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No. 10
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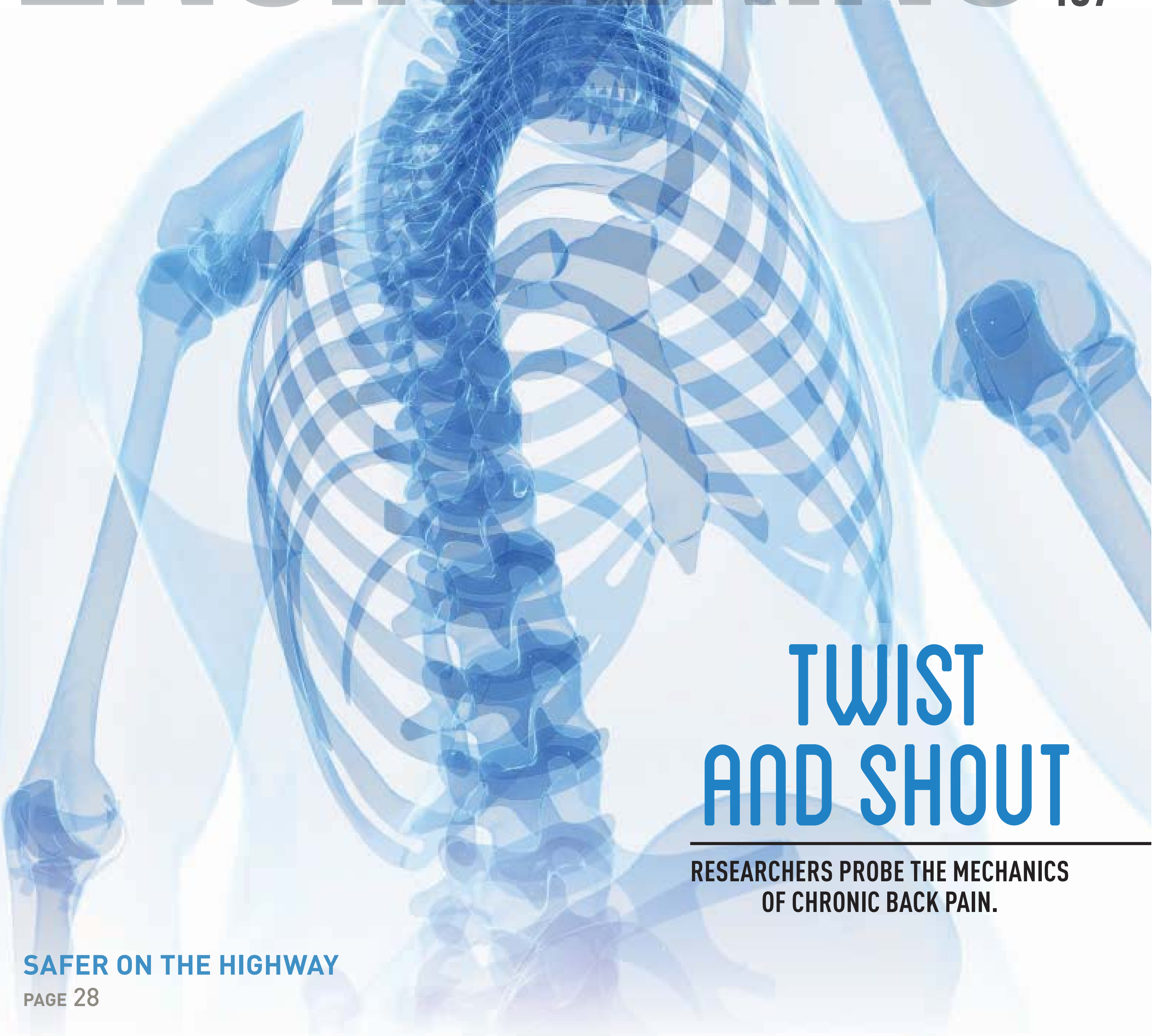

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SOLAR STORAGE WHEN THE SUN GOES DOWN

ANY SOLAR CELL EFFICIENT ENOUGH TO SOLVE OUR ENERGY PROBLEMS HAS TO KEEP working when the sun goes down. Researchers at the University of Texas at Arlington have created a cell that does just that. By using a liquid electrolyte, the new storage system gives back nearly all it takes from the sun, as soon as it's not there. The novel system is likely to beat photovoltaic cells in the budget sphere since it's cheap compared to noble metals needed for today's solar cells.

A KID'S KITCHEN

AS PART OF THE University of Tulsa's Make a Difference Engineering (MADE) program, seven senior engineering students recently designed and built a small portable kitchen as an educational tool for developmentally challenged children.

VIDEO: THE FUTURE OF HYDRAULIC FRACTURING: BIG DATA ANALYTICS

NIGEL YIP CHOY, CONSULTING partner with Halliburton Consulting, describes the advances in software and data analysis that have made hydraulic fracturing more accurate, efficient, and ultimately, more productive in recent years.

3-D PRINTING LAB TOOLS

LOW-COST 3-D PRINTING is just one of the new tools giving rise to a new generation of do-it-yourself lab instruments for citizen scientists.

NEXT MONTH ON ASME.ORG

VIDEO: NANOTECHNOLOGY IN ACTION
Cleanrooms are essential for fabricating micro- and nanoscale devices. In this video, James Marti, senior scientist at the Minnesota Nano Center, highlights the benefits of cleanrooms and how they support interdisciplinary research in nanoscience and applied nanotechnology.

PODCAST: HOW CELLS TURN ROGUE AND CAUSE CANCER
Denis Wirtz, the vice provost for research and T.H. Smoot Professor of Chemical and Biomolecular Engineering at Johns Hopkins University, discusses how cells turn rogue, escape incarceration, and become a cancer upon their surroundings.

TABLE OF CONTENTS

10 137

FEATURES

ASME

SETTING THE STANDARD

GHOST KNIFEFISH IN THE MACHINE

Robots are getting animal abilities.

BY DAN FERBER

44

11 COMMERCIAL PLANS FOR ELECTRIC AIRPLANES

A two-seat, battery-powered twin-engine plane flies across the English Channel. What next?

BY R.P. SIEGEL

28 TRENDING

A look at an engineering triumph: automobile safety.

BY ALAN S. BROWN

DEPARTMENTS

64 COLD COMFORT

Painless injections.

BY JAMES PERO

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Give me the place to stand, and I shall move the earth
—Archimedes

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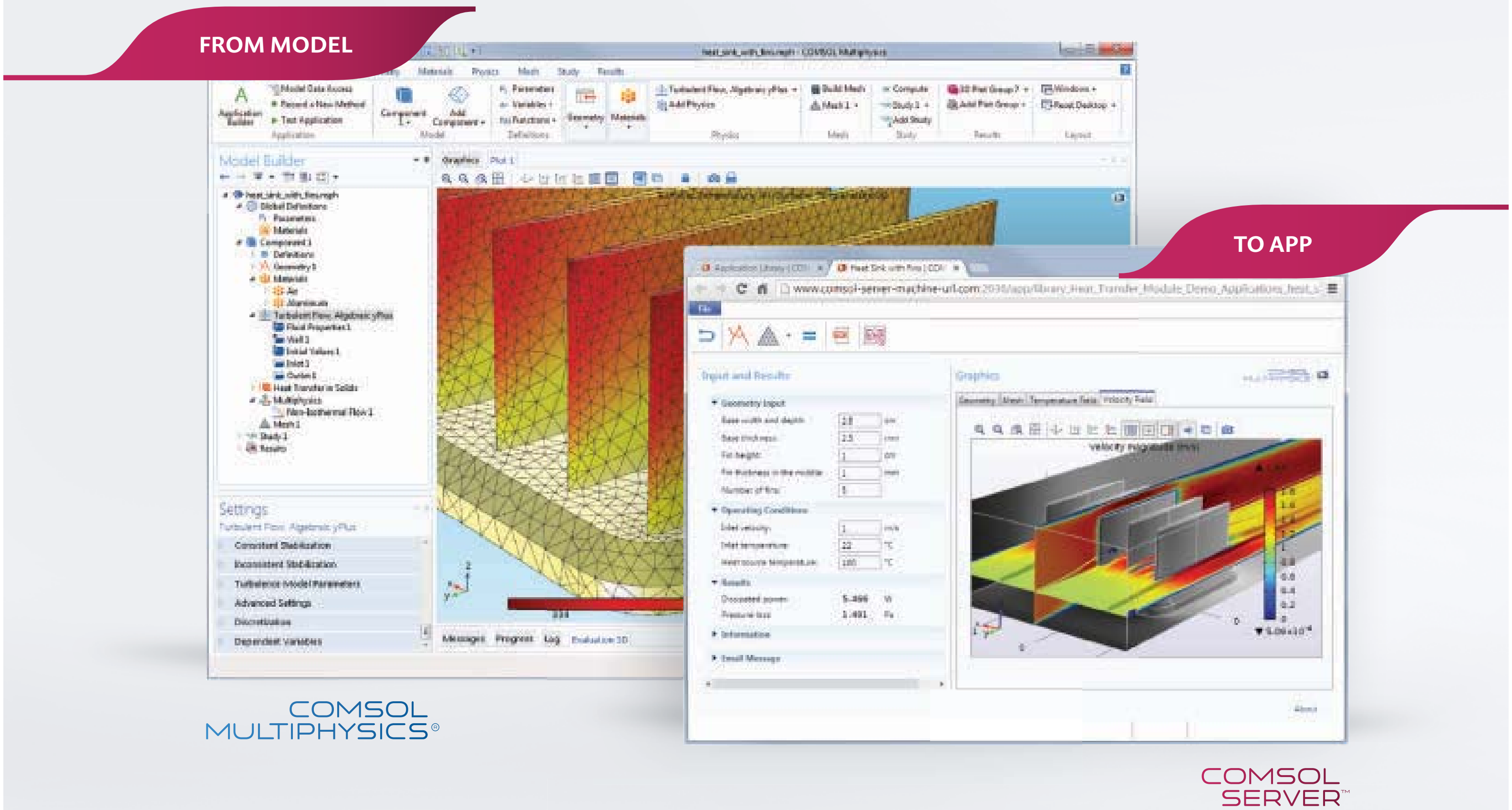

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John G. Falcioni
Editor-in-Chief

FEEDBACK

Are engineers too involved in the work of physicians and physical therapists? Email me.

falcionij@asme.org

THE BACKBONE OF ENGINEERING

There was the time when the elderly man who was driving drunk after a holiday party rear-ended me. He didn't hit me hard, but hard enough for me to feel as though my lower back was attached to a live wire. Then there was the time when the driver of an SUV missed a stop sign on a dangerous blind turn by my train station and plowed into me as I was crossing the street. I flew off his truck's incoming grille—a memory so ingrained I will never forget it—and landed on my lower back. I was lucky. Except for being covered in black and blues for about a month, the biggest strain was to my lumbar vertebrae. All this, of course, on top of the first time I landed on my lower back, when I was a husky nine year old and fell hard on the play yard cement when I was roller skating. Overall, I must say that with the help of a little physical therapy, my back has held up pretty well through the years.

Sometimes that surprises me. A body is a complex series of systems whose components serve specific functions to keep it operating. There are biological pumps, valves, pipes, filters, wiring, and a lot of contents under pressure. Just like a mechanical system, if the stresses become high enough, the parts can fail. Those who study how bodies work often use the tools and expertise developed over the last 100 years in mechanical engineering to solve problems related to human health.

In fact it was more than 300 years ago, in 1680, when the Italian scientist and mathematician Giovanni Alfonso Borelli—with his treatise *De Motu Animalium*—opened a new field of study that looked at living bodies as machines. Borelli, who is recognized as the father of biomechanics, described the motions of the body in mathematical terms and illustrated the musculoskeletal system of a body as a series of simple levers, pulleys, and wheel-axles that can flex, extend, rotate, and bend.

More than three hundred years later, engineers, scientists, and doctors are still trying to pick apart the nuts-and-bolts of skeletal and muscle movements and figure out how the actions of motor and cytoskeletal proteins such as actin and myosin lead to the contraction of muscle fibers, hoping a molecular understanding of motion may lead to new therapies and treatments for muscular disorders.

In this month's cover story, "The Secret Life of the Spine," a present-day Borelli, William S. Marras, the executive director of the Spine Research Institute and the Honda Chair professor at Ohio State University, takes us on a journey through the load and tolerance relationship that when modeled can help doctors and other researchers determine why our backs hurt.

Marras's work also involves ergonomics and human factors, which are areas that designers rely on to guide the creation of human-friendly products that ease the stresses on the back and other parts of the body.

Despite the occasional aches and pains, my back is holding up pretty well, especially considering that approximately 80 percent of the population have or will suffer low back pain. According to Marras, back pain is the second most common reason we visit the doctor. I haven't visited a doctor for my back in a while. Now if the rest of me would be that lucky. ME

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COMMENT

A STUDENT CONNECTS THROUGH THE NSF

One of the most important aspects of college today is obtaining research experience to further your insight into your field.

I am a junior studying engineering at the University of Tennessee and found not one, but two research programs that will help further my knowledge in my field. The programs are both associated with the National Science Foundation.

At the University of Tennessee, the RISER (Research and Instructional Strategies for Engineering Retention) program was developed to benefit and retain engineering students, especially females like me, by illustrating "how their chosen majors can be intellectually challenging, personally satisfying, and beneficial to society" through different opportunities, including research experience.

Claudia J. Rawn, the principal investigator for the program, not only reaches out to students about RISER, but also helps pair every student in the program with a professor doing research that matches the student's interests. RISER is funded by the NSF's Science, Technology, Engineering, and Mathematics Talent Expansion Program.

Being proactive, I found the RISER program as soon I started my freshman year at the university. I worked closely with Dr. Rawn researching different opportunities until I was referred to David K. Irick, faculty advisor of the university's EcoCAR 2 hybrid vehicle design team. EcoCAR 2 was a three-year collegiate engineering and automotive design competition in which fifteen schools competed. While the main sponsors of the competition are the Department of Energy and General Motors, the NSF is a platinum sponsor. For the competition, students took a stock 2013 Chevrolet Malibu, donated by GM, and rebuilt it from the ground up as a plug-in hybrid electric vehicle.

The EcoCAR 2 competition ended in 2014, giving way to EcoCAR 3, which challenges students to further reduce the environmental impact of a 2016 Chevrolet Camaro over a four-year period without compromising performance, safety, or consumer acceptability.

The first year involves modeling and simulation in preparation for the next three years, when the team will be working with the physical car. While a team of senior engineering students designs and builds the car, there is also a project management team and a communications team. Each team has specific deliverables for the competition.

I am a member of the communications and the project management teams. By working with these teams, I have had the opportunity to learn more about advanced automotive technology, alternative fuels, and advanced topics associated with mechanical engineering. It has given me a head start in my field of study.

While working on the EcoCAR 2 and EcoCAR 3 teams, I have coordinated outreach events at elementary through high schools, the FIRST Robotics Regional competition, EarthFest, and around the university's campus; I have written and edited technical deliverables (including the project management plan, communications plan, and implementation plan); and I have improved my teamwork abilities, leadership skills, and technical knowledge specifically in the automotive field.

I also believe that "the Karson Model" will revolutionize the UT EcoCAR 3 team. Before I joined, the team had always been made up of only senior and graduate students. It was a senior design capstone course, which resulted in a large turnover from year to year. By introducing students to the team as freshmen, like I was when I joined, there could be a lower turnover and a higher knowledge transfer from year to year. This gives underclassmen a hands-on introduction to research and engineering design not normally seen before the senior or graduate levels. The early exposure provides a platform to link undergraduate course work to real-world engineering problems.

Through the EcoCAR competitions, I have had the opportunity to meet industry leaders, travel to competitions with a team, and above all, further my knowledge of engineering concepts and applications through research and real-world experiences. To find out more about the EcoCAR 3 competition and students like me, visit http://www.ecocar3.org or follow the team on Twitter/Instagram: @EcoCARUTK. ME

KARSON STONE is a junior studying industrial and systems engineering at the University of Tennessee, Knoxville.

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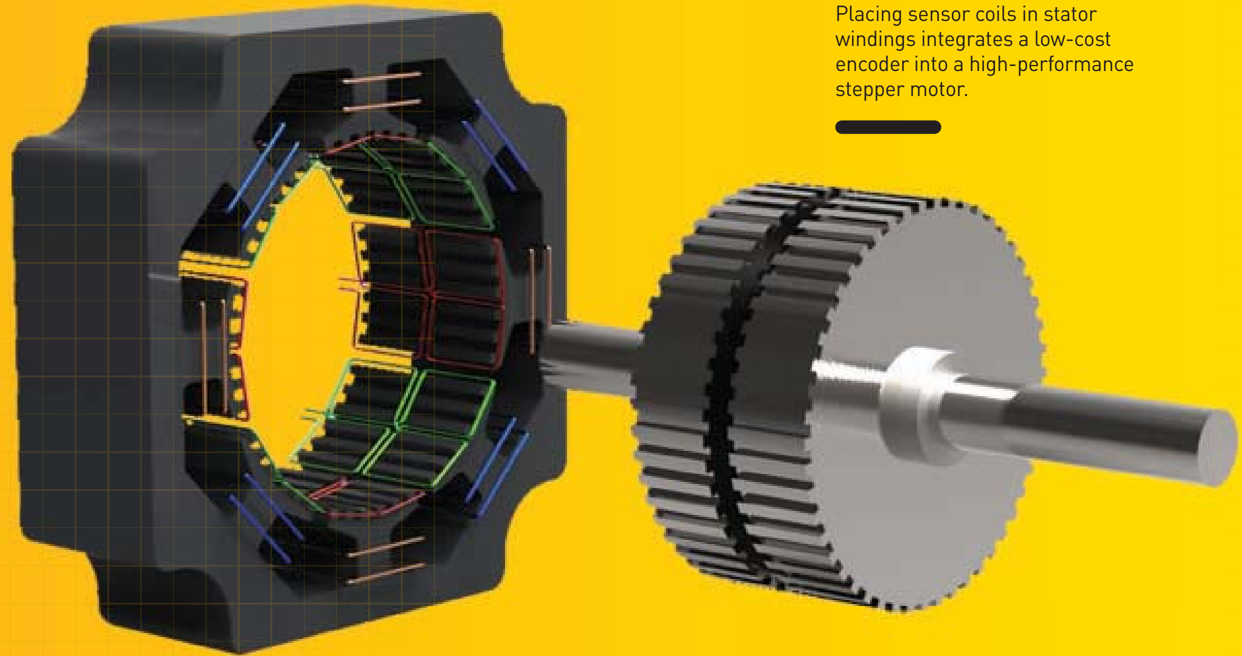
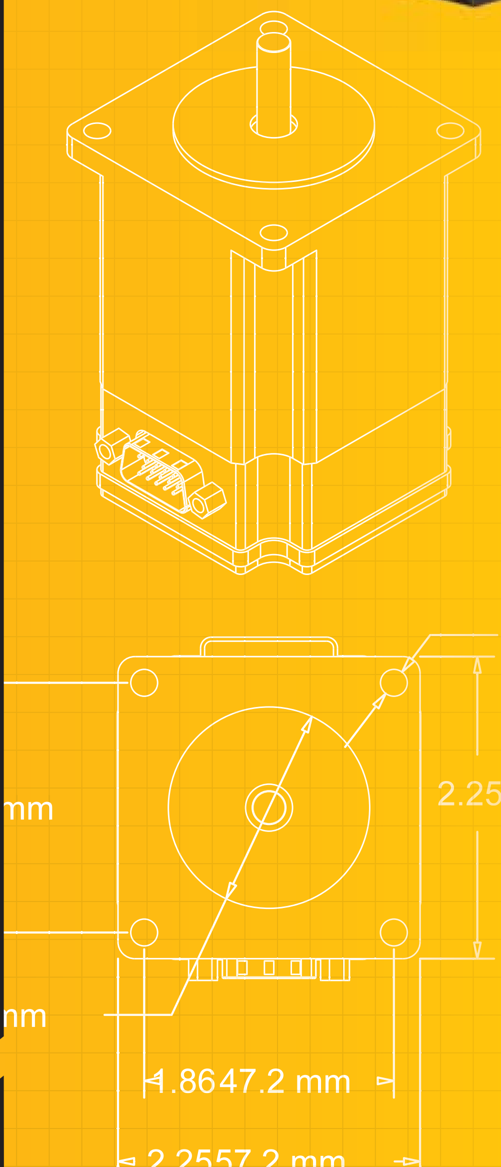


Placing sensor coils in stator windings integrates a low-cost encoder into a high-performance stepper motor.



EMBEDDED ENCODER

FOR YEARS, A DESIGNER TRIED TO THINK OF A WAY TO MAKE ENCODERS CHEAPER AND MORE ROBUST. NOW HE THINKS HE HAS ONE: EMBED IT IN THE VERY STRUCTURE OF A HIGH POLE COUNT AC MOTOR. THE RESULT IS A RUGGED MOTOR THAT PROVIDES 32,000 POSITION COUNTS PER REVOLUTION.

The ability to fine tune a motor's position comes with a high price tag, especially in smaller motors.

It takes an encoder, which typically costs as much as twice the price of the motor itself, and it is also the most likely part of the power system to fail, according to Don Labriola, president of Quicksilver Controls of San Dimas, Calif.

Labriola spent years looking for an alternative.

"I knew that when we energized a motor, it knows where to move," he said. "So something in its magnetic structure has that information."

The solution came to him while visualizing the inside of a motor during a long, boring drive. He could visualize the windings he needed. When he got back to his lab, he cut apart a few motors with a Dremel tool, stripped some wire, wound it into shape, and removed an insulating coating with fingernail polish remover.

Those first sensors showed that his idea might work. He then began designing sensor coils that he could integrate into the stator's windings.

Labriola started with his company's stepper motors. These motors divide each rotation into 100 or so steps, and they can move to these steps without a feedback sensor. Labriola, however, drives the motors with a four-quadrant vector controller (similar to a variable-frequency drive) that makes his motors act like servomotors. The drive takes advantage of the changing magnetic flux as the rotor teeth pass the stator teeth to provide very fine control over position. This is called microstepping, and it achieves up to 8,000 position counts per revolution.

Once Labriola embedded the encoder sensors into the motor's stator, taking measurements was a matter of timing. He likens it to running between a moving elephant's feet.

Here's how it works. The same processor that controls the servo drive voltage also controls the timing of the analog-digital converter that reads the voltage from the sense coils. So Labriola takes his measurements in between servo pulses, after the rotor has time to settle into position and 30 to 40 nanoseconds before a new pulse moves it to the next position.

"As long as you know and control the timing of the servo signals, and synchronize the readings, then a solid signal is available," he said. "We do not even need to shield the sensor wires from the motor wires for good signals."

The resulting NEMA 23 hybrid servo achieves 32,000 position counts per revolution at a lower price than conventional servo-encoder combinations. Since the encoder is part of the motor body, it is not vulnerable to misalignment or dust. It also retains the high sustainable torque at low speeds for which stepper motors are known.

Potential applications range from machine screws and belt drives to medical devices and solar panels. Labriola is working to expand the range of embedded encoder motors and improve their performance with high inertial loads. **ME**

ALAN S. BROWN

The Airbus E-Fan: Across the Channel, perhaps on its way to bigger things.

COMMERCIAL PLANS FOR ELECTRIC AIRPLANES

THE MISSION FOR COMMERCIAL AIRCRAFT is pretty straightforward: Carry dozens, if not hundreds, of people and their luggage over vast distances at high speeds. That mission has been accomplished for decades courtesy of fossil fuel.

On July 10, 2015, Airbus Group successfully completed a 21-mile flight across the English Channel with a tiny airplane that the company hopes someday will challenge the dominance of fossil fuel. Airbus developed the 31-foot wingspan demonstrator prototype it calls the E-Fan.

The E-fan burns no fuel. The two-seat, twin-engine carbon-fiber aircraft is powered by electricity. Two ducted variable-pitch fans are mounted on the fuselage, behind the wings. Each fan is capable of 0.75 kN of thrust. Maximum speed is 200 km/h.

Of the three main types of aircraft engines—turbojets, turbofans, and turboprops—the E-fan is closest to a turbofan in configuration, except a 30 kW electric motor drives each fan. The electric power comes from a 250 V lithium-ion polymer battery pack that weighs 167 kg. The pack holds 29 kWh, enough charge to keep the plane aloft for about an hour with a 50 percent reserve.

A separate 6 kW motor drives the aft wheel, which is used for taxiing and to assist during takeoff. Because of its light weight and all-electric power train, it's expected to cost about $23 an hour to operate.

Airbus said the prototype could lead to a 70-passenger hybrid-electric regional aircraft. Such an aircraft could provide significant improvements, particularly in the areas of fuel burn, noise, and emissions.

According to Detlef Müller-Wiesner, director of the Airbus Group electric aircraft program, such an aircraft might enter commercial service in thirty years, maybe less. The experimental 600 kg E-Fan, which has already made over 100 flights, is a work in progress. The configuration that crossed the channel has seen its battery capacity increase

continued on p.19 »

3-D FOOTPRINT GROWS

The largest 3-D printer in the world is the Big Area Additive Manufacturing Machine.

Photo: Oak Ridge National Laboratory

As the range of applications for 3-D printers becomes wider, development times are shrinking while equipment is growing larger. New 3-D printers are getting big, and one now has a build volume of 8 x 20 x 6 feet and a flow rate of 100 pounds an hour of composite thermoplastic material.

The printer's developers, Cincinnati Inc. and the Department of Energy's Oak Ridge National Laboratory, have enlarged their original creation, the Big Area Additive Manufacturing, or BAAM, machine, which has a build volume of 6 x 13 x 3 feet and prints as much as 40 pounds per hour.

The new machine uses a new extrusion system developed by ORNL engineers to reach its print rates of 100 pounds an hour.

The smaller BAAM was demonstrated in 2014 at the IMTS show in Chicago, where over the course of 44 hours it printed all the parts for a Strati, an automobile developed by Local Motors, the custom-car startup based in Phoenix.

BAAM also printed parts earlier this year for a Shelby Cobra.

Most impressive, according to Lonnie Love, group leader of ORNL's Automation, Robotics, and Manufacturing Group, is that engineers developed the Big Area technology over a span of six months.

ORNL signed a cooperative agreement with Cincinnati in March 2014, with the goal of printing a Local Motors Strati vehicle at the International Manufacturing Technology Show in September. "We committed to printing a car with this technology before we had a system," Love said.

ORNL first began work on 3-D printing in 2012 with polymer systems, Love said. The lab's manufacturer demonstration facility is charged to develop new materials and processes, and then move technology to mainstream manufacturing. Love said a wide variety of end users, such as aeronautical firms, visit and work there, looking for an eventual end product.

> **"WE HAD TO FIND THE SWEET SPOT IN THE MIDDLE, AND TRY TO KEEP THE ENERGY INTENSITY AS LOW AS POSSIBLE. THE FIRST TIME WE PRINTED CAR PARTS, THE LAYERS SPLIT LIKE A DECK OF CARDS."**
>
> — LONNIE LOVE, OAK RIDGE NATIONAL LABORATORY

Researchers started with refining plastics used in 3-D printing, which were problematic because of variable internal stresses. The first big breakthrough came in January 2013, with the introduction of carbon fiber to the raw plastics. "It was a game-changer," Love said. "You've got these stresses. When you put carbon fiber in, all of that goes away."

The next step was to find a company to build a printer capable of producing large objects. At the begin-

continued on p.14 »

LICENSE REQUEST FOR WATTS BAR 2

THE TENNESSEE VALLEY AUTHORITY has written to the Nuclear Regulatory Commission to affirm that construction of the Watts Bar Unit 2 nuclear reactor is substantially complete and to request an operating license.

According to the letter, construction has proceeded to the point where the TVA can submit "a substantial number of plant structures, systems, and components to Preoperational Startup Engineering (PSE) for testing."

Testing of the new unit, which it refers to as WBN Unit 2, is continuing, TVA said.

According to the letter, "Hot functional testing has been completed, and the containment integrated leak rate test and integrated safeguards tests are scheduled for completion. The transition plans that were implemented to confirm that the WBN staff is prepared to safely operate WBN Unit 2 are complete. These plans provide reasonable assurance that dual unit operation of WBN Units 1 and 2 can be conducted in compliance with the Commission's rules and regulations without endangering the health and safety of the public."

TVA said that, over a period of eight weeks, operators used the heat generated by plant equipment to increase the temperature and pressure of systems to normal operating levels. The unit's main turbine was also rolled up to normal operating speed using the plant's steam.

It was the first time that nearly 60 important systems functioned together at operational temperature and pressure as designed and built. Important safety-related systems were also tested to show they can help keep the reactor safely cooled. Completion of hot functional testing meets a critical pre-operational requirement for NRC to issue a license, TVA said.

When it comes online, Watts Bar 2 will generate 1,150 megawatts of electricity, or enough to power 650,000 homes.

The full text of the letter and its attachments is available online at http://www.tva.com/news/releases/julsep15/wb2-letter.pdf.

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continued from page 12 »

3D FOOTPRINT GROWS

ning of 2014, Cincinnati executives became interested. The firm manufactured high-speed gantry and laser-cutting systems, which dovetailed nicely with ORNL's preliminary work on large-scale 3-D printers. Within three months Cincinnati developed its first gantry for a 3-D printer.

"Oak Ridge had the concept to use plastics and large-scale extruders and mount on a gantry," said Rick Neff, Cincinnati's head of market development. "We had been asking, 'How do we get involved in 3-D printing?' We make gantries. So it is a little like chocolate and peanut butter."

Scaling up involved some trial and error. Love said most 3-D printers are fairly small machines that work slowly, building parts about one cubic inch per hour for a final product that is usually less than one cubic foot in volume.

Love and his team found challenges in maintaining thermal control. There were distortion and slumping issues with smaller pieces that melted, and bonding problems between layers of large pieces. As the extruder's nozzle lays down material, the greater distances the nozzle must pass for larger parts can allow the material to cool. That causes bonding problems when the next layer is applied.

Oak Ridge lab's Lonnie Love works on 3D-printed Shelby Cobra.
Photo: Oak Ridge National Laboratory

"We had to find the sweet spot in the middle, and try to keep the energy intensity as low as possible," he said. "The first time we printed car parts, the layers split like a deck of cards."

The team now works with standard injection molding pellets heated to 210 °C, at low pressures. "We're not pushing at high pressure. There's not a lot of heat and speeds are moderate," Love said. "Now we can put a lot of material down very fast." Material costs in the range of 3 cents to 10 cents per cubic inch also make printing in large volumes affordable, he said.

Cincinnati's gantries can operate at 200 inches per second, and researchers were tasked with developing an extruder capable of pushing large volume of materials precisely. When the project began, the gantry worked at about one inch per second, applying 10 pounds per hour of material through a 0.3-inch nozzle. At that rate, it would have taken over a week to print the parts for Local Motors' Strati.

Love says two weeks before they were scheduled to print the car parts, ORNL engineers perfected a new screw that pushed the flow rate to 40 pounds per hour, pushing the gantry speed to four inches per second, and cutting down the time to print the car to 44 hours. Researchers are now experimenting with different nozzle sizes and speeds. Local Motors has already said it will leverage the technology and open two car printing facilities, one in Knoxville, Tenn., close to ORNL.

According to Neff, Cincinnati has produced five machines so far, and sold three of them. "This is so revolutionary," he said. "When we were printing the car at the IMTS show, people were looking at it and were wowed. But they weren't saying, 'I have the perfect application for this.' "

Neff and Love believe the technology will have impact in producing machine tools and industrial molds. "The killer application is going to be in tooling," Love said. "If you can make a mold in one day for $1,000, it will be a game changer for the manufacturer." **ME**

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DEVELOPMENT ENGINEERING IN THE U.S.

The wild and starkly beautiful lands in U.S. Native American reservations are home to some of the nation's poorest people. Swaths of wilderness cut residents off from the electrical grid, running water, and the Internet. Conditions like those seem foreign to urban Americans, but isolated pockets of the country get by with no greater technological progress than some rural communities in the developing world.

The U.S. Census Bureau identifies more than 5 million people as American Indians and Alaska Natives, and one-third of them live on land set aside for tribal rule. That land is a nation-spanning patchwork totaling 87,500 square miles, slightly smaller than the size of Great Britain.

In the rural parts of the reservations, services are scarce and so is housing. Unemployment is high and poverty entrenched. Which is to say that there are opportunities for global development engineering within the U.S. borders.

"It's a chicken and egg problem," said Heather Fleming, the co-founder of Catapult Design in Denver. "There are no jobs because there's no infrastructure, and no infrastructure because there's no money to pay for it, and there's no money because there are no jobs."

Fleming and her firm work in the Navajo Nation, the country's largest reservation, which encompasses 27,400 square miles of the high desert of the American Southwest. Their work on the reservation is not the traditional engineering of water and power access. Instead, they apply a systems engineering approach to reducing poverty by lowering barriers that block the creation of small businesses. New businesses have to navigate a tangle of regulations, including a letter of support from the tribe's president, an archaeological survey, and cooperation from a slow-moving political system.

With funds from a grant by the National Endowment for the Arts, Catapult has held an event called Change Lab to promote innovative thinking and seed networks of community support for businesses. Now Catapult is designing a product that can succinctly explain the steps required to start a business.

Meanwhile, Roger

continued on p.17 »

MENTAL TOUGHNESS

Mental toughness is an attribute of athletes that separates the world-class from the average and the winners from the losers. The mentally tough consistently perform up to or above their potential. Some people come by mental toughness naturally and aren't shaken by anything; they are "in the zone." Others fall apart as soon as the clock starts or the ball is tossed.

Sports psychologists have long known that an athlete's mental state is as important as conditioning and training. Factors that negatively affect performance are distractions, lack of self-confidence, pressure to perform, and fear of failure. These can provoke physiologic responses that trigger a downward spiral toward defeat. Breathing shallows, the heart races, the muscles tense, the mouth goes dry, and vision narrows. This is the fight-or-flight response, and nobody performs well in this state.

These same responses can manifest any time you perform, whether it's a musical solo, a public speech, or a P.E. license exam. You might even feel uneasy simply introducing yourself at a conference roundtable.

The mentally tough are not vexed by these physical reactions. In his book, *Mental Toughness Training for Sports*, James E. Loehr describes an "Ideal Performance State" that is calm, confident, energized, and joyful. Psychologists like Loehr say that mental toughness can apply to work and life, not just sports.

There are proven techniques to attain an ideal performance state. Many are holistic or Zen-like systems for self-improvement. *The Inner Game of Tennis* and other Inner Game books by W. Timothy Gallwey are classic examples. However, just knowing you need to calm down won't help. The specific techniques of relaxation, visualization, and concentration will.

Relaxation starts by controlling your breathing. Steven Ungerleider, in his book *Mental Training for Peak Performance*, writes that proper breathing "reduces stress and anxiety, and increases performance." Try taking six full breaths, inhaling each over six seconds, holding for three seconds, exhaling for six. Maintain a comfortable, steady tempo thereafter. (Hyperventilating is just as pernicious as shallow breathing.) Then relax your musculature. Slowly clench your hands into fists, hold six seconds, then let them go limp.

Can you feel the difference? Continue with forearms, shoulders, chest, abs, legs, even your jaw. You might find that some muscles had been tensed without your knowing it. This "progressive relaxation" should put you into a calm but ready state.

Top athletes visualize their desired outcome. Jack Nicklaus sees a putt roll into the hole before striking the ball; Lindsey Vonn, eyes closed, hands curving and twisting, imagines her run at the top of the downhill course. You can prepare for an interview by picturing yourself confidently entering an office and firmly shaking hands as your eyes meet those of your future boss. "See yourself succeed," Ungerleider writes. Relive your greatest successes and try to recapture your feelings from those times. Relive your happiest moments, too. Smiling precipitates a positive mindset (and frowning the opposite).

Concentrating is as much about not focusing on distractions as it is focusing on the immediate task. "Trying hard to concentrate doesn't work," Gallwey advises, saying it comes naturally from an interest in the undertaking. Intense study or relentless repetition immediately before a challenge is misguided. Many people benefit from a period of physical isolation. Of course, preparing well beforehand is imperative; it boosts confidence, enabling the ideal performance state. But as the challenge approaches, your concentration should consist of being "in the moment," fully aware of everything, distracted by nothing.

It is best to practice achieving an ideal performance state, which makes getting there easier when you really need it. But even if you master mental toughness, you will be anxious and nervous at times. Learn to savor these emotions. Think, "I love this feeling of butterflies. It's so exhilarating!"

Mental toughness training is beneficial for anyone, including engineers. An ideal performance state can help with everything from interviews to confrontations to presentations, even a thorny design challenge. Relax, visualize, and concentrate. ME

JAMES G. SKAKOON is a retired mechanical design engineer and a frequent contributor.

continued from page 14 »

DEVELOPMENT ENGINEERING IN THE US

A nearby spring could soon water this corn field in Navajo Canyon through a new micro-irrigation system.

Photo: Instagram @willopeterson

Hansen coordinates trips to the Navajo Nation for volunteers from Engineers Without Borders–USA. Their projects include building and repairing homes, and laying a pipeline from a spring for micro-irrigation.

Before retiring last year, Hansen coordinated infrastructure projects and student and professional volunteers through his post at the U.S. Bureau of Reclamation in Provo, Utah.

"We worked on a variety of water projects, some as simple as rainwater harvesting, solar-powered groundwater pumping, and micro-irrigation. And some more complicated, like using green technologies to bring indoor water and power to isolated locales. We also did feasibility studies on a variety of more typical engineering projects," Hansen said.

Families in Navajo Canyon have no running water in their homes, so they carry buckets to a spring. Developing the spring will put a water tap into a large home and irrigate a cornfield and an apple orchard to benefit a total of 45 people.

The EWB—Great Salt Lake is heading the project, and one of its members, Will Peterson, helped map out the work with community leaders.

Peterson has worked in global development engineering, and he saw similarities between rural American reservations and the developing world.

"The urge is always to go to developing countries to do this kind of work, and that's great, but there's a lot of need in the United States," Peterson said. "We're always looking for people with different skills to join in the conversation."

Domestic engineering work is not immune to the failure that hassles many projects in developing countries.

Fleming has a *Navajo Times* article about a $1.9 million program to install solar electric systems in 88 homes. Eight years after installation, most of the systems weren't working. ME

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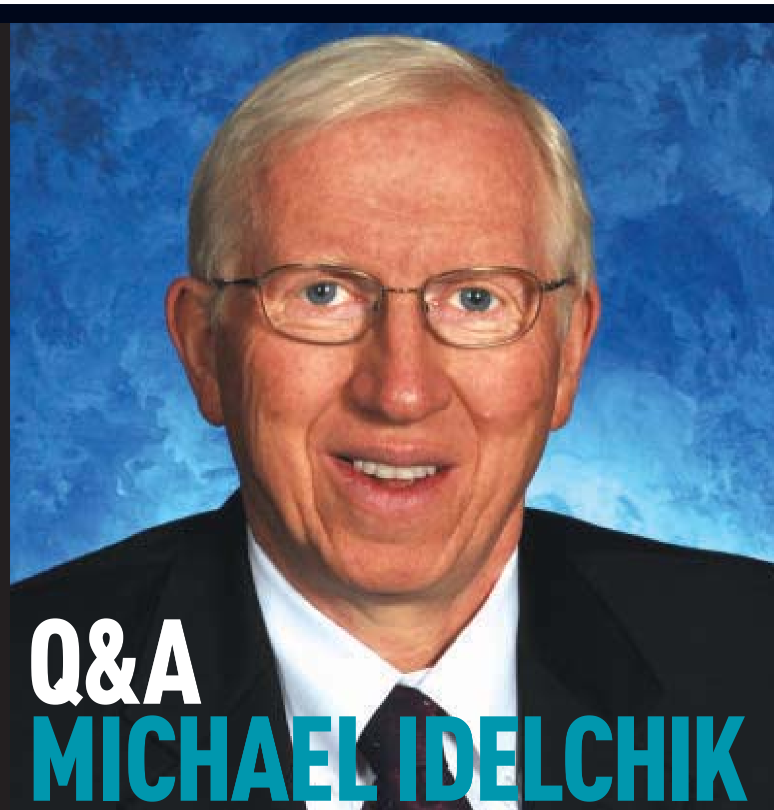

Q&A MICHAEL IDELCHIK

MICHAEL IDELCHIK JOINED GENERAL ELECTRIC as an aircraft engineer in 1978 after graduating with mechanical engineering degrees from Columbia University and the Massachusetts Institute of Technology. He spent the next three decades working on GE's jet turbine engines and medical imaging products, and headed the company's research operations in China. Since 2004, he has led GE Global Research's long-term research as vice president of advanced technology programs.

ME: At GE, what do you mean by long-range planning?

M.I: It really varies. Our first patents for titanium aluminide, a material midway between a metal and ceramic, date back to 1998. It weighs one-third less than nickel alloys in jet engines, and that has many benefits. But we cannot substitute aluminides directly for nickel. They behave differently. We spent a lot of time and money on the fundamental science, because they give us an advantage in the market.

On the other hand, it took only seven years to develop our first silicon carbide-based electronics, and they are flying now. Sometimes it takes even less time.

ME: How do you identify promising technologies?

M.I: We are well connected with our businesses. Their CEOs come here three or four times per year, and we have an understanding of their key technologies. They have strong engineering teams, so we focus on the fundamental work here. Of course, we have to make choices, and we want to make sure we have the right combination of talent and partners.

ME: How important are collaborations?

M.I: We're trying to solve some very difficult scientific problems, so we need to get thought leaders wherever we can find them.

For example, our latest medical ultrasound systems put very detailed imaging in a very small package. We do this by embedding customized chips inside lightweight transducers to steer our scans and process information. You'd never think of GE doing something like this. We do it by partnering with a handful of chip suppliers who have the ability to make what we need.

ME: Do you pursue technologies without any obvious application to your core businesses?

M.I: We always look at new inventions outside our businesses, where we are a small fish in big pond. We've also been very successful with DARPA, ARPA-E, and other large grants. Competing with other groups on big challenges is very important for our organization. It forces us to adapt to things we are going to need in the future.

ME: What excites you about GE's technology today?

M.I: I believe we are really going to surprise everybody with the next-generation beyond the GE-9X turbofan engine. We have the enabling technology to reach 65 percent combined efficiency, compared with 60 to 61 percent today. It could have a huge impact on greenhouse gas emissions.

In our energy portfolio, the combination of renewables, large power plants, and distributed generation will create new and more resilient ways of managing the grid. It's going to be more local and more efficient. We're talking about a 10 megawatt block of power with 70 percent efficiency sitting at your local substation, combined with economically competitive wind and solar, backed by 300 to 400 megawatt gas turbines that can be online in 10 to 12 minutes.

ME: GE was founded by Thomas Edison, a seat-of-his-pants engineer with little formal education. How do you find today's Edisons?

M.I: I believe people in some emerging disciplines, like the people who live in the 3-D printing space, will redefine engineering. Are we willing to hire them? Yes, even if they don't have an engineering degree, as long as they create great things.

This is not much different from programming, before we defined it as computer science. There were mathematicians, physicists, all sorts of people solving problems who did not realize they were writing software. I can see mechanical engineering community evolving the same way with 3-D printing. ME

continued from page 11 »

ELECTRIC PLANES

by 60 percent since its inception. But, to get from this point to a regional jet will take several orders of magnitude improvement in the power-to-weight ratio.

Müller-Wiesner laid out Airbus Group's three-stage strategy to achieve this.

First, in the short term, it will continue to develop small electric aircraft like the E-Fan. It sees a potential market in two-seat planes with light sport aircraft certification for pilot schools and personal use. This will provide the opportunity to investigate technologies that are ready today for electric propulsion.

In the medium term, the effort will focus on conventional electrical engines in the 1-2 MW range with the potential to go to 5 MW, which is equivalent to a medium range regional aircraft. For comparison purposes, the electric propeller motors of the *QE2* are each 44 MW. Initially, Airbus will use a non-flight model called a hybrid ground demonstrator to develop understanding of the interaction of the different systems—mechanical, thermal, electrical, guidance, and control—to see what the architecture of a future regional aircraft could look like.

For the longer term, research and technology projects will look at contributing technology for a more advanced hybrid aircraft. Unlike the E-Fan which is pure electric, a hybrid would use a conventionally fueled engine to drive a generator, and in some circumstances, as in takeoff, would drive the fans directly.

Rolls-Royce has partnered with Airbus Group to explore a number of advanced propulsion options. Rolls-Royce has so far invested $1.43 billion in the effort. One option under consideration is distributed electrical aerospace propulsion, an embedded propulsion system that requires a high level of integration with the airframe.

The system was developed in response to European Commission's target of reducing aircraft emissions: CO_2 by 75 percent, NO_x by 90 percent, and noise by 65 percent from year 2000 levels.

Another possibility is the programmable alternating current superconducting machine, which includes a programmable superconducting stator as well as a superconducting rotor. The superconductors and lightweight epoxy frame replace the copper and iron structure associated with conventional generators. The result is a more powerful, lighter, lossless design. It can reverse to charge the batteries during descent. **ME**

R.P. SIEGEL, P.E., is a writer based in Rochester, N.Y.

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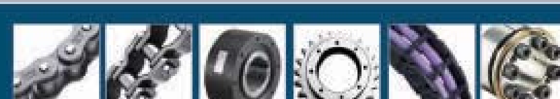

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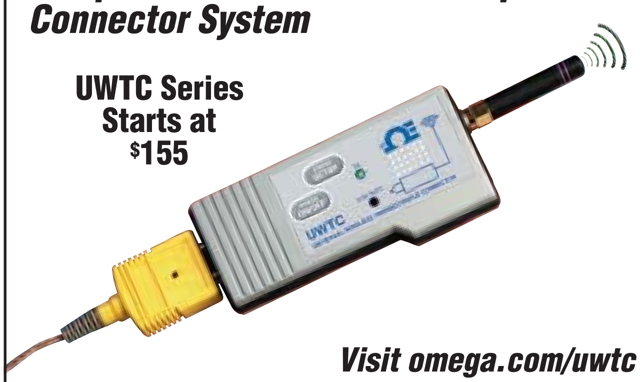

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OLD CRACK TAKES BLAME FOR A PIPELINE RUPTURE

A report by the Transportation Safety Board of Canada has found that a gas pipeline rupture and fire in Manitoba in January 2014 were caused by incremental stresses on a crack half a century old, possibly the result of a faulty weld.

According to the agency, the crack formed when the 30-inch pipeline, Line 400-1, was built in 1960. According to the report, P14H0011: "The pre-existing weld crack had likely formed at the time of the pipeline's construction due to poor welding quality and an inadequate welding procedure. There was no indication that it had grown in service."

The report noted that the original standard for the pipeline's construction, ASA B31.1.8, did not require every weld to be inspected using radiography, nor did it require the retention of records. According to the TSB investigators, "Based on standard industry practice at the time of construction, the weld at the failure location had likely been inspected only by visual means."

Supervisory control and data acquisition records established that the operating pressure of the pipeline system at the rupture site was about 6,330 kilopascals, below the maximum rated pressure of 7,030 kPa.

Line 400 consists of 3 parallel pipelines. Because of low demand, gas had not been flowing since Jan. 5, 2014, in pipeline 400-1. Pressurized gas was present in the line, however, between closed valves.

After the pipe ruptured in the early morning hours of January 24, residents of five homes in the vicinity, near Otterburne, Manitoba, were evacuated until the resulting fire burned itself out.

When the damaged pipe was studied at a lab in Edmonton, investigators found similar, but less-severe weld cracks in other parts of the pipe section.

Some surface corrosion and stress corrosion cracking also were present, but they were not considered as contributing to the pipe failure.

The TSB deemed that the fracture was caused by incremental stresses to the pipeline, which may have been the result of weakened soil support from maintenance activities over the years; record low temperatures that winter; recent work near the valve site that may have driven frost deeper into the ground; and thermal contraction as the pipeline cooled during a 20-day shutdown.

As required by the National Energy Board, TransCanada performed numerous excavations, inspections, and repairs along Line 400-1 before returning it to service. After the pipeline returned to service, TransCanada performed in-line inspections to rule out other threats to the pipeline's integrity. ME

AN EYE ON THE WATER AS ASH BASINS CLOSE

As it prepares to shut down 14 coal plants in the state, Duke Energy is working with North Carolina to protect groundwater from the ash basins that will also be closed.

The company is submitting comprehensive groundwater assessments to the state Department of Environment and Natural Resources for each of the plants.

According to Duke Energy, the assessments are based on thousands of hours of work by outside experts and contain information about the groundwater near the coal ash sites.

The company and the agency will use this and other information to determine how best to protect groundwater as ash basins are closed.

According to Duke Energy, the data were gathered through the installation of about 900 new monitoring wells and more than 5,000 soil and water samples across the state.

An assessment of operations at the H.F. Lee Energy Complex in Goldsboro found, for instance, that groundwater near ash basins is flowing away from neighbors' private wells to isolated areas where there are no private wells. Studies also find that water in the Cape Fear, Neuse, and Lumber rivers has not been affected by ash basin operations.

An overview and executive summaries of the reports will be posted at www.duke-energy.com/ash-management.

The next phase of work includes additional sampling and computer modeling to better understand how groundwater conditions are expected to change over time. Where groundwater impacts need to be addressed, the sampling results and modeling will inform the engineering solutions to protect groundwater over the long term.

In addition to completing groundwater assessments, Duke Energy has ash excavation in progress at three coal plants (the Asheville and Riverbend plants in North Carolina and the W.S. Lee plant in South Carolina) and recently announced its recommendation to excavate an additional 12 basins in North Carolina for technical reasons unrelated to groundwater concerns.

It continues to study remaining basins in North Carolina and will use this groundwater data and modeling to inform recommendations for effective basin closures. ME

Roger Boulton with one of the 152 high-tech fermenters developed for the Teaching and Research Winery. *Photo: UC Davis*

FRUIT OF THE VINE

THE UNITED STATES HAS become the largest market for wine, according to the International Organization of Vine and Wine, an intergovernmental agency based in Paris. Meanwhile, the Wine Institute, which calls itself "the voice of California wine," reports consistent increases in annual U.S. wine production—totaling more than 830 million gallons in 2013, about 90 percent of it from California. Two university wine labs—one on each coast—are offering grape growers and winemakers high-tech assistance in both production and analysis techniques.

The huge number of variables affecting the style and quality of wine have challenged producers for centuries. Researchers at the UC Davis department of viticulture and enology have taken control of one very important factor: fermentation temperature.

"There has always been temperature variation in wine production," said Roger Boulton, the Stephen Sinclair Scott professor of enology at the university. Fermentation temperature can be influenced by the weather during the harvest, as well as by overactive yeast.

According to yeast producer Wyeast Laboratories, red wines should be fermented between 70 and 85 °F (20-30 °C) for better color and tannin extraction. Higher temperatures can yield cooked flavors, and yeast start dying. For white wines, fermentation temperatures should be between 45 and 60 °F (7-16 °C), to help preserve fruitiness and volatile aromatics. Cooler temperatures can slow fermentation or stop it altogether.

UC Davis partnered with T.J. Rodgers, founder and CEO of Cypress Semiconductor and owner of Clos de la Tech Winery, to design and build 152 state-of-the-art stainless steel research fermenters controlled by Cypress programmable chips. Each 50-gallon unit has an automated temperature control, an automated system for pumping juice over grape skins when making red wines, and a sensor that monitors fermentation progress. Surrounding each fermenter is a jacket filled with water, which is automatically cooled or heated as needed.

Data from the fermenters are transmitted to a nearby computer control

NOT TOO HOT, NOT TOO COLD

THE LAB The Teaching and Research Winery, University of California, Davis; Roger Boulton, the Stephen Scott Professor of Enology, director.

OBJECTIVE To build the most advanced and environmentally sustainable teaching and research winery in the world.

DEVELOPMENT Precise wireless control and monitoring of wine fermentation temperatures.

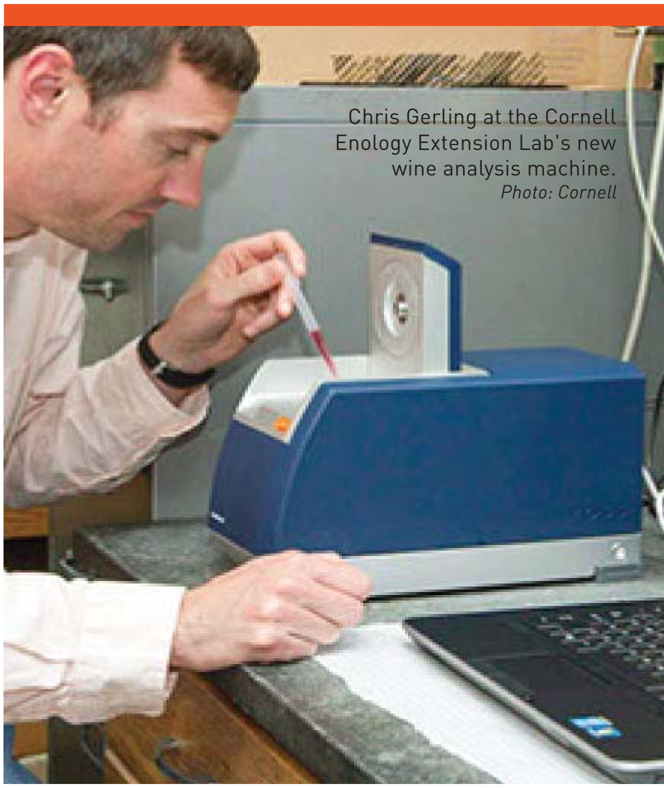
room at a programmable rate up to once per minute and automatically graphed on a large monitor in the control room.

"This radically new fermentation system is unlike anything available at the moment to commercial or research wineries," Boulton said. While some facilities can monitor temperatures and sugar content, this system provides real-time data for Web-based applications.

"It equips us, for the first time, to perform reproducible fermentations with precise temperature control and uniform mixing," he said. "From a research perspective, keeping this constant allows us the kind of control we need to focus on other factors affecting wine." Other factors include behavior of yeast strains and bacteria, vineyard micro-climates and geology, and grape and wine chemistry.

The strong concentration of wireless signals coming from one room was an initial challenge in receiving the electronic data. This was overcome by switching to Cloud-based internet technology. Researchers set and then monitor fermentation temperatures, using computers, tablets, or smart phones.

With 152 tanks, the lab can study wine from up to 50 different vineyard sites at one time. "Remember, winemakers only get one chance each year to both produce wine and evaluate what they are doing," Boulton said. "The importance of precision is critical, or else you have to wait another year for results." ME



Chris Gerling at the Cornell Enology Extension Lab's new wine analysis machine.
Photo: Cornell

HIGH TECH FOR SMALL PRODUCERS

THE LAB Cornell Enology Extension Lab, Cornell University, Ithaca, N.Y.; Anna Katharine Mansfield, associate professor; Chris Gerling, extension associate.

OBJECTIVE Conduct applied trials and transfer research-based information back to the farm-based wine industry.

DEVELOPMENT Fast and complete analysis during all phases of winemaking through rapid measurement of key parameters.

With the recent acquisition of its OenoFoss wine analyzer, Cornell Enology Extension Lab adds considerable speed and range to its wine analyzing capacity. It can also lend a hand to small wine producers in Upstate New York.

"The OenoFoss can measure sugar, tartaric and malic acids, pH, nitrogen, alcohol, and numerous other key parameters in both must and wine," said Chris Gerling, extension associate at the lab. Must is the juice of grapes before it is fermented.

"In the past, we'd have to conduct a number of separate tests using several instruments, and it would have taken four to eight hours to get the results for one sample," Gerling said. "Now, we can do it all on one machine and it takes about a minute to get the readings."

A few drops of juice from grapes grown in various parts of the vineyard can give winemakers immediate information on sugar and acid levels to determine the best time to harvest each plot. It also allows for segregating the best grapes to make separate batches of higher-quality wine. During fermentation, the transformation of must to wine can be closely monitored allowing the winemaker to adjust conditions for best results. When wine is put in barrels or tanks for aging, the analysis can detect problem batches before they are blended with other wine.

While the new equipment uses Fourier transform infrared technology, as the lab's old machinery does, the new OenoFoss offers a number of advantages.

"It has better processing power and improved calibration," Gerling said. "Its predecessor also had solvents and internal pumps. The new machine has no moving parts. And we now only need a small sample for the refractometer in the machine. With just one machine, we can get a full analysis very fast."

The lab began working with Foss, which makes the OenoFoss, about 10 years ago. The technology been available for several years, but only larger wine producers could afford the $45,000 price tag.

Now, the lab can use the equipment for its own research work, and make it available to smaller local producers in the nearby Finger Lakes wine region. Gerling said he regularly accepts must and wine samples from growers for evaluation.

The ability to get wide-ranging and accurate analysis almost immediately could make a huge difference to small-scale winemakers who have not had access to such technology before. ME

LARRY LEVENTHAL is a writer currently based in Bangkok. He also holds a diploma from the Wine & Spirit Education Trust.

STUDENT TEAM SETS ANOTHER LAND SPEED RECORD

A land speed racing team composed largely of students at Ohio State University has set another international record for heavy electric vehicles at Bonneville Salt Flats.

Summer rains had soaked surface of the Salt Flats, in Wendover, Utah, and presented difficulties for the team's professional driver, Roger Schroer. He managed to achieve an average two-way speed of 240.320 miles per hour (386.757 kilometers per hour) in the team's latest streamliner, the Venturi Buckeye Bullet 3.

The record is waiting for confirmation by the world racing body, the Fédération Internationale de l'Automobile.

This is the second year the team has competed in FIA's Category A Group VIII Class 8, for electric vehicles over 3.5 tons.

Weather interfered last year, as well, when the team set a record in the same category at 212.615 mph (342.171 kph).

The ultimate world record for electric vehicles, set by the same team in 2010, is 307.6 mph (495 kph) in FIA's Category A Group VIII Class 4.

The crew was able to prepare 10 miles of the track this year. The typical course is 12 miles. The salt surface, best for racing when it is compact and dry, was left bumpy and wet.

The new record did not come without costs. Intense vibration disrupted the vehicle's electronic system and generated weld cracks in components, including the front cooling tank.

According to Schroer, "In eleven years here I have never driven on such a difficult track. The vehicle was sliding on the surface from one side to the other due to soft spots and bumps."

The electric streamliner was designed and built by undergraduate and graduate students over the past five years at The Ohio State University Center for Automotive Research. It is propelled by two custom electric motors developed by Venturi Automobiles, a Monaco-based electric vehicle manufacturer that is the team's partner. Power comes from more than two megawatts of lithium ion batteries produced by A123 Systems.

Schroer is a veteran team driver from Transportation Research Center, an independent automotive proving ground and vehicle testing organization in East Liberty, Ohio. ME

CHINA-THAILAND RR CONNECTION

China and Thailand expect to hold a commencement ceremony in October to mark a new cooperative agreement to build a rail line that will connect the two countries, according to a report in *People's Daily*.

Zhu Xijun, general manager of the Southeast Asia Co. of China Railway Construction Corp., the two countries had held six rounds of negotiations before they agreed in August to the railway project.

China has begun to develop a plan it calls One Belt, One Road. The name notwithstanding, the plan involves two major trade routes.

One is a land-based system connecting the countries from China to Europe that were part of the Silk Road of antiquity. The China-Thailand railway project is part of that plan.

The second route is intended to connect with Southeast Asia, Oceania, and North Africa, through the South China Sea, the South Pacific Ocean, and the Indian Ocean.

According to Zhu, the China-Thailand railway will be completed in three years. It will extend 867 kilometers and have an operational speed of 180 km/h. The original goal was to run at 250 km/h, but the lower speed will reduce costs.

The railway will pass through Thailand's northeastern Nong Khai province and then proceed to Bangkok and Rayong province.

The ticket between Kunming, China, and Thailand's capital, Bangkok, a journey of more than 1,000 kilometers, will cost about 3,600 Thai baht or 700 yuan, a little more than $100, about half or a third the price of an airline ticket, the newspaper said. The cost of rail freight is expected to be about one-ninth the cost of air freight.

Wu Zhiwu, interim chargé d'affaires at the Chinese embassy in Thailand, said the collaboration on the railway may lead to other cooperative infrastructure projects including construction of sea ports and airports. ME

"WE HAVE NO OTHER OPTIONS. This is not the policy of the Oil Ministry but the government. If Iran does not increase its oil production in time, we will permanently lose our share in the global market."

Iranian Oil Minister Bijan Namdar Zanganeh announcing that Iran would increase its oil production at any cost. Reported by Mehr News Agency *on August 23.*

ATOMIC ENGINEERING?

BY THEODORE VON KÁRMÁN, CALIFORNIA INSTITUTE OF TECHNOLOGY

Less than two months after the bombing of Hiroshima and Nagasaki, one of the world's leading minds in aeronautics saw potential applications of nuclear power for constructive uses—and skills that the new field would require.

Now it seems we are at the threshold of the new atomic age. I do not know whether or not this is true, but certainly we shall have "nuclear engineering" in the fields of energy and transportation. Are we prepared for the problems involved? …

I raise the question: Do we give today to the future engineer enough fundamental knowledge in basic questions of the structure of matter, the nature of energy, the relation between matter and energy, so that he will be able to think intelligently in the new field, to have good engineering judgment on possibilities and methods? …

First, I believe we have a tendency to restrict our teaching to scientific knowledge which has immediate applications. We often forget that almost every new physical or chemical discovery might have engineering application. After all, engineering is the conquest of nature, i.e. matter and energy, for human comfort, and therefore an engineer cannot know too much about the inner structure of the matter, against whose whimsical moods he struggles, and the laws of energy, which he wants to exploit and harness.

Second, we underestimate the interest of our students in "natural philosophy." We are reluctant to present the fundamentals of physics and chemistry as a living science full of question marks and changing concepts. We believe we ought to introduce the findings of research only after the unshakable truth has been established. We tend to stick to classical concepts. I found, while teaching mechanics of continuous media, elasticity, and fluid dynamics, my students listened eagerly as I told them something about atomic structure of the materials and kinetic theory of gases. I wonder how many engineering students obtain a picture of entropy, chemical reaction, and the like from a modern point of view. And why should ordinary combustion be an engineering topic, and nuclear reaction a mystery of modern alchemy? **ME**

LOOKING BACK

Public awareness of nuclear power was brand-new when this article was published in October 1945.

ATOMS (MOSTLY) FOR PEACE

It was nine years after Theodore von Kármán's article appeared before the first nuclear power plant sent electricity to the grid. The 5 MW Peaceful Atom power station in Obninsk, Russia, began delivering electricity in June 1954 and continued to operate until 2002. The first industrial scale nuclear plant, Calder Hall in the U.K., with four 60 MW units, began operating in 1956. It also made weapons-grade plutonium for the British government. The first strictly commercial nuclear power plant came online in Shippingport, Pa., in 1957.

Calder Hall Reactor No.4. near Seascale, U.K.
Image: The British Nuclear Group Ltd.

U.S. AGENCY ISSUES UPDATE ON NEW NUCLEAR REACTOR DESIGNS

THE U.S. GOVERNMENT ACCOUNTABILITY OFFICE has issued a technology assessment of new concepts for nuclear reactors.

The report, prepared for Senator Dianne Feinstein, Ranking Member of the Subcommittee on Energy and Water Development of the U.S. Senate Committee on Appropriations, looks at the current status of several advanced designs, including a high temperature gas-cooled reactor, a sodium-cooled fast reactor, and four small modular light water reactors.

The nearest to completion are the light water reactors. Small modular light water reactors have some features, including the coolant used, in common with the current fleet of large U.S. nuclear power plants.

Design groups for all small modular light water reactors have held preliminary discussions with the Nuclear Regulatory Commission about possible certification. One of the designers in that group, NuScale Power LLC, has said it plans to apply for design certification in 2016.

None of the other reactor design programs has announced a schedule for application.

The GAO's report considers both the expected benefits of small modular light water reactors and challenges remaining before they can be put into operation.

A small footprint is expected to provide flexibility, possibly opening new markets for nuclear power plants. Modular designs can be manufactured in factories, and so reduce construction time and cost compared with current large-scale nuclear plants.

Challenges include demonstrating that the reactor designs are safe. According to GAO, "If the light water SMR designers are unable to demonstrate that their designs can operate safely without adding to the complexity of the design, their construction and maintenance costs may increase and thus weaken their economic competitiveness."

The Department of Energy has provided financial support to the designers of two small light water reactor programs for reactor certification and licensing work. The DOE also supports research and development activities on the high-temperature gas reactor and the sodium fast reactor.

The Energy Department provides this support in areas such as fuels and material qualification and reactor safety studies, the report said. Energy and Nuclear Regulatory Commission officials said they do not expect applications for design certification of advanced reactors for at least five more years.

Reactor designers told GAO's researchers that one of the major challenges they face is the cost to develop and certify a design, which can run to $1 billion or even $2 billion. From the time a completed reactor design has been submitted to NRC, the licensing process and construction can take years, possibly a decade or more, before a reactor is operational.

The GAO consulted a group of 20 experts, who provided information on reactor development, economics, and licensing. The experts also reviewed comments that were included in the final report.

DOE officials, members of GAO's expert group, and reactor designers said that the cost and time needed to certify or license a reactor design and construct it, and uncertainty about the energy market in the future and potential customer interest, pose serious obstacles to the opening of new nuclear power plants.

The title of the 46-page report is "Nuclear Reactors: Status and challenges in development and deployment of new commercial concepts." The text is available online at http://gao.gov/assets/680/671686.pdf. ME

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BY THE NUMBERS: SAFER ON THE ROAD

Engineering changes have saved an estimated 600,000 lives in auto accidents over the past 50 years.

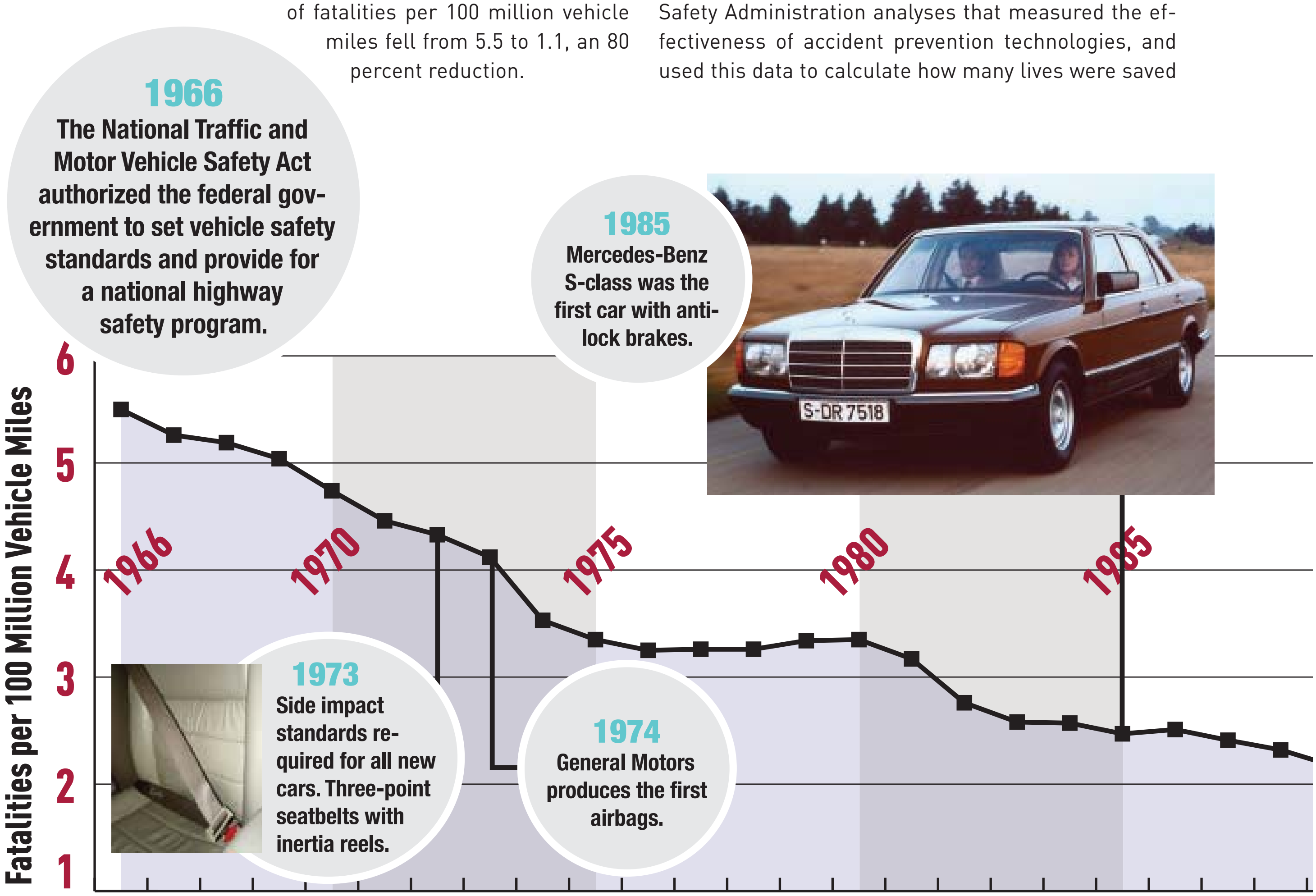
Vehicle safety is one of the great triumphs of engineering over the past fifty years. In the United States, the number of people killed each year in traffic crashes declined 36 percent, to 32,719, between 1966 and 2013, while the U.S. population rose more than 60 percent.

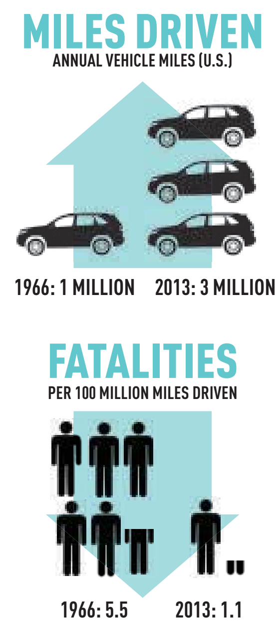
The numbers look even more impressive when examined in terms of fatalities per mile. Between 1966 and 2013, American drivers more than tripled the number of miles they drove each year. Yet the number of fatalities per 100 million vehicle miles fell from 5.5 to 1.1, an 80 percent reduction.

Engineers have played an outsize role in saving lives, according to a 2015 analysis by the National Highway Traffic Safety Administration, *Lives Saved by Vehicle Safety Technologies and Associated Federal Motor Vehicle Safety Standards, 1960 to 2012*.

The study found vehicle safety technologies saved 613,501 lives between 1960 and 2012, and 27,621 lives in 2012 alone.

The study examined passenger car and light truck occupants. It looked at 82 National Highway Traffic Safety Administration analyses that measured the effectiveness of accident prevention technologies, and used this data to calculate how many lives were saved





Between 1966 and 2013, American motorists more than tripled the number of miles they drove each year. Yet the number of fatalities per 100 million vehicle miles fell 80 percent.

by a particular technology.

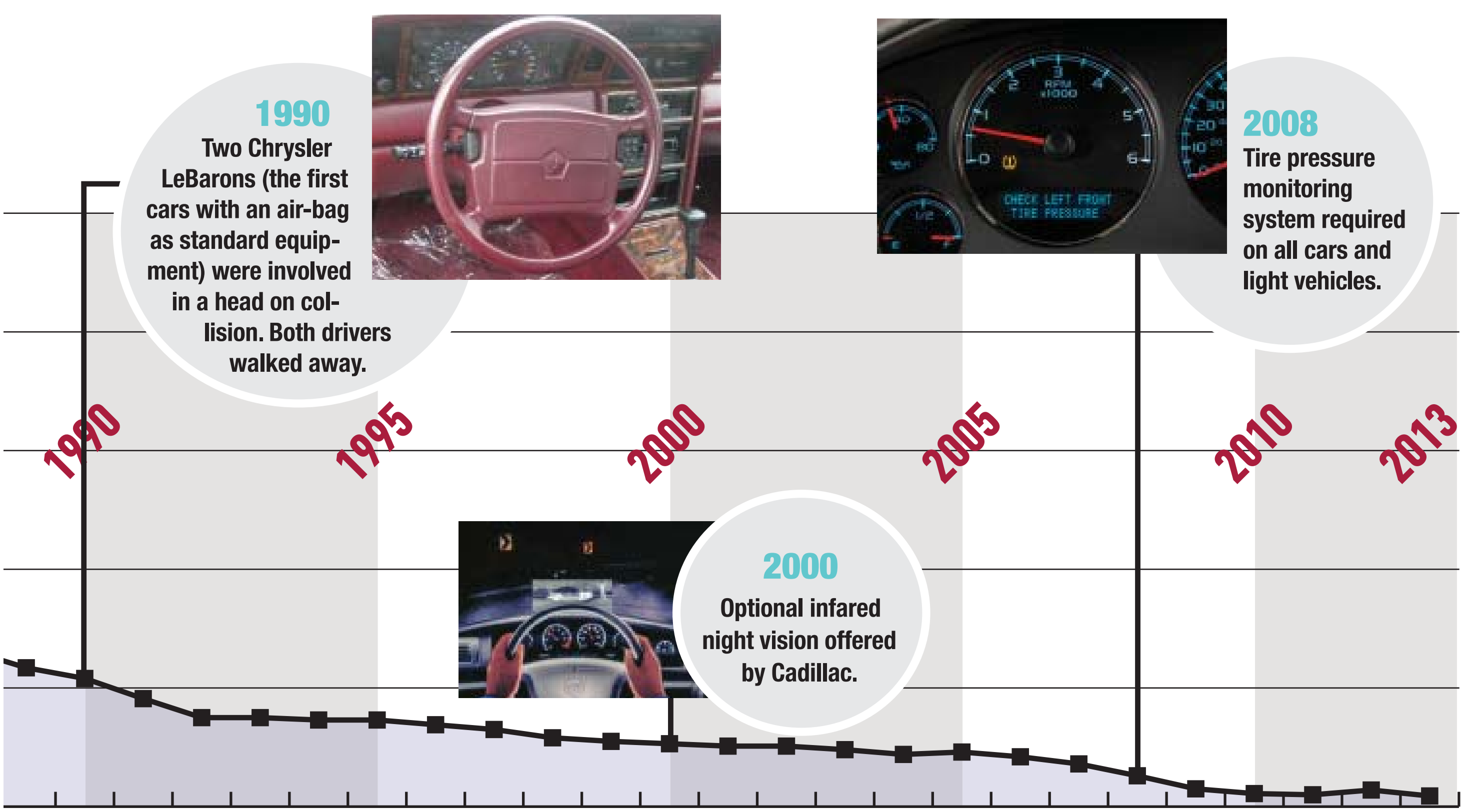
Over the past 50 years, the most important life-saving technology has been the seat belt, which is credited for more than half the estimated lives saved in 2012. Without the restraint of seat belts, a collision can eject passengers from a car or smash them into hard surfaces or one another. Frontal air bags and energy-absorbing steering assemblies prevented an additional estimated 5,337 deaths in 2012.

Protecting against side impacts saved an additional 1,500 lives in 2012, according to the report. This involved three distinct technologies: stronger side door beams for impact with trees and other fixed objects; improved structure and padding, which protect against near-side crashes; and curtain and side air bags, which are also effective against near-side impacts.

Electronic stability control was the fourth most important life-saving technology in 2012, even though it was installed on only 20 percent of U.S. cars and 22 percent of light trucks and vans. ESC steps in when a vehicle is about to lose traction, automatically braking individual wheels and reducing engine power to help drivers maintain control.

The report also acknowledged other factors contributing to the decline of fatalities and injuries. They included safer roads with more guardrails, better emergency medical services, and a crackdown on drunken driving. Still, it found engineering improvements the most important contributors to the decline in fatalities. ME

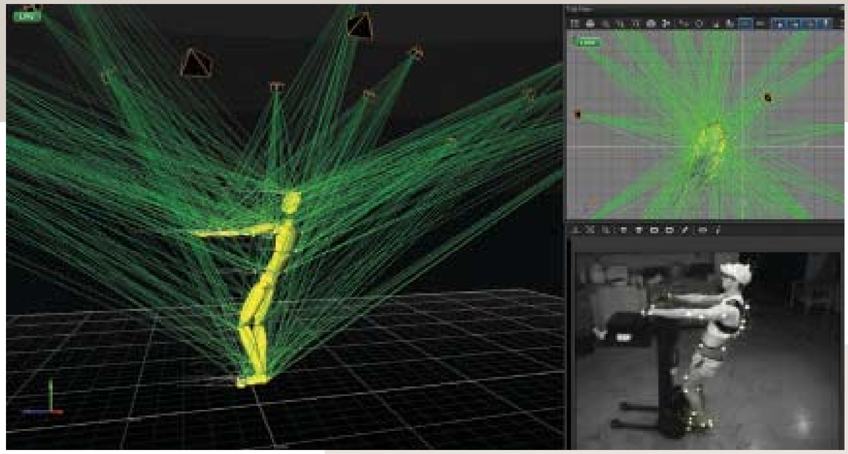
ALAN S. BROWN



THE SECRET LIFE OF THE SPINE

Little is understood about a critical body structure; engineers are changing that.

By William S. Marras



Using a combination of force monitors and optical sensors to track position, researchers can find links between body position and spinal loading.

LOWER BACK PAIN IS THE SECOND MOST COMMON REASON PEOPLE VISIT THEIR PHYSICIANS AND THE WORLD'S LEADING CAUSE OF DISABILITY. IN THE UNITED STATES ALONE, BACK PAIN ACCOUNTS FOR MORE THAN 100 MILLION ANNUAL LOST WORK DAYS AND $90 BILLION IN TREATMENT COSTS. THAT IS AS MUCH AS WE SPEND FIGHTING CANCER.

The culprit is usually the spine.

And despite all the problems spines cause, we know shockingly little about them. Physicians fail to provide a precise diagnosis for 80 to 90 percent of lower back pain cases. MRI images and computed tomography scans provide useful information a paltry 10 to 15 percent of the time. Diagnoses are mostly subjective, treatments usually trial and error. Surgery fails more than half the time, and follow-up surgeries have an even lower rate of success.

For the past three decades, the Spine Research Institute at Ohio State University has sought to unlock the secrets of the spine. We did this by measuring spines under different loads and building models accurate enough to simulate their behavior. We use these models to discover more about the causes of back and neck pain.

Our biomechanical models are not mere academic exercises. We have used them to redesign tasks to reduce the risk of spinal injuries on assembly lines and in such professions as nursing. Our most recent work seeks to provide physicians and surgeons with more precise ways to diagnose and treat back pain.

To get there, however, our biomechanical models had to come a long, long way.

MUSCLES AND LOADS

The first attempts to model the spine yielded generic models based on moments, or force times distance. They treated the spine as a fulcrum, the center of our biological seesaw. One side of the seesaw carries the weight of our body and anything we lift or move. On the other side, muscles anchored to our spine counterbalance the load.

To create these early models, engineers used inverse dynamics. Working backwards, they noted the static force on one side of the seesaw and calculated the counterbalancing torque applied by the spine.

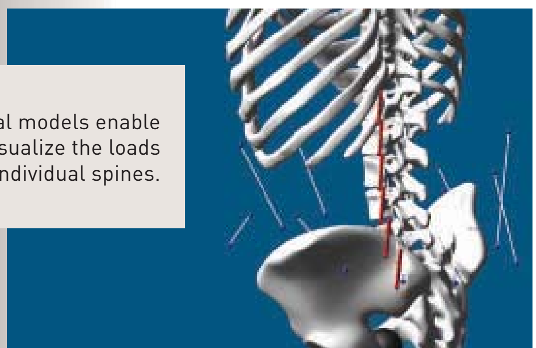
As an athlete who played basketball in college, I knew this approach had to be wrong. Totally wrong. This is not how muscles respond to force.

Instead of a single counterbalancing torque, the muscles in our back, torso, arms, and legs engage in a constant tug of war with one another. They have to, because the loads on our spines are rarely static. We constantly bend, twist, lift, run, jump, and move.

Moreover, every spine is as unique as our teeth or face. For example, while the dictionary definition of the lumbar vertebrae is the five vertebrae between the pelvis and rib cage, our own imaging studies showed that a surprisingly large number of people have six rather than five lumbar vertebrae. (This has led to failed operations because surgeons failed to verify the location of a vertebra by counting from both the top and bottom of the spine.)

Even when spines have the same number of vertebrae, they behave differently. Their vertebrae come in all sizes, densities, and shapes. Each one handles loads differently. The same is true of muscles. Not only does strength vary from person to person, but each of us uses our muscles differently. LeBron James, for example, recruits his muscles a lot differently than I do.

A simple mechanical model cannot pos-



Detailed spinal models enable researchers to visualize the loads placed on individual spines.

sibly predict spinal behavior. That is why, more than 25 years ago, we made a strategic decision to develop biologically assisted models. To do this, we needed to understand the construction of the spine (fairly straightforward), and also how muscles—down to individual vectors of force within a muscle—worked with one another to generate force.

That meant finding ways to tease out how muscles generate force.

One way was electromyography (EMG), which reads the body's electrical signals to tell us which muscles act together and how strongly they contract. We took EMG readings while subjects did specific tasks, then calibrated that data with the force exerted by those muscles.

> We found the dynamic forces on the spine were higher—sometimes as much as 70 or 80 percent higher—than quasistatic models predicted.

We spent years doing this experimentally. Equally important, we wanted to capture those forces dynamically, rather than settle for the static measurements used by previous models.

We developed a 10-foot-tall dynamometer that pivoted to match the twisting, turning, and bending of the lower back so we could measure torque. We asked people to push, pull, lift, move, and stand on force plates to measure force. We outfit our subjects with cables to goniometers that measured the angles of their spines as they moved in space.

This let us triangulate where the spine was relative to the force plate. We also noted the moments of force. This let us work backward from the force on the force plates, and let us make predictions about the moments on the spine.

It was slow work, and the first models were not very good. We rarely achieved more than 60 percent agreement of predicted and measured forces. Rapidly advancing technology helped us raise our accuracy to greater than 90 percent.

One important advance was the introduction of graphics-ready Windows computers. Before them, we would make measurements, then spend the next few days crunching long columns of numbers and generating graphs.

Windows let us plot and compare our predictions with experimental measurements. If the predicted moments deviated from the observed data, we could reexamine the behavior of the muscles and change the model on the spot. Then we could run the experiment again and see if the model did better. Before Windows, that process would take days or even weeks.

We also learned to use magnetic resonance imaging and computerized tomography scans to study muscle size, location, and lines of action. We could focus down to individual vectors of force within a muscle, and use what we learned to predict how they would generate lines of action within groups of muscles.

Imaging let us see how close muscles were to the center of the spine, which determined their mechanical advantage and ability to load the spine. This proved part of the secret sauce that let us leap from EMG data to an accurate picture of the forces placed on the spine.

INTO THE WORKPLACE

By the late 1990s, we were ready to take our models out into the world.

Early on, we teamed up with the Ohio Bureau of Workers Compensation. It was struggling with claims from factory workers who injured their backs lifting. While the National Institute of Safety and Health had developed safe lifting guidelines, factory owners and managers had problems working the formula.

Research into auto manufacturing showed that tilting cars on assembly lines improves accessibility, reduces injuries, and saves millions of dollars.

There were also issues with the formula. Many early spine models were based on quasi-static data. This involves taking measurements of moments and forces at various stages of a task, and assuming they are equivalent to the dynamic forces generated during the same task.

We knew that wasn't the case. To model the dynamic loads, we built a mockup assembly line and measured the forces involved in each task. Then we entered them into our model to see how those actions loaded the spine.

The first thing we found was that the dynamic forces on the spine were higher—sometimes as much as 70 or 80 percent higher—than quasi-static models predicted.

We also found that body motion often mattered as much as weight and sometimes even more. For example, the difference between lifting 25 pounds or 50 pounds from the same position was miniscule when compared to the difference between lifting a load from different positions (such as floor versus waist level).

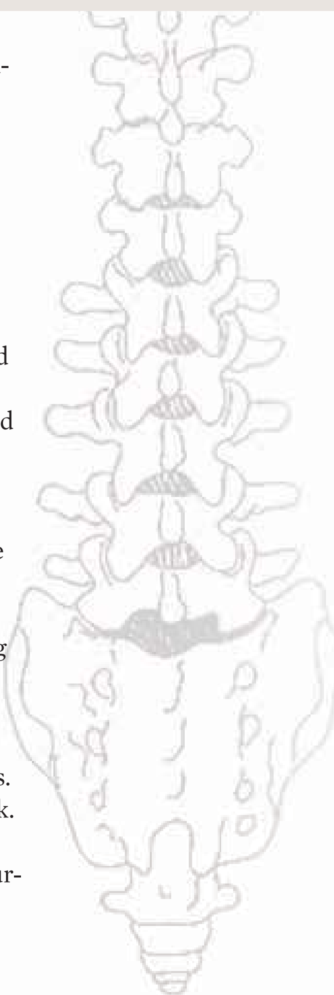
Using this information, we based our safety guidelines on the height of the load, how far from the body a worker held it, and how much he or she had to twist while holding it. The Ohio Bureau of Workers Compensation used our data to create a web app that yields safety limits with only a few inputs. The app still draws about 2,000 queries each month.

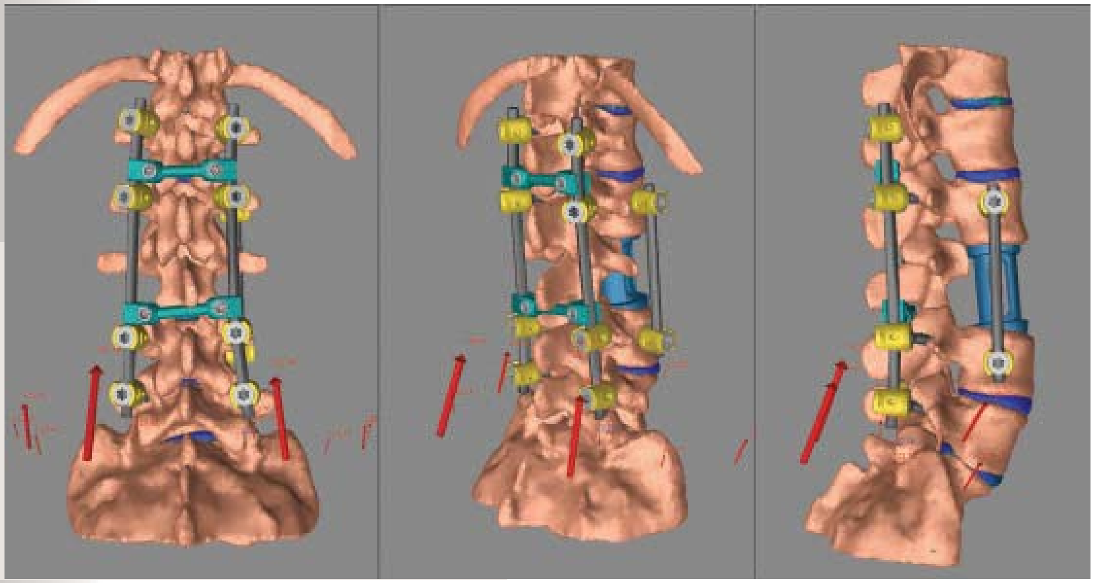
We began teaching short courses in quantitative ergonomics to share what we had learned about back safety. A Honda manager who took one of the courses invited us to meet the company's leadership.

In the early 2000s, Honda was experiencing lots of musculoskeletal problems on a door assembly line. We looked at injury records, identified the top 10 riskiest jobs, and recreated the work conditions in our lab so we could learn what made those jobs so risky. We wired up workers and monitored their lifts, holds, and twists. Once again, we used that data to drive our models and see how those forces acted on the spine.

We were looking for risky conditions and we found them. In some cases, our recommendations were obvious, like rearranging the workplace so that workers never had to lift anything from the floor. We also proposed relocating racks to reduce twisting, and redesigning carts to minimize pushing forces.

Then—nothing. Honda did not get back to us. We assumed they were unhappy with our work. One year later, they returned. Some managers had initially resisted changing their manufacturing process, but were swayed by our hard data





Physicians operating on a spinal tumor have many options. Here, they assess how the distribution of forces along the spine will change if they replace a bone and two discs. Models enable them to pick the procedure with the best long-term outcome.

on risks and spinal loading.

Honda spent $89,000 to implement five of our 10 suggestions. The reduced injury costs and increased work efficiency saved the company $360,000 the first year at five workstations. Over the next five years, Honda would save $1.8 million by rolling out a single workstation solution in other plants.

Honda wanted to go further. It became a founding member of Ohio State's Center for Occupational Health in Automotive Manufacturing, or COHAM.

COHAM's 8,000-square-foot space looks like a manufacturing facility. It includes ceiling-mounted cranes and a rotating auto conveyor. The lab has the ability to raise, lower, and rotate cars, as well as provide workers with different types of assistance. It enables us to quantify things that have never been measured before.

COHAM also benefits from new technology, such as motion-capture technologies that use optical, inertial, and infrared sensors instead of cables. By applying the lab's findings, Honda reduced musculoskeletal injury rates by 70 percent throughout its North American factories.

The same approach has also begun to make a difference in the occupation most prone to back injuries—nursing. Nurses are constantly lifting and manipulating patients. They move them in or out of beds, roll them over to empty bed pans, give them showers, take them to commodes, or work with them in physical therapy. As a consequence, nurses suffer an epidemic of back problems. By the mid-1990s, the State of Washington was debating whether to require that patients could be lifted only by groups of two or more nurses.

On the face of it, this made sense. Our research showed that the issue was not so clear-cut.

Individuals could generate dangerous compressive loads on the spine when lifting patients alone. Yet when two nurses worked together, they typically stood too far away from the patient to get their legs under the load, so their spine was bent when they began to lift. This put enormous shear loads on the spine. In fact, lifting together was often just as bad as working alone.

This small study made a big impact. Washington enacted a zero-lift policy, and required

> The State of Washington was debating whether to require that patients could be lifted only by groups of two or more nurses. Our research showed that the issue was not so clear-cut.

nurses to use patient-handling devices. While some nurses initially resisted these recommendations, the hard data behind our recommendations helped mobilize many more to demand assistive devices.

Many hospitals complied. Based on our studies, the Veterans Administration invested $280 million at its national network of care centers. A Stanford University study estimates that it is saving many times that amount by reducing disability costs and improving medical care.

HOW BAD DOES IT HURT?

Going forward, our models could help doctors diagnose and treat back pain. Until now, there has been no objective way to quantify the extent of an ailment or how well a treatment is working. Instead doctors typically ask patients about activities of daily living, such as whether they have trouble getting out of bed or dressing.

They may also ask patients to rate their pain on a scale of one to 10 as they bend, twist, and stretch. Experienced physicians will quickly pick out small hiccups in those motions, unexpected variations in movement that look unnatural.

Yet while humans are very good at assessing distances, they are terrible at estimating changes in velocity and acceleration. Yet these small variations in body motion provide powerful clues to the nature of back problems. A combination of movement sensors and models might help doctors capture this information—and how it changes over time—and use it for more accurate diagnoses.

We also believe spine models will become important tools for surgeons. For the past 30 years, the Spine Research Institute has sought to discover the causal pathways of back pain. We knew our answer started with a force, and we turned to biomechanics to understand how that force creates muscular or structural problems in the spine.

While we can solve muscular problems with physical therapy, structural problems usually require surgery. Yet spinal surgeries are successful less than half the time because it is so difficult to quantify what is wrong with the spine.

> This is information surgeons have never had before. They will see the source of the problems previously hidden from them and test which surgical strategies provide immediate relief. without long-term complications.

Spinal models can provide that type of information. We can individualize them by modifying our general models with information about individuals captured by video analysis and gathered from MRI and CT scans.

These models generate animations that show how the spine reacts to force as it moves in space. They highlight where—and why—discs bulge and shifting sections of the vertebrae impinge on nerves. They automatically pinpoint structural overloads.

This is information surgeons have never had before. They will be able to see the source of the problems previously hidden from them. Equally important, they can test surgical strategies virtually to see which ones provide immediate relief without long-term complications.

It would, quite simply, revolutionize spinal surgery.

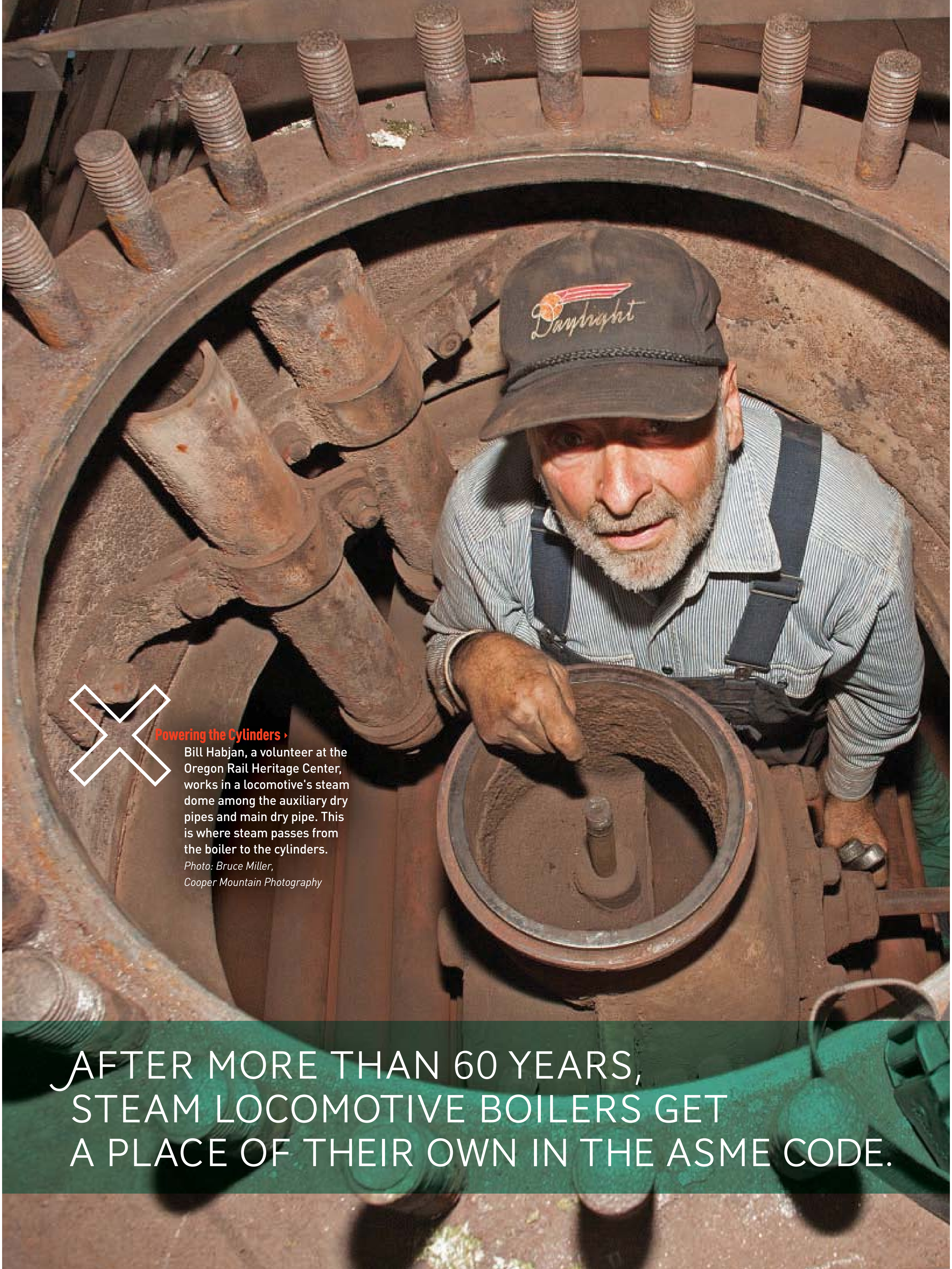
This is because spines are like teeth. We all have teeth, but some are large, small, straight or crooked. The spine is the same way. We all have one, but it is unique. The devil is always in the details. Dentists navigate those details by taking an X-ray, checking our bite, and poking and prodding our teeth and gums.

Spinal surgeons cannot do anything like that, at least not physically. Solid models give them a way to poke and prod our spines virtually. They can add a screw here or a titanium rod there. They can change their size, shape, and material properties, or perhaps add a disc or two.

The hardware is the easy part. Knowing where to put those parts is difficult. This is why we are working with Ohio State Medical Center's spine surgeons to apply our models to surgical decision-making and planning.

It has taken more than 30 years of research, but we finally have tools that give the ability to see back problems more clearly. **ME**

WILLIAM S. MARRAS is executive director of the Spine Research Institute and the Honda Chair professor at Ohio State University in Columbus. He is also president-elect of the Human Factors and Ergonomics Society.



Powering the Cylinders ›
Bill Habjan, a volunteer at the Oregon Rail Heritage Center, works in a locomotive's steam dome among the auxiliary dry pipes and main dry pipe. This is where steam passes from the boiler to the cylinders.
Photo: Bruce Miller, Cooper Mountain Photography

AFTER MORE THAN 60 YEARS, STEAM LOCOMOTIVE BOILERS GET A PLACE OF THEIR OWN IN THE ASME CODE.

ROLLING BACK HOME

Steam locomotive boilers have not been built in the United States since 1952. Well, not exactly. They have not been built in the same numbers and sizes, but they have been built.

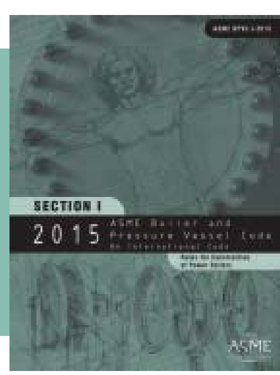
When the 1952 edition of the ASME Locomotive Boiler Code—Section III of the Boiler and Pressure Vessel Code—was issued, it was the last formal Code acknowledgement of steam locomotive construction. The "L" stamp was retired, and eventually the nuclear folks absconded with Section III.

It was felt by all that any steam locomotive boilers could be built in accordance with the current Section I, Rules for Construction of Power Boilers, and that is where matters have stood until 2015. This July, Part PL, Requirements for Locomotive Boilers, made its debut in the latest edition of BPVC Section I.

As the decades passed since the demise of the original Section III, many boilers have been built and put on steam locomotives. These were mostly smaller affairs that would never see many of the service demands that their ancestors did in the heyday of steam railroading.

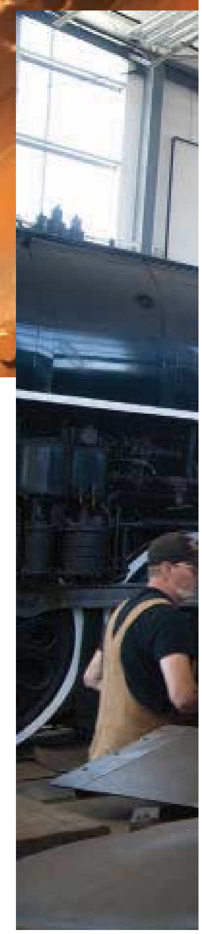
Once in a while a boiler did find its way into "normal" railroad service and some did not fare very well.

Old Is New Again ›
For the first time since 1952, rules for construction of locomotive boilers are addressed in the ASME Boiler and Pressure Vessel Code, in a new Part PL.



By Linn W. Moedinger

Friends of SP4449
The Southern Pacific 4449 locomotive is maintained by volunteers at the Oregon Rail Heritage Center. Gary Oslund has been primary welder since the 1980s.
Photo: Bruce Miller, Cooper Mountain Photography



Additionally during this period, the Code rules advanced to provide sound guidance for the construction of higher and higher pressure boilers that utilized an ever-increasing number of advanced materials.

Design margins came down as it became impractical to keep boilers in service for the historically common longer periods simply because technology was advancing quickly enough to make a perfectly sound boiler obsolete long before it was worn out.

This is where we begin to see the need for steam locomotive boiler construction rules. In the railroad heritage industry, people expect a new boiler to last as long as their old one did—one hundred years not being uncommon—and they expect to be able to use it just as hard as it was originally designed to be used. It will not become obsolete other than by its own accord.

Prior to 1950, boilers for steam locomotives were built in the United States using primarily lower carbon steel products. Riveting was the joinery of the day with some minor experimentation with arc welding. Staybolts were made from wrought iron or very ductile steel and they were invariably threaded through the sheets.

Flanging was required to form the various shapes necessary for the riveted lap seams used in circumferential seams and firebox seams. Plate strength commonly ranged from 55 ksi to 65 ksi and flanging was done both hot and cold. Rivet seams needed to be caulked after riveting and hard sheets were not amenable to that process.

One of the curious things about locomotive boilers is that they work at all, especially the bigger ones. If you think about it, attaching a steel box rigidly to a steel box with steel or iron rods doesn't seem like such a great idea considering the mean

RAIL HERITAGE ROAD

The new Part PL, Requirements for Locomotive Boilers, just like the rest of the ASME Boiler and Pressure Vessel Code, has the potential to become an international standard. After all, it seems that nostalgia for older forms of travel, especially rail travel, may be universal. Clearly, there has to be substantial interest to support all the activity in retro railroading.

Entering "heritage railroad" in an online search engine turns up an abundance of information.

In the U.S., there are more than 250 heritage railroads in 47 states and Puerto Rico. There are

Steam on the Rails ›
A view of the throat sheet and lower outside portion of the combustion chamber (right) shows staybolt sleeves and caps. Crown sheet and roof sheet (below) are supported by an array of crown stays. OR&N 197 undergoes restoration work at the Oregon Rail Heritage Center in Portland (bottom).
Photos: Bruce Miller, Cooper Mountain Photography

As the 'normal' boiler world embraced welding, steam engines came along for the ride.

more than 30 old-time railroads across Canada.

The steam-powered railroads range from former logging and mining lines to short lines and newly constructed tracks for historic equipment. Some operate in public parks; others are privately run non-profit systems staffed by dedicated volunteers, and many, including the Ghost Town and Calico Railway at Knott's Berry Farm in California, are commercial tourist attractions.

Heritage railroads operate in dozens of countries around the world on all six habitable continents. They include electric railways, trams, trolleys, and funiculars. But the majority of the world's heritage railroads are devoted largely or entirely to the age of steam.

We couldn't find a heritage railroad in Antarctica. The closest one we could identify was the End of the World Train in Tierra del Fuego. ■

‹ Late to the Party
A manufacturer's model of a double Belpaire boiler, which was being considered by the Pennsylvania Railroad at the end of steam.

˄ Providing Flexibility
A boilermaker at Baldwin Locomotive Works in Eddystone, Pa., in the early 1940s taps for staybolts in a locomotive boiler.

Something needs to give and that something is the staybolt.

temperature of the inner box will be 300 degrees hotter than the outside box and that both boxes are subject to wide thermal swings that can sometimes be rather abrupt.

Obviously, something needs to give and that something is the staybolt. It bends. Often. Eventually, it breaks and you replace it. In the early days, wrought iron was used for staybolts exclusively and this stuff was very flexible. Later on, ductile steels were used instead of iron.

Larger locomotives made it evident that even the most flexible material would not hold up in the extreme distances from the mud ring, and the flexible staybolt was developed to help cut down on breakage. Staybolts were threaded into the sheets, bucked and hammered to expand into the threads to make a steam-tight joint. If the staybolt material was harder than the sheet material, the metal in the sheet deformed and the harder staybolt had a tendency to oval the hole in the plate during service as it tried to bend.

Welding was just beginning to be discussed in railroad circles as diesels came into favor. The subject of the staybolt became irrelevant and was dropped.

As the "normal" boiler world embraced welding, steam locomotives kind of came along for the ride and took advantage of the easier construction methods that welding afforded. Usually these methods worked before higher strength materials became the norm. Probably the first problems arose in the repair field as riveted plates were replaced with much harder material that did not lend itself to riveting.

Welded staybolts mitigated the hardness differential between stay and sheet material, but the change also deleted the requirement for a key feature that monitors the staybolt.

That change was a very bad idea for steam locomotive boilers simply because the feature, known as a telltale, is the best indicator

On a Smaller Scale › Hot flanging a backhead (above) for a smaller locomotive. The front end of a smaller locomotive (below) where there is no superheater header. *Photos courtesy Linn Moedinger*

It bends. It breaks and you replace it.

of when the staybolt breaks.

A telltale is a 3/16-inch diameter hole on the longitudinal axis of the staybolt. This hole can be drilled from each end a distance of no less than one-half inch beyond the water side of the sheet so as to include the highest stress area of the staybolt. Hollow staybolts have the hole all the way through, which is preferable.

When a staybolt cracks, it typically cracks on one side only. Once this crack reaches the telltale hole, leakage will be observed and the staybolt can be replaced before it breaks completely off and throws all the pressure load on adjacent staybolts.

Square corners in fireboxes are easy to make but they impede circulation and often lead to a staybolt pitch problem on the wrapper sheets in the front and rear. This led to much thicker sheets being used than would otherwise be necessary which could increase the weight beyond the limits of the frame. It became quite common for firebox sheets to be the same thickness as wrapper sheets in order to minimize the number of stays used. Staybolt

WRITING THE CODE RULES

The ASME Boiler and Pressure Vessel Committee on Power Boilers (BPV I) maintains Section I of the Boiler and Pressure Vessel Code, rules relating to pressure integrity governing the construction of power boilers and high-pressure, high-temperature water boilers.

At the request of the locomotive boiler industry, BPV I formed the Subgroup on Locomotive Boilers on February 10, 2010. Chaired by Linn W. Moedinger, president of the heritage Strasburg Rail Road, this subgroup was assigned the duty of developing new Section I construction rules for locomotive boilers.

In four and a half years the subgroup has completed its task, and the publication of the new Part PL, Requirements for Locomotive Boilers, is included in the 2015 Edition of BPVC Section I, Rules for Construction of Power Boilers, published on July 1, 2015. ■

UMBERTO D'URSO, ASME project engineering advisor, Secretary, ASME BPV I

Concerned Stakeholders ▾
The Subgroup on Locomotive Boilers was formed in 2010. Four and a half years later, its work was published as Part PL, Requirements for Locomotive Boilers.

CATCHING THE TRAIN

Steam locomotives operate in densely populated environments. Millions of people stand next to these things.

diameters grew to accommodate the larger pitch. All this led to far less flexibility in the firebox and much poorer heat transfer through the thicker sheets.

A key element that disappeared with the 1952 Code was the 7,500 psi stress limit on staybolts. This limit served the railroad industry well and was an acknowledgement that the stays did indeed bend and that minimizing the tensile stress tended to lengthen the staybolt's service life, especially when a stay broke between inspections and the stress was thrown on the adjacent staybolts.

Interior Repairs ▸ Restorers work on a superheater header. The viewer is looking from the front of the smokebox toward the front flue sheet.
Photo: Bruce Miller, Cooper Mountain Photography

On the flip side, some advances in materials were not accommodated by the successive Boiler Codes. A great example is the roof sheet calculation that began life predicated on a safety factor, or design margin. At some point the design margin became fixed at 5 and eventually was dropped altogether and the number 11,000 was substituted based on the assumption of 55 ksi steel and a design margin of 5. This was changed in Section I subsequent to a Code change request early in this century.

Other changes were made in Section I to the point that it appeared steam locomotive boilers needed their own home again.

Some have questioned why a modern code should address this arcane technology. The simple reason is that steam locomotives operate in densely populated environments where the need to ensure safe boilers is paramount. Millions of people ride behind and stand next to these things every year.

Heritage railroads operate across the United States. Here is a brief look at four out of the many that offer excursions.

1. Strasburg Rail Road (www.strasburgrailroad.com) is a short-line railroad established in central Pennsylvania in 1832. In the 1950s, the railroad was rescued by a group of investors. The heritage railroad today runs five steam engines and one diesel over 4.5 miles of track between Strasburg and an Amtrak station in Paradise, Pa. Strasburg Rail Road also hauls freight for local customers, often using its steam locomotives. The group offers its restoration services to other organizations.

2. Cass Scenic Railroad State Park (www.cassrailroad.com) in West Virginia runs Shay steam locomotives on a rail line built in 1901 to bring timber from the mountains to the town of Cass. Many passenger coaches are remodeled flat cars that were used to haul logs. The line rises 4,800 feet to Bald Knob, third-highest peak in West Virginia. The train travels on a switchback and at times climbs a grade of 11 percent. The 22-mile round-trip to Bald Knob takes about 4 ½ hours. Exhibits at a museum along the way include a Lidgerwood tower skidder, which was mounted on railcars to carry logs out of the woods on aerial cables for distances up to 3,000 feet.

3. The Oregon Rail Heritage Center (www.orhf.org/oregon-rail-heritage-center/) is a museum established to house three historic steam locomotives that had been donated to the city of Portland. It took thousands of volunteer hours over three decades to get two of the engines operational. A third locomotive, the Oregon Railway & Navigation 197, is still being restored. The tracks at the heritage center connect to the Union Pacific Railroad's north–south main line to enable excursion trips. The center also houses other engines and freight cars.

4. The Illinois Railway Museum (www.irm.org) in Union, northwest of Chicago, claims to be the largest railroad museum in the country. In addition to electric and diesel equipment, the museum has 25 steam locomotives, two of which are operational. The facility includes ten equipment storage barns with a total of about two miles of track under cover, five miles of track for excursions, and a depot that dates to 1853. ■

‹ Mountain Climber Cass Scenic Railroad State Park in West Virginia follows an old logging line that rises 4,800 feet in 11 miles. Its Shay No. 5 engine, built by Lima Locomotive Works for the Greenbrier and Elk River Railroad, entered service in 1905.
Photo: J. Mueller

Big and Strong ›
No. 2600 was one of three articulated camelback locomotives built in 1907 by American Locomotive Co. for the Erie Railroad. Designed to handle grades in the Allegheny Mountains, they were replaced by larger engines in the 1930s.

Secondly, real working knowledge of what these boilers see when in service and how their various structures work together while bouncing down the track is not too prevalent. Since the late 1950s there has been a growing knowledge base about locomotive boilers, but it has been pretty much outside the mainstream boiler industry. It had become such that it was quite possible, if not probable, that a perfectly reputable "normal" boiler shop could legitimately build an unsatisfactory steam locomotive boiler in accordance with the Code and with all good intentions.

When the ASME formed the Subgroup for Steam Locomotives, the intent was to get this special information in print. The subgroup has taken the approach of codifying both best practices and Code material from steam days. Additionally, we have attempted to meld modern technology into the process where that technology has been tested and proven.

While this may seem to be a once and done process, it is far from that. People worldwide are tinkering with, building, and operating steam locomotives. Many countries advanced the technology beyond what the United States did because they waited much longer to dieselize.

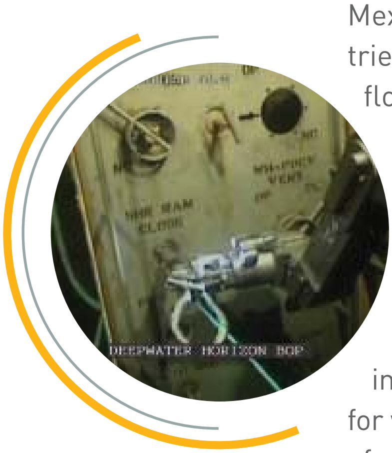
The new locomotive code, Part PL in Section I can truly be looked at as a beginning. New materials and methods will now have a place to be vetted within the unique perspective of steam locomotive operation so as to ensure safe steam locomotive boilers for centuries to come. ME

LINN W. MOEDINGER, president and chief mechanical officer of Strasburg Rail Road, is chair of the ASME BPVC subgroup on locomotive boilers.

GHOST KNIFEFISH IN

BY DAN FERBER

In the desperate weeks after the Deepwater Horizon drilling platform exploded, as thousands of barrels of oil spewed from a mile-deep well into the Gulf of Mexico, BP sent down remotely operated vehicles and tried one strategy after another to try to stanch the flow. And for two months, those efforts failed—in part because the people piloting those ROVs could not see what they were doing.



Not only did oil cloud the water, but every time the pilots tried to maneuver the ROVs, the thrusters stirred up sea-floor sediment. "The ROVs were so difficult to maneuver that they sometimes slammed into the oil wellhead and delayed capping operations for weeks at a time," said Malcolm MacIver, a professor of mechanical engineering and neurobiology at Northwestern University. "There is a very big need in technology for vehicles that can move with higher agility."

Ghost Knifefish ›
Armed with extraordinary agility and electrical sensors that show the location of insect larvae, the black ghost knifefish hunts at night.

‹ Deepwater Horizon
A remotely operated vehicle's arm tries to activate the Deepwater Horizon's blowout preventer. Clouds of oil and mud later made underwater operations difficult.

THE MACHINE

BY LEARNING THE **SECRETS OF ANIMALS,** RESEARCHERS AIM TO **ADVANCE THE ABILITIES OF ROBOTS.**

MacIver is building a prototype of such an agile ROV in his laboratory. But he's not designing it from scratch. Nature, he said, has already provided the model, in the form of a dusky and decidedly carnivorous fish that not only moves through the water differently from most other fish, but also senses the world differently as well.

Animals perceive the world in ways we cannot. Bald eagles can see fish in the water from several hundred feet above. A great gray owl can hear rodents scurrying under two feet of snow. Bloodhounds can smell so well that what they sniff out is admissible in court.

But some animals use senses we don't even have, senses that could give ROVs and robots much needed new abilities. Fish detect flowing water with a lateral line sensing system, which senses movement and pressure changes as water moves by. Flies have a

‹ Mechanical Knifefish At Northwestern, Malcolm MacIver has developed a prototype that uses electrical sensing to navigate through an underwater obstacle course.

biological gyroscope that gives them exquisite balance and responsiveness in mid-air. And the black ghost knifefish, which lives in murky streams in the Amazon, uses electricity to navigate its world.

The knifefish, on which MacIver works, emerges at night to hunt for insect larvae and small crustaceans. It emits an electrical field around its body. Nearby objects alter that field. The fish uses thousands of receptors on its skin to detect the changes, forming what amounts to an electrical image of the object. This, along with its phenomenal agility in the water, enables the knifefish to avoid head-on collisions and nab small critters rather than small rocks.

MacIver aims to build an equally agile swimming robot with similar electrosensing skills, which he said will let it do tasks no underwater robot can manage today. If he succeeds, new robots could scope out deep-sea oil wells, help police divers find bodies in murky waters, swim fish-like through sewer pipes to find leaks, or explore cabins inside a sunken ship.

And that's just the start, said Tom McKenna, who directs the biorobotics program at the Office of Naval Research. "If you're looking for innovative solutions," McKenna said, "you have principles available in nature that are the results of eons of evolution and clearly show superior capability."

RIDING WAVES

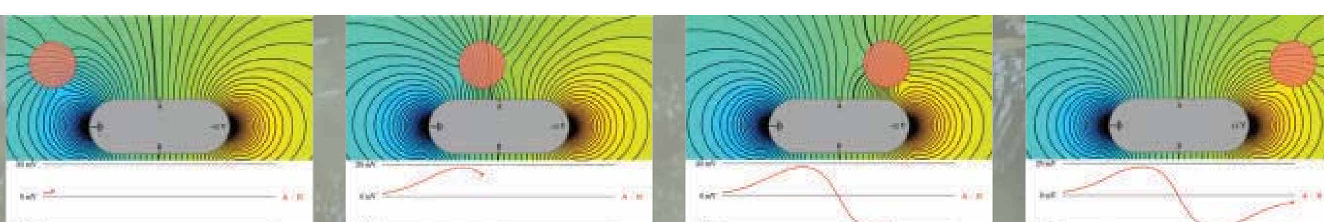
In MacIver's lab, a blind robot that resembles a large white lozenge signals a gantry above, which steers it slowly through an underwater obstacle course of closely packed pylons. Then the robot tries again, but this time the water is muddy and opaque. The course mimics the complex underwater environments that the electric fish—and an underwater vehicle—must sometimes navigate. Yet the robot, which uses only active electrosensing and no video cameras, glides smoothly through the maze.

This is MacIver's SensorPod, and it was years in the making.

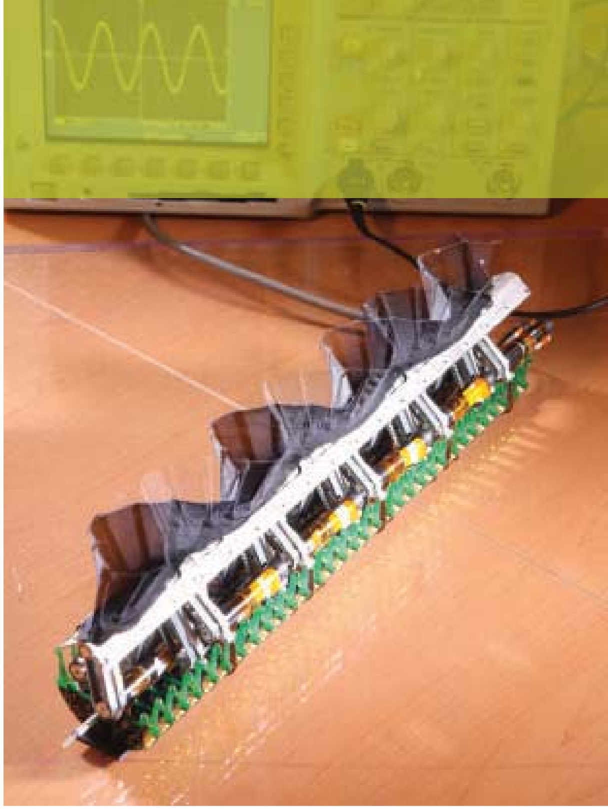
As an undergraduate, MacIver double-majored in philosophy and computer science, which sparked a burgeoning interest in artificial intelligence. After a stint trying to diagnose jet engine faults for the Canadian government, he decided to pursue a cognitive science doctorate at the University of Illinois, Urbana-Champaign. Two years later, he switched into neuroscience.

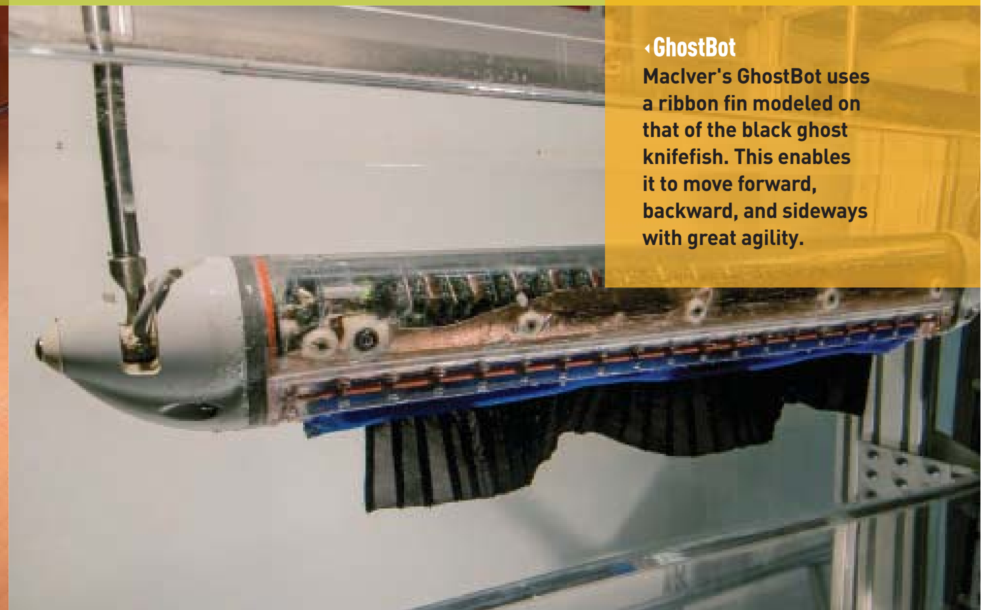
That led him to the black ghost knifefish and its extraordinary agility. A knifefish can move forward and backwards like other fish, but it can also do full body rolls like a kayaker. What's more, it can swim sideways, as if it was a car that parked by driving sideways into a tight spot.

To understand the basis for such superb water acrobatics, MacIver began examining how knifefish swim. Most fish swim either by undulating their bodies, or by wiggling a pair of fins, one on each side. In contrast, knifefish have a single bottom fin called a ribbon fin along their midline, and they swim by waving it.



˄ Electric Sensations MacIver's SensorPod can identify nearby objects as they cross its electrical field.





‹GhostBot
MacIver's GhostBot uses a ribbon fin modeled on that of the black ghost knifefish. This enables it to move forward, backward, and sideways with great agility.

MacIver noticed that as the ribbon fin waves, two waves propagate toward each other from each end of the fin. This makes the animals more stable and more agile at the same time. "It turns out to be the secret of the animals' maneuverability," MacIver said.

MacIver proved that idea by building a foot-long robotic fish. Called GhostBot, it has an artificial ribbon fin consisting of 32 spines covered with Lycra. The fin undulates just like the knifefish's ribbon fin. The first time MacIver's team put it in a flow tunnel, which laboratory researchers use to observe fish swimming, GhostBot swam forward and backward. The team fine-tuned the frequency, amplitude, and speed of the undulations to better control the fish's swimming speed. But the robot still needed a way to avoid things that go bump in the night.

That's where electrosensing came in. Black ghost knifefish employ electricity much as a bat uses sonar. Bats navigate and hunt by shrieking ultrasonic screams that humans can't hear and listening for echoes bouncing off inanimate objects and flying insects.

The black ghost knifefish instead emits a weak (1 mV), high-frequency (1 kHz) oscillating electric field from a specialized electric organ in its trunk. Each object disrupts the field in a unique way. By combining data from thousands of tiny electroreceptor organs in its skin, its brain senses an image of an object.

The fish senses only a few centimeters away from its body, but it senses in every direction, as if it has eyes on the back of its head and the top and bottom of its body. The knifefish also repositions itself to better perceive signals, using its body as a tunable antenna.

"It's like an electrical bat," MacIver said.

"An underwater robot based on the ghost knifefish could work in the murkiest waters."

MAKING ELECTROSENSE

As MacIver thought about how to incorporate electrosense into a swimming robot, he started talking with engineers who build ROVs. ROVs typically use video cameras and sonar to avoid obstacles. Both technologies are good at sensing long distances underwater, but struggle up close, MacIver said. Even short-wave sonar, which works better in tight quarters, fails in water cluttered with objects.

Lighting the way for the video cameras presents other problems. "Huge wattage goes to powering lights so you can see a tiny space in front of the robots," he said.

Active electrosense would help ROVs and underwater robots overcome all these problems. "That became part of the motivation," MacIver said.

Active electrosensing is not new to engineering. Physicians diagnose lung cancer with electrical impedance tomography, which sends a small current throughout the body and uses electrodes on the body to pick up abnormalities in the chest cavity. Geologists inject current into the ground and use electrodes on the Earth to detect cavities, including saline aquifers and oil reservoirs.

MIT engineers have also built robotic fingers with electrosense that detect an object before the robot hand grasps it. This is a skill people do routinely—for example, we position our hand like a "C" around a cup before we grasp it—but most robots today can't do that. Active electrosense would let them.

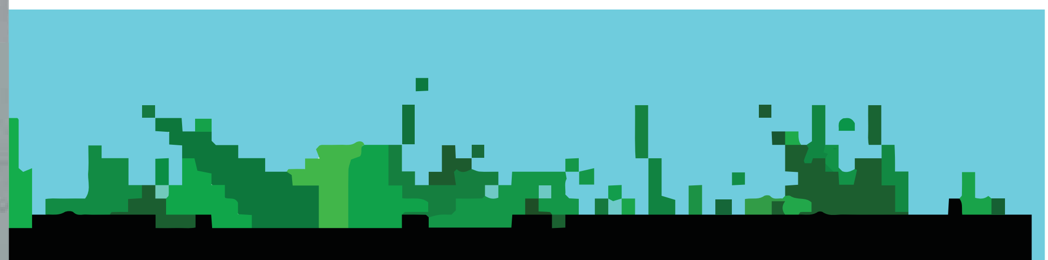
Combine that ability with good contact sensors, which are available today, and robot hands could move with unprecedented deftness. An underwater robot that "sees" with active electrosense could manipulate objects with equal dexterity.

Active electrosense could do more for ROVs and robots, MacIver said. It may soon be able to distinguish living organisms, including divers, from inanimate objects by sensing capacitance—the ability of a material to induce a phase lag between voltage and current—MacIver reported in 2012 at the International Conference on Intelligent Robots and Systems.

Living organisms, and little else in nature, possess this electrical property. Sensing capacitance would be like adding color to black-and-white images, MacIver said.

Over the next few years, MacIver plans to build a robot that combines SensorPod's electrosensing skills and GhostBot's agility. Such a robot would be slow, like the black ghost knifefish, but it would swim forward and backward, roll, and parallel park like the real thing, and it would extend the range of underwater robots to the murkiest of environments. If it is commercialized, it could one day plug pipelines, seal wells, supply frogmen, and find drowned bodies.

> **"Sensing capacitance would be like adding color to black-and-white images."**



Ant Vision European desert ants see visible and ultraviolet light. This makes the sky bright and everything else dark, enabling them to recognize local landmarks by their silhouettes and make their way through complex terrain.

SKY LIGHTS

While electrosensing could help robots navigate at sea, other unusual animal senses could help them find their way on land. Barbara Webb, a bioroboticist at the University of Edinburgh, started her career exploring artificial intelligence, and soon began building computational models to reproduce aspects of human perception. She quickly gave up on humans and turned to ants.

"They have a simpler brain than humans," she said, "and we can actually have some hope of understanding the connections between perceptual systems and motor systems, and how that controls behavior."

She and Michael Mangan, a postdoc in her laboratory, study how European desert ants navigate. Many ant species do this by laying down a trail of pheromones, then following their scent. But these desert ants live in hot, semiarid southern Spain, where ground temperatures exceed 50 °C during the day—hot enough to quickly destroy pheromones. Unlike most desert creatures, European desert ants head out at mid-day, in their case to find tasty, dying insects baking in the sun. They then head back to the nest, and quickly.

"I have to trot after them," Mangan said.

Biologists suspected that desert ants navigated with a form of vision that rivals Superman's, though rather than X-rays, they see ultraviolet light. Webb and Mangan investigated. They replaced the glass lens and optics in an ordinary digital camera with components made of quartz, which is transparent to both visible and UV light, and added some off-the-shelf algorithms. Then they took pictures on the ants' home turf—an abandoned field with grassy tussocks in a semi-industrial area on the outskirts of Seville.

Sure enough, in these images the sky looked bright and everything else looked dark. "This allows them to distinguish sky from ground very clearly," Webb said.

A graduate student in the lab then

Ant Tracks A graduate student navigated Edinburgh as if he were an ant, using a UV camera to detect silhouettes of the city's skyline.

walked around Edinburgh, testing the UV camera to see if it could help a person navigate like a desert ant. The UV images highlighted the contrast between sky and buildings, just as the setting sun creates a silhouette of the Manhattan skyline. Software compared these UV skyline images to reference images they'd obtained several months earlier in different weather conditions. Silhouettes for nearly all points on the path matched. The results showed that UV sensing alone would be enough to help a person find the way around the city successfully, they reported in a peer-reviewed publication presented at the 2014 Robotics: Science and Systems Conference.

Mangan and Webb suspected that the ants navigated by checking skyline images against those in their memory, continuing straight if they matched, and turning if they didn't.

To test that idea, they built a ground-hugging ant robot with a panoramic UV lens and a skyline recognition algorithm. "It's actually a mobile phone on wheels," Webb said. It navigated the abandoned field in Spain just fine, according to results the researchers reported during the Living Machines conference in August.

Both actual ants and Webb's ant robots screen out information on contrast, color, and texture, and detect only the silhouette of the surrounding skyline. Less information to process means a robot brain would need less in the way of hardware, software, and the electricity to run. "Where we can gain insights for engineering would be where we have similar constraints in terms of power and computation. Maybe you want to have robots in the field a long time," Mangan said.

Down the road, the bioroboticists hope to incorporate another ant navigational skill into a robot—a neat ability to detect polarized sunlight and use it to determine compass direction, Mangan said.

Nor are bioroboticists limiting themselves to the earthly plane. Mark Willis, an insect biologist at Case Western Reserve University in Cleveland, has used Air Force funding to build a contraption he calls Robo-Moth, modeled on moths' ability to follow plumes of pheromones as they fly. Once they can model the sense of smell better, researchers could build an artificial nose on a stick to help military forces avoid having to guess where terrorists are hiding in a building. "If we gave special ops guys a flying moth that could fly down the hallway and tell them what's down there, they would use it tomorrow," Willis said.

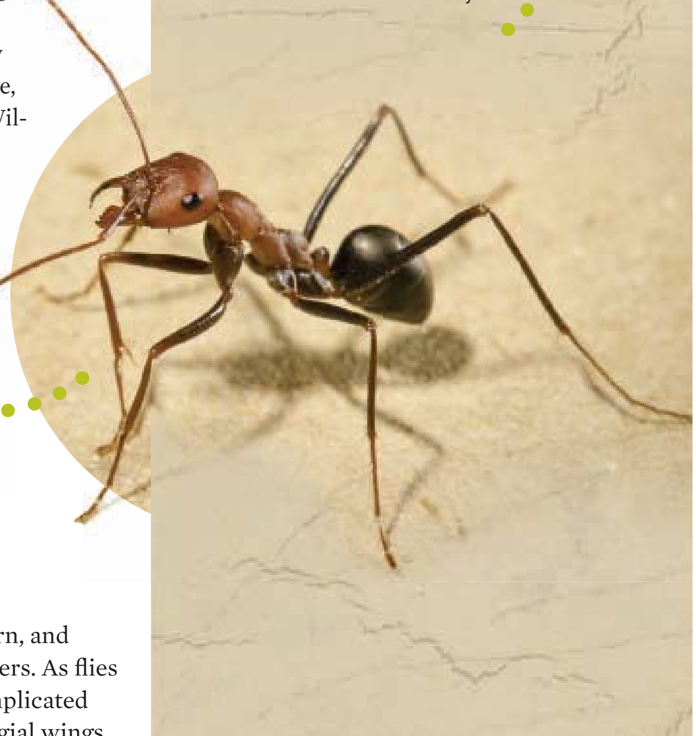
Meanwhile, Jessica Fox, a Case Western biorobotisist, is investigating a unique sensing system that allows flies to fly forward and backward, turn, and hover in mid-air like helicopters. As flies carry out these relatively complicated maneuvers, they rely on vestigial wings that function as a gyroscope does in airplanes and helicopters—to detect the Coriolis force that indicates whether the flying machine is rotating.

"They have some of the best flying behavior that we know, so we might be able to improve flying behavior for some of our vehicles," Fox said.

According to Webb, "Insects tell you a lot of things we'd like robots to do." That includes flying, swimming, crawling, and scrambling across uneven ground. "They're incredibly energy efficient, so they don't need huge amounts of battery power," Webb said.

Webb's admiring words about insects could also hold for animals in general. As she put it, "They're amazingly more competent than the best robots we have." ME

DAN FERBER is a journalist based in Milwaukee who writes about science, engineering, and technology. He is the co-author, with Paul Epstein, MD, of *Changing Planet, Changing Health: How Climate Change Threatens Our Health and What We Can Do About It.*



Desert Warrior Most ants follow pheromone scents along established trails. In the desert, pheromones evaporate and desert ants must use their eyes.

Antmobile
A panoramic UV camera mounted on a mobile smartphone ignores color and contrast, using only silhouettes against the skyline to navigate.

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MC121 Design by Analysis Requirements in ASME Boiler & Pressure Vessel Code Section VIII, Division 2 — 3-4 Nov
MC111 Piping Vibration Causes and Remedies - a Practical Approach — 4-5 Nov
MC113 Techniques and Methods used in API 579-1/ASME FFS-1 for Advanced Fitness-For-Service (FFS) Assessments — 5-6 Nov
MC127 Bases and Application of Design Requirements for High Pressure Vessels in ASME BPV Code Section VIII, Division 3 NEW! — 5-6 Nov
MC117 Piping Failures - Causes and Prevention — 6 Nov

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NOVEMBER 2015 – SAN DIEGO, CALIFORNIA USA

PD107 Elevator Maintenance Evaluation — 9-10 Nov
PD382 How to Predict Thermal-Hydraulic Loads on Pressure Vessels and Piping — 9-10 Nov
PD077 Failure Prevention, Repair and Life Extension of Piping, Vessels and Tanks ASME STANDARDS COURSE — 9-11 Nov
PD146 Flow Induced Vibration with Applications to Failure Analysis — 9-11 Nov
PD389 Nondestructive Examination-Applying ASME Code Requirements (BPV Code, Section V) ASME STANDARDS COURSE — 9-11 Nov
PD410 Detail Engineering of Piping Systems — 9-11 Nov
PD506 Effective Management of Research and Development Teams and Organizations — 9-11 Nov
PD513 TRIZ: The Theory of Inventive Problem Solving — 9-11 Nov
PD515 Dimensioning and Tolerancing Principles for Gages and Fixtures — 9-11 Nov
PD702 Process Safety and Risk Management for Mechanical Engineers NEW! — 9-11 Nov
PD359 Practical Welding Technology — 9-12 Nov
PD448 BPV Code, Section VIII, Division 2: Pressure Vessels ASME STANDARDS COURSE TOP SELLER — 9-12 Nov
PD013 B31.1 Power Piping Code ASME STANDARDS COURSE TOP SELLER — 9-13 Nov
PD665 BPV Code, Section I: Power Boilers ASME STANDARDS COURSE — 9-13 Nov

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PD624	Two-Phase Flow and Heat Transfer	16-17 Nov
PD706	Inline Inspections for Pipelines	16-17 Nov
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PD583	Pressure Relief Devices: Design, Sizing, Construction, Inspection and Maintenance ASME STANDARDS COURSE	18-20 Nov
PD596	Developing a 10-Year Valve Inservice Testing Program	18-20 Nov
PD591	Developing Conflict Resolution Best Practices	19-20 Nov

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DECEMBER 2015 – ABU DHABI, UNITED ARAB EMIRATES

PD506	Research and Development Management	6-8 Dec
PD714	BPV Code, Section VIII, Division 2: Alternative Rules – Design and Fabrication of Pressure Vessels ASME STANDARDS COURSE TOP SELLER	6-8 Dec
PD715	Principles of Welding and PPV Code, Section IX: Welding & Brazing Qualifications ASME STANDARDS COURSE	6-8 Dec
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DECEMBER 2015 – NEW ORLEANS, LOUISIANA USA

PD100	Introduction to the Maintenance & Inspection of Elevators and Escalators	7-8 Dec
PD539	Bolted Joints and Gasket Behavior	7-8 Dec
PD570	Geometric Dimensioning and Tolerancing Fundamentals 1 ASME STANDARDS COURSE	7-8 Dec
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PD115	The Gas Turbine: Principles and Applications	10-11 Dec
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PD577	Bolted Joint Assembly Principles Per PCC-1-2013 ASME STANDARDS COURSE	10-11 Dec
PD721	Optimization of Plant Layouts Utilizing 3D CAD/CAE Systems	10-11 Dec
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DECEMBER 2015 – AMSTERDAM, NETHERLANDS

PD389	Nondestructive Examination – Applying ASME Code Requirements (BPV Code, Section V)	14-16 Dec
PD442	BPV Code, Section VIII, Division 1: Design & Fabrication of Pressure Vessels ASME STANDARDS COURSE TOP SELLER	14-16 Dec
PD714	BPV Code, Section VIII, Division 2: Alternative Rules – Design and Fabrication of Pressure Vessels ASME STANDARDS COURSE TOP SELLER	14-16 Dec
PD616	API 579 /ASME FFS-1 Fitness-for-Service Evaluation	14-17 Dec
PD642	ASME B31.1 Power Piping Code ASME STANDARDS COURSE	14-17 Dec
PD643	B31.3 Process Piping Code ASME STANDARDS COURSE	14-17 Dec
PD675	ASME NQA-1 Lead Auditor Training	14-17 Dec
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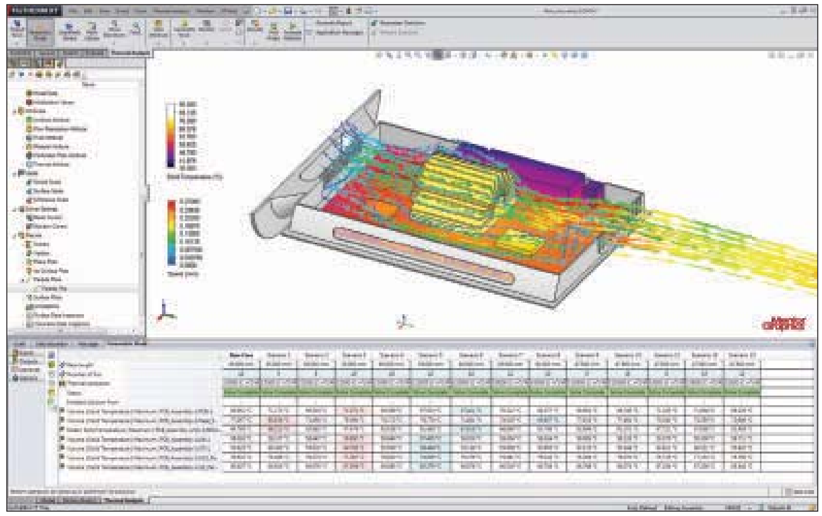

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3-D PRINTING

MAKERBOT, BROOKLYN, N.Y.

The manufacturer of small 3-D printers has released version 3.7 of its operating software, MakerBot Desktop. The upgrade contains a new custom profile editor that allows users to edit properties of the print, such as infill and extruder speed; those settings can be saved as a template for future projects. Custom tabs let users of all experience levels create custom settings. The layer height of the print can be changed within a single print, allowing for faster print speeds, and the device preferences window now offers such data as temperature and total print time.

PRODUCT VISUALIZATION

ACTIFY, SAN FRANCISCO.

SpinFire Ultimate 11.0 is intended to make product data, especially CAD data, more easily accessible to both technical and non-technical users. The goal is to provide access to 2-D and 3-D visualizations without the use of a CAD system, allowing manufacturers and their suppliers to use a single software solution enabling them to view, measure, mark up, and share files. SpinFire Ultimate 11.0 supports files created in major CAD file formats, such as the latest versions of Catia V5 and Unigraphics NX, and features a new underlying architecture to enable better handling of large files. Actify says there are more than 100 enhancements in this latest version of the software, including a more intuitive graphic user interface.

SUBMISSIONS

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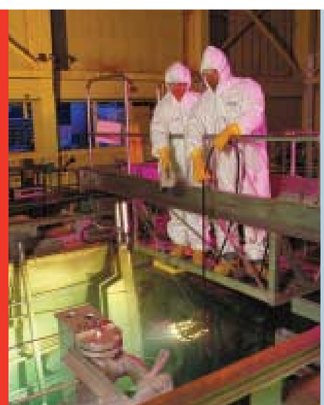

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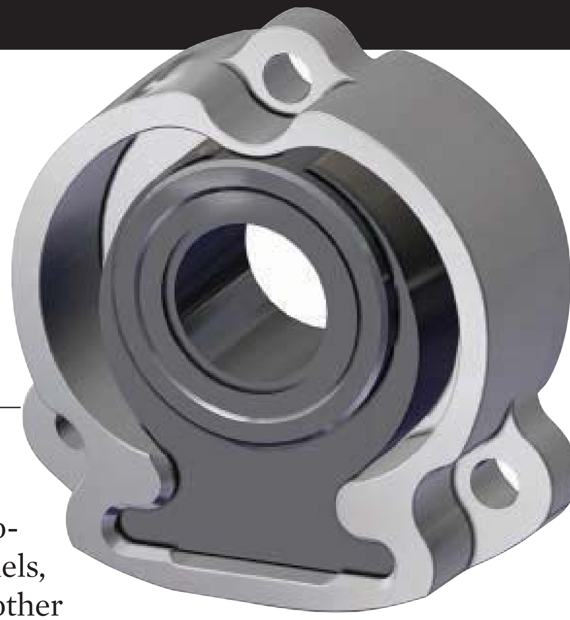
POSITION HINGE



REELL PRECISION MANUFACTURING,
ST. PAUL, MINN.

The PS-100 position hinge enables precise and sustained positioning of heavy devices and end-products with long moment arms—trays, displays, control panels, keypads and keyboards, armrests, and other demanding position-control applications. The hinge allows for infinite positioning with full 360-degree range of motion, reliably maintains a selected position for as long as necessary, easily adjusts, and has a qualified service life of 50,000 cycles. Torque ranges from 7 to 11.5 newton-meters (61.9 to 101.8 lb.-in.) in increments of 1.5 Nm (13.2 lb.-in.). The hinge is currently engineered with symmetric torque (the same torque in both directions) and will be available later this year with patent pending "one-way" torque (high torque in one direction with virtually no torque in the other).

PACKAGING ROBOT

ADEPT TECHNOLOGY, PLEASANTON, CALIF.

The Hornet 565 is a change in direction for Adept. The company is best known for its high-speed Quattro delta robots, which have a fourth arm for better stability. The Hornet is a small, fast, three-armed pick-and-pack robot with a 3 kg payload capacity. It has a 0.36 m^3 workspace and 0.32-second cycle times, and Adept is promising less than 5 mm repeatability at all conveyor speeds. The Hornet's base contains all controls and amplifiers, which eliminates external controls and reduces installation cost. Users can also program it directly from a PLC if they are familiar with ladder logic. Users can deploy the robot for pharmaceutical packaging, since it is rated IP65 (protection against particles and resistance to water). It is made from corrosion-resistant materials and designed for easy wash down.

SUBMISSIONS

Submit electronic files of new products and images by e-mail to **memag@asme.org**. Use subject line "New Products." *ME* does not test or endorse the products described here.

THERMOCOUPLES AND RTD ASSEMBLIES

ASHCROFT INC., STRATFORD, CONN.

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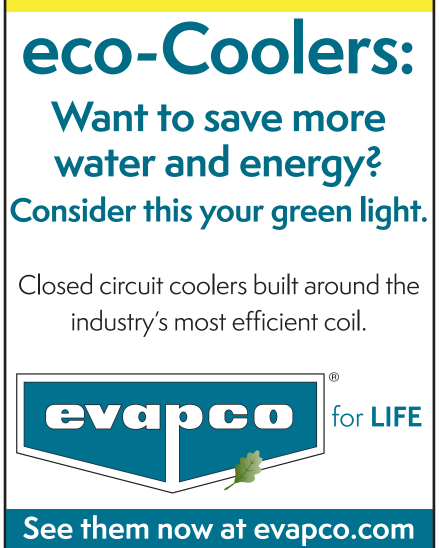

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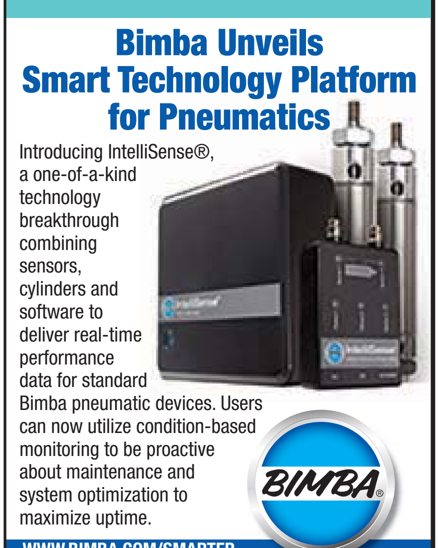

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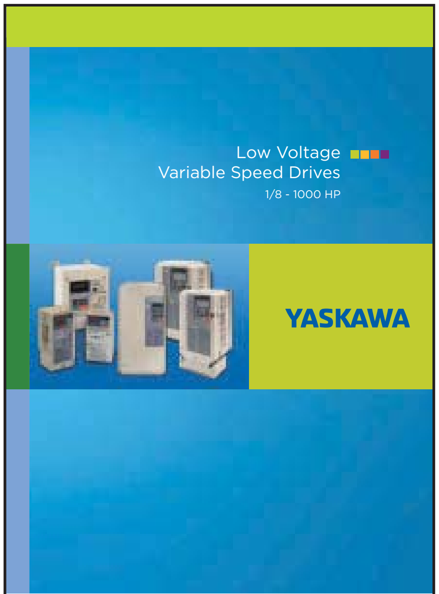

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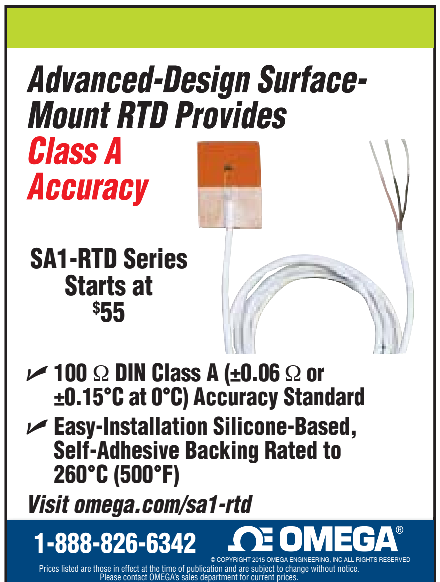

OMEGA

SPG MOTOR

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US TSUBAKI

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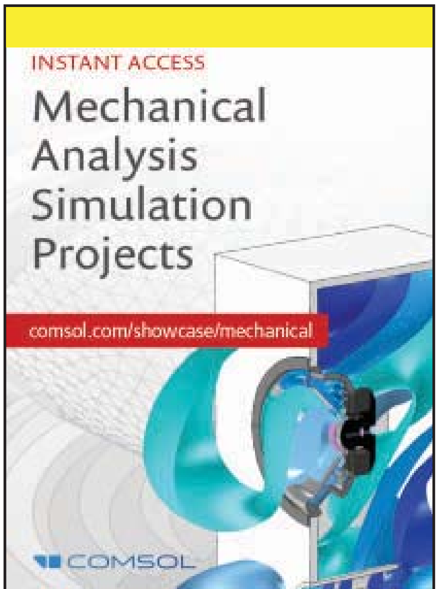

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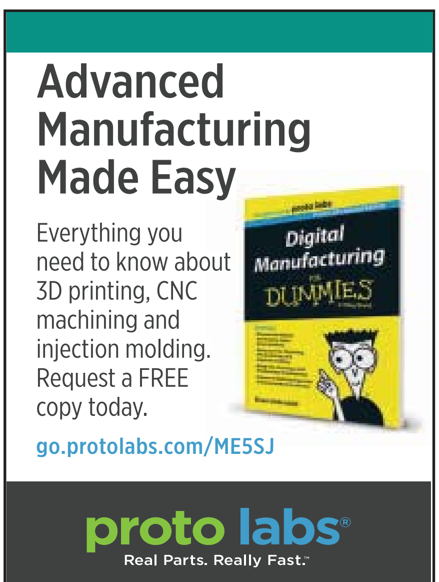

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Applicants must have an earned doctorate in an appropriate engineering field and a background conducive to the development of an applied and/or educational research program by being able to work closely with industry and/or government agencies. Candidates are sought in the areas of advanced manufacturing (including but not limited to additive manufacturing processes), welding and allied processes, and related design and innovation. Preference will be given to applicants with relevant industry or government experience.

To apply, go to www.tamengineeringjobs.com (Posting FVN0362014). Full consideration will be given to applications received by December 15, 2015. After that date, applicants may be considered until positions are filled. Appointment begins fall 2016.

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ASSISTANT PROFESSOR

August 5, 2015

The Department of Mechanical and Aerospace Engineering (MAE) at Princeton University is conducting a broad search for two (2) tenure-track assistant professors. We welcome applications from all areas in mechanical and aerospace engineering, including but not limited to the fields of particular interest, namely, (1) robotics and (2) aerospace-related sciences and engineering. Applicants must hold a Ph.D. in Engineering, Materials Science, Physics, or a related subject, and have a demonstrated record of excellence in research with the potential to establish an independent research program. We seek faculty members who will create a climate that embraces excellence and diversity, with a strong commitment to teaching and mentoring.

Princeton's MAE department has a long history of leadership in its core areas of Applied Physics, Dynamics and Controls, Fluid Mechanics, Materials Science, and Propulsion and Energy Sciences, with additional strength in cross-disciplinary efforts impacting areas such as biology, bio-inspired design, the environment, security, and astronautics. We seek creative and enthusiastic candidates with the background and skills to build upon and complement our existing departmental strengths and those who can lead the department into new and exciting research areas in the future.

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Princeton University is an equal opportunity employer and all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability status, protected veteran status, or any other characteristic protected by law. We welcome applications from members of all underrepresented groups. This position is subject to the University's background check policy.

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This position requires an earned doctorate in Mechanical Engineering (or a related field), relevant experience, and a strong interest in effective undergraduate teaching, integrating theory, applications and laboratory practice. A Bachelor of Science Degree in Mechanical Engineering or related degree from an ABET-accredited program is preferred. In addition to teaching duties; the successful candidate will be expected to become involved with academic advising, course/curriculum development, supervision of student projects, and continued professional growth through a combination of consulting, scholarship, and research. Excellent communication skills are required. The review of applications will begin as they are received and continue until the position is filled.

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NEW FACULTY SEARCHES IN MECHANICAL ENGINEERING

Through strong support from the Provost and Dean, The Department of Mechanical and Nuclear Engineering at The Pennsylvania State University is pleased to announce there will be a significant growth of faculty over the next several years. In 2015/16, the Department is seeking excellent applicants to fill six tenure-track positions in ME. The areas of interest include, but are not exclusive to: advanced manufacturing and materials processing, energy systems, computational fluid dynamics, intelligent systems and sensors, autonomous systems, and other emerging areas. Applicants should have demonstrated outstanding scholarly research and teaching interests in mechanical engineering or a related field.

The Department is home to 55 faculty, 280 graduate students, and 1100 undergraduate students. The faculty conduct in excess of $25M per year of funded research across a broad spectrum of traditional and emerging areas. Penn State actively encourages and provides resources for interdisciplinary research collaboration through university-level institutes primarily focused on materials, health, and energy. In addition, many faculty in the Department work collaboratively with scientists and engineers in our Nuclear Engineering Program, the Applied Research Laboratory and the Center for Innovative Metal Processing by Direct Digital Deposition (CIMP-3D, http://www.cimp-3d.org/). The Department offers separate B.S., M.S., and Ph.D. degree programs in both mechanical engineering and nuclear engineering. The Department also offers online graduate degrees in both mechanical and nuclear engineering. Further information on the Department can be found at: http://www.mne.psu.edu/.

Qualifications for these positions include a doctorate in engineering or a related field. The successful candidates will be expected to teach courses at both the undergraduate and graduate levels, to develop an internationally-recognized externally-funded research program, and to contribute to the operation and promotion of the department, college, university, and profession through service.

Nominations and applications will be considered until the positions are filled. Screening of applicants will begin on September 15, 2015. Applicants should submit a statement of professional interests, a curriculum vitae, and the names and addresses of four references. Please submit these three items in one pdf file electronically to job 57752 at https://psu.jobs/job/57752

CAMPUS SECURITY CRIME STATISTICS: For more about safety at Penn State, and to review the Annual Security Report which contains information about crime statistics and other safety and security matters, please go to http://www.police.psu.edu/clery/ , which will also provide you with detail on how to request a hard copy of the Annual Security Report.

Penn State is an equal opportunity, affirmative action employer, and is committed to providing employment opportunities to all qualified applicants without regard to race, color, religion, age, sex, sexual orientation, gender identity, national origin, disability or protected veteran status.

SMU. BOBBY B. LYLE SCHOOL OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

Assistant Professor Position No. 52680

SOUTHERN METHODIST UNIVERSITY, Department of Mechanical Engineering invites applications for a full-time tenure-track faculty position at the rank of assistant professor (Position No. 52680). We are seeking a highly qualified faculty member in the area of Dynamic Systems & Control and related fields to start in August 2016. Candidates must have a Ph.D. degree in mechanical engineering or a closely associated field, and will be expected to teach undergraduate and graduate courses, develop and sustain internationally recognized active research programs, and participate in multi-disciplinary research projects in the Lyle School and the University. Exceptionally qualified candidates may also be considered for a position at the associate or full professor level.

With over 10,000 students, SMU is a leading private University located in the Dallas - Fort Worth Metroplex, a dynamic region with leading high-technology companies in the aerospace, defense, energy, information technology, life sciences, semiconductors, telecommunications, transportation, and biomedical industries. Some of these companies and research institutions include Texas Instruments, Raytheon, Bell Helicopter, Lockheed-Martin, Turner Construction, Trinity Industries, Baylor Research Institute, and the University of Texas Southwestern Medical Center. The supercomputing facility at SMU currently has over 11,000 CPUs, and is capable of supporting large-scale modeling and simulations.

The Mechanical Engineering Department resides within the Lyle School of Engineering and offers B.S., M.S., and Ph.D. degrees in mechanical engineering. The ME Department is home to the Research Center for Advanced Manufacturing, the NSF Industry/University Cooperative Research Center for Lasers and Plasmas for Advanced Manufacturing. It is also the home of several other research laboratories in the areas of mechanics of materials; dynamics, systems and controls; biomedical instrumentation and robotics; porous materials applications; nanoscale electro-thermal sciences; opto-electronics packaging; laser micromachining; micro-optical sensor technology; bio-microfluidics; 3-D printing/additive manufacturing, and experimental fluid mechanics (http://www.lyle.smu.edu/me/).

Applications received by December 15, 2015 will be given full consideration but the search committee will continue to accept applications until the position is filled. Curriculum vitae, statement of teaching and research plan, and a list of four references should be sent to MESearch@lyle.smu.edu. Hiring is contingent upon the satisfactory completion of a background check. SMU will not discriminate in any program or activity on the basis of race, color, religion, national origin, sex, age, disability, genetic information, veteran status, sexual orientation, or gender identity and expression. The Executive Director for Access and Equity/ Title IX Coordinator is designated to handle inquiries regarding nondiscrimination policies and may be reached at the Perkins Administration Building, Room 204, 6425 Boaz Lane, Dallas, TX 75205, 214-768-3601, accessequity@smu.edu.

IUPUI | **SCHOOL OF ENGINEERING AND TECHNOLOGY**

INDIANA UNIVERSITY–PURDUE UNIVERSITY Indianapolis

CHAIR, DEPARTMENT OF ENGINEERING TECHNOLOGY

The Department of Engineering Technology within the Purdue School of Engineering and Technology at Indiana University-Purdue University Indianapolis (IUPUI) invites applications and nominations for the position of Department Chair. This senior level leadership position within the School is intended for candidates who are dedicated to the advancement of engineering technology education, have a distinguished record of applied research and professional accomplishment, have strong leadership and management abilities, and a steadfast commitment to faculty governance. Candidates with the ability to enable synergistic collaborations, within the department and outside the department including collaborations with the engineering departments in the School, will be given preference. This is an outstanding opportunity to impact the future direction of the department and its programs with the potential to guide the department's ascension to among the premier engineering technology departments in the nation. Anticipated start date is July 1, 2016.

Per the latest edition of ASEE profiles of engineering and engineering technology colleges, the School of Engineering and Technology at IUPUI ranks #3 nationally for the number of bachelor's engineering technology degrees awarded and #2 nationally for total engineering technology degrees awarded to women. The engineering technology department at IUPUI includes 5 ETAC of ABET accredited B.S. programs, as well as 2 other affiliated B.S. programs. The department also supports the M.S. in Technology, an interdisciplinary program in collaboration with other technology departments in the School. Additional information about the department is available at **engr.iupui.edu/departments/ent/**

The School of Engineering and Technology at IUPUI has 7 academic departments with an extensive undergraduate and graduate degree portfolio, including numerous CAC, EAC, and ETAC of ABET accredited B.S programs. The School has over 3,000 students, including 400 graduate students pursuing either M.S. or Ph.D. programs. More information about the School is available at **engr.iupui.edu/**

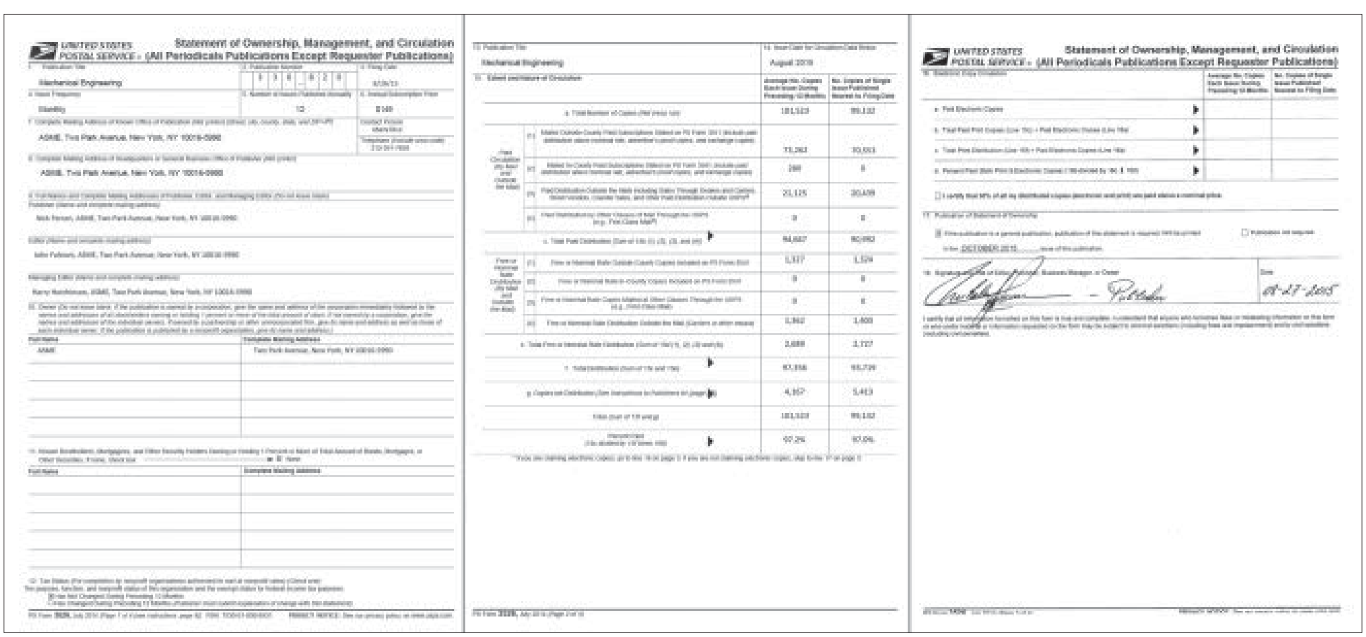
The IUPUI campus has approximately 30,000 students and over 200 degree programs with annual research expenditures totaling over $280M. IUPUI has received the Higher Education Excellence in Diversity (HEED) Award for three consecutive years. More information about IUPUI is available at **www.iupui.edu**

The most competitive candidates will hold a Ph.D. or equivalent in engineering technology, engineering, or a closely related field with scholarly accomplishments commensurate with appointment as a tenured professor at a RU/H Carnegie classified campus. Applications should include a statement of interest, curriculum vitae, and contact information for at least three references. Apply for this position at **https://www.et.iupui.edu/apply/index.asp?pos=00042595** Applications received by November 1, 2015, will receive full consideration. However, applications are welcome until the position is filled.

IUPUI is an Equal Opportunity/Affirmative Action educator and employer and affords reasonable accommodations to persons with disabilities.

POSITIONS OPEN

ASSISTANT PROFESSOR IN THE AREA OF MECHANICAL AND AUTONOMOUS SYSTEMS The Division of Engineering and Applied Science at the California Institute of Technology invites applications for a tenure-track faculty position in the Department of Mechanical and Civil Engineering. We are interested in applicants from a broad range of research areas related to mechanical and autonomous systems. Specific areas include, but are not limited to robotics, controls, energy systems, distributed sensing, manufacturing and structural control and monitoring systems. The search is aimed at the assistant professor level.Interested applicants should submit an electronic application at https://applications.caltech.edu/job/mce. Review of applications will begin on 01 October 2015 and will continue until the position is filled. The term of the initial appointment at the assistant professor level is normally four years, with appointment contingent upon completion of a PhD in a relevant field. EOE of Minorities/Females/Protected Vets/Disability.Questions about the application process may be directed to mas-mce@caltech.edu



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OCTOBER 2015

09-27-2015

University of Illinois at Chicago

Assistant/Associate/Full Professor

Mechanical and Industrial Engineering

The Department of Mechanical and Industrial Engineering at the University of Illinois at Chicago (UIC) invites applications for a tenured position in the area of advanced energy storage systems in Mechanical Engineering and Industrial Engineering. The department is looking to strengthen its thrust area in advanced energy storage systems. We are looking for candidates with expertise in energy storage systems in the areas of predictive modeling, designing novel systems, and advanced manufacturing.

The ideal candidate should meet the requirements for an appointment as an associate or full professor with tenure. Candidates at the assistant professor rank will also be considered. Successful applicants are required to have earned a PhD in Mechanical or Industrial Engineering or a related field, and are expected to have developed and maintained active externally-funded research programs. Candidates should also have demonstrated success in leading and obtaining interdisciplinary collaborative research grants, preferably, in advanced energy storage systems or related areas. They should also have expertise in teaching courses at both the undergraduate and graduate levels.

The Department offers BS, MS, and PhD degrees in Mechanical Engineering, Industrial Engineering and Operations Research, and currently has 32 faculty, an undergraduate enrollment of about 700 and a graduate enrollment of about 300. More information about the Department can be found at http://www.mie.uic.edu. Applicants are required to send a letter of application indicating their qualifications, an up-to-date CV including the names and contact information of five references, and separate one-page statements outlining their future teaching and research plans. For fullest consideration, applications must be submitted online at **https://jobs.uic.edu/job-board/job-details?jobID=55192** by **January 4, 2016**. Applications will be accepted until the position is filled. The expected starting date is August 2016.

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THE UNIVERSITY OF BRITISH COLUMBIA

Department of Mechanical Engineering

THE DEPARTMENT OF MECHANICAL ENGINEERING AT THE UNIVERSITY OF BRITISH COLUMBIA SEEKS OUTSTANDING INDIVIDUALS FOR **TENURE-TRACK POSITIONS AT THE ASSISTANT PROFESSOR LEVEL** in the broad area of **APPLIED MECHANICS.** Areas of particular interest include, but are not limited to, solid mechanics and vibrations. The starting date will be **JULY 2016**, or as soon as possible thereafter.

An ideal candidate will complement our existing strengths and develop an internationally recognized, externally funded research program. Applicants must have either demonstrated or possess a clear potential and interest in achieving excellence in teaching, and provide service to the University and community. Industrial experience is an asset. The successful candidate(s) will hold a Ph.D. degree or equivalent in Mechanical Engineering or a closely related field and will be expected to register as a Professional Engineer in British Columbia. Further information on the department is available at www.mech.ubc.ca, and information on the employment environment in the Faculty of Applied Science is available at www.apsc.ubc.ca/about/careers.

The University of British Columbia hires on the basis of merit and is committed to employment equity. All qualified persons are encouraged to apply. We especially welcome applications from members of visible minority groups, women, Aboriginal persons, persons with disabilities, persons of minority sexual orientations and gender identities, and others with the skills and knowledge to engage productively with diverse communities. Canadians and permanent residents of Canada will be given priority.

Applicants should submit a curriculum vitae, a statement (1-2 pages) of technical and teaching interests and accomplishments, and names and addresses (fax/e-mail included) of four referees. Applications should be submitted online at http://www.hr.ubc.ca/careers-postings/faculty.php.

Applicants to faculty positions at UBC Applied Science are asked to complete the following equity survey: https://survey.ubc.ca/s/MECH-AppliedMechanics/. The survey information will not be used to determine eligibility for employment, but will be collated to provide data that can assist us in understanding the diversity of our applicant pool and identifying potential barriers to the employment of designated equity group members. Your participation in the survey is voluntary and anonymous. You may self-identify in one or more of the designated equity groups. You may also decline to identify in any or all of the questions by choosing "not disclosed".

The closing date for applications is November 1, 2015. Please do not forward applications by e-mail.

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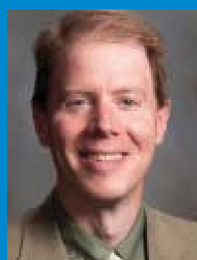
MYKLESTAD AWARD FOR PARKER

Robert Parker, the L.S. Randolph professor of mechanical engineering at Virginia Polytechnic Institute and State University in Blacksburg, has been named the recipient of the 2015 ASME N.O. Myklestad Award for innovative contributions to vibration engineering and research. The award was presented Aug. 3 at the ASME International Design Engineering Technical Conferences in Boston, where Parker, an ASME Fellow, also gave the Myklestad Plenary Lecture. Parker, who is recognized as an expert on the vibration of high-speed power transmissions such as geared and belt-pulley systems, recently received the 2015 Doak Prize from the *Journal of Sound and Vibration* for his research on instabilities in high-speed planetary gears inside airplane engines.



NEW ASME JOURNAL ACCEPTING PAPERS

The editorial board for a new ASME journal, the *Journal of Verification, Validation, and Uncertainty Quantification*, is currently accepting submissions.

The new quarterly journal is intended to serve an audience of both engineers and scientists and will feature peer-reviewed research, discipline-specific applications, and policy and regulatory perspectives, as well as sections dedicated to review articles and technical briefs.

The journal will launch in early 2016.

Ashley F. Emery of the University of Washington in Seattle is the editor.

Papers submitted to the journal must address one or more of the following areas: code verification, calculation verification, validation, or uncertainty quantification.

To submit a paper, visit ASME's journal submission site, journaltool.asme.org, and click "Verification, Validation, and Uncertainty Quantification."

Best Innovative Design winners for their Compliant Hand, Tennessee Technological University

STUDENTS INNOVATE AT DESIGN CHALLENGES

Student engineers took part in two events—the Innovative Additive Manufacturing 3D Challenge (IAM3D) and the Innovative Design Simulation Challenge (IDSC)—held on Aug. 2 in Boston during the ASME 2015 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, and Additive Manufacturing + 3D Printing Conference (IDETC/CIE/AM3D).

Sixteen teams faced off at the final round of IAM3D, which offers undergraduates the opportunity to re-engineer products or create new designs that minimize energy consumption or improve energy efficiency. Winning entries in each category earned a $2,000 award.

The Best Overall Design Award was captured by a team from Texas Tech University in Lubbock for a vacuum-driven water purification unit. Students **Shaun Foreman** and **Taylor Cychowski** represented the team in Boston.

The Best Innovative Design Award went to **Scott Hill**, **Chas Davies**, and **Nikola Tepavac** of Tennessee Technological University for a life-size, flexible prosthetic hand that could be used by either a robot or a human.

Soumay Gupta and **Ramanjeet Singh** from India Institute of Technology Roorkee won the Best Freshman Design Award for their project, which used 3-D printing to create a piston cylinder-based speed bump capable of generating energy from cars and trucks that pass over it. The team members, who remained in India, presented their entry via Skype.

Twelve teams demonstrated their skills in developing and deploying simulations for prediction models at the finals of the ASME Innovative Design Simulation Challenge. Each winning entry received a $2,000 prize.

Two teams received the Best Overall Simulation Award, commercial software category. Receiving the top award were **Yu Han Cheng**, **Yen Ting Wang**, and **Han Yu Lee** from National Taiwan University, and **Sharanga Bora** of NIT Silchar, India. The Best Utility/Impact Award for commercial software went to **Jonathan Alcocer**, **Eduardo Arvea**, and **Miguel Rodríguez** from Universidad Autónoma del Carmen, Mexico.

In the mixed software category, **Sohail Reddy** of Florida International University won the Best Overall Simulation Award, and **Rohit Solanki**, **Jeet Trivedi**, and **Harsh Pandya** from B.H. Gardi College of Engineering and Technology in Rajkot, India, received the Best Utility/Impact Award.

In the custom software category, **Pin Yi Chen** of Taiwan National University was recognized with the Best Overall Simulation Award. ME

INNOVATION SHOWCASE HIGHLIGHTS GLOBAL ENTREPRENEURSHIP

This year marked a new phase in the Innovation Showcase, which launched in 2007. The competition, which highlights hardware-led social innovations that improve the quality of life in communities around the world, held finals in India and Kenya as well as in the United States.

Ten finalists faced off at each of the 2015 ASME Innovation Showcase competitions, where they pitched and demonstrated their products in front of a panel of experts. The three winners at each site received an extensive design and engineering review from a team of industry experts in addition to a share of a $150,000 cash prize.

Winners and judges from IShow Kenya

At the inaugural IShow India event, which took place April 20 in Pune, the winners were:

Akash Agarwal for an off-grid refrigeration system that uses renewable energy sources to cool milk, fruit, and vegetables before they are transported to market.

Syauqy Aziz for a system that enables farmers to monitor the water condition of shrimp embankments and ponds and to access data in real time via text and the Internet.

Rajeev Kumar for a robotic system designed to conduct medical tele-examination of patients from remote locations.

At IShow Kenya, held June 24 in Nairobi, the winners were:

Brian Bosire for an electronic device that works with mobile phones to help rural farmers measure soil characteristics and relay that information by text to an analysis center.

Henri Nyakarundi for a portable solar-powered kiosk that can be used to charge up to 30 mobile phones or small devices at a time.

Emily Woods for a sanitation service that offers in-home toilets for families in poor urban areas and converts the waste collected from the units into fuel.

The three winning innovators at the U.S. IShow, held May 14 in Washington, D.C., were:

Lou Auguste for a low-cost diagnostic system that uses a smart phone to transmit digital images to pathologists.

Kamila Demkova for a carpet that harvests power from ocean waves.

Malvi Hemani for a device for midwives to monitor uterine contractions.

For more information on ASME IShow and these winners, visit www.thisishardware.org/. ME

ASME STUDENT SECTION LAUNCHED AT NINGBO UNIVERSITY

The first ASME student section to be established in the People's Republic of China was launched at Ningbo University in Zhejiang. After the student memberships were approved in early May, the inaugural meeting of the ASME Ningbo University student chapter was held on June 23 at the university's Xiushan Engineering Hall of the School of Mechanical Engineering and Mechanics.

Ningbo University's School of Mechanical Engineering and Mechanics has more than 1,000 students and more than 100 faculty members.

Professors **Ji Wang**, **Fuxing Miao**, **Tingfeng Ma**, and **Lijun Yi**, who are all active ASME members, are the faculty advisors for the chapter, which has approximately 35 members. The ASME Beijing Office assisted the Ningbo University's efforts to launch the new student section by answering questions about ASME and how to set up a student section and establishing communication between the university and staff at ASME's headquarters in New York.

Ji Wang (standing) at Ningbo's student section meeting.

During the meeting's keynote presentation, ASME Fellow **Horn-sen Tzou**, a professor at Zhejiang University and the former chair of ASME's Board on Technical Knowledge Dissemination, provided details on ASME and talked about his experiences within the Society. He impressed upon the students that ASME membership would be beneficial to their studies and careers.

For more information on Ningbo University's student section, contact Erin Sun of the ASME Beijing Office at SunY@asme.org. ME

A team of students aims to make needle injections painless by using an endothermic reaction to numb a patient's skin.

COMFORT FROM THE COLD

Three freshman engineers at Rice University who call themselves "Team Comfortably Numb" have been tasked with making a needle puncture much less painful, especially for children. They have come up with the idea of applying the same endothermic reaction used in cold compress packs to numb skin before the needle punctures it.

The device is currently external. The next step is to incorporate the endothermic device inside the cap of a needle for more convenient use.

The team is made up of computer science major Greg Allison, bioengineering major Andy Zhang, and mechanical engineering major Mike Hua. They currently have a functioning prototype that has been shown to produce a measurable numbing effect in 60 seconds, which in turn reduces the pain from an injection.

The team got started on the project by taking a class called Introduction to Engineering Design taught by Ann Saterbak and Matthew Wettergreen. Students elect to enroll in this class and are placed into interdisciplinary design teams to work on one of the offered projects, which include design for disabilities, enrichment devices for the Houston Zoo, medical devices, and solutions for low-resource settings.

In the course, the student teams learn and apply engineering design to solve a challenge. The teams are also eligible to compete in the annual Rice Engineering Design Showcase.

The course lasts for one semester, but students can continue their work when the semester is over.

Team Comfortably Numb was given the project by its sponsor and co-inventor, Mehdi Razavi, a cardiac electrophysiologist at the Texas Heart Institute. The students were asked to design and make a low-cost, easy-to-use numbing system that would be compatible with existing hypodermic syringes.

"Our device is 3-D printed and consists of two sealed chambers containing the chemical ammonium nitrate and water," said Mike Hua, the mechanical engineering major. "A simple twisting motion moves the chambers into alignment to allow the chemicals to flow through the chamber to produce a rapid endothermic reaction. We then numb the skin by contacting the device's metal surface to the patient's skin."

The team has also done further work for both prototype development and testing. For example, they are still working on optimizing the temperature to numb the skin and are also working on miniaturizing the device.

Currently, the team has filed for a provisional patent. The students are thinking of either starting a company around the product to commercialize it or to license their device and idea to a medical device company.

The students are not authorized to actually puncture anyone's skin with a needle. Razavi, their project sponsor, has experience in the area of medical testing. He said the team will need approval from an institutional review board before it can test the product on people.

The bioengineering major, Andy Zhang, said commercialization of a product is still a bit down the line for the team, but in mass production the cost of their device will be comparable to that of a syringe and a needle. They estimate that it will cost roughly $2 if it is mass produced. ME

JAMES PERO

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