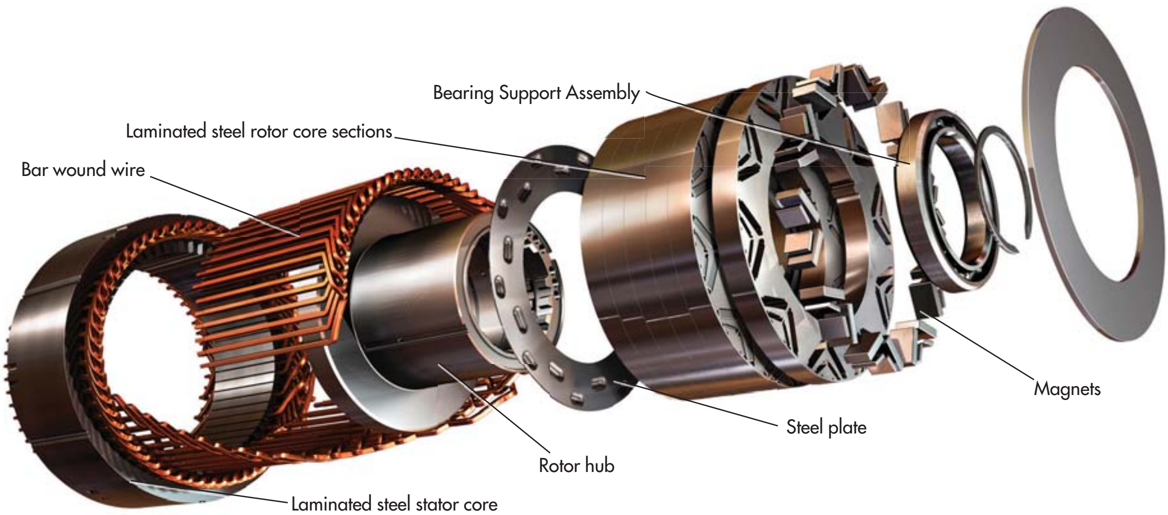
Infrastructure and legislation are helping the electric vehicle become the driving focus for automotive manufacturers.

While debate continues over whether electric vehicles (EVs) are actually environmentally superior and more cost-efficient than those powered by fossil fuels, the fact is that fully electric cars and hybrids are gaining in popularity and sales.

Sales of EVs, such as the Nissan Leaf and Chevy Bolt, have grown steadily since 2011. While last year saw a slight drop in this segment overall, Tesla Motors CEO Elon Musk says his company currently has almost 400,000 pre-orders for the Model 3. To maintain EV growth, the industry will have to consider economical cost, environmental cost, and infrastructure.

The U.S. government has been aiding efforts to increase the popularity of EVs and

Tesla Motors Model 3 is setting sales records, with nearly 400,000 pre-orders of the electric vehicle.



GM's exploded view of the permanent-magnet electric motor used in the Chevy Volt. Over time, companies such as GM have reduced or eliminated rare-Earth metals from EV motors to further reduce the energy and pollution associated with making them.

grow their infrastructure. In December 2015, the federal government extended incentives for EV charging stations through 2016. More state governments are signing a Memorandum of Understanding for a State Zero-Emission Vehicle Program by which signatory states, in short, will support the expansion of EVs. Some states are even offering incentives for people and businesses that purchase EVs and EV charging equipment.

Charging is also possible with a basic 120-volt plug. However, that approach can take a long time. Eight hours of charging on a 120-volt plug might offer about 40 miles of driving. In contrast, installing a 240-V line allows a range of 20 to 40 miles after two hours of charging. Some companies have designed rapid chargers that supposedly provide a full charge in as little as 15 minutes.

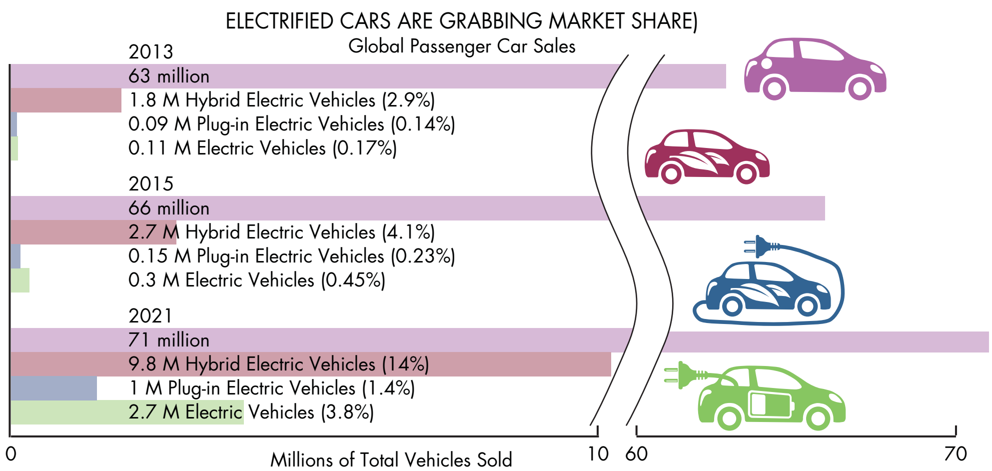
Rapid charging and high-load requirements can decrease the life expectancy of the battery by adding stress. Like many things, reducing stress over time can prolong a component's life. Keeping Li-ion batteries "topped off" is the best option, but not always realistic. Researchers are helping to prolong EV range while keeping batteries charged. At Oak Ridge National Laboratory, researchers testing wireless options were able to transmit 20 kW to a passenger vehicle at about 90 to 95% efficiency. By comparison, the Advanced Power Electronics Lab (APEL) at Kettering University collaborated with HELLA, an automotive electronics company, to develop a compact vehicle charger with an efficiency of 97%, more than 3% over the average for these plug-in chargers.

SAE J2954 focuses on wireless suppliers and infrastructure involved in wireless charging. It will be important to manufacturers and utilities to have standards for cohesive charging

EV SALES

Year	Sales
2011	about 17,500
2012	52,607
2013	96,000
2014	122,438
2015	116,090

Data courtesy of InsideEV.com



There is a lot of attention directed toward electric vehicles (EVs), although they currently represent less than 1% of the automotive market. Hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs) are helping to gain market share and introduce users to EVs. *(Data courtesy of Yole Developpement)* and safety. While wireless charging isn't inherently dangerous, a system to prevent foreign-object debris from entering the area between the primary and secondary charging units while active will reduce problems, damage, or inefficiencies.

"You have two types of wireless charging," says Joachim Taiber, CTO of the International Transportation Innovation

THE BUMPY RECENT HISTORY OF EVs

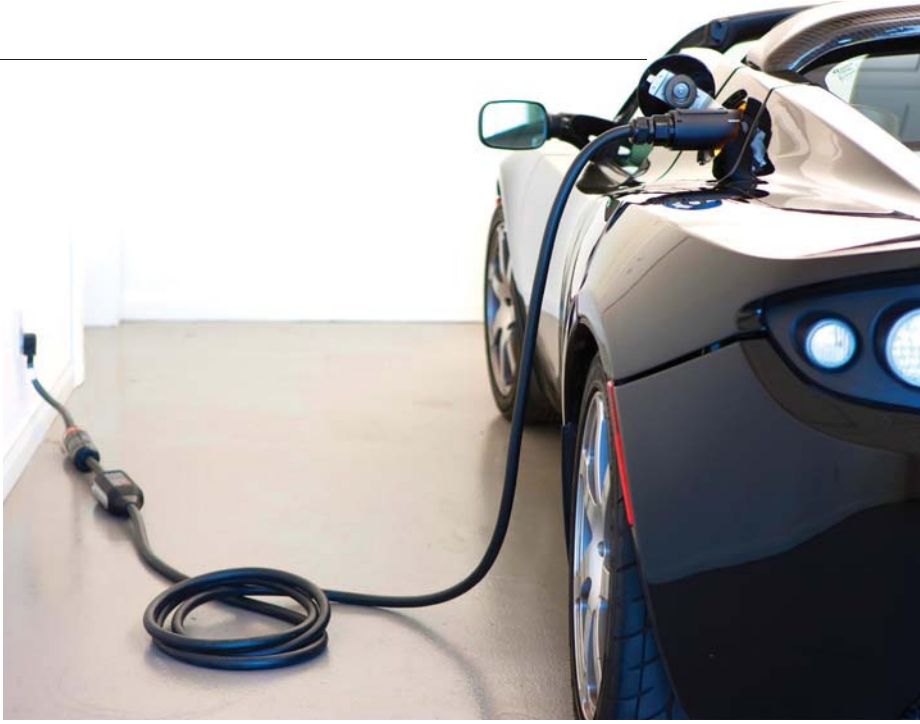
IN 2010, INVESTING in an EV may have been questionable. There were far fewer charging stations, concerns about the vehicle's range, and uncertainty over whether it was saving the buyer any money. In addition, memories of General Motors' EV-1 (also known as the Saturn EV-1) from the mid-'90s might have scared away potential buyers. The first major automobile brand to produce a modern, full-plug-in EV was wrought with controversy that ultimately left those who leased the car forced to return them to the manufacturer. With all of the cars officially leased and no option to purchase and own one, General Motors was able to take back the cars and ended up destroying them. There is only one working model left; it is on display at the Smithsonian. (The controversy of the EV-1 sparked enough outrage that in 2006, Jessie Deeter produced a documentary called "Who Killed the Electric Car?").

Beyond that PR nightmare, the plethora of inaccurate and conflicting information certainly didn't help the electric vehicle's cause. In 2007, CNW Marketing Research published "Dust to Dust: The Energy Cost of New Vehicles from Concept to Disposal," a report stating that an H1 Hummer produced less pollution cradle-to-grave than a Prius. It only took about two months until the Pacific Institute published "'Dust to Dust' Report Misleads the Media and Public with Bad Science." Others have come forward to confirm the poor research presented in the CNW report, but proponents are still quoting and sharing its information. Other studies question the economic and environmental benefit of EVs, but they typically depend on what region the EV is located in and what vehicles the study is comparing.

Today, EV adoption is finally gaining traction. Aftershocks from the EV-1 recall are mostly resolved. Charging stations have steadily been increasing over the years. It's also become more common for EV owners to have permits so they can have charging stations at home. In addition, EV boosters are pushing government officials to streamline the process whereby they can have a charging station installed in their homes.

Center (ITIC). "The first type is when a vehicle is stationary. This could mean parked or, for example in a city, stopped at a red light. Looking forward, a second type allows an EV to charge while moving. A car could drive over a sequence of coils in the road to charge. You could charge multiple vehicles in parallel without needing them to stop."

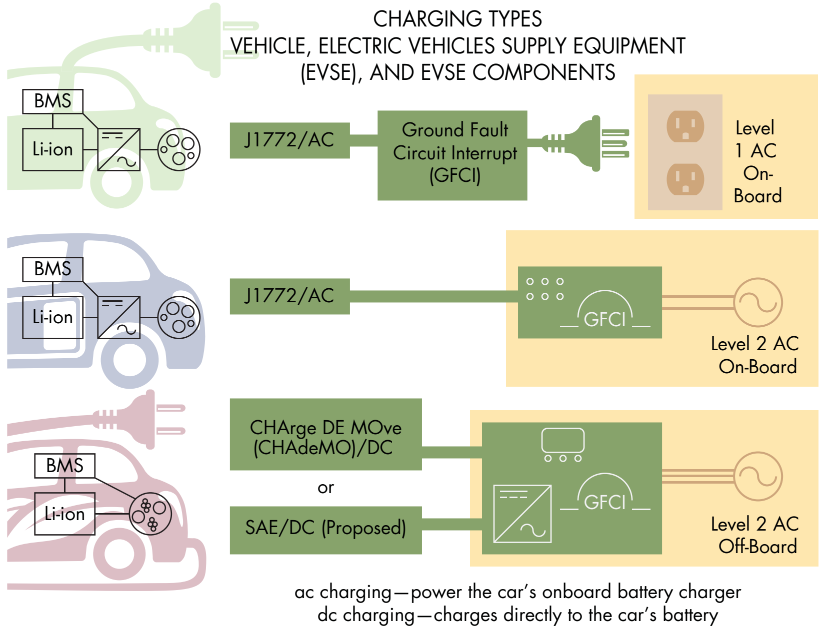
Both types of wireless charging can extend range and extend battery life for EVs. The infrastructure to integrate either type will be expensive, but could also present new ways for generating income. More complex infrastructure, such as wireless charging in the road could aid in automated driving capabilities. However, charging can be more complicated as some EVs use alternating current (ac) and others are direct current (dc). This means it's critical for EV and charging-station manufacturers to communicate and set up standards so that all EVs have the right equipment to charge.



Charging requires a different thought process than filling up. While the number of charging stations is increasing, users will not be in and out in 3 to 8 minutes like at a traditional gas station. However, there are many apps available to help electric car users stay charged. Incorporating charging stations around shopping stations, apartment complexes, and parking lots where people leave their cars for extended periods may be the new "gas" station.

Some of the advantages of dc motors include immediate high torque, and they are relatively cost-effective. On the downside, they should not be run without a physical load, as it could damage the motor. That is why running a dc motor to turn a belt could be a poor design. If the belt brakes, there is no load, and the motor could spin into a catastrophic failure. These motors are also not ideal for maintaining speed over varying load conditions—e.g., an EV with this motor might not perform well in hilly terrain. And while adjusting the voltage can control dc motor speed, the motor has a maximum rpm rating beyond which it cannot go, so speed is inherently limited.

Compared to dc, ac motors offer higher torque and speeds. They also are more adaptable to variable speed and loads, so they work better for hills. They also accept energy from regenerative braking easier than a dc motor. But the coil

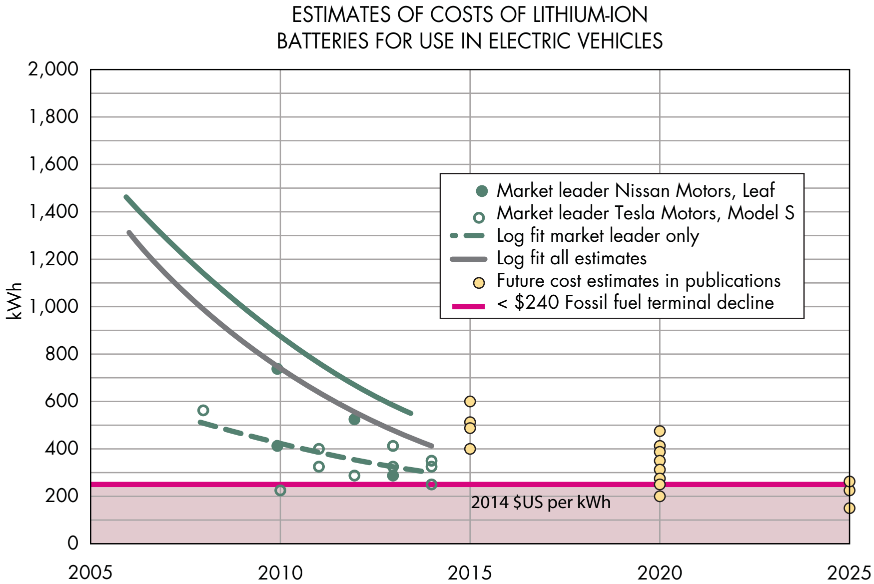


According to IEEE, off-board charging is more expensive than on-board, yet companies are still interested in it. Off-board charging can reduce the weight on the electric car, charge faster, and open contract opportunities between utilities and potential charging-station locations, such as shopping malls and restaurant owners. Another reason for the interest in off-board charging is the ability to use EVs as energy storage for the grid, called "vehicle-to-grid." *(Data courtesy of EATON)* winding can be heavy, and an inverter is necessary when using batteries to convert the dc battery to an ac motor. In general, an ac motor costs more than a comparable dc motor.

Overall, there are automotive and off-road applications for ac and dc motors. But to make electric motors and EVs viable, it will take major advances in battery technology. The current energy storage necessary to power EVs adds too much weight, making the weight-to-power ratio too high. Wireless charging could be part of the answer. There are also the problems of slow recharging and environmentally clean disposal.

INFRASTRUCTURE

According to the Natural Resources Defense Council, "While electric vehicles are cleaner than petroleum-fueled vehicles today, the greenhouse gas reductions can be maximized by charging vehicles from a cleaner grid. With a



Citigroup said in 2014 if the cost of batteries drops below $240 per kilowatt-hour, fossil-fueled vehicles will start a terminal decline. A report from UBS read that $240 per kilowatt-hour could happen within the next few years, and the cost could fall as low as $100 per kilowatt-hour in the future.

(Data courtesy of Bjorn Nykvist and Mans Nilsson)

62% share of light- and medium-duty vehicles in 2050, electric vehicles would consume 13% of grid-supplied electricity." A 120-V overnight charge will pull about as much power as a 1500-W window air conditioner. Level 2 charging—the 240-V plug—is the same as an electric dryer or oven. This demand for power is not abnormal. Also, considering users would probably charge during off-peak hours to save money, some reports say any increase in electricity demand from EVs will not be an issue. However, some grids will run coal plants in the evening that will reduce the environmental benefits of the EV.

In fact, EVs might not only pull electricity from the grid, but could act as a resource. The German utility STEAG is investing about $112 million in Li-ion battery storage to help with short-term fluctuations in energy demands on the grid. LG Chem will supply 140-MegaWatt-hours (MWh) to the energy storage system in Germany. Mass adoption of EVs means that the batteries can help stabilize fluctuations in electric demand. Battery size changes with each model, but electric storage like this represents about 2,000 to 7,600 smart cars plugged into the grid. This would require a smart system to make sure the EV user is able to have enough of a charge at the end of the day. Southern California Electric (SCE) is working with the U.S. Department of Defense on a one-year pilot at the LA Air Force Base looking at the feasibility of this concept. In addition, SCE believes a significant increase in EV charging may help integrate renewable energy, such as solar, into the grid.

INCENTIVES

Both federal and state governments are offering rebates to help offset the cost of EVs and charging equipment. According to IRC30D from the IRS, up to $7,500 in credit can be received per vehicle. "For vehicles acquired after December 31, 2009, the credit is equal to $2,500 plus, for a vehicle which draws propulsion energy from a battery with at least 5 kilowatt hours of capacity, $417, plus an additional $417 for each kilowatt hour of battery capacity in excess of 5 kilowatt hours." In its current wording, however, this incentive does have limits: "The credit begins to phase out for a manufacturer's vehicles when at least 200,000 qualifying vehicles have been sold for use in the United States (determined on a cumulative basis for sales after December 31, 2009)."

Incentives can help offset the difference in the cost of EVs and fossil-fueled vehicles, but how large is the price gap? The U.S. Department of Energy provides a calculator (www.afdc.energy.gov/calc/) that lets users compare cost and emissions of specific cars side by side. A comparison of the 2016 Nissan Leaf and Versa showed a difference in $0.04/mile for about 12,000 miles a year for New York state. Despite this, the Versa is still more cost effective, largely due to the lower purchase price. After five years, the cost difference can be about $15,000 according to the calculator. Incentives can help reduce this difference in cost. If a user is considering a full-size vehicle, for example the Nissan Altima, EVs become more cost-competitive—keeping in mind that cost difference varies on fuel and electric cost.

Some consumers have the preconceived notion that EVs are inherently better for the environment, but research conducted by the Union of Concerned Scientists in 2012 shows that EVs generate about one metric ton more in greenhouse gases during manufacturing than a similar gasoline vehicle. Consumers instead should be alerted that, as stated in the report, using an EV will rectify this difference in emissions in the first year of driving. If the batteries are recycled properly, a cradle-to-grave analysis shows EVs do have about a 50% emission savings, according to the Union of Concerned Scientists.

This can change, depending on from where the electricity comes. For example, according to the U.S. Energy Information Administration, the highest weight of CO2 per kW-h produced is lignite—a brownish coal with traces of plant structure. Lignite can produce up to 2.17 lb of CO2 per kW-h, which could greatly increase emissions if an EV was using this to charge. However, coal produces 33.28% of U.S. electricity, and the environmental benefit of EV charging increases with different energy sources. Natural gas produces 1.22 lbs. of CO2 per kW-h, and alternative energy sources produce even less.

A recent report in Scientific American notes, "As it stands, a conventional Toyota Prius hybrid vehicle, which burns gasoline when its batteries are not engaged, and the all-electric Nissan Leaf produce roughly the same amount of greenhouse gas pollution: 200 grams per mile, according to data from the U.S. Department of Energy." In comparison, the EPA reports that an average passenger vehicle with 24.1 mpg would produce 368.4 g/mile, and 513.5 g/mile for light-duty trucks with 17.3 mpg.

The Scientific American report continues, "In California, which has one of the highest proportions of clean electricity in the country, the electric vehicle would produce only 100 grams per mile, half that of the hybrid. Ditto for Texas and even Florida. But in the Midwest and South, where coal fuels the bulk of electricity generation, a hybrid produces less CO2 than an electric car. In fossil-fuel–dependent Minnesota, an electric car would actually emit 300 grams per mile of greenhouse gases. As a result, some researchers suggest that a regional approach to clean vehicle standards makes more sense than national standards that effectively require electric cars across the board. Minnesota could go for hybrids and California could go for electric vehicles."

With government support, a growing infrastructure, and exponential growth in public interest, it looks like the EV market will continue to expand despite argument. However, some aggressive projections as far out as 2050 still do not have EVs overtaking the traditional internal-combustion-engine vehicle. md

KYRI MCDONOUGH | Marketing Services Manager
Parker Hannifin Corp., Hose Products Div., Wickliffe, Ohio

Designing Hydraulic Hoses for Extreme Conditions

Hydraulic hoses must withstand extreme temperatures to minimize downtime and maintain productivity.

Hydraulic hoses can be found in the most remote parts of the world, or right around the corner. They are commonly used under the hoods of automobiles, as well as in aircraft-support and forestry equipment, heavy construction vehicles, and the drills, vehicles, and rigs used in mining and the oil and gas industries.

HOSES FOR ALL FLUIDS

Hoses transmit any number of industrial fluids, including motor oils, heavy-duty coolants, and transmission and brake fluids. Most of these fluids tend to be petroleum-based oils, but engineers also work with many obscure fluids as well, including antifreeze and other glycol-based coolants.

The challenge in dealing with such a wide variety of fluids is finding the right hose for a particular fluid. On top of that, fluid manufacturers and oil companies regularly update their products, says Nathan Groves, a chemical engineer and project manager with Parker Hannifin Corp. Fluids are usually changed after five to 10 years, with a typical update being a change to the additive package, he says. Although the base fluid remains the same, changing the additives often affects the fluid's compatibility with the hose's inner elastomer tube. Hose manufacturers are aware of these changes and maintain compatibility databases based on material testing.

"If an OEM changes a fluid's base materials, such as going from a distillate to a synthetic, that can be more of a concern than changing additives because the chemical makeups of the two types of oils differ and the fluid may now be more aggressive," Groves says, referring to its effects on a hose's tube.

Parker's GlobalCore 722TC (ToughCover) works at temperatures ranging from -40°F to 257°F (-40°C to 125°C). Several layers of precisely oriented wire reinforcement create a hydraulic balance, which keeps the hose from moving too much when under pressure.

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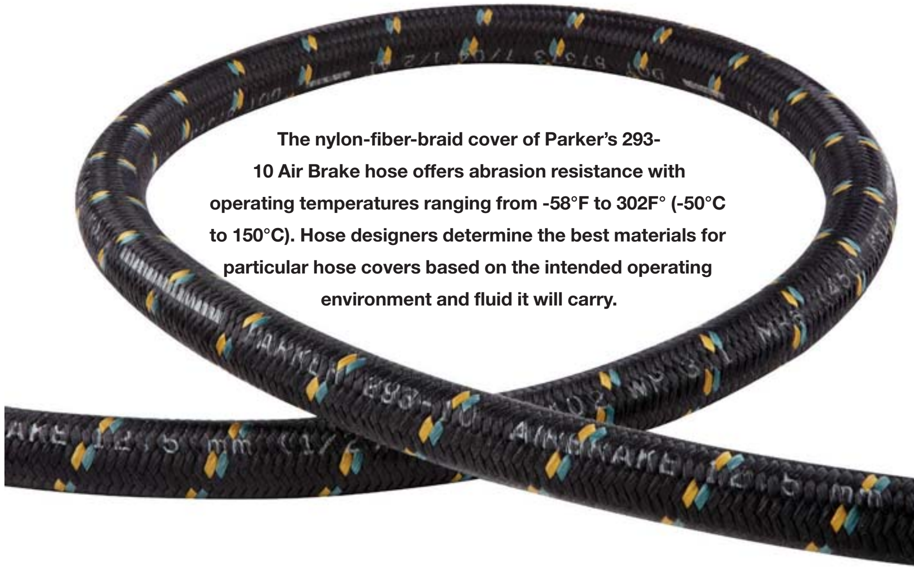


The nylon-fiber-braid cover of Parker's 293-10 Air Brake hose offers abrasion resistance with operating temperatures ranging from -58°F to 302F° (-50°C to 150°C). Hose designers determine the best materials for particular hose covers based on the intended operating environment and fluid it will carry.

Aggressiveness refers to a fluid's chemical makeup, which is reflected in the solubility of the polymer in the fluid. This is one of the key variables engineers must consider when designing hoses for particular applications, Groves says. Some components within a blended fluid may tend to be absorbed into the hose's rubber compound or extract oils out of the rubber, changing the hose's physical properties.

TIPS FOR INSTALLING HOSES

HERE ARE SOME best practices for installing and routing hoses that should prolong their life and prevent failure:

Many hoses, including those from Parker, have continuous labels, or "lay lines" printed on the outer cover. Paying close attention to these lay lines during installation prevents the hose from being twisted.

To prevent abrasion, a primary cause of premature hose failure, clamp hoses in place as applicable. But don't clamp them so tightly they can't move when pressurized. They should also be clamped individually to keep them from rubbing against each other, which leads to abrasion failures.

Such changes in physical property can include swelling or contraction. Swelling restricts fluid flow through the hose and softens the rubber, which can lead to fittings leaking at elevated temperatures. Extracting oils makes the hose much stiffer at low temperatures, which causes cracking when the hose is stressed or flexed.

"Some end-users actually immerse hoses in fluids they are trying to transfer, whether by accident or on purpose," Groves says. "This can degrade the properties of the hose cover."

The hose cover, usually rubber, primarily acts as a protective barrier against external conditions such as abrasions and ozone. In most cases, the cover layer should never be exposed to fluids because it can cause the hose to either crack or lose its abrasion resistance. This could expose the hose's reinforcement layers to the environment, weakening the hose.

It's up to hose designers to determine the best materials for a particular hose based on the fluid it will carry and its intended operating environment.

BEATING THE HEAT

The second most important variable to consider is the temperature of the fluid being transmitted. This is especially true with hoses carrying oil in high-

Hoses must be designed to meet strict requirements for each application, including bend radius, flexibility, and life. Variables, including environment temperature, application pressure, and fluid being transferred, can all affect the hose's ability to meet those requirements.

temperature applications, says Greg Reardon, business development manager with Parker. If the oil temperature exceeds the hose's threshold temperature, usually around 257°F, the heat can bake the inner tube, causing it to harden and crack. This happens when running a system for too long without giving the oil a chance to cool, he says.

"This is a common issue with heavy mobile machinery," Reardon notes. "In a perfect world, all mobile equipment would come with oil regulators and coolers to keep oil temperatures in check. However, this is not always the case due to size or cost restraints. Without cooling, and with the vehicles running for eight to 16 hours at a stretch, the oil heats up and starts baking the hose."

Some companies, including Parker, design hoses with inner tubes that handle transfer-fluid temperatures of up to 302°F. But Reardon still cautions customers to closely monitor the temperature of any transfer fluid during operation.

Ambient heat is also of significant concern, he adds. Hoses in the engine compartment of a vehicle, for example, see higher temperatures than those in open areas where there is some natural cooling and the heat has an avenue of escape. Because engine compartments are generally closed off, heat is prevented from escaping. The resulting high temperatures affect hoses from the outside in.

In addition to oil temperature and ambient heat, nearby operations can expose hoses to dangerously high temperatures. Anything from vats of molten metal to stray welding spatter can heat up unprotected hoses and increase the possibility of failure.

For these situations, Parker and other companies have developed a variety of sleeves to cover and further protect hoses. Sleeve materials range from fabrics to fire-resistant polymers to steel braid, and some also protect against injuries in the event a hose bursts.

All Parker hoses and tubing exhibit their best physical properties at room temperature, 68°F (20°C). As elastomeric materials are exposed to higher temperatures, they soften and their physical properties, such as flexibility, may change.

Couplings attached to hoses are held in place in part by the rubber compounds' pliability. If a hose becomes brittle due to excessive operating temperatures, the coupling can break free. To avoid this, conscientious end-users institute preventive maintenance and planned replacements for at-risk components.

"When selecting and constructing

hoses for customers, we complete a thorough analysis of how the hoses will be used and under what conditions," Groves says. "We ensure all hoses are tested in a controlled, safe environment. Hoses must perform to strict specifications, such as SAE or ISO industry standards, under operating conditions dictated by the product's planned operating environment before we deliver them to customers."

FIGHTING THE COLD

Although temperatures above 257°F are a cause for concern, customers also experience issues with temperatures at the other extreme, -40°F and lower. When exposed to extremely cold temperatures, rubber hoses stiffen and cannot flex like they should, causing them to crack. This leads to potential hose failures. Two industries that rely on low-temperature hoses are land-based oil rigs and the logging industry.

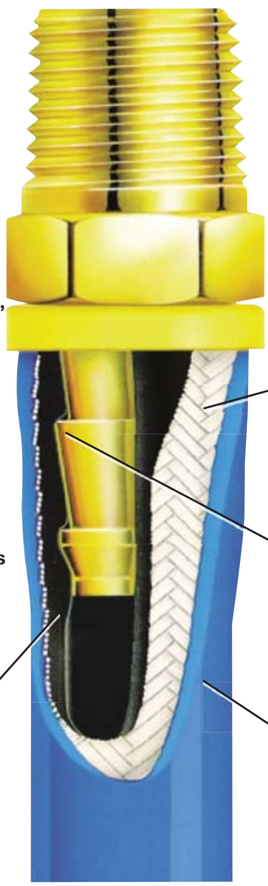
Fortunately, hoses can be designed for specific operating temperature ranges and there are versions that operate at temperatures as low as -70°F and with working pressures as high as 6,000 psi. Designing hoses for extreme cold is a matter of getting the right combination of fluid compatibility and the chemistry of the hose layers, according to Derek Garceau, engineering manager for Parker's Hose Products Division.

"Variables ranging from temperature, working pressure, and fluid compatibility, along with restrictions inherent in the customer's application, make it challenging to determine the right hose for an application," he says.

"It's a balancing act between the compatibility of the inner tube with the fluid being used, and the conditions of the specific application, such as repeated flexing or high operating temperatures," Garceau says. "Both can affect each other's performance. For example, having more material in the polymer to resist the fluid often decreases its ability to withstand extreme temperatures."

Cold temperatures can also affect the fluid being transferred through the hose. For example, cold temperatures may thicken the fluid, decreasing its flow rate. And adding more insulation or heated sleeves to the hose isn't always viable. In many of today's vehicles, hose are routed to save space and cost. This does not leave a lot of room to install an insulated hose or additional sleeving.

"We can't make the hose two inches in diameter if the client needs it to be half-an-inch in diameter," Garceau says. "We usually recommend end-users complete a warming procedure prior to



Hoses are designed in layers that get stacked on top of each other, starting with an inner tube layer that resists the transmitted fluid, followed by a reinforcement layer for pressure carrying capability, and a cover (perhaps an elastomer) that makes helps it resist abrasions.

Certain materials let hoses be built with thinner layers, allowing for decreased outside diameters and increased bend radii while maintaining the same level of performance. The chemistry for hoses is chosen based on what they are going to be used for, but the goal for all hoses is the same—maximum durability, high flexibility, and long service life. Hoses are expected to perform in both extreme heat and cold, so they are tested in some of the worst conditions.

use in which they let oil circulate through the hose until it's up to a working temperature."

OTHER CHALLENGES

Not all challenging applications involve extreme temperatures. In one case, for example, Boeing wanted to simulate flight conditions in its 787 Dreamliner while it was still on the assembly line to check the hydraulic pressures. The Dreamliner uses higher hydraulic pressures than most commercial aircraft. For the test, Boeing needed a 6,000-psi hose to validate the aircraft's functions.

At the time, no hose on the market compatible with aviation fluid carried a 6,000-psi rating. In fewer than four months, Parker designed, tested, and manufactured its F42 hose made out of an ethylene propylene diene monomer (EPDM-based rubber). Rated at 6,000 psi and compatible with aviation fluid, the hose also meets other Boeing requirements for bend radius, flexibility, and life.

EPDM is a base polymer used to make rubber hoses. It is a high-density synthetic rubber compatible with fireproof hydraulic fluids, ketones, hot and cold water, and various alkalis. EPDM hoses resist heat, ozone, and weather, and maintain excellent flexibility at high and low temperatures. Parker's EPDM hose provides reliable, constant working pressures of up to 6,000 psi in temperatures from -40° to 176°F (-40°C to 80°C).

A second commonly used chemical is a nitrile-based polymer, which is a synthetic rubber copolymer of acrylonitrile

(ACN) and butadiene. Nitriles provide good compatibility with oils and standard hydraulic fluids.

"When designing nitrile rubber hoses for customers, engineers pay close attention to the ACN content in the mixture," Groves notes. "The higher the ACN content, the better the polymer resists certain nonpolar solvents such as mineral and vegetable oils, benzene/petrol, ordinary diluted acids, and alkalis."

However, there is a tradeoff between ACN content and low temperature flexibility. The higher the ACN content, the more resistant the hose is to fluids, but the worse it will be for low temperature flexing, which can lead to cracking and failure when the hose flexes when it is below its stated operating temperature.

The way chemicals in the recipe bond together gives the hose its different resistances, he says. Hoses are built like sandwiches with several layers of material stacked on top of each other, but all those materials must bond with each other.

"How easily the materials bond is important," Garceau says. "Otherwise, hose failure could lead to delamination while in use. The inner tube could separate and rip itself out."

A hose's pressure rating is determined by its reinforcements, he says. Hoses are constructed in layers, starting with an inner tube, then alternating layers of rubber and reinforcements, such as steel wire. Each reinforcement layer is placed to work with the layer above or below it, so when the hose is pressurized, it creates a hydraulic balance. This balance restricts the hose from moving too much under pressure. If there is no balance, the hose twists or "bounces" under pressure and could start to come apart due to the forces from the pressurized fluid, he explains.

While hoses under the hood of vehicles are usually fairly stationary and don't move around very much, hoses used on a piece of equipment that has a flexible joint, like a backhoe, must flex reliably in all conditions.

Parker also engineers its hoses with a number of SAE-tested and approved additives to increase resistance to ozone and ultraviolet (UV) light. Without such additives, constant exposure to direct sunlight (like on a piece of construction equipment) degrades the rubber, causing it to break apart and fall off in chunks, which is made worse by any flexing motion.

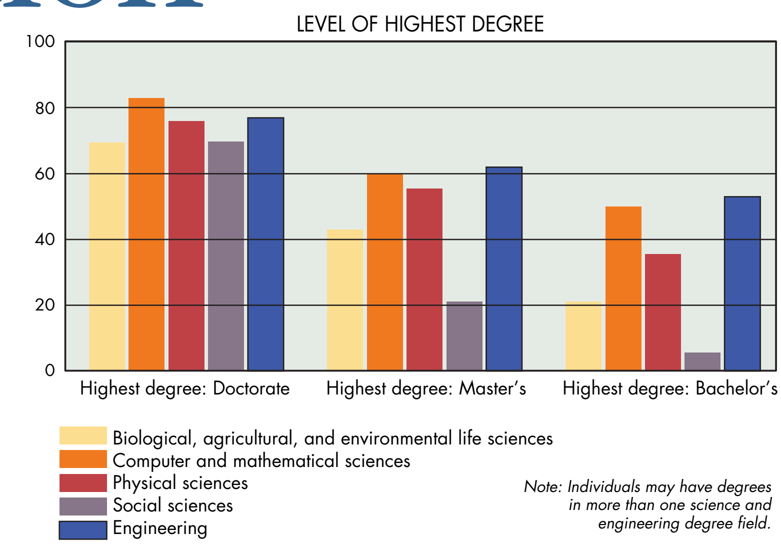
"Additives impart their characteristics and properties to the rubber compound," he says. "Other additives include processing aids such as waxes and oils, and abrasion-resistant and fire-resistant polymers added to the hose cover." md

The Value of a Continuing Engineering Education

Recent studies have shown that going back to school and getting an extra degree will help further your career.

Many engineers start out in the industry with only a bachelor's degree to their name. This is a rarity in the world of major science professions, as most advanced professions require further education before you can enter that field. Doctors and research scientists, to give two examples, require post-bachelor studies (i.e., doctorate or master's degree, thesis statement), certifications, or a state license to work in those professions.

Engineering graduates are an exception to the rule. Many engineers enter the industry straight from college after achieving their bachelor's degree, and not all engineers require a professional engineering license. Licensing for engineers typically depends on the type of field one enters, and many can go their entire careers without obtaining one.



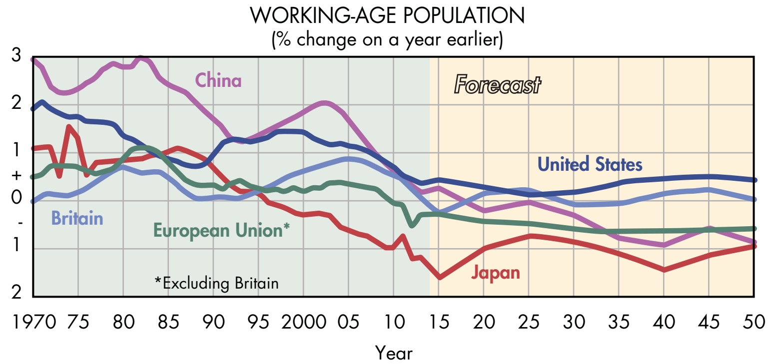
The figure above highlights how many science and engineering degree holders also work in science and engineering occupations. *Source: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT) (2013)*

However, continuing education is an important and growing concern for many of today's engineers. *Machine Design*'s *2015 Salary Survey* (http://machinedesign.com/salarysurvey) showed that the majority of our readers (35.7%) have a bachelor's degree. The next largest group was 22.4% with a master's degree. Both groups were primarily comprised of engineers over the age of 50—60.6% with a bachelor's degree and 72.1% with a master's degree. As the workforce for engineers continues to age, it is important for engineers to stay in the loop with the latest engineering developments.

Our *2015 Salary Survey* listed "staying current with modern technology" as the third-highest concern among engineers, at 28%. There is also higher pressure today for current young engineers to obtain higher degrees from the start. The latest statistics show that the more education one obtains throughout their career, the higher income and job status is possible. Fortunately, there are several methods today's engineer can employ to receive the education and training necessary to stay in the game.

EDUCATION AND EXPERIENCE AMONG WORKING ENGINEERS

Occupations in the science and engineering (S&E) fields have been on the rise since the 1960s. According to the National Science Board in its *Science & Engineering Indicators 2016 Report*



The working-age population is on the decline not just for the United States, but also for other major industrial countries like China and those in the European Union. *Source: World Bank (2015)*

(www.nsf.gov/statistics/2016/nsb20161/#/report), S&E occupations grew from 1.1 million in the 1960s to 6.2 million in 2013. That is an annual growth rate of 3% compared to a 2% growth rate in total employment for the same time period. In 2013 and 2014, 27.2% of people employed in S&E jobs were in engineering fields and had a bachelor's degree or higher.

The percentage growth in engineering occupations from 2003 have risen 1.8% for professionals with a bachelor's degree, 2.6% with a master's degree, and 3.1% with a doctorate. Of the students coming out of school in 2013, 21.1% had a bachelor's, 24.6% had a master's, and 18.6% had a doctorate in engineering, according to the National Science Board.

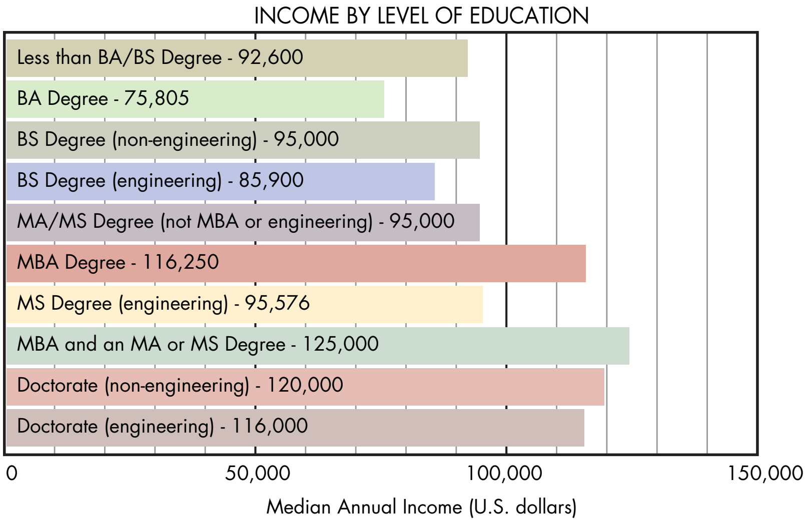
The trend shows that the more you have invested in your engineering education, the more likelihood you will work in that field. In 2013, 40.7% of professionals with at least a bachelor's degree are in engineering work within a field of said degree. The percentage of engineering degree-holders employed in engineering occupations is 77.1% for engineering doctorates, 62.5% for engineering masters, and 52.9% for engineering bachelors. Engineers with a bachelor's degree are the largest group out of the other S&E occupations. Bachelor's degrees in computer and math sciences are second at 50.4%, and the physical sciences come in third at 35.8%.

The *Science & Engineering Indicators 2016 Report* also states that 27.5% work in non-related engineering fields, but the majority of those workers report that their "work is related to their S&E training, suggesting that the application of S&E skills and expertise extends well beyond jobs formally classified as S&E occupations." Managerial jobs are examples of this.

It is also important to note that we have an aging workforce with many skilled workers retiring soon. According the World Bank, one third of North America's workers are over 50 years old, and by 2020 more than 115 million skilled workers will have retired or be near the retirement age of 65. The European Union, China, and Latin America are seeing similar problems in their skilled workforce as well.

THE BENEFITS FROM CONTINUING EDUCATION

With the statistics listed above, we can start to analyze why continuing education is beneficial. The numbers show that there is a growing field of engineers with a master's degree or higher. This holds especially true if one wants to continue in engineering. The more education one obtains, the better income they will obtain. According to a salary survey (https://www.asme.org/getmedia/788e990f-99f5-4062-801c-d2ef0586b52d/32673_Engineering_Income_Salary_Survey.aspx) done by the American Society of Mechanical Engineers (ASME) in 2012, full-time salaried engineering



The graph above shows how the level education for engineers impacts their median annual income. *Source: The American Society of Mechanical Engineers (2013)*

employees with a doctoral degree earned a median income of $116,000. Compared to those full-time employees with a master's or bachelor's degree, the median income was $95,576 and $85,900 respectively.

These numbers also lined up with *Machine Design*'s *Annual Salary Survey* from last year, which reported engineers with a master's degree made an average of $105,616 and engineers with a bachelor's degree an average salary of $89,620. Engineers with a doctorate in engineering versus a bachelor's in engineering earn a median of 35% more.

The pattern of higher education producing a higher income is even true when you account for length of experience. Engineers with a bachelor's degree and 20-24 years of experience made a median income of $110,000, and $122,000 with over 25 years of experience. Engineers that had a master's degree made a median of $120,000 for 20-24 years and $131,000 for over 25 years of experience. Lastly, engineering doctorates made a median of $124,750 and $140,500 for experience ranging from 20-24 and over 25 years, respectively.

Continuing education is not limited to just obtaining more degrees, but also licensing and certification. For engineers, having a license makes you a Professional Engineer (PE). Engineering students graduating from college are encouraged to take the Fundamental Engineering (FE) exam. Once they have obtained experience (at least four years) under an already licensed PE and have passed the FE, they can apply to take the Professional Engineering exam to earn a license under their state's licensure board.

Being a PE allows engineers to prepare, sign and seal, and submit engineering plans and drawings to a public authority for approval for work on public and private projects. According to the salary survey from ASME, the median salary for a PE is $100,500 and the median salary for a non-licensed engineer is $95,775. And licenses vary, so there are subsets of PEs. By having a PE license in an engineering specialty, the median salary jumps to $110,300. For example, a license in environmental engineering provides a median salary of $113,000.

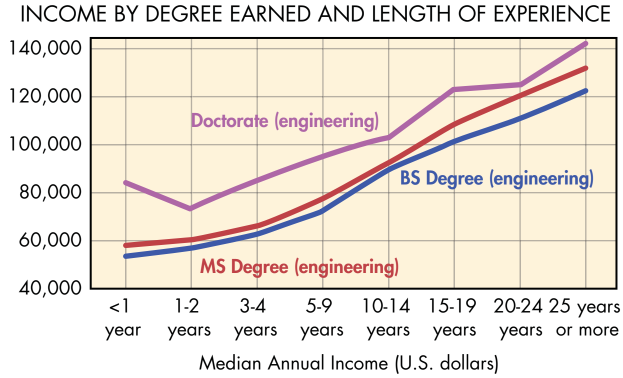
For those considering obtaining a PE license, the decision of returning to school might become a necessity. An effort is being put forth by the American Society of Civil Engineers (ASCE) to raise the minimum requirement for PE licensing to a master's degree or an additional 30 credits of graduate or upper-level undergradu-

ate coursework. The movement is being called "Raise the Bar" (www.asce.org/raise_the_bar/).

The ASCE believes that an undergrad degree is no longer enough to prepare engineers for the future. This movement has yet to become official, but is supported by many engineers within the industry. Considering how many engineers are graduating with a master's degree, it may only be a matter of time before it becomes effective.

The benefits of continuing education benefit both the employee and the employer. The study "Measuring the Benefits of Continuing Engineering Education" by Amy C. Prevost, graduate assistant, and Philip R. O'Leary, chair of the Engineering Professional Development (EPD) department, at the University of Wisconsin-Madison states that continuing education is an important part of the engineering profession in the 21st century.

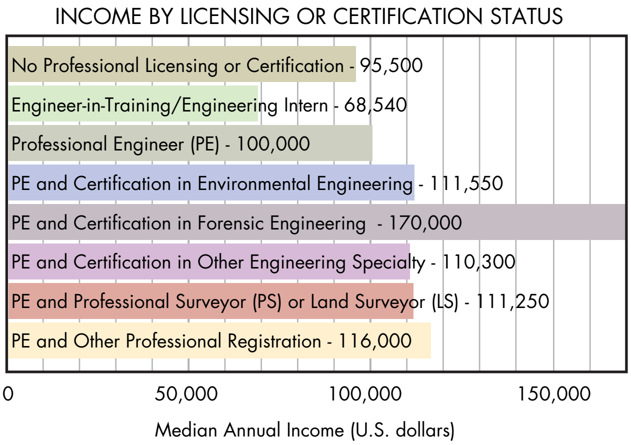
According to their study, engineers will assume a prominent role as future leaders of interdisciplinary teams focusing on the new technological developments. "Education must respond to the new reality of globalization, the information revolution, sustainable development, lifelong learning, and gender equality," it says. Prevost and O'Leary conducted a research survey on two groups taking training in EPD courses: storm sewer/culvert design and ammonia refrigeration. They concluded



The graph above shows how years of work experience affect the income of different engineering degree holders. *Source: The American Society of Mechanical Engineers (2013)*

that 93% of the participants saw the training as useful toward their current job, and that 54% would see direct savings in either cost or labor because of their training.

The study concludes that many of the effects from continuing education cannot be measured. For example, employees feel more satisfied and secure in their knowledge. Continuing education provides career maintenance and helps prevent obsolescence as our current technology becomes more



Many engineers can benefit from having a Professional Engineering license, especially if the license is in a particular field of interest.

Source: The American Society of Mechanical Engineers (2013)

complex, requiring interdisciplinary skills. An engineer that learned how to code PLCs 20 years ago will now need training on how to program modern PLCs that have touchscreen displays, based on JAVA script, and have Ethernet capabilities.

Lastly, one of the main reasons to return to school and receive more education is to stay with the current tide of engineers entering the field. For employers, by helping engineers stay up-to-date with current technology, they help extend the usefulness of their senior engineers and makes their labor force more efficient. An educated staff will lead to time, cost, and labor savings. According to the study, a 10% investment of training expenditures provides a 1.0-1.2% increase in labor productivity.

For the engineer looking to move ahead, continuing education is also beneficial for networking and career changes. Many engineers switch jobs and even industries. Having higher degrees or different certifications can provide job mobility within one's current job or transfer to new settings. A PE engineer working in HVAC can look for new opportunities in the construction markets since many drawings used for building plans require a PE's signature and approval. By placing yourselves in new and different educational settings, networking outside of your industry is easier.

HOW TO PURSUE CONTINUING EDUCATION

We return to the main problem many engineers face when trying to pursue new educational opportunities: time. Approximately 70% of salary survey respondents reported working more than 40 hours a week, with about 7% working from home.

For PEs, each state has a minimum number of continuing education credits per year. The amounts can vary from none to

15 or 30 hours of credit courses. Societies require a minimum credit to continue being a member. The National Council of Examiners for Engineering and Surveying and the ASCE requires every licensee to complete 15 professional development hours (PDH) per year.

To help facilitate an engineer obtaining these PDH credits is a vast resource of online classes and programs. The ASCE offers training and educational resources (www.asce.org/continuing_education/) like online live webinars and on-demand learning courses. On-demand courses can be accessed 24/7 based on the engineer's schedule. The ASCE also offers conferences and conventions that put engineers face-to-face with many leading experts for hands-on training. For PE studies, they offer exam reviews and instructors. The National Society of Professional Engineers (NSPE) offers similar educational venues. Regular conferences and 15 free courses are included with your NSPE membership (www.nspe.org/resources/pe-institute).

The more traditional route of education is to obtain a graduate degree. Several of the top schools have programs online that offer the same level of education as on-campus learning, with increased flexibility for distance and time. According to *U.S. News* (www.usnews.com/education/online-education/engineering?int=ae4509), the top five schools with online engineering graduate programs as of 2016 are:

- University of California – Los Angeles (Samueli)
- University of Southern California (Viterbi)
- Columbia University (Fu Foundation)
- Pennsylvania State University – World Campus
- Purdue University – West Lafayette

There are also sites like Coursera.org (https://www.coursera.org/) that partner with universities like Yale, Georgia Tech, and the University of Colorado-Boulder to access to their online classes. They provide the coursework and peer-to-peer learning for their classes, which finalize in certificates for recognition of your work.

Certification is an important method of continuing education because it offers qualification for less invested time. Instead of having to dedicate one's self to an entire degree program or exam, which can take years, certification can be achieved within a few months' time. An example of this is the certification resources offered by ASCENT (www.ascented.com/). ASCENT provides the learning material for many of today's top modeling and simulation software offerings, including Autodesk, CATIA, Creo Parametric, and Pro/Engineer.

ASCENT offers education modules to either software resellers or the engineer directly, which they can use for either certification in a particular or PDH credits for association memberships. The top three professions they cater to are mechanical engineers, civil engineers, and architects. The tools offer introductory and advanced lessons as engineers become more familiar with them.

Paul Burden, director of product development at ASCENT, understands that flexibility is key to education for engineers currently in the field. ASCENT's materials are transitioning to more online content, such as e-books with video-enhanced lessons. These lessons can be taken online or offline in a downloadable e-book format.

According to Burden, "The way we develop content is everything; it is extremely modular. The advantage we offer is that we are able to customize all our content to a particular company's use of work flow. We can reorganize context based on workflow or on recognized gaps of employee skill set."

This is the key to a continuing education: Addressing skill-set gaps via a flexible-scheduling approach that will help reinforce and strengthen our engineering workforce. md

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Has the PLC Met Its Match?

Decentralized technologies like PAC can work with PLCs, but by offering more features for machine vision and IIoT, they may be in a state of diminishing returns.

USB and Ethernet ports are standard on most current PLCs to improve connectivity, and help expand memory. The P3-550E high-performance CPU has multiple communications ports, including two USB and Ethernet ports, and one each for RS-232 and RS-485. The system is expandable with the P3-RS, P3-RX, or P3-EX modules. It also offers local, expansion, and remote I/O.

One of the key parts of automation is observing variation, and a process' ability to control it. Reducing variation leads to increased production and efficiency. Machine vision and motion control are helping to reduce variation and add more flexibility to modern machines and automation. In turn, flexibility increases the range of automation, but can also push some legacy hardware to its processing limit.

Currently, programmable-logic controls (PLCs) are an industry norm. Often, new technologies will add to the cost directly in terms of upgrades to equipment, and/or indirectly for additional training for new operating systems. However, adding motion control or custom input modules to a PLC can also greatly escalate cost.

Relative cost, expandability, functionality, and user options are large drivers in the controller industry. As demands for data, memory, and processing power intensify, PLCs may no longer be the go-to industrial computer anymore.

PROCESS CONTROL

In its simplest form, a control process has three main parts: the sensor, controller, and actuator. The sensor sends information or a reference signal from the process to the controller called a feedback or closed-loop control system. The information sent back to the controller is process-critical or valuable in some way.

For example, temperature and gas detection in a nitrogen-annealing oven might be important, while data about humidity or vibration may offer less or no benefit. Adding extra data makes systems more complex than needed. Thus, reducing that complexity becomes crucial, as it decreases the effort needed to program, troubleshoot, or adjust a process.

Next, the central processing unit of the controller, which acts more or less like the human brain, will process informa-

A process fieldbus (Profibus) is a typical automation-technology communication. If a line integrates industrial Ethernet (Profinet), a PLC's modular design allows for easy replacement.

tion from the sensors and make decisions based on algorithms and programs. If a value is outside a set limit, the controller will send a signal to an actuator to adjust the process until the error returns to an allowable tolerance. Actuators are like the muscles of the control system. They are the hands that operate modifications dictated by the controller onto the physical system. Some common components for actuators are motors, drives, and pumps, but also include pinions, pulleys, and chains.

"The controller knows what is going on and it is able to make decisions accordingly. The king of controlling devices in industrial automation contexts is surely the PLC," says Matteo Dariol, product support engineer for Bosch Rexroth AG. "The acronym contains 'programmable logic' because at the beginning of the electronic revolution (1960s-1970s), controlling devices were obtained with discrete electronic components in a fixed topology. Changing project specifications meant redesigning and reengineering the whole control logic, with physical components shuffled and moved around. With PLCs, the design efforts for the control algorithm are confined almost entirely into the software."

Whereas PLCs are robust and their programming language standardized, their development environments still lack a defined standard—all major players offer their own unique solutions. Programming and troubleshooting a PLC can be easier than a personal computer (PC) that implements more complex or open-source software. PLCs are modular and able to plug into various setups according to the needs of each project: additional I/O ports, safety modules, and specific Ethernet-based communication cards are just some examples.

Modular design allows for expandability, which is one advantage of using a PLC. Other advantages include cost, simplicity, and robust design. When replacing older technology such as relays, another benefit emerges in the reduction of moving parts. Integrating a more complex system, such as a PC controller, can add other benefits, but one must also consider the added cost and training.

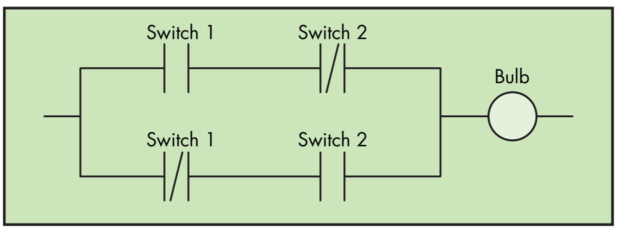
As a result, many production lines that already use PLCs will likely continue to work in the same manner for years to come. Familiarity and simplicity gives existing momentum that will carry the PLC for some time into the future. However, we are starting to see an evolution of the industrial computer. As production lines incorporate machine vision and more complex robotics, the controls are branching out.

LIMITATIONS OF THE PLC

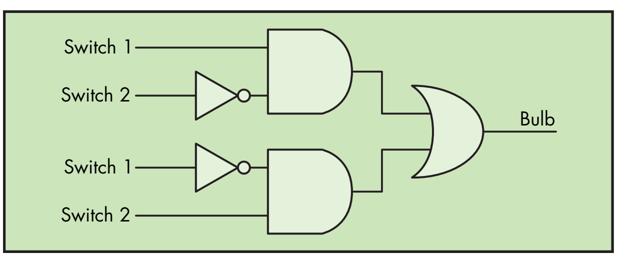
PLCs restrict memory, software, and peripheral capability when compared to a personal computer (PC). Motion control (e.g., automation and robotics) can have many inputs and outputs, requiring extra PLC control modules or outside electronics. However, a PC processes more data faster, which can reduce the physical size and better handle machine vision, motion control, and data flow. Additional data is increasingly important as more companies integrate lines and plants with the industrial Internet of Things (IIoT) into production lines and plants.

Original equipment manufacturers (OEMs) are able to maximize plant productivity by allowing machines to simultaneously perform multiple operations. Computationally intensive and/or time-critical processes running simultaneously might cause a PLC to become overloaded. To keep less time-critical tasks from affecting those with a deadline, machines can use multiple computing platforms. Typically, these incorporate one or more motion controllers, and one or more supervisory processors that support the operator interface for programming, machine operation, data collection, and maintenance functions. However, using multiple processors is costly. New software specifically targeted at PC platforms can help solve this problem, though.

Engineers are able to overcome some of these hurdles with a PC. But a PC is not as robust and can't survive harsh industrial conditions like dust and extreme moisture. Using a PC with complex software, or more software options, can take lon-



Ladder logic diagram of staircase bulb control implemented in a PLC



Staircase bulb control logic implemented using "gates"

Using ladder logic for PLC programming can be easier to maintain, or change, as it mimics electrical drawings. With a simple line-by-line visual structure, ladder logic can be faster to learn than other modern software that uses code or structured text.

ger for technicians to learn and thus increases training time. Advanced software may also need to have a programmer on-site for maintenance, troubleshooting, and upgrades. A PLC's software may be basic, but having its time-tested standard languages can ensure longevity of a device despite its speed and linear nature.

PLCs typically employ an industry-standardized set of programming languages (IEC 61131-3), including a "ladder diagram." Electrical diagrams read similarly to ladder logic, reducing training time and simplifying maintenance, troubleshooting, need for a programmer, etc. Another language from the IEC standard is Structured Text, which looks and operates more like a "high-level language." However, the use of other non-standard high-level languages, such as C++ or Visual Basic, can be difficult with a PLC. Only recently have new software tools allowed users to talk to a PLC as if it was a normal PC.

A PLC sequential program scans all of the instructions every scan cycle. A scan cycle will take about 10 ms or more to complete. Only upon completion of all instructions within a deadline will the program move to the next scan. If a deadline isn't met in a set time, it will cause an error and the program will stop. This hard-time software can limit the length of a program and any input signals to a frequency less than 100 Hz.

Cypress offered the following example in a white paper: If you want to read a speed sensor input to measure 1,200 rotations per minute (1,200/60 = 200-Hz signal frequency), a microcontroller-based PLC cannot measure the speed correctly using this input. Integrating a custom input module with a decoder or integrated-circuit counter to read the signals at high frequency and convert them into a count value to pass to the microcontroller might be necessary in some applications. Alternatively, consider controlling a flow-control solenoid value with a pulse-width-modulation (PWM) signal at 10-kHz frequency. A PLC needs a custom output module with PWM generators. Adding such high-speed counter modules and PWM generator modules increases the PLC cost two to threefold.

THE NEXT GENERATION OF PLC

A system called a programmable automation controller (PAC) is helping to mitigate some of the limitations of older PLCs. Some claim the name PAC is marketing, and that it is a more software-focused PLC, but there are differences. Unfortunately, definitions vary, so finding a definitive line between the technologies might be difficult. PACs are similar to the PC solution, but more robust like the PLC. For example, an industrial PAC can handle temperature ranges from −40 to 158°F, 50-g shock, and 5-g vibration.

A PAC typically incorporates PLC functionality. Both are digital computers, but a PAC tends to expose advanced programming capabilities and often has greater functionality, peripheral capability, and memory. PACs offer more complex system architectures when there is a need for greater I/O connectivity. Furthermore, PACs usually have more built-in connectivity capabilities, from networking to logging data to a USB storage device, and often they can interact directly with databases.

Additional software options and features sounds beneficial, but you must define your goals. Be aware that controllers may not follow standard languages (IEC 61131-3), which may cause training in addition to the issues previously mentioned. "Typically PLCs are used more for 'production-line controllers' and PACs are more suitable for 'plant controllers,'" says Dariol.

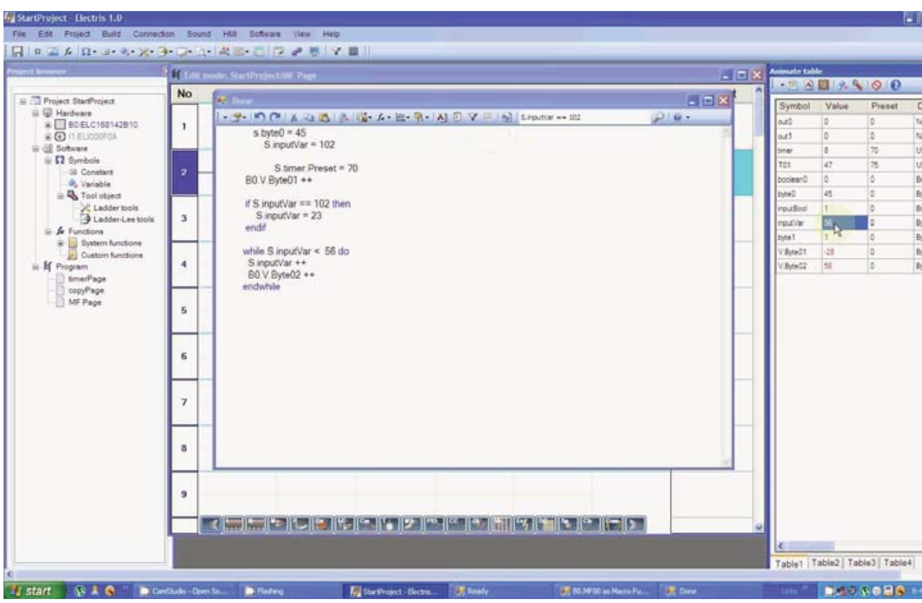
There are also different models of these new technologies. PACs, for example, can offer models that focus on machine vision or others that may focus on operating multiple processes at once.

Selecting a technology or model must take into account any future considerations (e.g., expansions, upgrades) and standards (e.g., safety) that may alter what technology or model is needed. Planning could extend the life of the controller by meeting future requirements, but it might also help set up a foundation for the IIoT and decentralized (also called edge computing) control systems.

PLCs still have a place, but with machine vision, motion control, and dynamic robotic processes, the desire for more data is increasing and older PLCs might lack the required processing power or memory. Decentralized technology can help expand a legacy line by offering products such as SoCs and FPGAs that provide processing and memory directly on the sensor. This means that adding a complex process to an existing line may not require an expensive PAC, but a group of smart sensors designed for the application.

POSSIBLY NEITHER, OR BOTH

Further confusing the PLC/PAC conversation is that it is possible to build a system without either one. A network of smart sensors and software can combine



Standard text is finding its way into PLCs so that they can handle more data, or to add in more features.

to eliminate, or perhaps more accurately scatter (decentralize), the programming controller across the plant floor. SoCs are one of the technologies that can decentralize a process. However, trying to put too many protocols onto a single SoC may increase the amount of verification cycles needed to validate a process or part—similar to overloading a PLC.

In addition, it is possible for the different technologies to work together. PLCs, decentralized technologies, and PACs can work in tandem for full plant control. Some basic steps must be taken

TERMS AND DEFINITIONS

THE DIFFERENCE BETWEEN PLCs and PACs can leak into many other technologies. For example, systems on a chip (SoCs), embedded PCs, and field-programmable gate arrays (FPGAs) represent some of the technology that is replacing or expanding the PLC industry. However, it seems the definitions of these technologies are not set in stone. Bosch Rexroth's Matteo Dariol defines the following:

PLC: A programmable logic controller is a digital computer designed for automation and industrial controls. It was created to resist to a wide range of operating conditions, including temperature, pressure, electrical noises, and vibrations. The most important feature that truly led to its success is that it is a *hard real-time system*.

Real-time: Generally, real-time is translated as being "as fast as possible." This is not true. A real-time system guarantees that all inputs, outputs, and computations process within a specific time constrain, often referred to as a deadline. A *hard* real-time system considers missing a deadline to be a total failure. A *soft* real-time system, on the other hand, accepts missing some deadlines even if it degrades the output quality. Some examples include audio and video streaming, VoIP, and video conferencing. The quality may be lacking if the audio and video aren't able to process a few frames during a conference call, but the message still comes across. This example could be similar for machine vision; a hard deadline may not necessarily be a total failure.

Every time that a PLC program compiles, it calculates whether the needed resources are available to perform all of the operations that we are commanding. Then it comes up with a solution for meeting the desired deadline.

PAC: A programmable automation controller is a digital computer that incorporates PLC functionalities. A PAC is a relatively recent innovation, having been introduced around 2000. In the majority of cases, the PAC represents an evolution of the PLC. PLCs are a bridge from electric automation, made with cables and relays, to electromechanical programmable automation, where the emphasis moved into the software side of the operation (we are talking about 40 years ago).

SoftPLC: This is a *soft real-time system*, whereby (as specified before) it does not give guarantees on timely execution of operations. For this reason, they do not work for motion-control tasks. Instead, SoftPLCs are preferred for plant-/shop-floor connectivity, for human-to-machine interfaces (HMIs), and supervisory control and data acquisition (SCADA) applications. It is possible for certain PACs to be SoftPLCs.

Embedded PC: An embedded PC is a non-general-purpose computer, designed and optimized for a single custom application. It is typically built with all of the components on a single board, including microcontrollers or microprocessors, memory, bus, I/O, and other custom chips. The system even includes the software or firmware (firmware usually resides in read-only memory, or ROM). Embedded PCs are truly the intersection between hardware and software, as a tight relationship exists between the two parts: One could not work without the other. Designing with embedded PCs can answer hard or soft real-time needs.

to find what technology or technologies a company may need.

"First, it is important to understand the factors critical to the success of an operation and the level of obsolescence risk that can be tolerated," says Julie Robinson, marketing manager, Rockwell Automation. "Once the risk is determined, users should develop a strategy for mitigating and ultimately eliminating that risk, and plan the first work-cell upgrade. Factors that drive some of these changes include:

- Meeting future production demands or improving current production performance.
- Complying with the latest safety, security, and regulatory requirements.
- Increasing flexibility to allow for efficient equipment expansion or upgrade.
- Improving asset utilization by reducing downtime.
- Enhancing safety and security measures.

"Next, users must understand what modifications have been made over the years that may not be in the latest drawings and wiring schematics."

Accurate documentation of legacy equipment will help integrate new technology. If a decentralized platform is integrated, documentation becomes even more important. Decentralized controllers have been shown to improve installation time of new equipment. Traditionally, technicians and engineers are able to plug into a centralized PLC to locate the problem, or upload and download programs as needed. If a system isn't in place to communicate from a central location or port—even if it is a virtual center—troubleshooting, upgrades, or changes may increase time and cost associated with these processes. A good system design must consider ease of maintenance, servicing, and scalability.

To make sure technicians don't have to physically walk around to connect to a decentralized system in order to troubleshoot a problem, service companies try to connect multiple systems so that technologies can work seamlessly together. Oftentimes, this means facilitating old systems with new technology and software.

"There is little return on investment in replacing hardware that is working," says Erik Dellinger, Kepware's Manager for the IoT. "These decisions should be made when designing the system. In the design phase, we have noticed there isn't always one company that has everything you need. Systems are often made up of hardware and software from multiple companies that need to work together toward a common goal."

To select the optimal technology to fit your application, it is important to understand what technology is available, will meet your current and future goals, and offer needed features without adding unnecessary complexity. It may be difficult for a company to have an expert to answer each of these concerns, and might be why service-provider companies are becoming a trend in the PLC and IIoT industries. md

Peristaltic Metering Pump Offers Double Capacity

THE QDOS 120 offers double the flow of the Qdos60 peristaltic metering pumps. With a capacity of up to 31.7 gallons per hour at maximum pressures of 58 psi, it targets applications in the water/wastewater,

industrial, and agri-chemical sectors. It maintains the same common interface, connectivity, and functionality as existing Qdos models, and delivers smooth, continuous flow for optimal fluid mixing. Numerous models are available for manual speed control, universal+ (manual, 4- to 20-mA input/output, pulse), and remote and Profibus control options.

WATSON-MARLOW FLUID TECHNOLOGY GROUP, www.watson-marlow.com, (800) 282-8823

Spool Valves Feature Impressive Sizing Specs

THE 362 and 562 series of brass and stainless-steel spool valves are available in ¾- and 1-in. sizes with 3-way and 4-way designs. They enable exceptionally high flow rates through small piping. The series includes both pneumatic and solenoid models with ATEX d and UL hazardous-location approvals. Low-temperature models are rated at -40° C, and a momentary manual override can be chosen as a select feature.

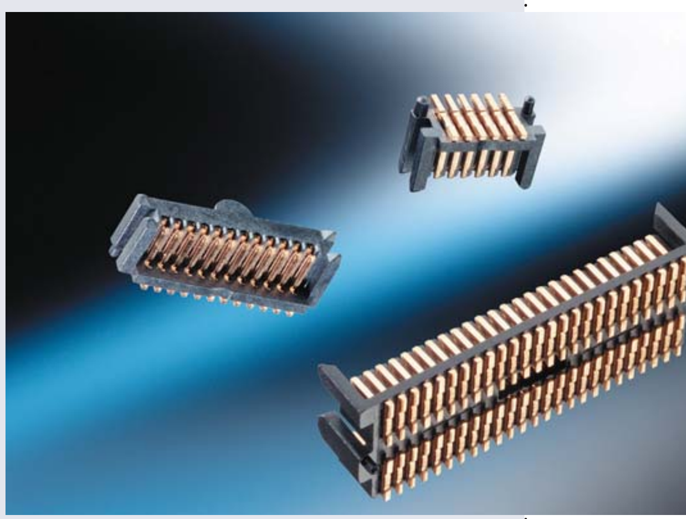
ASCO, www.asco.com

Linear Motors Feature Compact Design

THE U-521 ultrasonic piezo linear motor measures 35×35×15 mm and provides high speeds up to 200 mm/sec. Its direct-drive design eliminates rotating parts for a lower inertia when performing dynamic start-stop behavior, with settling times as low as a few milliseconds. In addition, an integrated optical linear encoder provides position feedback with resolution up to 100 nanometers. Higher resolution versions are available for OEMs. It targets applications in industry and research, including automatic micromanipulation, positioning of samples, and adjusting optical components like camera lenses. Two stages can be combined to an XY setup without an adapter plate.

PHYSIK INSTRUMENTE, www.pi-usa.us, (508) 832-3456

Non-Ferrous Connectors Target Medical Apps



THE MINIATURE 0.8-mm MicroStac SMT connector series now includes non-ferrous versions for use in medical applications like MRI machines. Both 12-pin (single row) and 54-pin (dual row) configurations are offered, with a 5-mm board-to-board stack height and a 1.5-mm effective wipe length. Based on the patented hermaphroditic design, they are easy to install and serve miniaturized and compact designs. They are designed to mate to themselves so that they only require one part instead of two.

ERNI, www.erni.com, (804) 228-4100

High-Torque Couplings Correct Misalignment

OLDHAM COUPLINGS for industrial conveyor systems are easily disassembled for cleaning, replacement and maintenance. Their three-piece design comprises of two anodized-aluminum hubs that are press-fitted onto a torque-transmitting center disk. They provide zero-backlash, and balanced accommodation of parallel, axial, and angular misalignment. The slots of the center disk—which is available in acetal or nylon—mate with the tendons of each hub to transmit torque during operation. They are offered in set-screw, clamp, keyed, and keyless styles with bores ranging from 1/8 in. (3mm) to 1-1/8 in. (30mm). Inch and metric hubs with the same outside diameter can be interchanged and combined into a single coupling.
RULAND, www.ruland.com

Epoxy Passes Tests for Low Outgassing

THE EP3HTS-LO single-component epoxy passes ASTM E595 tests for NASA low outgassing. It can be used to bond, seal, and coat components for applications in the aerospace, electronic, microelectronic, and optical industries. Its silver filler makes it electrically conductive with a low volume resistivity of less than 0.001 ohm-cm. Its thermal conductivity ranges from 1.73 to 2.16 W/(m·K). It is dimensionally stable and bonds well to metals, glass, composites, ceramics, and many plastics. It can withstand a variety of chemicals including water, oils, fuels and cleaning agents, and is resistant to temperatures ranging from -60°F to 400°F.
MASTER BOND, www.masterbond.com, (201) 343-8983

Self-Adhesive Rulers Available in Inch Sizes

THE GN 711 self-adhesive rulers are now offered with inch sizes to provide measurements on machine tools, woodworking equipment, etc., in industries such pharmaceutical, packaging, and the food industry. Three versions are available: stainless steel, .02-in. thickness, scale-etched; white plastic, .01-in. thickness, highlighted in silver, scale-printed; and transparent plastic, .01-in. thickness, transparent, scale printed. Each version is also offered with five different scale sequences. The rulers can be applied by removal of the protective strip on the back and direct application to the surface. A plastic film also protects the engraved side of the stainless steel version. GN 711.1 indicator arrows are also available.

J.W. WINCO, www.jwwinco.com, (800) 472-0670

Controllers Target High-Speed Apps

THE COMPACTLOGIX 5380 controller provides control for high-speed applications with up to 20 axes of motion. It can be combined with the Allen-Bradley Bulletin 5069 Compact I/O system for I/O response times as

Blue Light Inspection Kit Ensures Hydraulic Safety

THE SAFETYBLU SB-450 Blue-Light Inspection Kit aids in finding leaks in hydraulic systems. In addition, it can help detect and prevent dangerous injection injuries. The kit comprises of a high-intensity blue LED flashlight, which illuminates a FluidSafe fluorescent additive to pinpoint even the smallest fluid leaks in hydraulic system hoses, fittings, seals, and other components. FluidSafe should be added to the reservoir of hydraulic machinery so that in the case of

fast as 0.2 ms, while vent triggers from the I/O modules provide near-instantaneous task execution. A dual-configurable, 1-gigabit Ethernet port supports device-level-ring (DLR) topologies, as well as the use of multiple IP addresses. Diagnostic indicator lights display the status of communications and module health, along with I/O module activity.
ROCKWELL AUTOMATION, www.rockwellautomation.com, (440) 646-3434

Slotless Direct-Drive Motors Rival Traditional Ones

THE UTS series of slotless direct-drive frameless motors features a 3-phase ring-type design with a large through hole. They are available in diameters ranging from 29 to 240 mm, and are claimed to reduce cogging and enable sinusoidal torque angle curves. Their low phase resistance and inductance requires low power supplies. Optional windings are available for various voltages, speeds and currents, and custom windings are offered to optimize torque and efficiency. A standard set of iron rings are available for each motor, along with optional Hall-device feedback.
APPLIMOTION, www.electromate.com/applimotion

accidental fluid injection, it can be detected under the skin to accurately be removed surgically. The lamp is housed in an anodized aluminum body to resist corrosion; it has a 2-year warranty and is powered by a rechargeable NiMH battery. Smart AC and DC chargers are also included, in addition to yellow fluorescence-enhancing glasses, a protective rubber bumper, and a belt holster. All components are packed in a padded carrying case.
SPECTROLINE.COM, www.spectroline.com, (800) 274-8888

Motor Controllers Operate with Range of Motor Types

THE DVC series of motor controllers features digital four-quadrant servo drives that are designed and built to operate modern mobile electric vehicular platforms. They provide high power from battery supplies and an IP65-rated compact design. Multiple operating modes can control either permanent-magnet brushed or brushless motors in mobile robots, AGV's, UGV's, material handling, and transport vehicles in industrial and military environments. Capable of electrically driven actuation from traction and propulsion to steering and lifting, it also communicates over CANopen and can be configured with DriveWare 7 configuration software.

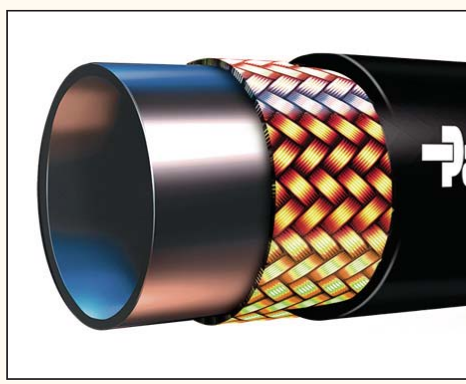
ADVANCED MOTION CONTROLS,
www.servo2go.com, (877) 378-0240

Flexible Cables Target Wearable Tech

HIGHLY FLEXIBLE data and transmission cables target wearable electronics from military biosensors to mobile computing and virtual reality headsets. Their thin profile and robustness makes them useful in confined spaces and dynamic applications. They are immune to shock,

Hose Offers Excellent Abrasion Resistance

THE 563TJ ToughJacket hose is designed to withstand strains in large-scale, heavy-duty applications. It is compact, light-weight, and rated at 3,000 psi. With a low length change under pressure, it targets boom and calve track applications, and its small



vibration, harsh weather, environmental hazards, solvents, submersion in water, and temperature extremes between -65 and 165°C. Round and flat versions are also available (Cat 5e), along with Cat 6, Dual Shielded Camera Link, USB 2.0 & 3.0, IDC Ribbon, Flexible Coax, HDMI, and Fire Wire Cables. Cables are available for quick delivery. Cable assemblies with connectors are offered in 3-ft., 6-ft., and 12-ft. lengths. Custom designs are available with minimum lead times. Low-friction coatings and custom shape and torsion designs are available by request.
CICOIL, www.cicoil.com

Servos and Amplifiers Feature Quick Response Time

THE SIGMA-7 line of rotary-, linear-, and direct-drive servos and amplifiers target automated equipment. With nearly double the bandwidth of the previous Sigma-5 series, they respond quicker to system commands, and leverage a 24-bit encoder to surpass industry precision standards. They feature a 20% smaller footprint than the previous series, and the new SERVOPACK amplifier design saves control-panel space. SERVOPACK amplifiers can be interfaced with EtherCAT, MECHATROLINK, or analog connections, and a SigmaLogic SERVOPACK can sequence motion via Add On Instructions (AOIs) used by programmable logic controllers. A SigmaTrac option is also offered for easy bolt-on, plug-in implementation of all products.
YASKAWA, Yaskawa.com

outer diameter makes routing easier on the tracks. It is resistant to abrasion, performing better than rubber and enhanced rubber in abrasion testing. They meet SAE 10017R requirements and are offered in sizes ranging from ¼-in. to ½-in. inner diameter.
PARKER HANNIFIN, www.parker.com, (330) 296-2871

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BRADFORD L. GOLDENSE | Contributing Technical Expert

Back to a Better Future: Product Definition

During the 1970s, as Japanese companies began eroding traditional western markets, the focus was on Just-In-Time and other rapid-cycle logistics and manufacturing techniques. In the 1980s, efforts shifted to product development and "Stage-Gate" was born (Robert Cooper, *Winning at New Products*, 1986). Initially, the emphasis was on moving away from "throwing designs over-the-wall to manufacturing." By the early 1990s, leading companies had achieved rapid cycle time. It became clear to industry leaders that the primary cause of poor cycle time was actually the product definition. Unless the product definition was robust, no amount of good engineering or organizational speed could turn an inadequate definition into a successful product.

Two studies were perhaps the most telling. The first was led by Hewlett-Packard and presented at the IEEE Engineering Management Conference by Edith Wilson in 1990. It laid out the top 10 most important factors for coming up with a good product definition. At the time, "product champions" were all the rage. Assign a product to a champion and all should work out fine. The HP study showed that it was much more complex than having a champion. In Pareto order, here are the 10 factors HP identified as leading to successful definitions.

- Understanding users' needs
- Strategic alignment
- Competitive analysis
- Product positioning
- Technical risk assessment
- Priority decision criteria list
- Regulation compliance
- Product channel issues
- Project endorsement by upper management
- Total organizational support level

The idea of a champion was not wrong; there were just eight things more important. The second piece of telling research was published in *California Management Review* in the Winter 1990 issue. Ashok Gupta wrote that the primary inhibitor for teams developing products was "poor definition of product requirements," cited by 71% of respondents. Shortly thereafter, Stage-Gate frameworks were modified to include a "formal definition phase" and an even earlier "concept capture activity." Voice-of-the-Customer was then coined by Abbie Griffin in 1994 and, for most of the rest of the 1990s, companies focused on getting a good definition. Focus groups reigned supreme. They were the best tool available at the time, with honorable mentions to Quality Function Deployment (QFD) and Kano Analysis.

The product-definition era ended 15 years ago. As software and the internet began to take over the world (both easier technologies to iterate to successful outcomes), up-front planning started to take a back seat. As a whole, society began to change as well. Critical thinking was gradually replaced by rapid doing. As 3D printing grew, making iterations faster for leading companies that could afford the quite expensive equipment, competitive advantages could be maintained. Today, 3D printing is down the cost curve and is available to all companies and to individual Makers working out of their homes. The playing field is nearly level again. Everyone, large and small, can now quickly and economically make physical models. Soon, 3D printing will turn out saleable market-ready products. Where does that leave us? It seems we are about to go back to the future, defining the right product.

As we head to a future that emphasizes definition, science will be on our side. While focus groups will continue to have a place, scientific advances and big data will put product managers and designers in a better position to more accurately validate requirements up front. Biometrics and neuroscience, independently and together, are already showing their improved accuracy over the synthesized words and body language from focus-group participants. When enough data has been accumulated, statistical analysis of scientifically obtained big data sets will provide more accuracy than spoken words and body language. When the tools to gather scientific data and perform big-data analyses hit the broad market, up-front planning and analysis will again prevail because competitors in most industries will have essentially the same execution cycle times. md

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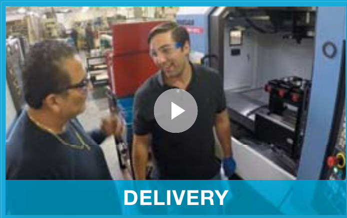

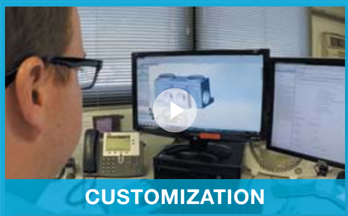

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