MECHANICAL ENGINEERING

THE MAGAZINE OF ASME
No. 07
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Technology that moves the world

FOOD 3.0

FROM LAB TO MARKET

Growing what feeds us undergoes a revolution.

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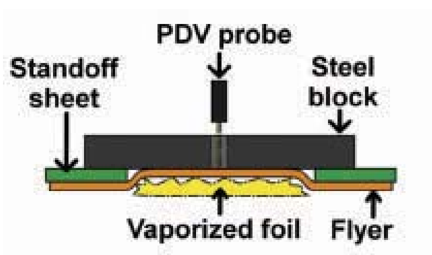
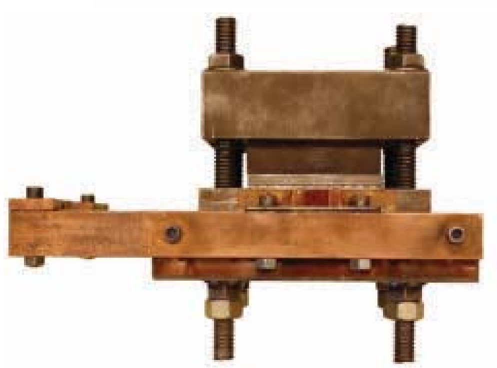
NEW WELDING PROCESS JOINS HIGH-STRENGTH METALS

THE ADVENT OF LIGHTER, HIGH-STRENGTH METALS has made the welder's job more difficult because high heat and re-solidification can weaken the material along the bond. Now, Ohio State University materials science professor Glenn Daehn and his team believe they've devised a solution that joins the new materials without melting. Their technique, called Vaporized Foil Actuator welding, uses less energy to create stronger bonds in hard-to-weld, high-strength metals. Its greatest promise is in automotive manufacturing, where advanced materials must be joined to traditional heavy steel.





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STOPPING LUNG CANCER, ONE BREATH AT A TIME

A MICROFLUIDIC DEVICE, developed by Kentucky-based Breath Diagnostics, captures breath—and may possibly warn you if you have lung cancer.

VIDEO: GLOBAL TRENDS IN THE AUTOMOTIVE INDUSTRY

GREENER AND SAFER IS the direction for most of the automotive industry in 2016. So says Subhendu Ghosh, EVP of Global Engineering and Design with Tata Technologies, who discusses trends from a global perspective.

NEXT MONTH ON ASME.ORG

ACCESSIBLE ROBOTICS SWARM

The Georgia Tech Robotarium offers researchers and students anywhere in the world access to a swarm of 20 robots. Its founder sees the Robotarium as a way to democratize access to robotics research.

VIDEO: OPTIMIZING FLYING OPERATIONS WITH BIG DATA

Dr. Eric Ducharme, VP Global Technology at GE Transportation, discusses the benefits and challenges of "Big Data" and tells how GE Aviation is harnessing its power.

VIRTUAL BUILDS BECOME ACTUAL REALITY

THERE'S NOW A WAY to make 3-D models better than by toying with an image on a flat screen. Thanks to new technology, anyone hoping to design an object for the real world can now do so in a virtual environment built on a CAD engine.

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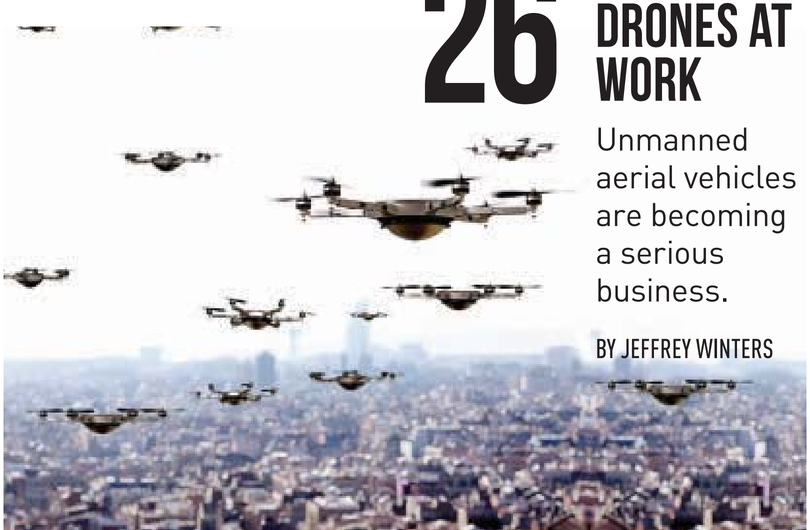
High-tech foods are migrating from the lab to the dinner plate.

BY SARA GOUDARZI



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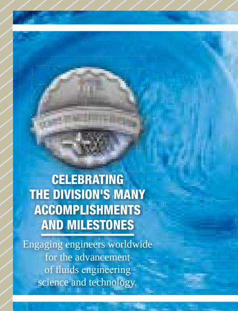

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Give me the place to stand, and I shall move the earth
—Archimedes

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John G. Falcioni
Editor-in-Chief

WHERE'S THE BEEF?

The last time I remember my son wanting to stop at a McDonald's, he was mostly interested in the Happy Meal toy—he just graduated college, so it's been a while. But we were in the car together a few weeks ago when we got hungry and pulled up to the first restaurant we saw, the one with the golden arches.

To our surprise, that McDonald's had gone high-tech. I'm late to the party on this, but I subsequently learned that McDonald's Create-Your-Taste has been around for a couple of years, mainly in Southern California and before that in global test markets Australia and New Zealand. About 2,000 U.S. locations have kiosks that give customers the option to create their own burger by selecting the kind of beef patties they want, and then choosing among the trademark special sauce, lettuce, cheese, pickles, onions, plus others: freshly roasted tomatoes, avocado, grilled mushrooms, and more.

Creating a made-to-order burger from a kiosk in a McDonald's, then having it delivered to your table by a friendly server, isn't just a novelty. It is part of the giant fast-food chain's surge to capitalize on a growing global food culture that includes fresher ingredients and healthier options.

The most recent change in how we grow what we eat and how we consume it evolved with the trend toward organic products and through television food shows and chefs who helped *celebritize* the art of cooking and eating.

The evolution of food, well before Emeril Lagasse and Rachel Ray, goes back to the development of the first commercially successful steel plow by John Deere in 1837, and to the invention of pasteurization in 1864. What has been described as the second food epoch, or Food 2.0, occurred in the 1900s when the agricultural revolution ushered in mechanization, chemical fertilizers, plant breeding, and hybrid crops.

Today's wave of agricultural advancements, some of which are described in Senior Editor Dan Ferber's article, "Watching the Crops Grow," on page 28, may be the bellwether of Food 3.0. The use of sophisticated robotics and drones for certain crop-breeding processes is helping the farming industry pave the way to serve a growing population on Earth, expected to reach 9 billion by 2050.

But farmers alone are not the only ones concerned with whether there will be enough food to go around.

In her captivating article, "Re-Engineering What We Eat," on page 34, contributor Sara Goudarzi reports that scientists and other researchers fear that Earth itself may prove incapable of sourcing all the food we'll need to feed ourselves, especially as the population grows in the next 35 years. Without sufficient land and water to produce beef, the alternative may be to engineer in vitro meat in the lab from precursor cells. Extensive research is also being conducted to genetically grow other meats and fish, as well as plants, in laboratory environments. A large amount of research is also being conducted on food printing, a process similar to the burgeoning 3-D printing we have become familiar with.

Even as I fancy myself a foodie, McDonald's—high-tech or not—remains a guilty pleasure, even when there is no one around hankering for a Happy Meal. But as the notion of ordering a "high-tech burger" grows, I can't help but feel nostalgic over the old McDonald's jingle and fearful of what one featuring a synthetic meat burger and fries might sound like. ME

FEEDBACK

How comfortable would you be eating a hamburger grown in a Petri dish? Email me.

falcionij@asme.org

MARCH 2016

Reader Thurman suggests that crickets swim through air, rather than jump.

« One reader would like more data on backup power. Another suggests we are losing engineering jobs to automation.

SWIMMING CRICKETS

To the Editor: Respectfully, I disagree with your observation that the spider cricket "jumps" through the air (TechBuzz, March 2016). Instead, I believe the tiny cricket swims or glides through the air similar to how humans swim or glide through water.

In water, humans walk or run very slowly in comparison to movement on land, and when humans use their legs to push off from a wall or similar object underwater, the reaction force causes humans to move very fast, to fly or glide through the water. Humans can travel for several body lengths in this fashion and move even faster than if they were on land.

I suspect sea creatures sprint underwater in this same basic fashion: They push against water like humans push against the side of a swimming pool or similar object.

Peter C. Thurman, *Bremerton, Wash.*

ON THE LEVEL

To the Editor: I enjoyed reading "By the Numbers: Renewable Energy Competitive on Costs" (Trending, April 2016). The author points out some amazingly low costs and the continuing rapid cost decreases for wind and solar photovoltaic power. Coal is mentioned as now more expensive than utility-scale wind and solar power, using levelized costs, and including cost of pollution controls. This is the reverse of common knowledge—which the author points out.

The author kindly referenced a data source, Lazard, an investment bank. Checking Lazard, the costs do not include the cost of backup power sources for when the wind doesn't blow or at nighttime, a significant cost. Perhaps the authors could do a follow-on article that does include these costs—it would be interesting to know if the traditional coal plants are then competitive or not. Lazard has that data, too.

Thanks for the article on an interesting topic on possibly passing a historic milestone in power costs.

Thomas R. Norris, P.E., *Orinda, Calif.*

CAPACITY FACTORS

To the Editor: The April 2016 Trending ("By the Numbers Renewable Energy Competitive on Costs") has a glaring omission: Conventional hydropower is not listed. Hydropower is a completely renewable energy source presently providing 6 percent of US electrical energy and 50 percent of Canadian electrical energy. Hydro is also the most reliable of the renewables, and has the highest capacity factor.

Capacity factor represents the percentage of time on average that the generation source is connected to the grid. That ultimately dictates how much conventional thermal capacity may be reduced as renewables are added.

In the case of wind power, the capacity factor is very low. Utilities must maintain what is known as "spinning capacity" to be brought online when the wind is not blowing. The base cost of wind power is shown to be very low in the article's graph, but in practice, 10 MW of wind power must be added to the grid to eliminate 1 megawatt of conventional generation. I believe if apportioned actual costs of maintaining spinning capacity were included with each renewable source, the graph of cost comparison between renewables would look much different.

G. Frank Ransley, *McFarland, Wis.*

AUTOMATION AND JOBS

To the Editor: Automation is software-driven machines doing work human beings used to do, or could never do. These machines do not have to look human. They just have to be able to do the job better, faster, or cheaper than a human.

ME magazine has said that ME jobs are expected to grow by 5.3 percent during the years 2014-2024 (Trending, March 2016), a period when the economy can reasonably be expected to grow by 20 percent. It looks like we will be losing ground, and automation will be part of the cause.

Ronald Corradin, *St. Paul, Minn.*

BEYOND BELIEF

To the Editor: In his April 2016 letter Mike Redler is so confident and convinced in his belief in anthropogenic global warming that he falsely concludes there must be something emotionally wrong with those who disagree. He suggests that people such as I must either believe in conspiracies, be anti-science, or be a denier motivated by greed. None of which are true. He illustrates how political the topic of climate change has become.

While incorrectly attributing motives to skeptics, Redler ironically fails to see how his arguments apply to himself and other believers in catastrophic AGW. What "we should acknowledge" is that billions of dollars are spent yearly in support of AGW claims for which many careers are now dependent. Also, "we should acknowledge" that NASA, the IPCC, and other agencies are government-paid employees, overseen by politicians who clearly do not tolerate skeptical positions in their organizations.

And unlike Mr. Redler, I would never hold a view simply because a majority of "experts" say so. Just as I would never argue the validity of $F = ma$ because a consensus of scientists believe it is true. It may be, but the argument is not a scientific one.

To be so confident in the face of such uncertainty cannot be the result of the scientific evidence, but of something else. I remain skeptical because that best represents the current state of understanding, not from any of the reasons alluded to in Mr. Redler's comments.

Gary Freitag, *East Aurora, N.Y.*

RECOMMENDED READING

To the Editor: After reading the article discussing the relationship of insects and birds to aircraft design ("Accelerated Evolution," April 2016), I would like to say the subject was covered quite eloquently in the seminal book, *The Simple Science of Flight: From Insects to Jumbo Jets* by Henk Tennekes. His first draft came out in 1990, and I have the revised and expanded version from 2009. Anyone interested in the subject should read this book.

Darold B. Cummings, *Coeur d'Alene, Idaho*

CHART CHECK

To the Editor: The article "Accelerated Evolution" (April 2016) was very interesting in its content. But the graph "Constructal Animals Human & Machine Technology Evolution," which displays velocity versus mass for various flying systems, seems to contain some errors, particularly in the velocity values for airplanes at the upper end of the mass axis.

While I did not check the accuracy of the relative masses, a quick online search yields velocities of the F-16, MIG-23, and F-14 at 670 m/s, 500 m/s, and 690 m/s respectively, which would not even be on the graph as presented. The Learjet 31 at a cruising speed of 230m/s should be up near the top of the existing graph with larger heavier commercial jets, which all have cruising speeds in the 228 to 255 m/s range.

Perhaps the author applied some unmentioned scaling factor that would cause fighter jets to fly slower than commercial aircraft?

R. Brian Peters, *Knoxville, Tenn.*

FEEDBACK Send us your letters and comments via hard copy or e-mail memag@asme.org (subject line "Letters and Comments"). Please include full name, address and phone number. We reserve the right to edit for clarity, style, and length. We regret that unpublished letters cannot be acknowledged or returned.

PRINTING THE FUTURE

A NEW MACHINE STREAMLINES ADDITIVE MANUFACTURING BY SIMULTANEOUSLY COMBINING MULTIPLE MATERIALS, TEXTURES, AND COLORS.

Nick Ervinck's *Wolfkiam* takes full advantage of new 3-D printing technologies.

Nick Ervinck spent years creating complex sculptures using CAD software. Made of hundreds of multi-colored interconnected pieces that resembled otherworldly animals, plants and sea life, many of these designs remained on his computer because there was no practical way to actually build them.

"It was really frustrating," said Ervinck, a Belgian artist. "There was nothing to make that a reality."

That was until Naomi Kaempfer, creative director of art and fashion design at Stratasys, a developer of 3-D printing solutions, called to see if he'd like to use the company's new J750 to create some of those sculptures. The 3-D printer could combine six materials for a variety of characteristics, explained Kaempfer, who became familiar with Ervinck's work after hearing him speak at a design conference. It can generate more than 360,000 colors to create countless gradients, shadows, and highlights. It can also create textures and produce ultra-smooth surfaces, minute detail, and layers as thick as 14 microns, about half the width of a human skin cell.

"Six months ago *Wolfkiam* would have been impossible because the technologies and tools didn't exist," Ervinck said of the sculpture that Stratasys printed on the J750.

Wolfkiam is an abstract sculpture made of yellow, white, and gray lines that intermingle and connect to suggest a sci-fi version of an animal skull. It was so complex that its design file weighed in at nearly three terabytes. Stratasys built the sculpture in about a week.

The J750, mainly aimed at rapid prototyping studios, is designed to do more than help artists build complex designs. It can create components from materials with different properties (soft, rubbery, stiff, brittle) and various colors and gradients in a single build. Those features can aid engineers who are looking to quickly make a prototype that resembles a finished product.

"What we combine in one machine can replace the need for four or five different 3-D printers and secondary steps, like spray painting," said Roger Kelesoglu, director of sales enablement at Stratasys. "This technology lowers barriers of entry and dramatically increases accessibility for many types of people."

With the PolyJet Studio software, which controls the printer, users can add hybrid characteristics to the system's materials by blending up to six photopolymers in specific concentrations. The software also automatically maps the colors, transparencies, and opacities of the materials.

Jose Sanchez, an architect, game designer, and assistant professor at the University of Southern California School of Architecture, relied on that functionality to create *Polyomino*, a series of pieces in different shapes and colors that are connected by embedded magnets and can be assembled to form sculptures and other types of objects, such as lamps and even chairs.

The J750 was especially helpful in creating the varying degrees of rigidity and flexibility the pieces needed to connect and support each other. The color gradients adds shades and textures that allows seamless blending and mixing of an unlimited number of pieces.

"The pallet of colors and flexibilities can take you to another level," Sanchez said. **ME**

JEFF O'HEIR

Stratasys's J750 doubles the number of print-head nozzles to increase speed and quality.

INFRARED CURE FOR 3-D COUNTERFEITING

As 3-D printing quality rises and costs drop, companies are looking for ways to protect their brand-name products from cheap 3-D knockoffs. A sophisticated strategy developed to foil pharmaceutical counterfeiters might provide a solution.

Knockoffs are big business, accounting for as much as $500 billion in global trade alone, according to the Organization for Economic Cooperation and Development. A substantial percentage are products that 3-D printers could copy, including watches, jewelry, medical devices, and spare military and industrial parts. Technology consulting firm Gartner argues that 3-D counterfeiting could reach $100 billion by 2018.

"The biggest problems come in industries where the brand-name version is worth tremendously more than a nonbranded part, and where it's hard for consumers to tell the difference between the two," said Sharon Flank, CEO of InfraTrac, a company that develops anti-counterfeiting technology for 3-D printers.

The growth of 3-D parts will make it easier for counterfeiters to enter the supply chain. Companies might license 3-D printing service centers to make products locally, the way soft drink makers and clothing designers do now. This would help companies boost capacity quickly or supply spare parts without stocking inventory. It would also give counterfeiters many new targets.

This is what happened in the pharmaceutical industry, where Flank got her start. Today, rogue drug makers duplicate legitimate bar codes and RFID tags, and even the fluorescent or rare earth chemical markers that signal a product's legitimacy.

To safeguard drugs, InfraTrac applies a thin layer of chemicals on tablet coatings, capsules, or packaging. Instead of a single chemical marker, InfraTrac uses a combination of chemicals. When the mixture absorbs near infrared light, it produces a unique "fingerprint" of peaks on a spectrometer.

The same solution also works for plastic, ceramic, or even metal 3-D parts. In that case, InfraTrac uses the printer to apply a thin marker layer directly onto the part.

Combining chemical mixures with spectroscopy has several advantages. It is difficult for criminals to reverse-engineer the spectra, since each chemical in the mixture influences the peaks of the others. It employs materials already used in drug coatings or 3-D products. And the falling price of hand-held NIR spectrometers makes the technology affordable.

"Last year, when we started showing this technology, 3-D users were just starting to think about protecting their intellectual property. Now, it's starting to catch fire with early adaptors," Flack said. **ME**

This digester system at the University of California, Davis converts 50 tons of campus and community food and yard waste into 12,000 kWh per day of renewable electricity. *Photo: UC, Davis*

ANAEROBIC DIGESTERS REDUCE FOSSIL-FUEL DEPENDENCE

Engineers have experimented with anaerobic digestion as a way to create fuel since the 1800s. Some British communities were using gas captured from sewage treatment operations to power street lamps over 100 years ago. However, throughout the 20th century, the abundance and relatively low cost of natural gas, oil, and coal has made it economically impractical to develop more advanced large-scale anaerobic digester technologies, especially in the United States.

That is starting to change. Small-scale digesters have been used successfully for years to provide energy and heat in developing countries—more than 8 million of them are estimated to be in use in China. This success is leading to the establishment of large-scale anaerobic digestion systems in Europe and North America.

Anaerobic digestion is a natural process by which bacteria break down organic matter in an oxygen-free environment to form biogas and a residual digestate. Feedstock can be food waste, manure, sewage, or other organic matter. Depending on the type of bacteria used, operating temperatures can range from 35-55 °C (95-131 °F). The final product is a mixture containing methane that can be used as a fuel for generating electricity. The digestate is usually spread on farm fields as a fertilizer.

The process reduces the volume of waste, which in some applications lessens the environmental risks of manure runoff and groundwater contamination. Being able to process waste organic matter through anaerobic digestion also relieves disposal burden on municipal landfills.

Several large-scale operations have come online in the U.S. in recent years. Sacramento started up one of the largest anaerobic digestion systems in North America in 2013. It can convert 25 tons of food waste per day into heat, electricity, and methane. The project produces the equivalent of 700,000 diesel gallons of compressed methane gas per year and prevents the release 18,000 tons of CO_2 into the atmosphere. The system also generates 1 million kW of electricity and produces 8 million gallons a year of organic soils and fertilizer products.

In 2014 the University of California-Davis opened its Renewable Energy Anaerobic Digester at the campus' former landfill. The digester converts 50 tons of campus and community food and yard waste into 12,000 kWh per day of renewable electricity. The same year, the University of Wisconsin-Oshkosh launched its new $10-million, 1.4-MW digester at the state's largest dairy operation. The digester processes 240 tons of manure per day from the dairy's 8,500 cows. That generates biogas, which is burned as fuel in power production, and a pathogen-free, nutrient-rich digestate that will be used as an organic fertilizer. The digester was built through a partnership between the University of Wisconsin and BIOFerm Energy Systems, a division of a German company, Viessmann Group.

"OUR DESIGN IS UNIQUE IN THAT IT'S SMALL ENOUGH TO SERVE A SINGLE HOUSEHOLD."
CAROLINE ANGELO, CO-DIRECTOR OF BIOD

Although the technology basics of anaerobic digesters are the same, components can vary according to project parameters, including project size, type

continued on p.15 »

SLICED BREAD AND BROKEN APPS

Nearly every store and bakery in Malawi, the southeast African country where I work, has a bread slicer that is missing one of its blades. Maybe it snapped off. Maybe it got lost. Maybe it got jury-rigged into a knife for the butcher to use at the same store. But you can bet that one of those blades is gone, which means every loaf cut by that bread slicer has at least one double-thick slice.

At the store I go to, it's the third one from the end of every loaf.

While this isn't exactly a critical problem, it says something about not-quite-working technology. Everything breaks eventually. And when things do break, a whole system needs to be there to identify the problem and resolve it. Someone needs to notice the missing blade in the machine, be able and willing to buy the parts to fix the problem, and know how to install the new blade.

To use an example more relevant to the context of technology and development, someone needs to know that a water pump is broken, identify the cause, have the funds, knowledge, incentive, and supply chain to buy the parts needed—and then have the trust of the users to take the pump apart to fix it.

Or at a rural school, someone has to be aware when the teacher isn't showing up anymore, and then have the gas money or phone credit to figure out what's going on, the authority to apply appropriate consequences or solutions—and the ability to hire another teacher who can fill the gap.

Every solar panel system needs maintenance. Every low emissions cookstove can crack. Every mobile phone app stops working when the phone stops working, or when the person checking in on the data from the app retires and isn't replaced because there isn't money to place the ad in the paper to advertise the position.

Every technology needs a system working to support it. Technology itself might bubble up good development indicators, but those bubbles burst every time the systems behind the technology aren't robust enough to keep it working.

Technology is fun, but the system supporting it is the critical piece.

KRISTINA NILSSON is a program director for the WASH (Water Sanitation and Hygiene) Catalysts initiative of Engineers Without Borders in Malawi. Since 2011, she has worked on sustainable service delivery.

FOR MORE, GO TO ENGINEERINGFORCHANGE.ORG

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ANAEROBIC DIGESTERS

of bacteria, temperature, feedstock type, and volume of production. Different tools and add-ons are available to increase the efficiency of the operation. For example, most wet fermentation applications (pumpable liquids) rely on a complete-mix tank reactor. "To improve efficiency, we offer an agitator package characterized by low-power consumption with high mixing efficiency," said Whitney Beadle, director of communications for BIOFerm Energy Systems in Madison, Wisconsin.

"Unique anaerobic digester systems are also available for dry fermentation [non-pumpable, high-solids feedstocks] digestion systems," Beadle said. "These can hold the material stationary inside the chambers, allowing for digestion of highly contaminated waste streams that may be unsuitable for traditional digesters, such as municipal solid waste, because pre-separation is not necessary. Smaller systems are also available for smaller feedstock amounts. This removes the need for a large amount of on-site construction because the system is delivered on site as a prefabricated, prepackaged container."

Because they can be designed for feedstocks and production volumes, and are simple to build and maintain, digesters are increasingly being used in developing countries to create energy for individual families. BioD, part of a Washington, D.C.-based startup incubator called Hatch International, is using digesters to turn farm waste into usable energy in Madagascar. BioD expects the technology to replace wood fires for cooking, which are a major cause of deforestation and indoor air pollution.

"Our design is unique in that it's small enough to serve a single household, and can even be picked up and moved around," said Caroline Angelo, an electrical engineer and co-director of BioD. "Since everything is above ground, it's easy to troubleshoot and repair if necessary."

Anaerobic digesters are also being used to facilitate human waste disposal in impoverished countries that have insufficient sanitation facilities. For example, less than 30 percent of India's population has access to toilets. Untreated human waste, often left out in the open, is responsible for outbreaks of diseases such as dysentery, diarrhea, viral hepatitis, cholera, and typhoid. A company called DRDO has perfected a biodegradation technology that converts human waste into usable water and gas in an ecofriendly manner. The gas can be utilized as cooking fuel and the water is suitable for irrigation. ME

MARK CRAWFORD is a technology writer based in Madison, Wis.

REALITY CHECK

People often rally around those who are **putting forth their best effort**—even if it comes up short.

Everyone knows the cliché that you learn more from your failures than you do from your successes. Ultimately, it is how you pick yourself up after a fall on the face that determines long-term success.

It is equally important to be able to evaluate yourself in an objective way. Two colleagues and I had a meeting with a student team months in advance of an international competition. At that meeting we pointed out a few egregious technical flaws in their entry. We also told them in no uncertain terms what the outcome would be. In addition, these flaws are well known to the particular competition community and can be found in Web searches.

The team responded poorly, both technically and professionally. They halfway took care of one issue, but ignored most of the others. As expected, the design judges took them to task for their obvious errors and ultimately their entry failed.

The vindication for the faculty was hardly satisfying. Failure is not necessarily an issue if the team is working to the best of its abilities.

But a lack of realistic self-assessment is far too common.

Let me relate a counter example. One of our students was on a team in a competition sponsored by the Department of Energy. Teams from our school had won first and second prizes in prior years. Initially, this team had five people. One day I showed up at the lab and found one guy left.

A few weeks later, he admitted to me that he almost quit the project and asked what he should do. I told him that I would support whatever decision he made.

As the year progressed, he did not make much progress, but he never quit.

The competition was to build a snowboard and the testing was in Colorado. I explained the situation to the organizer of the contest, the Institute of Paper Science and Technology: Everyone on the team abandoned him, but he did not give up.

They said he could attend and they would cover his expenses, as with the other teams. The day of the competition, I was sitting at breakfast. It was getting late. He finally showed up and later said he almost did not come because of embarrassment.

Graciously, the most senior person present from the Department of Energy spent 20 minutes talking to him—one on one—about life.

The student's snowboard broke in half on the first run. The other teams did what you often see at these competitions. They let him ride their snowboards down the mountain.

In the first two competitions we had won approximately $18,000. We hadn't spent it all, so after a very brief discussion, the students from prior years who were still around agreed that we would give our one-man team a scholarship to cover the tuition for a class the following semester.

When he came by to see me, he said that he could not understand why we had done this, since he was not successful. We had done it, I told him, because he had never given up.

UNDERSTANDING YOUR ABILITIES AND PERFORMANCE AND BEING HONEST ABOUT THEM GOES FAR, BOTH WITH YOURSELF AND OTHERS.

Admittedly, one rarely gets rewarded in the short term for failure. Usually the reward is in the long-term benefit to character development and better judgment in the future.

People will often rally around those who are putting forth their best effort even if they are coming up short. If you are not the most talented person in the group, but are honest about your limitations, people around you can often accept that.

Understanding your abilities and performance and being honest about them goes far, both with yourself and others. As with almost all things, identification of your shortcomings, professional or otherwise, is the first step in overcoming them. ME

RONALD A.L. RORRER is an associate professor of mechanical engineering at the University of Colorado Denver.

SOLAR POWER ROUND THE CLOCK

Solar panels now cover rooftops throughout the developed world, and costs continue to fall. But the solar photovoltaic technology used in these panels comes with a major drawback: It produces electricity only when the sun shines.

Concentrated solar power (CSP), a technology also known as solar thermal power, stores solar energy as heat before converting it to electricity. CSP could generate the steady supply of electricity the grid needs, but it has advanced at a snail's pace because it was too expensive compared with solar photovoltaic panels, whose prices have declined rapidly.

But a new solar plant with molten salt storage has been built that stays hot through a summer night. And that could make solar power an option around the clock.

SolarReserve's 110MW Crescent Dunes Solar Energy Plant in Tonopah, Nev., achieves this by using 10,347 different heliostats—motorized mirrors that track the sun and keep it reflected precisely onto a receiver — that are perched atop a 540 foot tower. That concentrated sunlight heats the molten salt to 1050 °F (566 °C)—much higher than previous molten salt storage systems.

The system uses a unique combination of high nickel alloy materials (originally developed by Rocketdyne) to help it store a great deal of heat with a relatively small amount of fluid. Reducing salt volume cuts the cost. It also helps the plant stand up to extreme thermal cycling stress from a desert environment that can move from chilly to broiling in half a day.

After it's heated, the hot fluid then moves through a heat transfer loop to drive a conventional steam turbine. Then the "cold" discharge fluid, which is still 550 °F, is pumped from the turbine loop into tanks. Heat from that fluid can continue to produce power for 10 hours after the sun has set, allowing the plant to meet the electricity demand around the clock, at least in the summer, when nights are short.

"On a large scale, CSP with storage can significantly improve the ability of a 100 percent wind, water, solar system to match power demand at a much lower cost than batteries," said Mark Z. Jacobson, who directs the Atmosphere/Energy Program at Stanford University.

And CSP might work even better when it's combined with PV, said Kevin Smith, SolarReserve's CEO. At some of the company's utility solar projects in South Africa and Chile, they now integrate both technologies, providing power from low-cost PV during the day, when demand peaks, and from CSP at night.

The utility NV Energy is already providing power from the Crescent Dunes plant to 75,000 homes, and in early May, SolarReserve signed an agreement with Shenhua Group Corporation, Ltd., to build 1,000 megawatts of solar thermal projects in China. ME

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

ME: When you were a kid, what did you aspire to be when you grew up?
K.R: I remember I thought it would be great to be a spaceman—I thought rockets were cool. At one point, I also thought it would really be cool to be in a band. But mostly I gravitated toward making things, figuring out how things worked, and working on technical and mechanical projects.

ME: What would one of your high school teachers say about you?
K.R: I was pretty shy as a child and, as the third of three boys close in age, I was pretty good at flying under the radar. So good, in fact, that my fifth-grade teacher told my father that my parents should lower their expectations for me. The teacher felt I would be lucky to graduate from high school. Somehow I found a way into Princeton.

ME: Who was the biggest role model in your life?
K.R: While my mother and paternal grandfather were important role models, the biggest is my father. He was high energy, smart, people-oriented, caring and personable, and a bit of a renaissance man. He taught me the value of hard work and the value of discipline. His love and dedication to his family was unconditional.

ME: What kind of wisdom would you like to leave your grandchildren?
K.R: When I was a boy, my dad gave my siblings and me a framed copy of Rudyard Kipling's poem, "If." It is one of the best things I have ever read to keep me grounded. I still read it periodically and I have passed it on to my kids. So as a start, I would want my grandkids to see the wisdom in this poem.

ME: What do you want to accomplish during your year as ASME president?
K.R: My aspirations for the coming year are high. Working with a strong Board and best-in-class staff, and aggressively pursuing our new technology-based enterprise strategy, I want to help us grow ASME's impact, cache, and relevance in strategic markets in the U.S. and globally. That won't happen overnight. But in the year ahead, I want to make strong, specific inroads, in partnership with the Executive Director, in helping to focus the organization and raise the level of our game, not only at the Board level, but across all ASME.

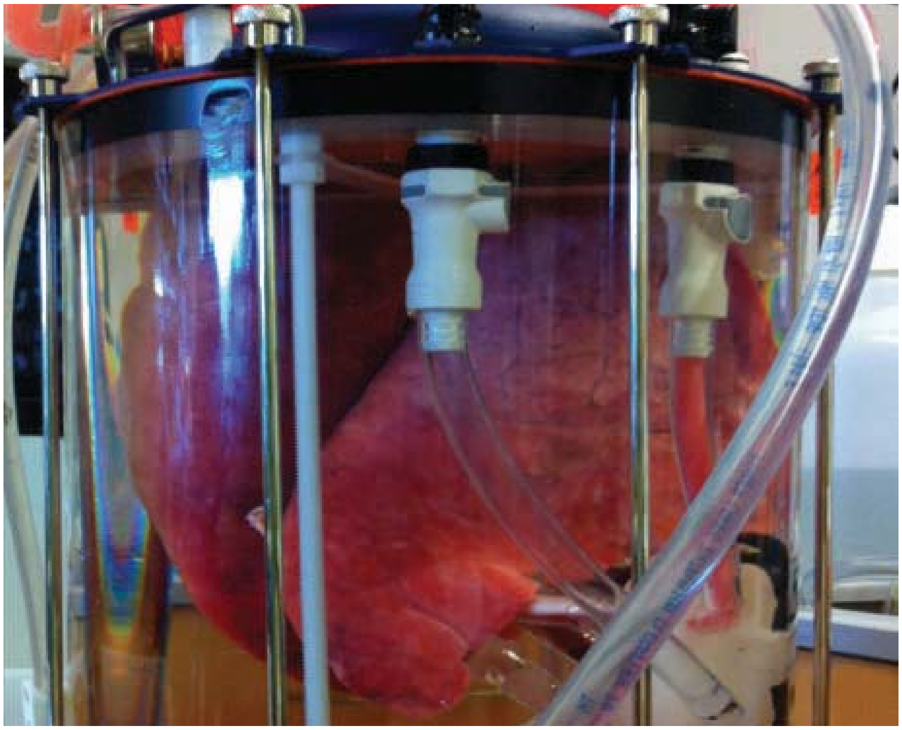
The potential future for ASME under our new strategy is exciting and will offer great opportunities for all our members and constituents. I am thrilled to have the opportunity to serve as ASME's president during this transformational time.

ME: What are your guilty pleasures?
K.R: My guilty pleasures are cruising on our boat and riding my motorcycle, both of which stem back to my time in the Navy when I loved being at sea. I bought my first motorcycle while in the Navy. I stopped riding for a while when my sons were teenagers, but now I ride a Harley Davidson Road King Classic.

ME: PC or Mac?
K.R: Mostly PC. I love the Mac, but don't know all the shortcuts, so it is very inefficient when I try to use it. I love my iPhone and iPad, so that gives me a bit of an Apple fix. ME

K. KEITH ROE

K. KEITH ROE, AN ASME FELLOW who has been an active member of the Society for more than 40 years, was installed in June as the 135th President of ASME. Roe (shown here with his wife, Elizabeth [Brownie] Roe) recently retired as chairman, president, and chief executive officer of Burns and Roe Enterprises Inc., a leading power engineering, procurement, and construction services company that his grandfather, Ralph Coats Roe, founded in 1932. One of ASME's highest awards is named after Ralph Coats Roe. Keith Roe's father, Kenneth Andrew Roe, served as ASME's 90th president from 1971-72.



NEXT-GEN IRON LUNGS

A mechanical system that supports regenerated pig lungs could eventually be used to grow engineered human lungs and other organs.

While the ability to grow complete organs from a patient's cells is still many years off, the new bioreactor could help to advance the clinical application of regenerated organs for use in transplants.

Micha Sam Brickman Raredon, a Ph.D. candidate at Yale School of Medicine who worked with a team of engineers and scientists from Yale and MIT on the system, acknowledged the field is busy with competing research. But he said this bioreactor, described in *BioResearch Open Access*, is designed to provide better control over perfusion, ventilation, and other parameters than previous devices.

Figuring out the fluid mechanics to mimic the blood flow and ventilation of the human chest—the optimal environment for growing a lung—was the toughest challenge the team faced during the two years it took to design and build the device, he said.

"We had to develop a set of machines that recreate conditions found in the human body," Raredon said. "We were constantly thinking of those physiological parameters and how to recreate them in the lab."

To do that, the team built the bioreactor with three main components: an organ chamber that replicates a chest cavity, a ventilation apparatus that mimics breathing, and a perfusion apparatus that circulates fluids. The components work together to teach the cells how to grow and behave.

"The bioreactor forms a blueprint on how to be a healthy organ," he said.

One key advance was in the design of the organ chamber to better replicate human physiology. The chamber consists of a compression-sealed glass jar that holds a decellularized donor lung infused with human cellular material. The lung is anchored vertically and sealed in a highly elastic silicone bag, which not only limits the amount of expensive culture medium but mimics the pleura membrane that envelops an animal lung and cushions it during respiration. A diaphragm membrane sits on top of the chamber and forces the lung to expand and contract, pulling and pushing air and fluids from an artificial trachea tube. Pig lungs used in the published studied were sustained for 24 hours.

The team is now working to improve three key areas of its research: developing tissue that looks just like a normal lung, eliminating blood clotting, and perfecting gas exchange.

"We are decades away, but the promise of this research is that it opens a potential door to generating custom-made organs that could be transplanted," Raredon said. ME

BIG NUMBER

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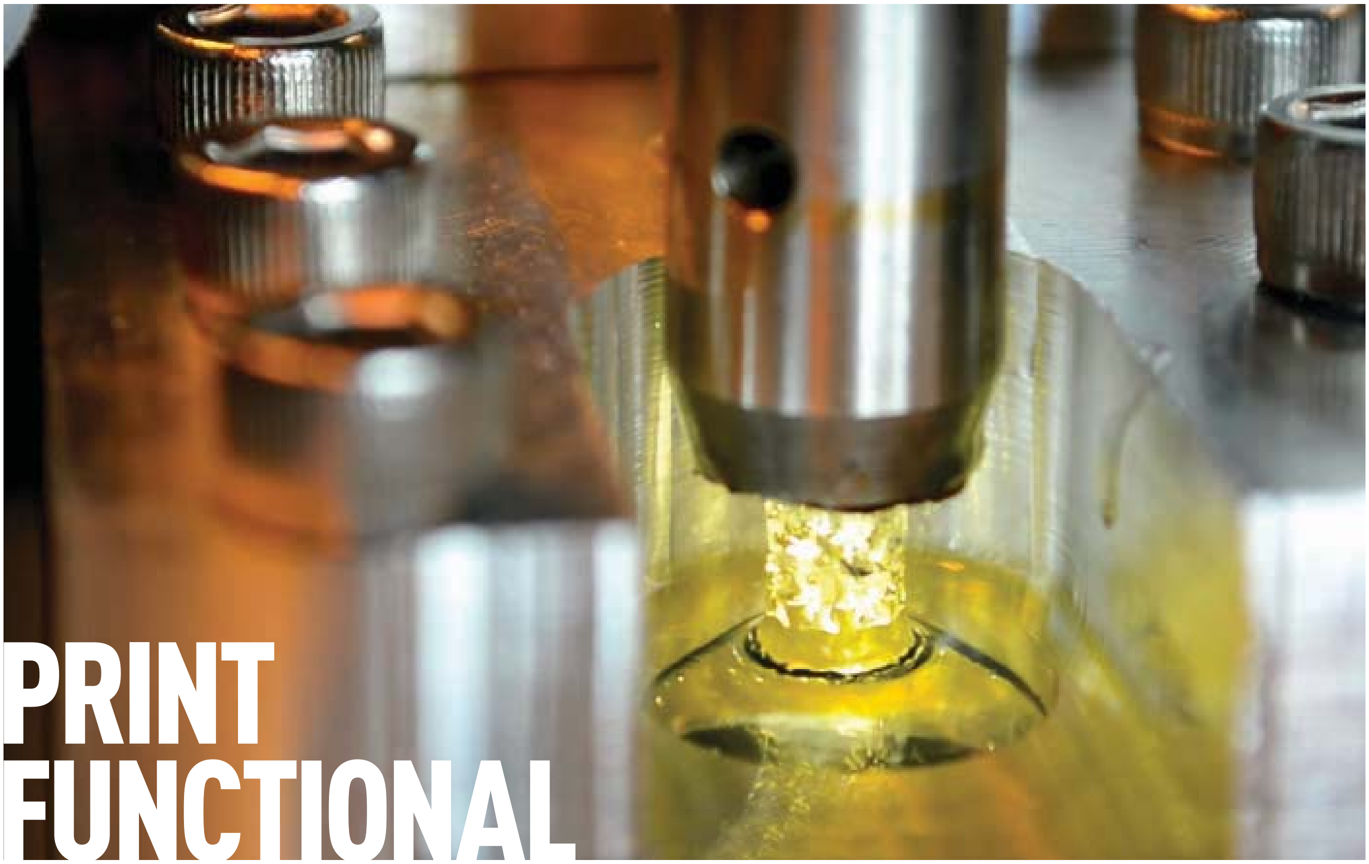
UNTIL RECENTLY, PORTUGAL HAD NOT EMBRACED its renewable energy potential. In 2008, wind, solar, and hydropower accounted for less than 30 percent of its electricity production. By 2014, however, wind power had doubled, and solar had increased by a factor of 15. According to Associação Sistema Terrestre Sustentável, a Portuguese nonprofit, the entire national electrical demand was met by wind, solar, and hydroelectricity from the morning of May 7 to the evening of May 11.

Number of consecutive hours that Portugal's electricity demand was met by renewable sources.



PRINT FUNCTIONAL MATERIALS

A metamaterial lens rises from a micro-stereo lithography printer.
Photo: Northwestern University

WHEN MECHANICAL ENGINEERS THINK about 3-D printing, they visualize prototypes and structural parts. Yet 3-D printed objects can also have unusual optical or chemical properties. This month we take you to two labs creating these types of materials: One produces distortion-free lenses using nanostructured arrays, while the other uses catalysts and other nanoparticles to make 3-D structures chemically active.

A new type of lens may help scanners better identify organic materials in airport security lines. The flat, nanostructured lens provides better resolution than conventional curved lenses. The lens was developed by the Cheng Sun Research Group at Northwestern University, which also pioneered the 3-D printing process used to create its nanoscale features.

The lens is based on metamaterials, which contain artificial nanostructures that interact with light and other electromagnetic waves in unusual ways. They are, for example, the technology behind the so-called invisibility cloak.

Metamaterials manipulate light and electromagnetic waves by guiding them through graded layers of nanoscale pyramids that alter their refractive index. This produces sharper, higher resolution images than conventional multilayer lenses.

Sun uses his lenses to interact with terahertz waves, which fall between microwaves and infrared.

"These frequencies interact with the vibrations of organic molecules," Sun said. "If you put a terahertz device near an X-ray machine, it could detect organic compounds that are invisible to X-rays."

VIEWING WITH METAMATERIALS

THE LAB Cheng Sun Research Group, Northwestern University in Evanston, Ill.; Cheng Sun, principal investigator.

OBJECTIVE Creating materials with unique optical or biochemical properties via projection micro-stereo lithography, a 3-D nanoscale printing process.

DEVELOPMENT Producing metamaterials that act as flat, distortion-free lenses to focus terahertz waves, which can be used in security scanners.

They could, for instance, identify such security threats as plastic explosives, dangerous chemicals, and biological weapons, he said.

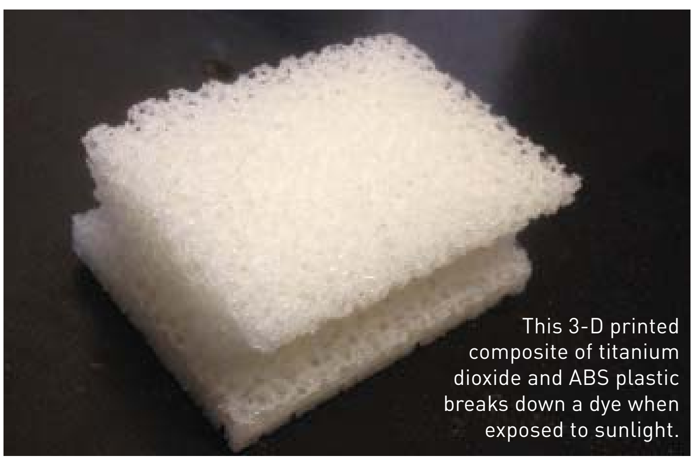
To manipulate 500-μm terahertz waves, the elements of Sun's arrays must be an order of magnitude smaller, or 50 μm with 5 μm resolution. To build these graded arrays, he uses projection micro-stereo lithography, a 3-D printing process he pioneered as a Ph.D. student at Penn State.

Sun's system starts with a liquid that forms a layer of solid polymer when struck by light. Unlike conventional 3-D systems, Sun solidifies an entire layer at once.

He does it by shinning UV light onto a digital mask that lets only the light needed to form the pattern get through. It reflects this light through a lens, which focuses it down to nanoscale proportions. A computer then instructs the digital mask to reconfigure its pattern to build the next layer, and the process takes place again.

A 3-D printed terahertz lens with graded refractive index.
Image: Northwestern University

Sun's lab is also collaborating with a Northwestern biomechanical engineer, Guillermo Ameer, to make 3-D print biodegradable vascular stents for children. The stent would contain anticoagulants to prevent clotting, and disappear after several months, leaving surgeons free to implant a larger stent to accommodate the child's growth. ME



This 3-D printed composite of titanium dioxide and ABS plastic breaks down a dye when exposed to sunlight.

Photo: American University

The chemical properties of nanoparticles are endless, Matthew Hartings, an assistant professor of chemistry at American University, argues. By embedding them in 3-D printed plastic, he hopes to make that potential real.

Chemically active 3-D objects could be used to make chemical sensors or filters. By embedding different catalysts along the length of a 3-D structure so they interact with passing gases or liquids, Hartings hopes to print small chemical factories.

Hartings tested his theory with titanium dioxide, which acts like a catalyst when exposed to light, and ABS, a durable polymer used in cameras and power tool housings. He found the TiO_2 in the ABS broke down a dye when illuminated.

PRINTING CHEMICAL REACTORS

THE LAB Hartings Group Lab, American University, Washington, D.C.; Matthew Hartings, director.

OBJECTIVE Creating on 3-D printed nanocomposites to carry out useful chemical reactions.

DEVELOPMENT Printing a composite capable of carrying out chemical reactions.

3-D printing the TiO_2/ABS blend "worked like a charm," Hartings said. The only tricky part was unclogging the head after printing. A graduate student suggested running piano wire (available in 88 diameters) through it, and that seemed to do the job.

The higher the percentage of TiO_2, the more active the sample. Above 10 percent, however, print head performance and part integrity begins to suffer. Hartings has several potential fixes in mind, but needs to make sure they do not keep the particles from fully dispersing.

TiO_2 is affected by water in the atmosphere. Embedded in ABS, these changes alter the polymer's refractive index. Hartings is currently working with National Institute of Standards and Technology to see if he can build a simple ABS/TiO_2 humidity sensor. By adding different types of nanoparticles, he hopes to sense carbon dioxide, methane, and other gases.

Hartings also envisions systems with two or more different nanoparticles. They could sense a variety of molecules, neutralize chemicals as they move past their surfaces, or even synthesize new molecules. "If you can print these systems, you can start thinking orthogonally about applications," he said.

Inspired by student research, Hartings is also looking at a protein that entraps nanoparticles. He envisions entrapping iron particles and adding active chemical groups to the protein's surface. The lab could then steer the particles magnetically towards pollutants and use the active sites to neutralize them. ME

ALAN S. BROWN

GASIFICATION OF SOLID WASTES IN FIXED BEDS

LOOKING BACK

Engineers were looking for innovative ways to deal with pollution when this article was published in July 1976.

A.C.W. EGGEN AND RONALD KRAATZ
K.T. LEAR ASSOCIATES, INC., MANCHESTER, CONN.

Large-scale waste incineration was a relatively new technology, but the authors of this article were already looking ahead to a cleaner and more efficient way of disposing of trash.

The problem with solid wastes is that they are seldom in a form that can be readily utilized. Wood wastes can be used in a hog fuel boiler or municipal wastes in a steam-rising incinerator. But the equipment is expensive and energy recovery efficiency low. As a result, it is often advantageous to convert the waste into a more readily usable fuel form. It is at this point that gasification of the solid wastes in fixed beds has a particular value.

The fixed bed gasifier uses simple, low-cost hardware to produce a fuel gas which can be fired in a wide range of receiving equipment. Conversion efficiency can be quite high. By adjusting process variables, such as gasification oxidizer, the fuel gas composition can be optimized to favor a particular user. The fuel gas also can be upgraded before firing.

Certainly other approaches to using solid wastes as fuel will be successful. For example, the firing of shredded, air classified municipal wastes has considerable potential. However, this approach is limited to boilers having bottom ash handling capability. Gasifying the solid wastes can extend the utilization to oil- and gas-fired boilers and furnaces, and potentially to gas turbines and fuel cells.

Systems and Use Considerations

The gas produced by a fixed bed gasifier has potential for use in a wide range of fuel burning and synthesis gas applications. Optimum performance will require a particular choice of gasification oxidizer, gasifier operating conditions, and, in many cases, fuel gas upgrading processes. In many applications, the highest energy recovery efficiency only will be possible through the integration of gas producer and gas using processes.

Combustion stability with the fuel gas is not a problem since the energy levels are high enough to produce reasonable flame temperatures unless extremely wet waste is being gasified. Excess air levels can be held to the normal minimums with conventional gas-burning equipment.

It should be noted that the common way of quoting gas heating value, gross Btu/cu ft fuel gas, is not a very good or fundamental measure of fuel gas performance. (For a dry scrubbed gas, its magnitude is in the order of 150 Btu/cu ft for air gasifiers, and 300 Btu/cu ft for oxygen gasifiers.) It is a good measure of fuel gas piping size, storage volume, or pumping power, although even here, net heating value would be a better measure. Except in applications requiring pipeline transport, the more important factors are those associated with the characteristics of the combustion products. These can be related at least roughly to the net heating value per unit mass or volume of fuel plus combustion air. ME

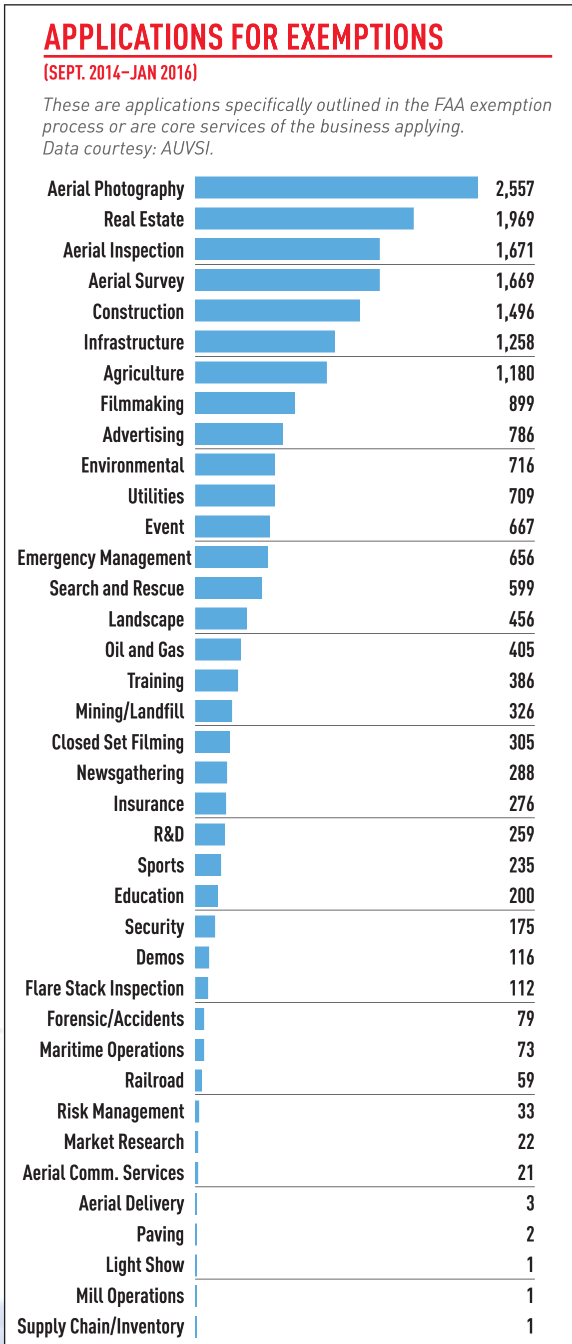
BICENTENNIAL

Readers of Eggen and Kraatz's article on gasification may have been distracted by the events of the bicentennial of the independence of the United States of America, which was celebrated in July 1976. Some of those events had an engineering edge to them: NASA's *Viking 1* probe landed on Mars that month, and the American Freedom Train, pulled by a Southern Pacific steam locomotive, made station stops as part of its 48-state tour. Most memorable, though, was the parade of tall-masted sailing ships in New York Harbor on July 4. The 16 tall ships were met by 50 modern warships from more than 30 nations in one of the largest naval reviews of all time.

Amerigo Vespucci in New York in 1976.

BY THE NUMBERS: DRONES AT WORK

U.S. companies that want to use unmanned aerial vehicles for business purposes have needed FAA approval. Their applications give a sense of what drones are being used for.



Aerial drones have been a hot plaything for the past few years. Small unmanned aerial vehicles can be purchased in toy stores, and quadcopter racing—and fighting—has become a sport for hobbyists.

But drones are also becoming tools for business. Companies are flying cameras and other sensors into hard-to-access areas to perform functions remotely that might otherwise require sending a human worker into a hazardous situation.

The Association for Unmanned Vehicle Systems International is a trade organization that promotes autonomous robotics. AUVSI keeps a database that tracks applications to the Federal Aviation Administration for exemptions to its rules for airworthiness. The FAA will grant a waiver to rules established for manned aircraft to any UAV operator for aircraft that weigh less than 55 pounds, operate at or below 200 feet during daytime visual flight rules conditions, fly within visual line of sight of the pilots, and stay certain distances away from airports, heliports, or restricted airspace.

As of early 2016, AUVSI's database had recorded 3,136 exemptions that had been granted by the FAA.

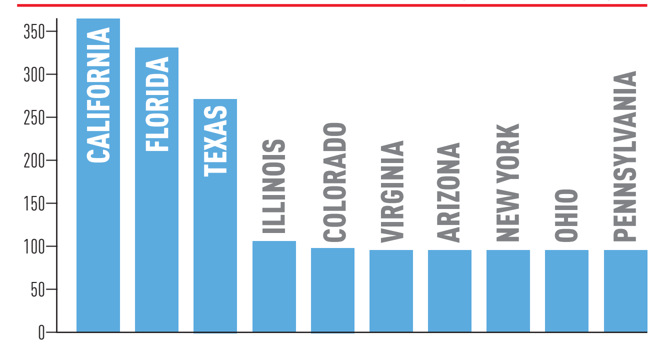
The database tracks facts about the companies seeking exemptions. Two-thirds are small operations with fewer than 10 employees and almost all have less than $1 million in annual revenues.

A diverse set of business applications had been given exemptions. Applications for aerial photography led the way with 2,557 granted, followed by real estate and aerial inspection, with 1,969 and 1,671 applications respectively. Aerial surveys and construction—with 1,669 and 1,496 applications—rounded out the top five.

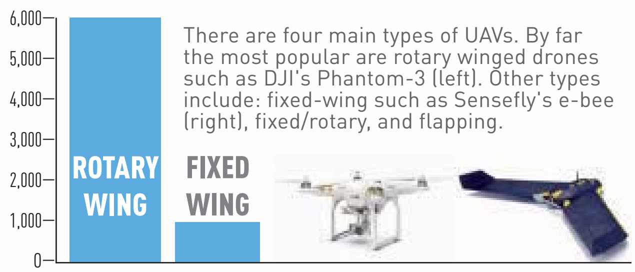
The total applications exceeds exemptions as one business might engage in multiple applications, such as conducting aerial videography for both films and commercials.

While videography and photography are hot now, others have the potential to be game changers. For instance, the AUVSI database reports there were 709 applications for utility work, which includes remote inspection of infrastructure such as electrical poles. Dispatching a drone to check the health of a transformer on the top of a utility pole is quicker and safer

TOP 10 EXEMPTIONS STATE BY STATE (SEPT. 2014–JAN 2016)



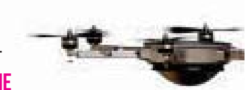
SALES ACCORDING TO TYPE (SEPT. 2014–JAN 2016)



There are four main types of UAVs. By far the most popular are rotary winged drones such as DJI's Phantom-3 (left). Other types include: fixed-wing such as Sensefly's e-bee (right), fixed/rotary, and flapping.

than sending up a lineman. Likewise, construction companies are beginning to use UAVs to check the quality of welds done on at the tops of tall buildings and can monitor how equipment and material are moving at the jobsite.

Still, the FAA rules are only temporary, and once permanent regulations are set, AUVSI expects commercial applications to soar. According to one study, UAVs could burgeon into an $82 billion industry once the rules are finalized—big numbers for something in the toy store. ME



JEFFREY WINTERS

F28

WATCHING THE

A new push to integrate remote sensing, robotics, genomics, and big data into crop breeding could help feed and fuel a warming world.

BY DAN FERBER

CROPS GROW

Addie Thompson is breeding better varieties of sorghum—but she's going about it the hard way. This spring, Thompson, a postdoctoral researcher at Purdue University, helped plant a 10-acre field of different genetic lines of sorghum in 144 large plots. Then she geared up to harvest data.

When the weather was still cool and plants were not yet knee high, a colleague marked three plants in each plot with small plastic tags. Then, at least once a week, Thompson and a dozen other researchers planned to spend an afternoon in the field revisiting each tagged plant. They'll measure stem diameter with a caliper, height with a piece of PVC pipe marked off in inches. They'll count the leaves, mark the level of the highest leaf with a Sharpie, and use a handheld fluorometer to gauge the plant's greenness.

Each month, as the Indiana sun beats down and the plants grow taller, they will take detailed measurements, weighing stalks, leaves and seed heads, which contain grain. They'll drive mulchers with threatening five-foot spinning blades to harvest samples of each crop line. Back in the lab, the researchers will dry and weigh the samples for yield and perform one biochemical analyses after another to learn more about them.

"It's a lot of work to convince people to do the work. It's not fun to do. It's hot, sweaty, buggy, and not very safe," Thompson said.

If the research succeeds, Thompson and her colleagues will help breed new sorghum varieties that could grow tall and thrive despite poor soil, heat, and drought. These new varieties could produce more biofuel per acre than any sorghum ever grown, while slashing climate-disrupting carbon dioxide emissions compared with gasoline and today's most popular biofuel, corn-derived ethanol. And the technology the team develops could spark a revolution in crop breeding.

But before any of that happens, Addie Thompson is breeding sorghum the hard way. That's because, for now at least, it's the only way.

A NEED FOR SPEED

Less than a century ago, the average farmer produced enough food to feed between 10 and 12 people. Then came the Green Revolution. Through the middle of the 20th century, crop breeders developed new lines of staple grains, agronomists mechanized soil management and crop production methods, and scientists developed better fertilizer, herbicides, and pesticides. Now the average farmer feeds 120 people.

But providing food and clean fuels to Earth's nine billion people in 2050 will require farmers to double crop production per acre, said Joe Cornelius, a plant physiologist who directs the Transportation Energy Resources from Renewable Agriculture (TERRA) program at the Advanced Research Projects Agency-Energy (ARPA-E). And they'll need to do it while using much less water and protecting what's left for people to drink.

Before landing at ARPA-E, Cornelius worked for a quarter century at the agricultural biotech giant

Addie Thompson examines sorghum plants that are being grown in a greenhouse to produce seed. *Photo: Purdue University*

Purdue University plant scientist Mitch Tuinstra's team aims to speed breeding of sorghum (background) for biofuel.
Photo: Purdue University

Monsanto, where he led efforts to breed new lines of crops to make more nutritious foods, vegetable oils, biodegradable motor oil, and biofuels. There he witnessed researchers use traditional crop breeding strategies and modern genetic engineering tools to develop better crop varieties. Yet time after time, they ran into dead ends.

Part of the problem was that crop plants take months to grow, so breeders can grow only a few generations each year. That limits how often they can pick winning varieties from each generation and discard the losers.

What's more, even though a plant variety's genetic characteristics are relatively easy to determine, scientists cannot predict how it will do in the field until they test it. This makes breeding crops as slow as watching plants grow.

As climate changes and global food and energy demand grows, we'll need to find or create crops that yield more, even in the face of drought, heat and other weather extremes—and to do so we'll need to breed them more quickly than ever before, Cornelius said.

The nation needs new bioenergy crops in particular to meet congressional mandates designed to reduce greenhouse gas emissions. By 2022, refiners must mix 21 billion gallons of renewable biofuels into gasoline and diesel. These fuels can be made from cellulose extracted and converted from plant material, including corn stubble, corncobs, wood chips, straw—and sorghum.

This ancient cereal crop grows like a weed. Even in poor soil with very little fertilizer, it reaches 20 feet tall. Originally from the Horn of Africa, it withstands hot, dry conditions that would wilt even a tough corn plant. Indeed, the U.S. Department of Agriculture has projected that it could replace fading crops like tobacco, cotton, peanut, rice, and citrus in a belt of land from eastern Texas to the southern Atlantic Coast—but only if crop breeders can develop better sorghum lines that are customized for biofuel production.

When Cornelius joined ARPA-E, he saw an opportunity to advance bioenergy sorghum, and also advance crop breeding more broadly. By finding a faster way to grow and select sorghum varieties, he realized he could lay the groundwork for technologies that would usher in the next generation of superplants.

The research would be risky, bringing together new technologies and costing more than the private sector would pay. To make that happen, in June 2015 ARPA-E

CROP MONITORING BY GROUND OR BY AIR

Camera- and sensor-loaded robots and UAVs could detect subtle changes in individual plants to spot rare varieties that yield more sorghum for advanced biofuels—and better technology to breed other crops faster.

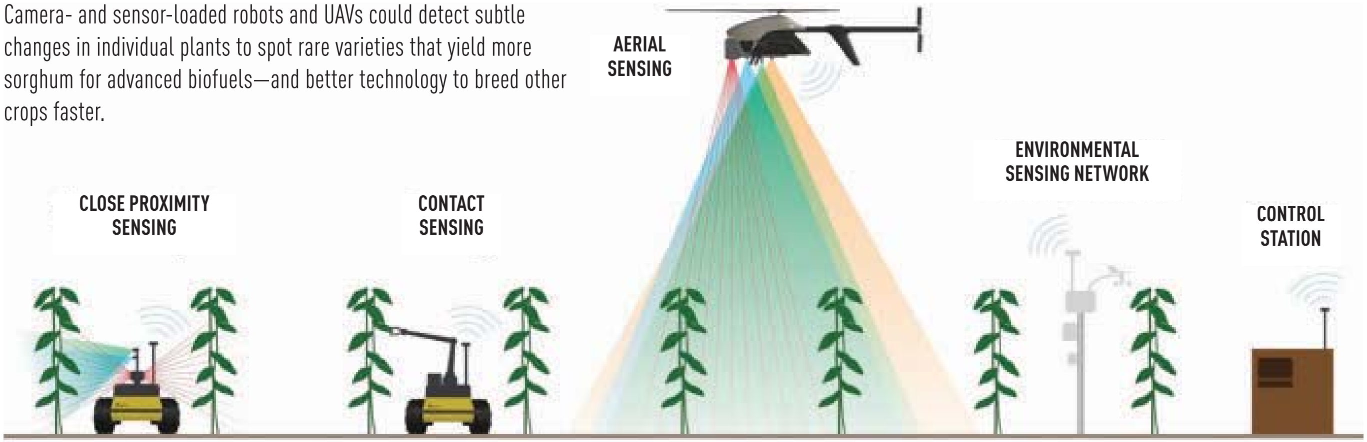


Image: Steve Kresovich, Clemson University launched TERRA. Their goal was to speed the breeding of bioenergy sorghum varieties, and they allocated more than $3 million to each of six interdisciplinary research groups, including the Purdue team.

Photo: LemnaTec

The largest field-crop analysis robot in the world, LemnaTec's 30-ton, 200-meter field scanalyzer moves its Volkswagon bus-sized instrument module like a line scanner to assess crops growing beneath it. The module's payload of cameras and sensors far exceeds any field robot or drone, yielding unprecedented data on individual crop plants from emergence to harvest.

BREEDER BOTS

To get the most biofuel from the least land, farmers must maximize the yield of raw plant material per acre per year, while using a minimum of fertilizer and chemicals. To rapidly develop crops that do that, sorghum breeders and other scientists want to identify the traits, or phenotypes, that predict which plants will be biggest and have the most biomass to convert into fuel. Such phenotypes may include early season growth rates, the number of leaves on a plant, how well it uses soil nutrients, and many more.

Right now no one knows exactly which of these many traits best predict biomass yield. To find out, TERRA-funded teams plan to monitor a diverse array of genes and traits in thousands of individual sorghum plants from the ground and the air.

They're using robots, UAVs, sensing technologies, and big data to make that happen.

None of these technologies are entirely new to the farm. For the past decade, farmers have been using UAVs to determine where they need to apply water and farm chemicals, thereby increasing productivity and profit while reducing farm pollution. Other farmers have begun using bots for labor-intensive tasks. In California, for example, self-propelled bots prune and monitor grape vines and smart, rolling lettuce bots thin out budding lettuce plants.

Until now, few have tried to adapt these technologies for crop breeding. For millennia, crop breeders who wanted better varieties walked their fields and tracked their plants to note which plants grew taller, for example, or withstood insects or yielded more grain or vegetables.

Image: George Kantor

Thompson and her supervisor, plant geneticist Mitch Tuinstra, and their colleagues augment these traditional methods by using low-tech devices and some modern lab equipment to laboriously screen for phenotypes.

To monitor crops from the ground, both the Purdue team and Clemson University's ARPA-E BOOST team are developing self-driving, instrument-equipped bots or vehicles that steer themselves through a breeding plot without trampling plants.

At Purdue, Tuinstra, crop physiologist Chris Boomsma and engineering professors Ed Delp and Ayman Habib are modifying a commercial sprayer to give it onboard data storage and autonomous steering capabilities.

By combining data generated from all these sensors, they plan to create a 3-D view of plants that reveals structure, including stem size, and the number, locations, dimensions, and angle of leaves. And by integrating these data, they hope to uncover clues about the plant's future growth.

The BOOST team, in contrast, is building a low-riding three-foot-long robot with a scaled-down version of the LIDAR laser scanner used in autonomous cars. The robot will roll by rows of crops, using cameras and a line scanner (a type of LIDAR) to create a 3-D, high-resolution model of the plants, said

George Kantor of Carnegie Mellon University, the lead roboticist on the project.

A manipulator arm on the rolling robot will be able to reach out and touch a plant, performing tasks for which a crop breeder like Thompson would use a handheld instrument. "From my perspective as a robotics researcher, this is one of the most exciting parts," Kantor said. For example, the arm will attach a clothespin-like sensor to leaves to measure the plant's chlorophyll levels, the gases it exchanges with air, and the leaf's response to light.

The Purdue team will also monitor crops from the air using a fixed-wing UAV. It will carry a laser scanner and standard RGB cameras—ordinary digital cameras that capture the same red, green, and blue light as the human eye—to provide an overhead view of the crop. It will also carry a hyperspectral camera, which detects hundreds of colors, including some the eye can't see, and a thermal camera, which detects infrared light. Together, these will determine crop canopy temperature, which indicates crop stress.

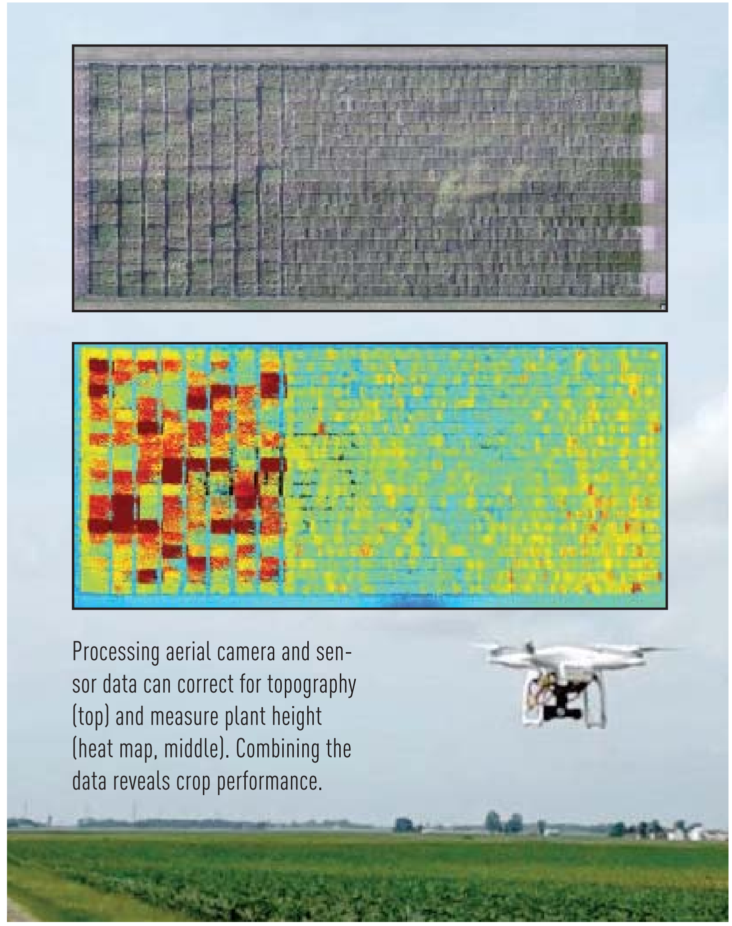
The scientists will use high-end GPS and inertial measurement units (GPS/IMUs) to pinpoint the locations of the phenomobile and UAVs. This will enable them to integrate image and sensor data from the different vehicles. "Between the UAVs and the ground-based platforms, it's going to be extremely precise—down to the centimeter level, which is crazy," Boomsma enthused.

The BOOST team also uses a rotary-wing UAV being developed at Near Earth Autonomy, a spinoff from Carnegie Mellon University. There, engineer Paul Bartlett and his team are mounting a 5.5-foot, 35-pound helicopter UAV with LIDAR and high-resolution RGB cameras to detect plant shape and structure, and hyperspectral cameras that sense red and infrared light. Again, the goal is to take a spectrometric fingerprint of plants that reveals greenness, nitrogen content, dying leaves, and other biological phenotypes.

"In 15 minutes, we can get a snapshot of the whole field," Bartlett said.

Another ambitious TERRA-funded project comes from Lemnatec, a German company that has built the

Sorghum's genetic diversity makes it ripe for breeding.
Photo: Steve Kresovich, Clemson University



Processing aerial camera and sensor data can correct for topography (top) and measure plant height (heat map, middle). Combining the data reveals crop performance.

Photo: Purdue University

largest field-scanning robot in the world: a giant 30-ton steel gantry that sits near Maricopa, Arizona. Its instrument module—the size of a Volkswagen bus—moves down two 200-meter tracks and can scan the field one 1.5-meter band at a time. The module carries two metric tons of instruments, far more than a UAV or ground robot, and Lemnatec is loading it with sensors to see which ones generate the most useful data. "We can image the plants from emergence to harvest and all the stages in between, with a variety of sensors throughout the season," said Todd Mockler, a plant biologist at the Donald Danforth Plant Science Center in St. Louis who's working with Lemnatec on the project. "This will be uncharted territory."

FARMING DATA

Once the data from the various sensors is downloaded, researchers will process and analyze it. This task requires a combination of data analysis and machine learning. "This is Big Data," said Melba Crawford, a Purdue professor of agronomy and civil and electrical and computer engineering who's coordinating the group's machine-learning efforts.

First, the engineering team will develop new image-processing algorithms to sift through processed sensor data to discern a variety of phenotypes, such as height, leaf number, position and angle, chlorophyll, water content, and other indicators of plant health.

Once scientists have information on various traits, they'll need to mine it for correlations that predict the biomass yield for a given sorghum variety, says Artur Dubrawski, a computer scientist and mechanical engineer at Carnegie Mellon University who's doing similar work on the BOOST project. Understanding these correlations will enable researchers to scrutinize plants the way medical devices monitor human patients in the intensive care unit. "This forecasting ability should help us make those decisions in advance of crops completing their whole growth cycle," Dubrawski said.

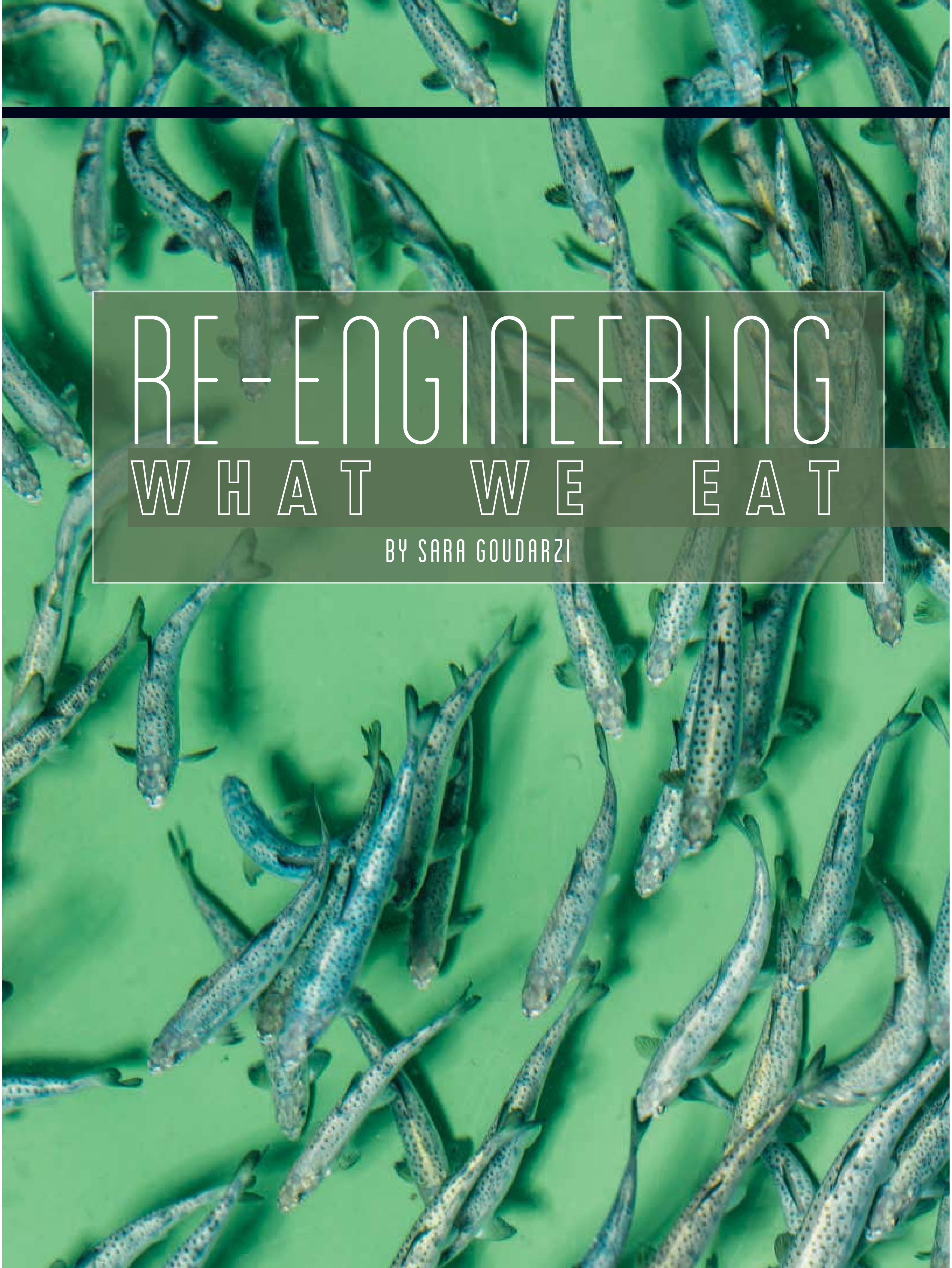
To make even better decisions, both the scientists are also tapping existing knowledge of sorghum genetics, using advanced statistics and machine learning to relate genetic variations, or genotypes, to the plants' phenotypes. The computations are challenging because multiple genes can influence each trait, just as multiple genes influence human height or build. What's more, a single gene can influence multiple traits. TERRA-funded scientists are also using advanced statistics and machine learning to build models that predict plant traits of interest.

Ultimately, such computations would help identify key genes that help plants grow faster, tolerate drought, or thrive with less nutrients. This could lead to high-end computational tools that combine artificial intelligence, superhuman recall, and the latest advances in biology. Such a system could game potentially winning phenotypes before they're even planted, much the way computational fluid dynamics helps engineers choose designs. "It's almost like IBM Watson for breeding," Mockler said.

Like all ARPA-E programs, TERRA aims to spin off commercial technologies. These could range from powerful sensors and improved field robots, UAVs to better computational methods. What's more, a lot of the engineering will translate into field-scanning technology that any crop breeder can ultimately use.

"We're bringing together genomics, engineering, breeding, and computational analytics," Cornelius said. "We have this complete suite of technologies that are working together, and now we can pluck out the needle from the haystack." **ME**

DAN FERBER is a senior editor at *Mechanical Engineering* magazine.



RE-ENGINEERING WHAT WE EAT

BY SARA GOUDARZI

AN EVER-CHANGING BALANCE OF SUPPLY, DEMAND, AND RESOURCES WILL REQUIRE US TO ALTER THE WAY WE CONCOCT WHAT WE CONSUME.

A curious group of a few dozen culinary students and a handful of chefs gathered in the amphitheater of the International Culinary Center in Manhattan last February to hear about a new way to make food. Drim Stokhuijzen, a visiting research scholar at Columbia University, told them about his work designing a machine that can print food and why such a technology is needed.

"Food printing allows for personal nutrition, convenience, sustainability and new food experiences," Stokhuijzen said. The technology, he explained, could be used for those with medical conditions, such as patients with diabetes and dysphagia, and professionals like soldiers and astronauts. Food printing provides "the possibility to create personalized food on demand, which tastes and looks better."

Rather than struggle with following incomprehensible recipes, a person who wanted a custom-made meal could download a file, plug in the right cartridges, and have their food printer lay down a dinner line by delicious line.

Much of how we live and work has been transformed by high technology over the past few decades, but food is one of the few areas that has remained largely the same. We still cook using very old techniques—over a flame—and for the most part use ingredients from sources that have been around for many years. The writer Michael Pollan has advised, "Don't eat anything your great-grandmother wouldn't recognize as food," and that can still be done, with effort.

However, with a growing population, warming climate, and limited resources, researchers are thinking of alternative ways of producing edibles. Three-D food printing is just one of the technologies that's shaping the future of food. To provide a growing population with enough to eat, we may have to reengineer the very plants and animals we consume.

IT'S WHAT'S FOR DINNER

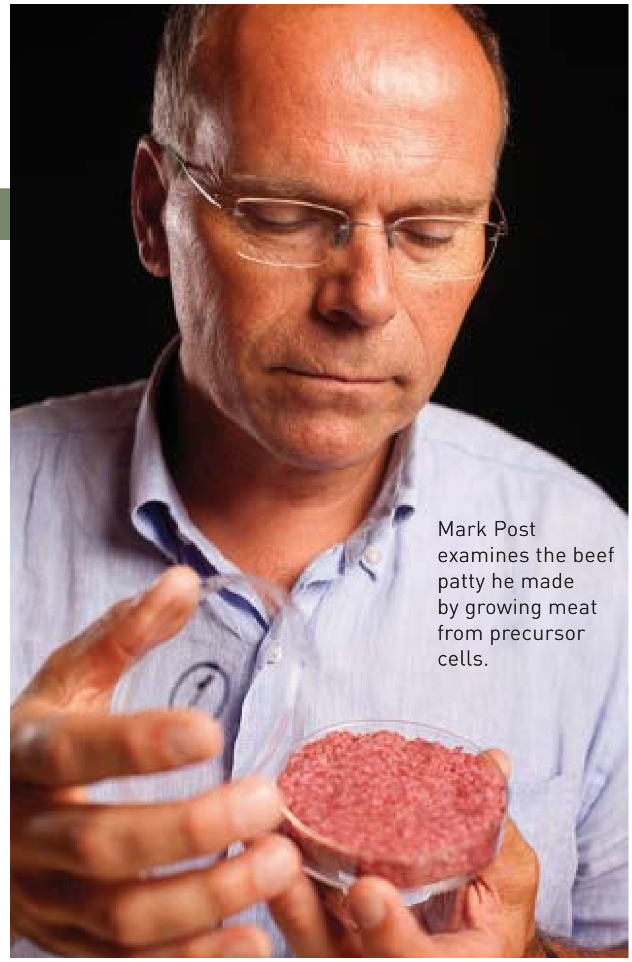
Sustainability is one major challenge for our present agricultural system—the way we produce food today demands too many resources. That pressure is only going to increase: According to the United Nations Food and Agriculture Organization, food production will need to double in the next 35 years to feed the expected global population.

The problem will be especially acute if the new mouths to feed expect a Western, meat-rich diet. Livestock production already uses more land than any other human activity and is said to contribute up to 20 percent of total greenhouse gas emissions. And beef is the biggest problem. In a 2014 study published in the *Proceedings of the National Academy of Sciences*, researchers estimated that beef requires 28 times more land and 11 times more water to produce than what is needed for other livestock.

To mitigate that, some researchers have taken beef production inside the walls of a laboratory. "The process is simple: Take a small muscle biopsy from a cow, harvest its stem cells, let the stem cells proliferate until you have trillions, and then let the muscle-specific stem cells produce muscle tissue," said Mark J. Post, professor and chair of physiology at Maastricht University in the Netherlands.

Post made headlines when he created the first morsel

THE FIVE-OUNCE PATTY COST A WHOPPING $325,000 TO PRODUCE. BUT WITH LARGE-SCALE PRODUCTION, THE PRICE WILL BE COMPARABLE TO CONVENTIONALLY PRODUCED BEEF.



Mark Post examines the beef patty he made by growing meat from precursor cells.

of lab grown meat in 2013. His five-ounce patty cost a whopping $325,000 to produce. With the right technology and larger scale production, he believes, the price ought to go down significantly and be comparable to conventionally produced beef.

Nutritionally the burger will also be similar to traditionally grown beef, "but some nutrients, such as vitamin B12, will have to be added to the feed of the cells," Post said.

One area that researchers are still working on with lab grown meat is the taste—a complex combination of proteins, glycosylated proteins, and other compounds in the fat. Up to now, while the tissue the research team has created closely resembles meat, it is lacking the fat contained in traditional beef. Post said they currently are working on fixing that.

Another area that needs improvement is texture. Animals are continually "exercised" as they move, and their meat has connective tissue giving it the chewy texture that carnivores are familiar with. However, critics contend lab grown meat lacks that type of texture and is, instead, mushy. Some researchers have proposed mechanical means of exercising the meat—such as using electrical stimulation.

Post, however, believes electrical stimulation is undesirable from an energy standpoint and that the meat exercises itself by spontaneously contracting. "The tasters actually mentioned that the texture was already pretty good," he said. "But can be further improved to make the fibers longer, for instance."

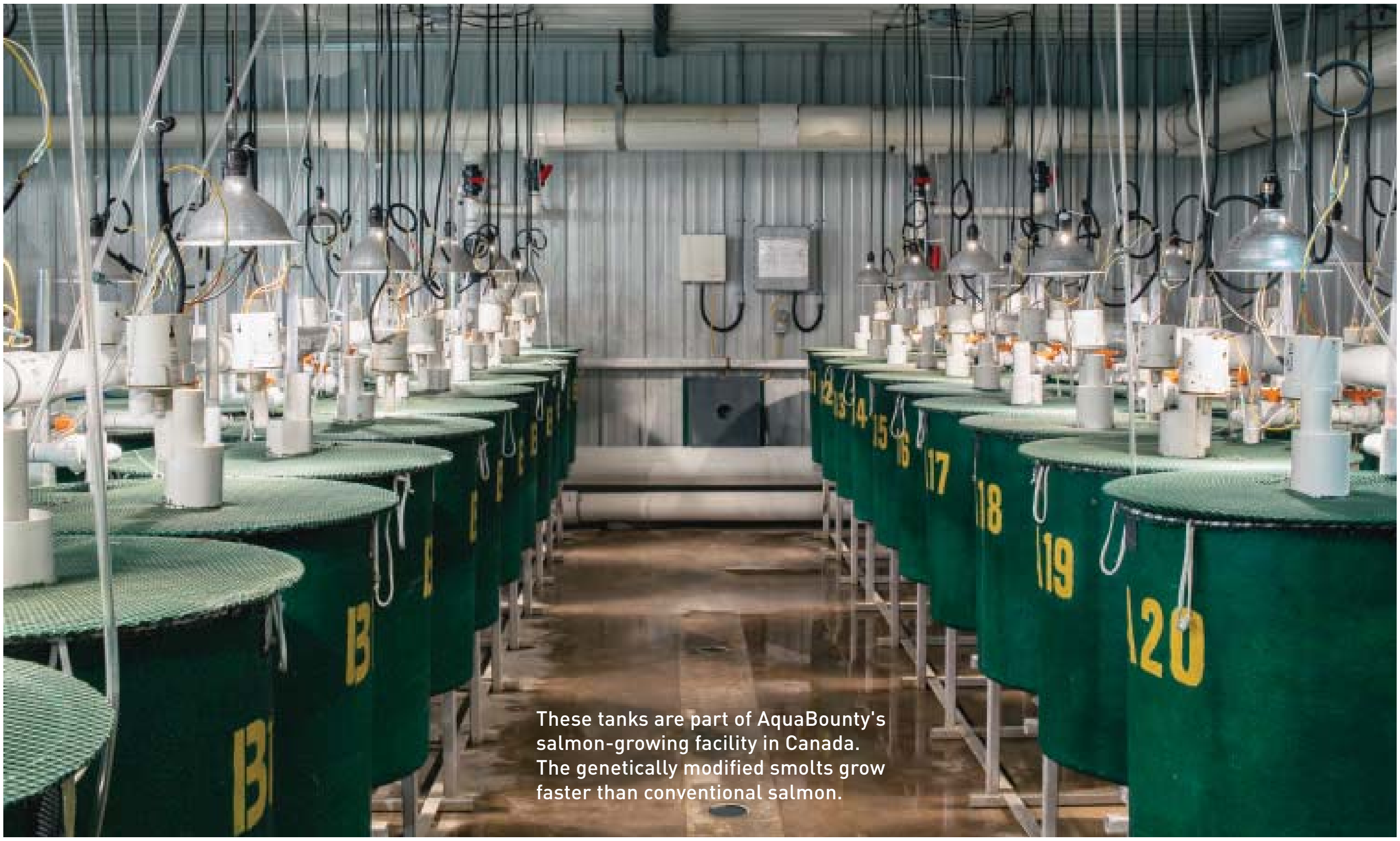
Accomplishing that is relatively easy, he said, and could be achieved by increasing the diameter of the central column (or distance between anchor points) around which the muscle fibers are placed when growing in a gel medium.

To make "test-tube steaks" available to the general population, producers would need large-scale cell fabrication, efficient production of feed for the cells, biomaterials that allow tissue formation, and bioreactors that create the right conditions to allow tissue growth on a scale that could be used in a mass market. While all that entails a lot of up-front capital costs, the payoff is faster meat production. The growth process should take around nine weeks to produce a salable slab of meat, compared to about 15 months to bring a calf to market.

Once the method takes off, researchers anticipate they could use it to produce chicken and even fish meat in the laboratory.

ENGINEERING GENES

Other researchers suggest the best way to produce animals and plants faster while using fewer resources is to embrace genetically modified and genetically edited foods. Unlike in vitro meat, GM meats are already closer to showing up at the butcher. Last year, for the first time, the U.S. Food and Drug Administration approved the meat of a genetically modified animal for consumption in the United States. The FDA-approved salmon, named AquAdvantage, grows


These tanks are part of AquaBounty's salmon-growing facility in Canada. The genetically modified smolts grow faster than conventional salmon.

to maturity in about 20 months, 16 months faster than conventionally farmed fish.

"The founder fish, from which the AquAdvantage salmon line was developed, was created by microinjecting the transgene (a Chinook salmon growth hormone gene coupled to a promoter sequence from ocean pout) into fertilized Atlantic salmon eggs," said Dave Conley, director of corporate communications at AquaBounty Technologies, Inc., in Maynard, Mass., the company who developed the fish. Chinook is the largest Pacific Ocean salmon, while an ocean pout is a fish capable of withstanding and growing during freezing temperatures. Conventional salmon don't typically grow during the colder months.

Although it's not clear when AquAdvantage salmon will hit the market, it's safe to assume that it will be at least two years for the first batch to mature and be ready for sale. Those involved with the fish believe that if well received, the technology could have a huge impact.

"Given the unpredictable nature of climate change, our ability to rapidly develop plants and animals for food production in the future is even more pressing [now] than it was in the 1980s when we first began our journey," Conley said.

Professor Wendy Harwood of the John Innes Centre at Norwich Research Park agrees that getting the gene just right in a food supply could have a whole slew of possible benefits. Her approach, however, is not by modifying the gene as in the AquAdvantage salmon but through editing genes via a tool known as CRISPR, short for clustered regularly interspaced short palindromic repeats. That tool could be used on any living organism and is causing excitement in both the medical and agricultural research fields due to its potential benefits.

"It could certainly have an impact on making plants more disease resistant," she said. "It could also have an impact in cases where there's a compound in the plant that you really rather wished wasn't there—maybe something you're allergic to or is toxic. It gives you a way of removing that type of compound from the plant."

Gene editing is a technique that allows researchers to have the ability to home in on one specific gene and make a very small change that disrupts the function of that gene so it doesn't work anymore. If that particular gene causes a disease, for example, then the ability to either stop that gene from functioning or make a correction to it is extremely powerful.

In plants, gene editing requires two components: A guiding system to direct all the bits necessary to the right location and an enzyme that makes a break in the DNA strand in that targeted gene. The guiding system—which can be a small guide ribonucleic acid (RNA)

CONSUMERS COULD FLIP THROUGH RECIPES ON A TABLET APP, LOAD THE NECESSARY INGREDIENT CARTRIDGES INTO THE PRINTER, AND WATCH THE DEVICE PRODUCE THE DISH.

molecule or a protein complex—takes the enzyme along with it, and makes a break in a very precise place in the gene. Then, the machinery in the cell tries to correct that break and in the process makes a mistake, introducing a mutation. In many cases that mutation disrupts the function of that gene so it doesn't work anymore.

So far, gene editing has successfully been used in a whole range of crops, such as barley, brassica, wheat, potato, and tomato. Although most of the work on crops is still at the research stage, an herbicide-resistant oil seed rape crop developed by the San Diego–based company Cibus is currently being grown in the fields in the U.S., opening the door to more genetically edited crops to hit the market in the near future.

"The outcome is actually very similar to mutation breeding and it can even be similar to a natural mutation because the DNA is changing and mutating all the time. It's possible that you could have a natural mutation which could be identical to one we have created using gene editing," said Harwood.

PRINT AND SERVE

When it comes to final preparation, however, the amount of control in gene editing pales in comparison to food printing.

During his February talk at the International Culinary Center, Stokhuijzen explained that the idea of food printing is very similar to 3-D printing—the layer-by-layer formation of an object from a computer-aided design file. There are different methods that could achieve that type of printing, or deposit of material. A machine might set down edibles—such as chocolate or dough—through syringe nozzles onto a plate, or it could work with powdered food that is selectively bound together with a fluid.

According to Kjeld Van Bommel, a research scientist at TNO, the Netherlands Organization for Applied Scientific Research in The Hague, the technology uses a printer head to deposit droplets into a layer of powder, such as sugar. "As a result the sugar will start to bind together," Van Bommel said. "If this is done in a controlled manner and layer by layer, this process will result in a 3-D agglomerated sugar object that can be taken out of the non-agglomerated sugar."

Confectionary chefs may soon have access to high-end machines like this. The manufacturer 3D Systems, Inc., has an event space in Los Angeles featuring sculptural deserts made of printed sugar. But main courses one could conceivably print at home will also have to start with highly processed ingredients, such as powders and gels, that can fit in a cartridge.

"You're not going to print a tomato or a steak," said Hod Lipson, a mechanical engineering professor at Columbia University and the author of *Fabricated: The New World of 3D Printing*. "But I have to say that more than half of what we eat is processed foods, so this is quite a large portion of foods."

Although devising the cartridges and their fillings will take some ingenuity, many home-cooked meals already start with ingredients that are powders, gels, liquids or pastes. For instance, the basic ingredients in everyday meals such as a pizza could be squeezed from tubes. In fact, in 2013, NASA awarded a $125,000 grant to a start-

up to develop a pizza printer for the space agency.

Researchers also are currently working on incorporating infrared cookers that cook the food as it prints, which would give users very precise control over the process. For example, one could get the edges of a pizza crust well done, while cooking rest of the pizza normally. "It's not a uniform oven that cooks everything in the same way but can cook different parts [of a dish] to different extents and different temperatures," Lipson said.

So how would a food printer work for the average household? One possibility is that the printer would have an interface on an app that runs on a tablet computer such as an iPad; consumers could flip through recipes, load the necessary ingredient cartridges into the printer, and watch the device produce the dish.

In the end, scientists envision a food printer to be a kitchen appliance that would not replace the idea of conventional cooking but supplement it when necessary.

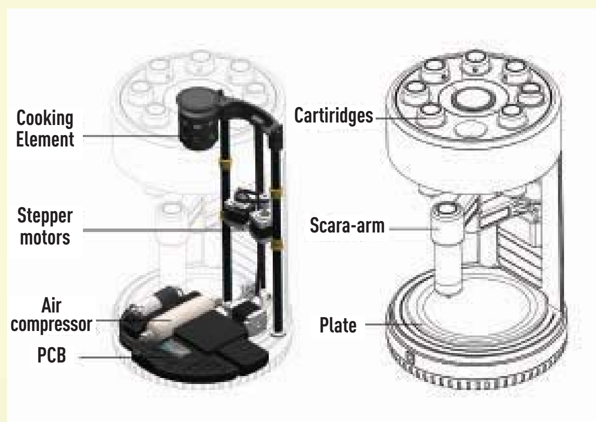
"A good analogy would be a Nespresso machine," Lipson said. "You pay $100 for the machine and then you pay a dollar or so per cartridge or per cubic inch of food or whatever the unit is going to be. I'm sure if it's a cartridge of caviar or a cartridge of cookie dough it's going be different."

While countertop food printers may make take the home cook one step further from the farm, it could also have some unexpected environmental benefits. "I'd like to say that because it's a print on demand it would use less material because you would print what you need instead of buying in bulk, though nobody has really done an in depth analysis." Lipson said.

Whether through tinkering with genes, growing foods in laboratories, or preparing them through printers or robots, technologies revolving around food are undergoing rapid research and development.

"The implications for human health, food production, and environmental remediation are very exciting," AquaBounty's Conley said. **ME**

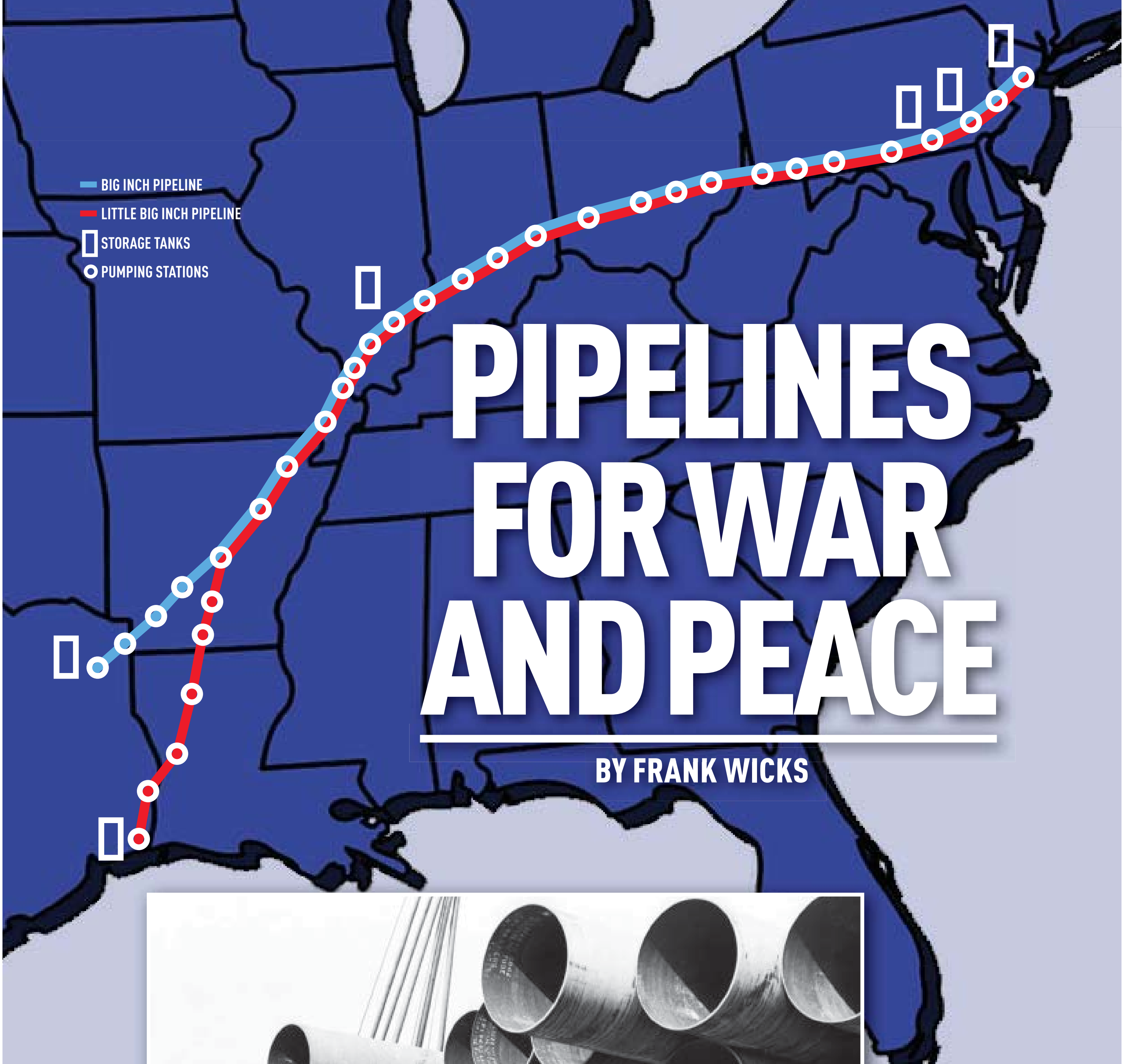
SARA GOUDARZI is a technology writer based in Brooklyn, N.Y.



Jerson Mezquita (top left) and Drim Stokhuijzen work with a prototype food printer at their lab at Columbia University. The machine would print powdered ingedients sold in cartridges (mocked up at botttom).

PIPELINES FOR WAR AND PEACE

BY FRANK WICKS



These 24-inch pipes were stacked and ready to be assembled into the Big Inch Pipeline, in this 1942 image from the U.S. Farm Security Administration. Photographer John Vachon took this photo in Pennsylvania.

World War II was largely about oil, and fought with oil. The United States factories and work force, largely idled by the lingering Great Depression, would convert to the massive production of land vehicles, ships, and aircraft. These war machines were transported to combat zones, but would be worthless without oil.

Of the seven billion barrels of oil used by the Allies, 80 percent came from the United States, mostly from Texas and the Gulf Coast. Prior to the war, much of the crude oil and refined products had been transported by coastal tankers to the northeast and then shipped across the Atlantic.

War started raging in Europe in 1939. The United States remained officially neutral until the Japanese attack on Pearl Harbor in December 1941.

When Hitler declared war on the United States a few days later, he gave Germany free rein for unrestricted warfare against United States shipping. U-boats were positioned along the coastal tanker route from the Gulf of Mexico up the Atlantic to New Jersey. Without any losses, the submarines sank or destroyed sixty tankers from January through April 1942.

Shipping oil by coastal tankers was abandoned. The alternative, transporting oil by rail, was more secure, but the capacity was limited.

Then an older, lapsed plan took on a new life. Two years earlier, Secretary of the Interior Harold Ickes had proposed an oil pipeline from Texas to New Jersey. Ickes acknowledged it would be costly, but said that it might be necessary in case of war. Ickes had done some initial planning, but no action had been taken toward construction.

The Roosevelt administration not only decided to put Ickes's plan into action, but also gave him the additional title of Petroleum Administrator for National Defense, more popularly known as the Oil Czar.

The tanker *Dixie Arrow* was torpedoed off Cape Hatteras in March 1942. Oil transport by sea was perilous at the beginning of World War II.

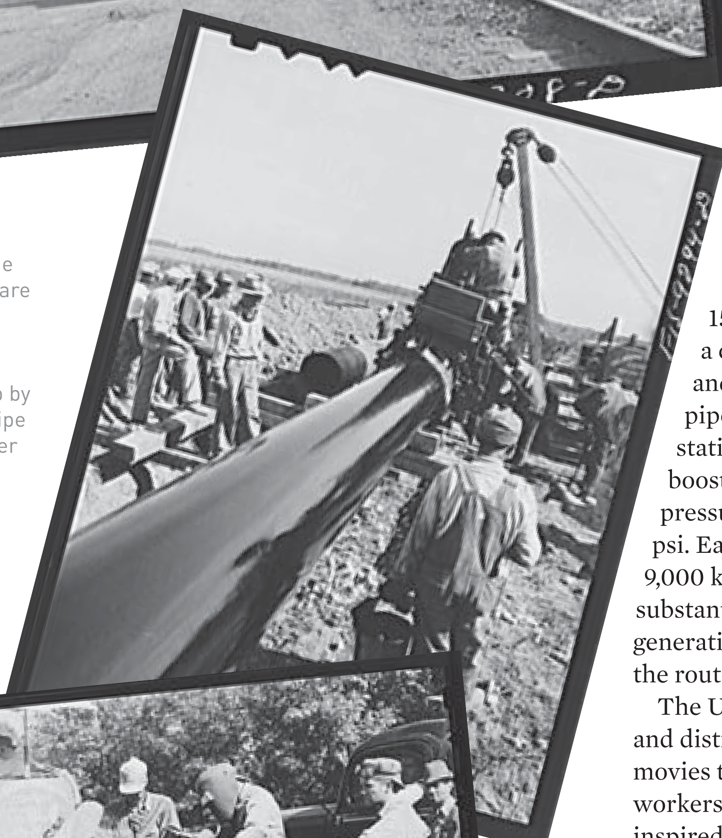
They wouldn't be the country's first pipelines, but they would be the largest. Building them would be the largest joint government and private industry project to that time. Executives and engineers from 67 companies met in Tulsa in March 1942, organized by Elton Jones, who would later run the pipeline project.

The group decided to build two roughly parallel pipelines. The most direct route was surveyed by air. It would cross mountains and traverse swamps, rivers, and lakes, and tunnel under hundreds of railroad lines and highways.

Earlier pipelines were typically 8-inch diameter and of limited length. These would be much bigger.

One pipeline, with a 24-inch diameter pipe, would carry crude oil and was affectionately called the Big Inch. It would run 1,254 miles from the oil fields of northeast Texas to refineries in New Jersey. It reached a capacity of 325,000 barrels per day.

The second line, a 20-inch diameter pipe eventually named the Little Big Inch, would transport refined products over 1,475 miles from the Texas Gulf Coast to New Jersey. Its daily capacity would



Once unloaded onto stringing trucks (top), the 40-foot sections of pipe are primed with hot asphalt paint (middle).
A crew follows the machine and touches up by hand the space where pipe has been welded together (bottom).

be 235,000 barrels, corresponding to 10 million gallons of gasoline. Both pipelines required many miles of smaller feeder lines from the wells at one end and to destinations at the other.

Forty-foot sections of 3/8-inch seamless steel pipe weighing 4,200 pounds each were delivered along the route. They were coated, wrapped, and welded, and then lowered into 4-foot-deep trenches. The first section of the Big Inch was laid in August 1942, and the pipeline was completed in August 1943. The Little Big Inch started later and was completed in December 1943.

The project had required up to 15,000 construction workers, and a comparable number of engineers and supporting staff. Up to 10 miles of pipe were installed per day. Pumping stations were installed every 50 miles to boost the pressure, and to limit the peak pressure in the pipe. It was tested at 650 psi. Each pumping station required about 9,000 kW of electric power. This was a substantial portion of the available electric generation and transmission capacity along the route.

The United States government produced and distributed posters, pamphlets, and movies to feature the heroic efforts of the workers and success of the pipelines. It inspired Americans on the home front and overseas. These movies can now be viewed on YouTube.

While it was still being constructed, oil czar Harold Ickes was already planning the fate of the Inch pipelines after the war, when the coastal tanker routes would no longer be threatened. One possibility was to totally dismantle the lines. There was also a surplus of tankers. During the war years about 500 tankers had been built to supply fuel to the combat theaters and to naval

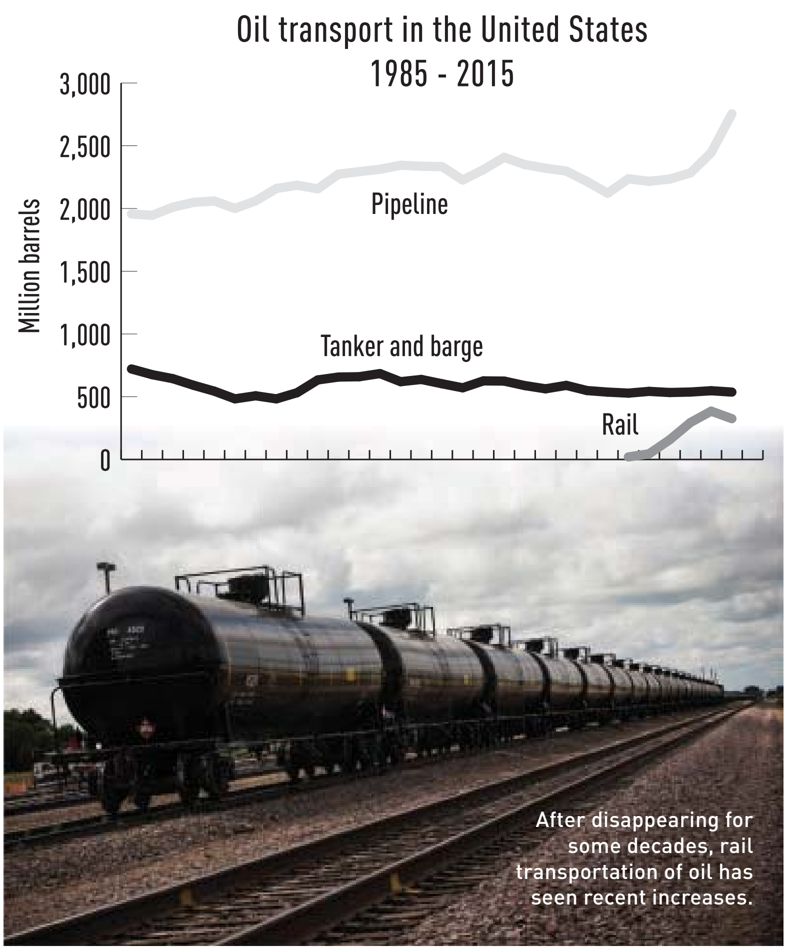
Trench digging for the Pennsylvania section of the war emergency pipeline carrying oil from Texas fields to eastern refineries. The Big Inch was completed in August 1943.

ships at sea. These T2 tanker vessels would cost less to operate and provide more flexibility along the coastal routes.

An alternative proposal would be to convert the Inch pipes to transport natural gas. While oil wells in the southwest had ramped up wartime production, most of the gas that was a byproduct of these wells had nowhere to go. Huge amounts were wastefully flared at the well head.

Meanwhile, major cities in the north, including Philadelphia, New York, and Boston, had no natural gas. Heating was done mostly by coal furnaces. Dump trucks with sliding chutes would typically feed coal to a bin in the basement. A coal furnace had no automatic temperature control. A resident had the disruptive, dirty, and time-consuming duty of shoveling coal into a furnace a couple times a day, and carrying out the ash.

Virtually every large city and most towns and villages had installed coal-fueled manufactured gas plants, called gas houses. Those gas houses were responsible for emitting all manner of pollution, including heavy metals and sulfur. They produced a low-heat-content gaseous fuel. It was piped locally to industrial customers and to homes for cooking and hot water. Some was used for central heating, although it was cheaper to burn the



After disappearing for some decades, rail transportation of oil has seen recent increases.

coal directly in the boiler or the home furnace.

FROM OIL TO GAS

While conversion of the Inch lines to transport gas would be achieved, there were many obstacles, which are described in a book, *From Texas to the East*, by Christopher Castaneda and Joseph Pratt (Texas A&M University, 1993).

The conversion required a permit from the Federal Power Commission, which had originally been created to regulate interstate water and electricity. The commission wanted an assurance of a 20-year supply, which was hard to prove.

An even bigger barrier was the opposition of vested interests. Natural gas was correctly recognized as a serious economic threat to the politically powerful coal mine owners, miners, railroads, and manufactured gas companies, all of which lobbied aggressively in opposition to gas pipelines.

Conversion would also require modifications, including conversion of the liquid-pumping stations to compressors. Also, due to the lower density of natural gas relative to oil, the energy transfer capacity is lower for gas for a given maximum pipeline pressure.

However, the potential of delivering large amounts of natural gas to the North overwhelmed the obstacles and conversion costs. A small group of oil industry investors started to raise money and formed the Texas Eastern Transmission Corp.

The partners took the company public to raise more money. In November 1947 the corporation bought the Big Inch and Little Big Inch from the federal government for $143,127,000.

There was no going back after coal customers suddenly enjoyed the marvels of natural gas. It was the beginning of a rapid expansion of gas pipelines to the North, and other pipelines to the central cities and the West Coast.

New York City received natural gas for the first time in 1952. Seattle in 1956 became the last major city to receive pipeline natural gas. Coal-fueled furnaces and gas houses have become a distant memory, except in Seattle, where people enjoy life around preserved gasifiers in Gas Works Park.

Meanwhile, hydraulic fracturing over the last decade has increased crude oil production from the Bakken formation in western North Dakota from almost nothing up toward a million barrels per day. For the lack of a pipeline, most has been transported to the East and the South by railroad tanker cars.

There have been several spectacular and highly publicized accidents with fire and explosions. While the immediate response has been the need for rail repairs, lower speeds, and safer tank cars, a pipeline could prove even safer.

In January 2015 an application was filed for constructing a 1,134-mile crude oil pipeline of 30-inch diameter and capacity of 450,000 barrels per day from North Dakota to southern Illinois. It has an estimated cost of $3.7 billion.

Arguments against a pipeline often include concerns for environmental impact and loss of land, and those concerns may slow the project. But they probably cannot overcome the counterarguments in favor of the pipeline: jobs created, taxes to be paid, and energy independence.

HOW LONG WILL IT LAST?

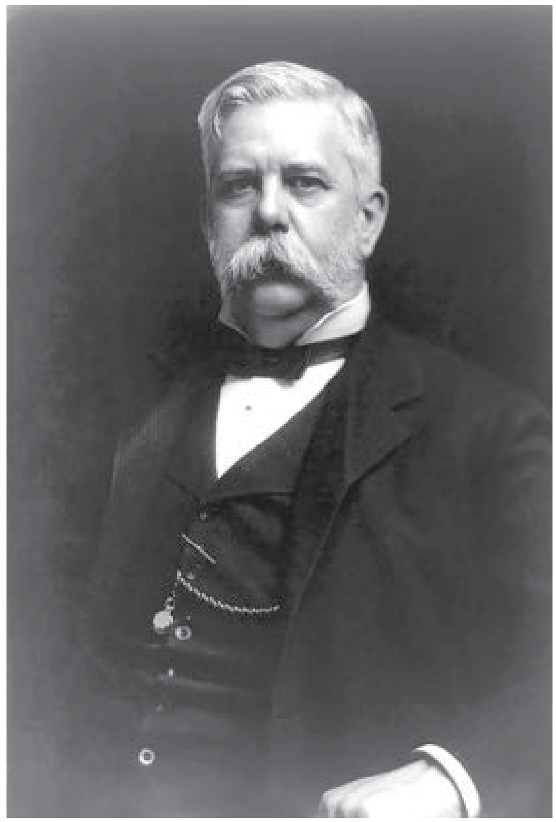
"The only thing constant is change," observed the Greek sage Heraclitus 2,500 years ago. He might use gas to prove his point. David Waples' book, *The Natural Gas Industry in Appalachia* (McFarland & Co., 2012), describes early use of gas up to the recent revival by hydraulic fracturing of the Marcellus shale. He notes curious developments in the use of gas: the Chinese, for instance, used bamboo pipes to direct gas from burning springs to produce salt by boiling the water out of brine. Commercial use of gas started in 1825 with street lighting in Fredonia, N.Y.

The bigger role for gas started in 1859 with the Drake Oil well in Titusville in northwestern Pennsylvania. The crude oil could be transported as a liquid and refined into lantern fuel, but dangerous amounts of gas were coming from the oil wells. It was flared, until pipes were laid to nearby Oil City for lighting in 1867. Threaded cast iron pipes competed with wooden pipes.

John Rockefeller extended his interests from oil to gas, and made Oil City the hub of his enterprises.

In 1884 George Westinghouse struck gas at 1,560 feet in the backyard of his Pittsburgh home. The well created a loud roaring noise and a spectacular 100-foot torch until a shutoff could be devised. Westinghouse proceeded to create a gas company, and was granted dozens of patents related to drilling, metering, regulating pressure, and installing pipelines. It can be speculated that Westinghouse's early experience in the gas industry provided insights and concepts for his better known pioneering achievements in electricity generation, transmission, metering, and use.

Natural gas produced in the Appalachian region supported much of the regional industry up through World War II. However, the wells were drying up and the new center of oil production



George Westinghouse innovated with gas before his pioneering work in electricity.

had moved to Texas and surrounding regions.

With the center of production shifting from Texas back up to Appalachia, major new pipelines and upgrades, with new issues, are needed for new markets. New England is a major growth market, but it must be routed through New York State, which has placed a moratorium on hydrofracking, due to environmental concerns. The intervening groups are now arguing that hydrofracked gas from elsewhere should not be piped through New York State.

Some proponents might also contend that the Big Inch and the Little Big Inch helped win World War II.

FRANK WICKS is a frequent contributor to *Mechanical Engineering*, an ASME Fellow, and an engineering professor at Union College, where he has performed research and instruction related to oil and gas pipelines.

Mission:

To provide an engineering and scientific forum for the promotion and dissemination of state-of-the-art pressure technologies that relate to the power, petrochemical, process, and sustainable and alternative energy industries.

Core Values:

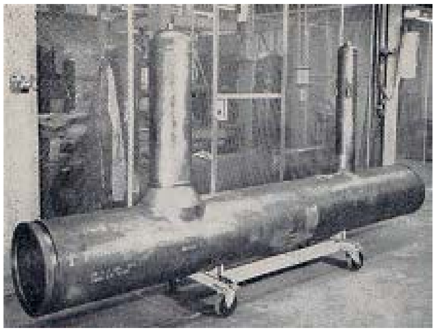
- To embrace integrity and ethical conduct and provide a welcoming climate for a diverse global community of students and engineers to foster creativity, innovation and intellectual growth.
- To disseminate its mission via global conferences organized to bring together the technical community to share technology development.

SALUTING A LEGACY OF INNOVATION AND GROWTH

The Pressure Vessels and Piping Division of ASME's ESP segment celebrates its 50th birthday!

THE EARLY YEARS

Originally conceived as the research arm of ASME, the Pressure Vessel Research Committee's (PVRC) founding members were the most experienced and qualified members in designing and manufacturing pressure vessels, valves and pumps for a myriad applications and industries. The Committee was initially involved in research programs on thin and thick shells theory in cooperation with the Atomic Energy Commission (AEC) and other organizations as early as 1958. Participating in the PVRC program were several academic institutions including Pennsylvania State, Illinois and Yale universities, as well as commercial/industrial enterprises. An early collaboration focused on stress analysis of pressure vessel nozzle inserts with different types of reinforcement pads under combined loading. The results were published in WRC bulletins of 1963 and 1964 by D. Hardenberg and S.Y. Zamrik (Illinois Un.), photoelasticity stress analysis by C. Taylor and computational analysis by E.O. Waters (Yale).
In view of the growing interest in Pressure Vessel technology



Early stress analysis of pressure vessel with nozzle inserts (manufactured by Taylor Forge).

and research results, Frank S.G. Williams of Taylor Forge (and an active member of the PVRC) spearheaded an organizational meeting at the 1965 ASME Winter Annual Meeting (WAM) in Chicago to form a Pressure Vessels and Piping (PVP) Division within ASME. The recommendation passed unanimously and Dana Young became the first PVP Division Chair on April 13, 1966.

VISION, MISSION AND DIVISION GROWTH

Over the years, the PVP division has grown from three to eight technical committees supported by a strong, vital membership. From the beginning, the Division's vision and leadership was truly global in nature — striving to be an international body featuring international participation and expertise. Joint conferences were held in The Netherlands, Mexico

The Editorial Legacy of JPVT

1974 – 1977:
Dr. Irwin Berman
1977 – 1980:
Dr. Robert E. Nickell
1980 – 1982:
Dr. Richard H. Gallagher
1982 – 1993:
Dr. G.E.O. Widera
1992 – 2005:
Dr. Sam Y. Zamrik
2005 – 2012:
Dr. G.E.O. Widera
2012 – Present:
Dr. Y.W. Kwon

and Canada. In 1978, the PVP Canada Conference was jointly held with ASME/CSME, Materials and Nuclear Engineering, and the Metal Properties Councils.

DIVISION LEADERSHIP, STRUCTURE & FUNCTION

The division's structure consists of an Executive Committee of five voting members and two incoming trainees with the past division chairs serving as advisors. In 1986, this advisory group was named the Senate Select and tasked with unique functions to ensure PVP success and growth. "Senators" possess the qualifications and experience needed to support and oversee Division activities. They are responsible for recording activities and history, as well as preparing the "Best Practices and Operating Guide." The Senate Select also nominates Fellows, awards honors for achievement in PVP technology, and organizes the annual Appreciation Dinner.

1989 Joint PVP and JSME Conference, Honolulu Hilton Hotel.
Left to right: Genki Yagawa and daughter, Sam Zamrik and wife Myrna.

THE PVP JOURNAL

The Journal of Pressure Vessel Technology (JPVT) was established in 1974 to house and preserve technical presentations. The dramatic growth of PVP technology and its impact on international development was mirrored by the expansion of the JPVT, published quarterly, with international contributors and distribution. Since inception, the JPVT editors have remained dedicated to promoting a balance between academic research and industrial applications.

From 2002 through 2007, the Journal evolved into an all-electronic publication and, by 2008, an online journal with accessible archived issues. Today, JPVT is available bi-monthly, in both print and on-line editions, and offers research papers, technical briefs, design innovation papers, technology reviews and literature reviews on a wide variety of pressure vessel and piping areas of interest.

PVP MEMBERSHIP COMMITTEES AND JOINT CONFERENCES

Between 1980 and 1985, the division's growth was dramatic. Division-sponsored short courses on the ASME Boiler & Pressure Vessel Code and other subjects, became so successful that a new Committee for Professional Development was established in 1980, chaired by James R. Farr with D.H. White serving as Chair for the new Honors Committee. Also in 1980, a new set of ASME technical books were published, including "Decade of Progress in Pressure Vessel and Piping Technology" (Dr. D.E. Dietrich and Dr. S.Y. Zamrik, editors). The books reviewed and consolidated the prior decade's PVP developments.

In 1982, the PVP Division expanded the conference program to include an exhibition for companies to showcase their products and services. The first expanded PVP Conference was held in June 1982 in Orlando, Florida. Attendees enjoyed a dedicated venue in which they could examine and learn about products and services directly from vendors. The 1982 edition of "Decade of Progress" was prominently displayed and available for ordering. This 647-page volume contained the latest information on design techniques for the pressure vessel and piping industry. A similar book was planned to cover Operations, Applications & Components (OAC) and Materials & Fabrication (M&F) articles for 1985. Also that year, the Division also published two newsletters.

In 1983, the 4th National Congress of Pressure Vessel and Piping Technology was held in Portland, Oregon. That year, the Pressure Vessels & Piping Award was given to Dr. W.E. Cooper, the PVP Division participated in the French Pressure Vessel Conference in Paris in October, and the Design and Analysis Committee developed a session entitled ASME Code – Design and Analysis Considerations.

In 1985, the PVP Conference and Exhibition was held in New Orleans in June, and the PVP Award was given to John. F. Harvey of The Babcock & Wilcox Company. There were 70 technical sessions and the new edition of "A Decade of Progress" (1985) was released.

1989 Joint PVP and JSME Conference, Honolulu Hilton Hotel.
Left to right: T.H. Liu and wife, Rita Artin Dermenjian and wife.

THE 20TH ANNIVERSARY

In July 1986, the PVP Division celebrated its 20th anniversary in a joint conference with the Computer Engineering Division in Chicago, chaired by James R. Farr. The Conference theme was "Engineers, Computers, and New Approaches to Technology for World Trade." Plenary sessions were held in which experts shared their viewpoints on the conference theme. The recipient of the 1986 PVP Award was E.C. Rodabaugh who addressed burgeoning safety concerns in the PVP industry. High points of the 1986 joint conference also included a reception for foreign registrants at the Illinois Athletic Club, B&PV Section XI–A Memorial Symposium to honor Dr. Spencer H. Bush, and the Symposium on Flow-Induced Vibration.

1989 Joint PVP and JSME Conference, Honolulu Hilton Hotel.
Left to right: Byre Gowda, Richard Gwaltney,, Greg Hollinger and wife, Pam.

Conference tutorials were also introduced at the 1986 conference. These consisted of half-day programs delivered by subject matter experts. More than 200 engineers attended programs that included: Remaining Life Evaluation and Life Prediction; Fluid Structure Interaction – Its Prediction and Measurement; and How to Manage Engineering Data with a Personal Computer. Tutorials were also expanded to include at least three technical tutorials given during the week and a special, non-technical tutorial on Sunday afternoon. Vendor-sponsored Technical Workshops were also offered to conference attendees.

25th Anniversary – 1991 PVP Conference

Technical Sessions – 90
Technical Papers – 750+
Panel & Plenary Sessions – 9

THE 25TH ANNIVERSARY CELEBRATION

In 1991, the Division celebrated its 25th Anniversary at the PVP 1991 Conference in San Diego, California, led by conference chair Dr. Sam Zamrik. The Conference featured more than 90 technical sessions with 750+ technical papers, as well as nine panel and plenary sessions, tutorials and forums. At this Conference, an Appreciation Dinner or "roast" was held to honor the Division's out-going chair, Otto Widera.

THE NEW MILLENNIUM

In 2000, the Division renewed its vision and commitment to promoting the founders' mission of creating an inclusive environment for global participation for new and early career engineers and professionals from academia and industry. The Executive Committee (EC) and the Senate Select continued their dedication to strong leadership and organizational diversity, adding Dr. Judy Todd, Ph.D. (Academia) as the first female EC Member, and Dr. Luc Geraets (Industry Professional, Belgium) as the first non-North American international EC member. The New Millennium was kicked off with the 2000 PVP Conference in Seattle, Washington, led by Arthur G. "Jack" Ware. Dr. Zamrik opened the plenary session with the history of PVP from 1966-2000. The PVP 2003 Conference, chaired by William J. Bees, was held in Cleveland, Ohio. Its theme was "Shaping Technology in the Pressure Vessels Industry."

THE 40TH ANNIVERSARY

The PVP Division Annual Conference marked its 40th anniversary in 2006 with the introduction of Conference Proceedings issued on compact discs. Held in Vancouver, B.C., the PVP 2006 Conference was a joint Conference with the 11th International Conference on Pressure Vessel Technology (ICPVT). The PVP Conference was chaired by Dr. Judy Todd and ICPVT tracks were co-chaired by Drs. Sam Zamrik and Otto Widera. A Nanotechnology Task Force was formed under the leadership of Dr. Young Kwon.

In the 15 years since the division's 25th anniversary, the Conference had grown significantly and was now organized into more than 210 technical sessions and 750+ technical papers, as well as a good variety of tutorials, workshops and the Student Paper Competition. Michael Pettigrew of École Polytechnique was the recipient of the 2006 Pressure Vessels & Piping Division Medal and Kohei Suzuki presented the Calvin W. Rice Lecture.

The PVP 2007 Conference in San Antonio, Texas, was also a joint conference with the 8th International Conference on Creep and Fatigue at Elevated Temperatures (CREEP8). James F. Cory, Jr., chaired the conference for the PVP Division and Carl Jaske chaired the CREEP8 Conference. Also in 2007, the 11th International Symposium on Emerging Technology for Fluid, Structure, Interactions (FSI) and the Recent Advances in NDE and ASME Conference was held in Chicago for the first time since 1986, chaired by Artin Dermenjian.

Continuing in its tradition of holding impactful annual conferences, the PVP 2009 Conference was held in Prague, Czech Republic, venturing outside North America for the first time since the 1969 PVP Conference (held in Delft, The Netherlands). Dr. Luc H. Geraets served as Conference Chair.

PVP Conference Technical Participation Growth

1991 — 90 technical sessions
2006 — 210 technical sessions

L. Ike Ezekoye (2015 Winner of S.Y. Zamrik PVP Medal)

AWARDS AND RECOGNITION

The PVP Division's growth was also mirrored in the changes to its prestigious awards and honors. In 2008, the Executive Committee approved name changes of the awards presented at annual conferences. Most notably, the S.Y. Zamrik Literature Award was re-named the G.E.O. Widera Literature Award; the Student Paper Competition was renamed the Rudy Scavuzzo Student Paper Competition; and the prestigious

PVP Medal became an ASME society medal, renamed the ASME S.Y. Zamrik Pressure Vessels and Piping Medal. The latter name change honored Dr. Zamrik's significant influence and a keen vision in guiding the PVP Division through its impressive evolution.

PVP LEADERSHIP IN ASME

Throughout its five decades, PVP Division members have played active roles, holding national offices and serving on pivotal committees within ASME. Among the most notable are Dr. Otto Widera, Dr. Sam Zamrik, Dr. Judy Todd, Bill Bees, Artin Dermejian, Dr. Jack Ware and Dr. Luc Geraets.

PVP Leaders in ASME

Dr. Otto Widera
ASME *Vice-President of the Materials & Structures Croup (1993-96)*

Dr. Sam Zamrik
ASME *Vice-President: Materials & Structures Group (2000–02), Board of Governors (2002–05), ASME President (2007–08), selected for ASME Honorary Membership in 2010.*

Dr. Judy Todd
Vice-President of the Manufacturing Group (2002–05),

Bill Bees
Group Leader (2006–08)

Artin Dermenjian
Group Leader (2008–11)

Dr. Jack Ware
ASME Nominating Committee Chair (2010)

Dr. Luc H. Geraets
ASME Vice-President of Knowledge and Community (2014).

MOVING TOWARD OUR GOLDEN ANNIVERSARY

In recent years, it has become obvious that more than half of PVP Conference participants come from outside the United States. After a successful conference in Prague, the Executive Committee committed to increasing emphasis on international participation. The 2010 conference, held in Bellevue, Washington, was planned jointly with the Korean Society of Pressure Vessel & Piping (KSPV&P). Dr. Young W. Kwon and Tae Eun Jin were conference co-chairs.

After the successful 2011 conference in Baltimore, Maryland, the 2012 PVP Conference moved north to Toronto, Canada, with Michael E. Nitzel serving as Conference Chair. Two plenary presentations addressed the heavy water reactors (CANDU reactors), which are used primarily in Canada. Delivered by W.M. "Mark" Elliott of Ontario Power Generation and Terry Jamieson of the Canadian Nuclear Safety Commission, they addressed "Nuclear Refurbishment at Ontario Power Generation" and "The Importance of Participation of Regulators at International Activities."

The PVP 2013 Conference then jumped the Atlantic to Paris. Co-chairs Ronald S. Hafner and Michael E. Nitzel led the second PVP Conference in a four-year period to be held outside North America with truly global participation. Attendees represented an astonishing 42 countries. The 2014 PVP conference returned stateside to Anaheim, California, chaired by Daniel T. Peters. Plenary speakers were Mr. John Bednar, BP's Technology Manager for Floating Structures, SURF and Subsea Control Systems; and Mr. Brian Skeels, Emerging Technologies Director, FMC Corporation.

VOLUNTEER AND CORPORATE RECOGNITION

PVP conferences are successful chiefly due to the dedication of volunteers who are, in turn, supported by their companies. At the Paris Conference, actual time without compensation spent by our volunteers in conference development exceeded 2,200 hours. In honor of such exemplary dedication, the Executive Committee established corporate recognition plaques to recognize outstanding corporate support. The first recipient in 2008 was Sargent & Lundy LLC. In 2015 after his passing, the award was re-named the "Luc H. Geraets Appreciation Award" to commemorate Dr. Geraets' decades of service to PVP. The 2015 recipient was The Babcock & Wilcox Company.

INTERNATIONAL RECOGNITION

From 1991 to 2000, the number of conference participants from outside North America grew from approximately 30 percent to 60+ percent of membership. Today, our conferences host attendees from more than 42 different countries. The technical content and quality of PVP Conference sessions now benefit from such increased international participation.

THE INTERNATIONAL COORDINATION COMMITTEE

To recognize international contributions, a committee was created in 2001 to foster and promote global participation. Dr. Luc Geraets was appointed the first International Coordinator (2001-2004), succeeded by Kohei Suzuki (2004-2006), David Lidbury (2006-2008) and Maher Younan (2008-2012). Over the years, this position has developed into a full Administrative Committee with representation on the Executive Committee and the establishment of a new award — the Outstanding International Session Award. This Certificate of Appreciation recognizes and promotes the development of multi-national sessions and is presented annually.

THE STUDENT PAPER COMPETITION

To encourage student participation and increase their interest in technical presentations, M.K. Au Yang, Senate President for 2007-2008 and Student Paper Competition Chair for 2008, proposed monetary awards for the top three finalists. Dr. Judy Todd, Senate President for 2008-2009 and Student Paper Competition Chair, proposed that the competition be re-named the Rudy Scavuzzo Student Competition Symposium" in recognition of Dr. Scavuzzo's decades of contributions to the PVP Division. In 2010, 43 student papers were submitted to the competition, up from 35 papers submitted the year prior.

Rudy Scavuzzo 23rd Annual Student Paper Competition Finalists Pose at the Honors and Awards Luncheon.
Front Row (sitting, L-R): Xiaoming Miao (P.R. China), Kosuke Mori (Japan), Seung-Hyun Park (Korea), Abdulla al Mamun (United Kingdom), Nicolas O'Meara (United Kingdom), and Timothy Galle (Belgium).
Back Row (standing, L-R): Xiaochen Zhao (P.R. China), Doug Scarth (PVP Division Honors & Awards Chair), Xiaoben Liu (China), Ming Zhang (China), Julie Adjiman (France), Sam Zamrik (ASME Past President), Dongsheng Hou (P.R. China), Vilas Shinde (France), Jun Young Jeon (Korea), Yuwen Qian ((P.R. China), and, Mike Nitzel (Vice Chair, PVP Division Senate).

Left to right: Jamila Zamrik Brenner, George Wrenn, Kristin Corey, Pam Dermenjian, Karla Mertiny, Unknown, (next row) Myrna Zamrik, Gloria Nitzel, Donna Jaske, Betty Scarth, CeCe Bees, Denise Geraets, Soon Kwon, Jenna Mertiny.

2016 International Participation

42 countries worldwide

SOCIAL EVENTS

PVP Conferences provides and promotes an agreeable atmosphere (spouses are welcome) that helps to further develop friendship, broaden relationships and extend interaction and networking. The PVP Division's social program is always scheduled for Wednesday evening of the annual conference and can run the gamut from dinner cruises to outings to local attractions and activities. Our Senate Select and Executive Committee spouses also work to create and maintain the "PVP Family" atmosphere that makes our social events successful.

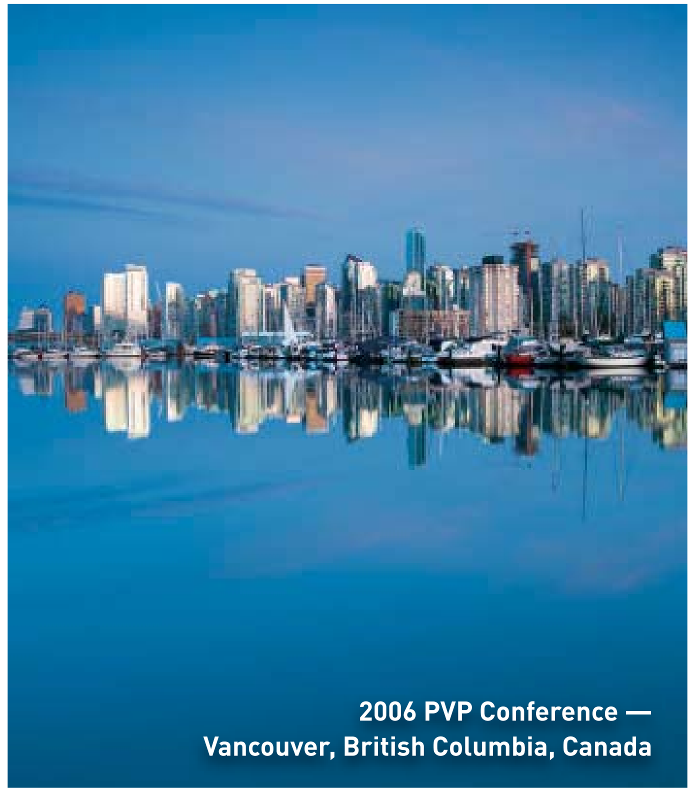
LIAISON ACTIVITIES

The PVP Division interacts with the ASME Board on Pressure Technology Codes and Standards. Members of the PVP Division Executive Committee were initiated as members of the Board on Pressure Technology Codes and Standards. Greg Hollinger served as our first representative, followed by Otto Widera, Sam Zamrik, William Short and Dan Peters who, along with Mike Nitzel, also serve on the ASME's Energy Sources and Processing Segment Leadership Team (ESP SLT). Additionally, Dan Peters represents the ESP SLT on ASME's Technical Event and Conferences (TEC) Council.

STILL GOING STRONG AT 50

New initiatives and global outreach continue to be noteworthy endeavors for our division. We are working diligently to identify and strengthen our portfolio of content and events. New programs and leveraging technology and knowledge will allow us to continue to grow and provide the outstanding technical content our Division is known to deliver to our membership and at our annual conferences. Our future looks bright for our energetic and dedicated membership. Come celebrate our 50 years of achievement with us at this month's 2016 PVP Conference in Vancouver, B.C., and help us ring in the next half century of Pressure Vessel and Piping innovation.

1969 PVP Conference —
Delft, The Netherlands



2006 PVP Conference —
Vancouver, British Columbia, Canada

2009 PVP Conference —
Prague, Czech Republic

2013 PVP Conference —
Paris, France

PVP TECHNOLOGY DEVELOPMENT

In the past 50 years, the PVP engineering field has evolved from a simple application approach to a complex application and analysis methodology. This has resulted in higher reliability, cost-efficiency and most importantly, safer equipment. In a nutshell, among other advances, the methodology has enabled:

- Improved finite element analysis that allows for more precise computation of stresses in metals,
- Computational fluid mechanics that improves understanding of the forces imposed on equipment, and
- Advances in fracture mechanics that increase the prediction of failure margins.

Additionally, meticulous analysis of in-service components yields a wealth of valuable information. For example, observed degradation and failure of equipment has led to the development of inspection, mitigation and prevention methods for intergranular stress corrosion cracking and corrosion fatigue; and new alloys, weld materials and nondestructive testing methods help ensure safety of joints and welds.

Of course, the ASME Boiler & Pressure Vessel Code has been continuously revised to incorporate and codify these new techniques and methods as they've been developed.

COLLABORATING WITH CODES & STANDARDS

In the late 1970s, high pressure technology (HPT) was an active area of development in polyethylene production, synthetic crystal growing, waterjet cutting, powdered metal production and other industries. To keep pace with the evolution of HPT, the Operations and Applications Technical Committee formed a task group on high pressure. This group eventually became the HPT Committee of the PVP Division which, in turn, spawned several ASME Codes and Standards groups including:

- The ASME Sub-Group on High Pressure Vessels — responsible for the creation and maintenance of ASME Section VIII Division 3.
- The High Pressure Piping Committee — responsible for maintaining Chapter IX of the ASME B31.1 Process Piping Standard.

Through the years, these groups have worked to develop and maintain rules and technology to support the design, construction and implementation of high pressure equipment. Significant manufacturing technologies have also been developed and codified through the collaboration between ASME PVP and Codes and Standards. A short list of these joint achievements includes:

- The manufacture of Composite Reinforced Pressure Vessels (CRPV) and wire-wound pressure vessels,
- Development and production of High Pressure High Temperature (HPHT) well head equipment for subsea applications,
- Exploration of the failures in order to update the codes and standards in the wake of the Fukishima incident,
- Symposia addressing fluid structure interaction for the evaluation of flow-induced and vortex-induced vibration in piping systems,
- Advancement and codification of bolted flange technology, and
- Stress concentration factors for cross-bored holes.


The Japanese Way, the JGC Way
Oil and gas plants rank among the most complex systems created by man. To build plants such as these requires the procurement of a vast array of materials and equipment from companies around the world.
At project sites, JGC often supervises at the peak of construction more than 50,000 workers from more than 60 nations.
Communication is the key. When we speak to one another, we use our words and our hearts to initiate a dynamic interaction, binding people and technology together across nations, ethnicities and cultures.
With each new project come countless new difficulties. The larger the project, the greater the obstacles are. Yet each and every time, we resolutely stand up to the challenges, determined to carry out our most important mission: It is to bring prosperity to our clients and to the countries where we do business.
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Pressure Vessel & Heat Exchanger / Piping / Structural (Software Modules)
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• Material Inspection and Traceability
• Fitup/Weld Visual
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• Dimension Reports
• Leak Reports
• Calibration Data
• Welder Log / Traceability / Defect Analysis
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The Answers You Need
"As past chair of the ASME's Pressure Vessels and Piping Division and Chair of Section VIII Division 3 on High Pressure Vessels, I understand the bases of the Code and how to apply it in practical ways. Our team's engineering know-how and hands-on experience can help you make the correct design choices and asset management decisions with confidence."
– Dan Peters
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Pressure vessels are critical to plant safety, and challenging service environments make them vulnerable to damage. As a global leader in failure prevention, Structural Integrity provides an array of engineering solutions to keep high-pressure equipment running safely:
• Design Review
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• Stress Analysis
• Fitness-for-Service Evaluation
• Non-Destructive Examination
• Linear / Nonlinear Finite Element analysis
• Material Sampling & Testing
• Remaining Life Assessment
• Repair/Replacement
• Risk Based Inspection planning
Along with the industry's most advanced technologies, we bring you a world-class team of technicians to implement them. With expertise in every aspect of high-pressure equipment, and the codes that govern them, Structural Integrity can help owners choose a course that instills confidence.
We have the answers you need.
(877-4SI-POWER)
877-474-7693
www.structint.com/PVP

OS FOR FIREWALLS

BELDEN, ST. LOUIS, MO.

Belden recently released Hirschmann Security Operating System 3.0, which now offers enhanced security features for customers using the EAGLE20/30 firewalls, including deep packet inspection and firewall learning mode. The flexibility of the EAGLE20/30 firewalls continues to enable many configuration options, the company says, eliminating the need for multiple devices. The multiport firewall is built to order with various configuration options for up to eight ports, including Fast Ethernet, Gigabit Ethernet, and symmetrical high-speed digital subscriber line.

WAVE TRACKING MODULE

MICROSTAR LABORATORIES, BELLEVUE, WASH.

The maker of data acquisition processor systems for PC-based high-performance measurement applications has released DAPtools Standard 6.2 with a new wave synchronization module. The module aligns measurements in real time to a reference time-base signal provided in the form of a precision sine wave, which can be synchronized to an external master time base. That capability complements the time-base synchronization module previously released, which required time base signals to be digital signals such as IRIG-B or GPS. DAPtools Standard also includes modules for advanced rotating machinery rate analysis, digital countermeasures to aliasing, and various data management, transform, and filtering operations.

CFD FOR HPC

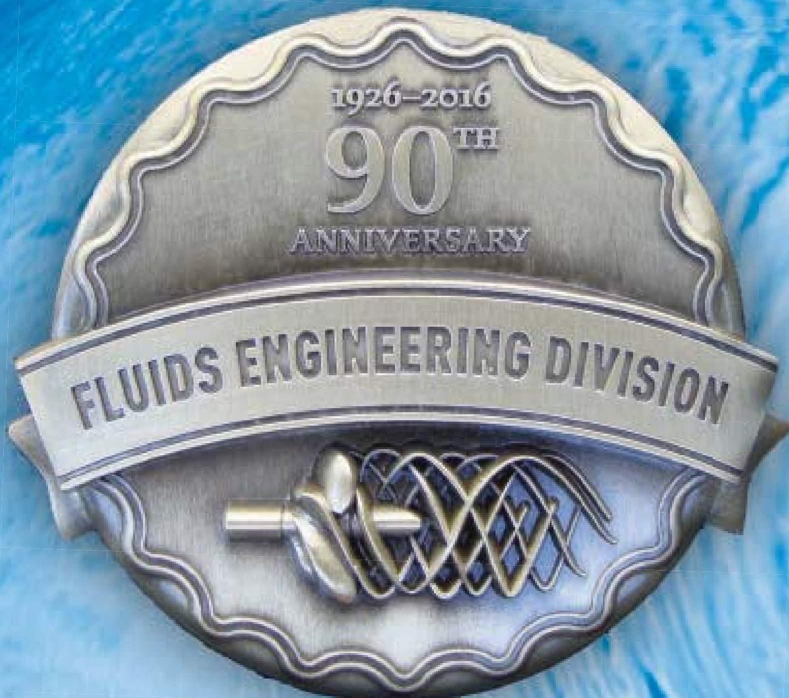
FLOW SCIENCE, SANTA FE, N.MEX.

FLOW-3D/MP version 6.1, the high-performance computing version of Flow Science's flagship computational fluid dynamics software, now includes active simulation control, batch post processing, and report generation. FLOW-3D/MP users will be able to take advantage of the sort of accuracy in solving complex physics and numerics found in FLOW-3D, but with a significant increase in performance. FLOW-3D/MP v6.1 is certified Cluster Ready by an Intel program intended to assure users that hardware and software will work correctly together.

FIVE-AXIS SIMULATION

MACHINEWORKS, SHEFFIELD, U.K.

MachineWorks version 7.4, the newest release of the computer numerical control application, can now simulate both additive manufacturing and subtractive manufacturing in a single environment. Version 7.4 offers many new features, including hybrid machine tool simulation, higher quality surface finishing, and greater accuracy of visual representation. The new sampling engine offers greater accuracy of graphical representation, the developer says. The enhanced ray-traced image contains surface details that would normally be lost when using a sampling technology.



CELEBRATING THE DIVISION'S MANY ACCOMPLISHMENTS AND MILESTONES

Engaging engineers worldwide for the advancement of fluids engineering science and technology.

Fluids Engineering Division: Celebrating 90 Years of Service

For nearly half a century after the founding of the American Society of Mechanical Engineers, members with an interest in the application of fluid power had no home of their own within ASME. However, in 1926 the Hydraulic Division separated from the Power Division to become the center for advancement of fluids engineering. Now known as the Fluids Engineering Division, FED has members that represent almost every country and cover many industries that have either direct or indirect connection with fluids engineering.

In commemoration of its 90th anniversary, the Fluids Engineering Division is presenting this special supplement to Mechanical Engineering magazine. Its aim is to document the history of FED, assess its current status, and provide an outlook toward its future.

Yu-Tai Lee, Chair of Fluids Engineering Division (2016-2017).

A proposal was made in early 2015 to celebrate the anniversary in connection with the ASME 2016 Fluids Engineering Division Summer Meeting (FEDSM2016), to be held July 10 to 14 in Washington, D.C. With the support of the FED's executive committee, a steering committee was assembled in May 2015 to mark this important milestone by planning a special celebration event at FEDSM2016 to recognize the personal and technical contributions of many FED members over the years. Furthermore, a collaborative effort by the steering committee, and assisted by the ASME support staff, designed the 90th Anniversary Celebration logo that is engraved on the commemorative medal shown on the cover of this section.

At the 90th Anniversary Celebration, the FED will recognize distinguished engineers and scientists who have contributed significantly to the advancement of the Division and to the science and practice of fluids engineering in the last ninety years with a special certificate and medal, designed by Efstathios E. Michaelides and Joel T. Park. This recognition will take place during a special awards banquet at FEDSM2016.

We are excited to see our past colleagues and get to meet a few new ones during this special event. The invitees include past FED chairs, Freeman Scholars, and winners of the Fluids Engineering Award, the Fluids Machinery Design Award, the Sankaraiyer Gopalakrishnan Flowserve Pump Technology Award, and the Henry R. Worthington Medal. Although that last award is administered by the Petroleum Division, it is more relevant to the FED's activities, since most of the award recipients have been FED members.

Additionally, William B. Morgan will present a history lecture, an important highlight of the celebration during FEDSM2016. And

Mohamed Gad-el-Hak of Virginia Commonwealth University, a contributor to the special issue of *Journal of Fluids Engineering* with an article entitled "Nine Decades of Fluid Mechanics," will be a plenary speaker at the conference.

This supplement grew out of previous efforts by Ali Ogut, Sam Martin, Upendra Rohatgi, Chris Freitas, and Urmila Ghia to document the history of FED. The discussion on the Division's past and present position has been contributed by four past chairs: Sam Martin, Paul Cooper, Tim O'Hern, and George Papadopoulos. In addition, a forecast for the FED's future outlook is jointly prepared by the FED's current technical committees' chairs and vice-chairs.

A special edition of *JFE*, to be published later this year, will include an expanded version of this supplement as well as a look at the progress in fluid mechanics during the last 90 years. It will also include papers covering a range of topics prepared by prominent researchers in mechanical engineering and articles capturing end-of-career research by retired faculty. Francine Battaglia, Jinkook Lee, and Keith Walters are the special editors overseeing this special edition of *JFE*.

FED's longevity and achievements are due to the commitment and engaging participation of its members, who support all of its endeavors, from organizing conferences and sessions to serving on committees and contributing to publications. The technical committees, administrative committees, and technical journals are the life force behind FED, and its successes are due to the collective contributions of all its members. We appreciate the support of the dedicated ASME staff, which has always been knowledgeable and resourceful.

I thank all of the volunteers for their service to the Fluids Engineering Division and to ASME. I am particularly indebted to everyone in the steering committee—Francine Battaglia, Paul Cooper, Bahram Khalighi, Sam Martin, Efstathios Michaelides, William B. Morgan, Tim O'Hern, George Papadopoulos, Joel Park, S. A. Sherif—and ASME staff members Norma Johnston, Jimmy Le, Greg Valero, Nick Ferrari, and Christine Reilley for all of their efforts in helping organize a tribute to 90 years of Fluids Engineering that we can all be proud of.

We owe a great deal of thanks to the groundbreaking fluids engineers who came before us, creating and growing both the Division and the fluids engineering community. The obligation we have to them is to continue to build on the foundation we have achieved so far. I am optimistic that, with the continued support of our dedicated volunteers, the Fluids Engineering Division has a promising future for many years to come.

Sincerely,

Yu-Tai Lee

History of the Fluids Engineering Division (FED)

The first decades of the 20th century were a time of great progress in fluids engineering. The development of hydroelectric power stations led to an intense focus on many aspects of this technology. Engineers worked to understand and perfect hydraulic turbines, especially the Francis, Kaplan, and Pelton designs, to increase their overall efficiency. But hydropower raised a host of challenges beyond turbine design—including water hammer, cavitation, and flow measurement—that were of particular interest to mechanical engineers.

Members of the American Society of Mechanical Engineers advanced the field considerably during and before that time. During the late 19th century, for instance, Robert Thurston, the first president of ASME, was an expert in steam piping systems design, a leading educator, and an accomplished mechanical engineer. Thurston published an article in ASME's *Transactions and Mechanical Engineering* in 1883 about water hammer in steam lines that formed condensates when the pipe was inactive. (Condensation-induced water hammer remains an issue to this day.)

Another example of the important role ASME played in the early development of fluids engineering appeared in a 1930 paper in *Transactions* by Lewis F. Moody and B. R. Van Leer entitled "Fifty Years Progress in Hydraulics." Moody and Van Leer cited numerous articles, including theoretical hydraulics, water hammer, fluid metering, the Pelton wheel, American hydraulic turbines, and pumping machines. At that time, 240 articles on fluids engineering had already appeared in *Transactions*.

ASME also helped promote advances in flow measurement, including impulse-momentum (the Gibson method), Charles M. Allen's salt-velocity method, and Clemens Herschel's Venturi meter for smaller piping systems.

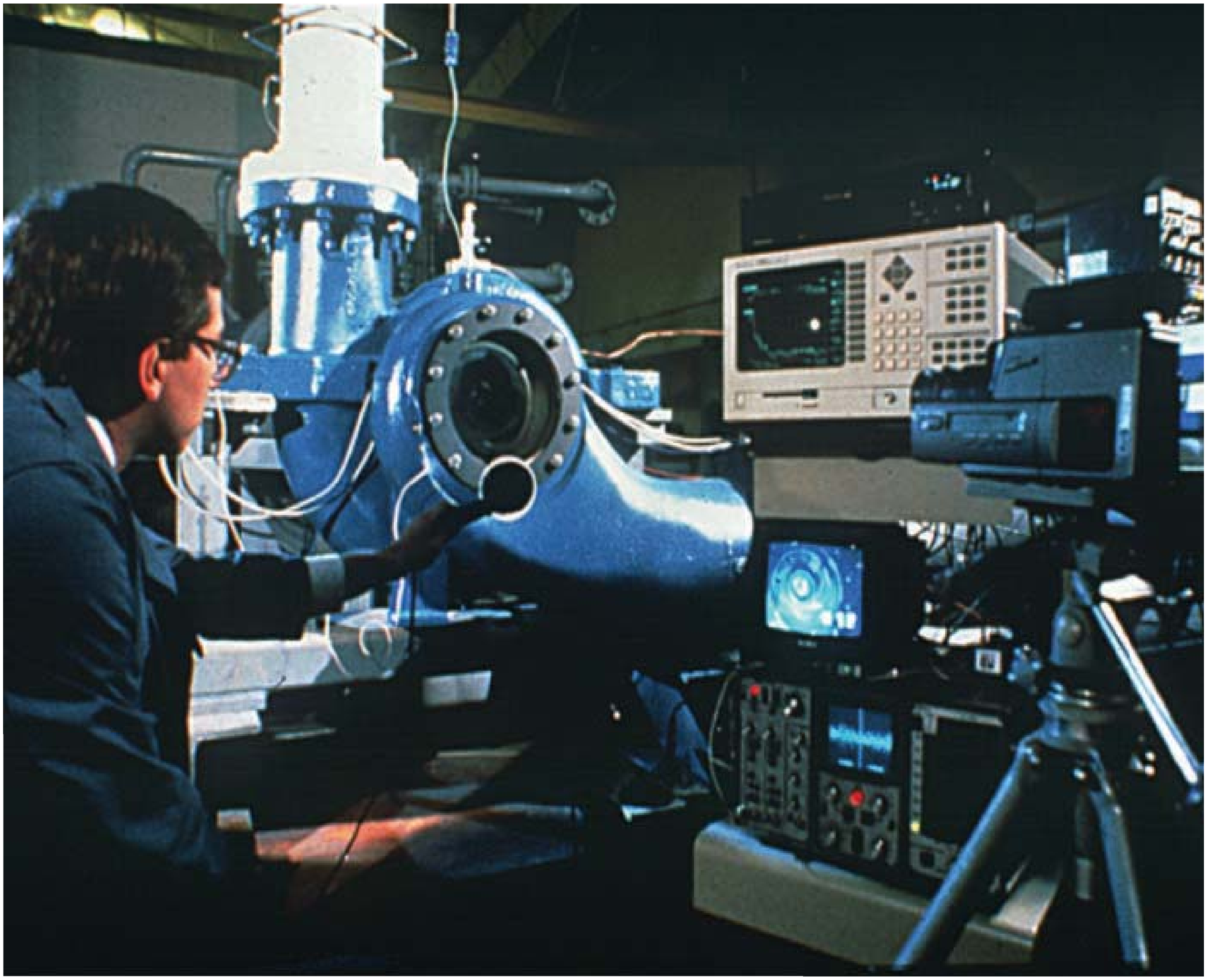
During that time, John R. Freeman made strong efforts to advance fluids engineering in the United States. A star in hydraulic activity from 1880 to 1930, Freeman conducted experiments on head loss in pipes and the characteristics of fire nozzles. Aware that European hydraulic laboratories were far more advanced than those in the United States, Freeman traveled to Europe. He encouraged other U.S. engineers to visit and publish their investigations. Freeman's effort led to a comprehensive ASME report, published first in German in 1926 and translated to English three years later.

Freeman, the twenty-fourth president of ASME and recipient of its Gold Medal, donated $25,000 to ASME to establish the Freeman Fund, a trust earmarked for hydraulics research. He expressly wished that ASME use part of the fund to translate groundbreaking works on hydraulics into English and for scholarships to support overseas travel of engineering students. The fund's focus eventually shifted from supporting travel and translation to sponsoring hydraulics and fluid mechanics research programs. Even with this early and deep connection between ASME and fluids engineering, the Society did not have a home for members with a strong interest in hydraulics. Many fluids engineers met at least once at the Winter Annual Meeting or with other divisions, mainly the Power Division. There was, however, a growing interest in establishing a division with a sole focus on hydraulics.

On November 25, 1925, Moody, as temporary chairman, led the effort to formulate a petition to establish the Hydraulic Division, later rechristened the Fluids Engineering Division, which was endorsed by 146 ASME members without any dissenter. Notable cosigners included industry luminaries such as J. R. Freeman, N. R. Gibson, L. F. Harza, S. L. Kerr, C. T. Main, and R. S. Quick. The effort was also backed by such notable academics as C. M. Allen of Worcester Polytech Institute, R. L. Daugherty of California Institute of Technology, W. F. Durand of Stanford University, and A. Hollander and J. N. LeConte of University of California, Berkeley.

Establishment of Technical Committees

A few years after the division started, technical committees began to bud off to focus on specific areas of research. The first was the Standing Com-



Worthington Medalist Donald Sloteman investigating pump cavitation at Ingersoll-Rand's A. J. Stepanoff Hydraulic Laboratory, circa 1990.

mittee on Water Hammer, founded in 1931. The phenomenon had been a subject of ASME research dating back to Robert Thurston, and the society remained active in promoting research and disseminating information related to water hammer and fluid transients. Under the auspices of the newly formed committee, the first Symposium on Water Hammer was held in 1933 under joint sponsorship with the American Society of Civil Engineers Power Division. In 1935, the Water Hammer Committee was officially recognized by the Hydraulic Division.

S. Logan Kerr was the first chairman and held the position until 1956. Other notable members of the original committee were Gibson, Strowger, Halmos, Moody, and Quick. The committee's efforts included compiling and translating literature from Europe, reviewing water hammer theory, and analyzing available experimental data to confirm the various theories and formulas.

The Cavitation Committee came out of two sessions devoted to cavitation at ASME's annual meeting in 1935. Increasing interest and discussions on the pitting resistance of metal under cavitation conditions and the relative resistance to cavitation erosion by the vibratory method were the highlights of a round-table discussion at the 1937 joint meeting of the Applied Mechanics and the Hydraulic divisions in Ithaca, N.Y. Following this discussion, the Cavitation Committee was officially formed. Moody served as chair through 1947; R. T. Knapp followed him in 1948.

In 1970, the committee changed its name to the

Polyphase Flow Committee and extended its scope to the general area of polyphase flows, partly to offset a decline in activity in the field of cavitation and partly to emphasize new areas. The name changed again in 1980, to the Multiphase Flow Committee, which focused on addressing constituent technologies of the combined flows of liquids, gases, and solids.

Large hydraulic turbines were a major emphasis of the Hydraulic Prime Movers Committee, formed in 1938. The committee was chaired by J. Frank Roberts for its first ten years, followed by 11 more chairs through 1967—three decades in which the United States saw significant development in its hydropower infrastructure.

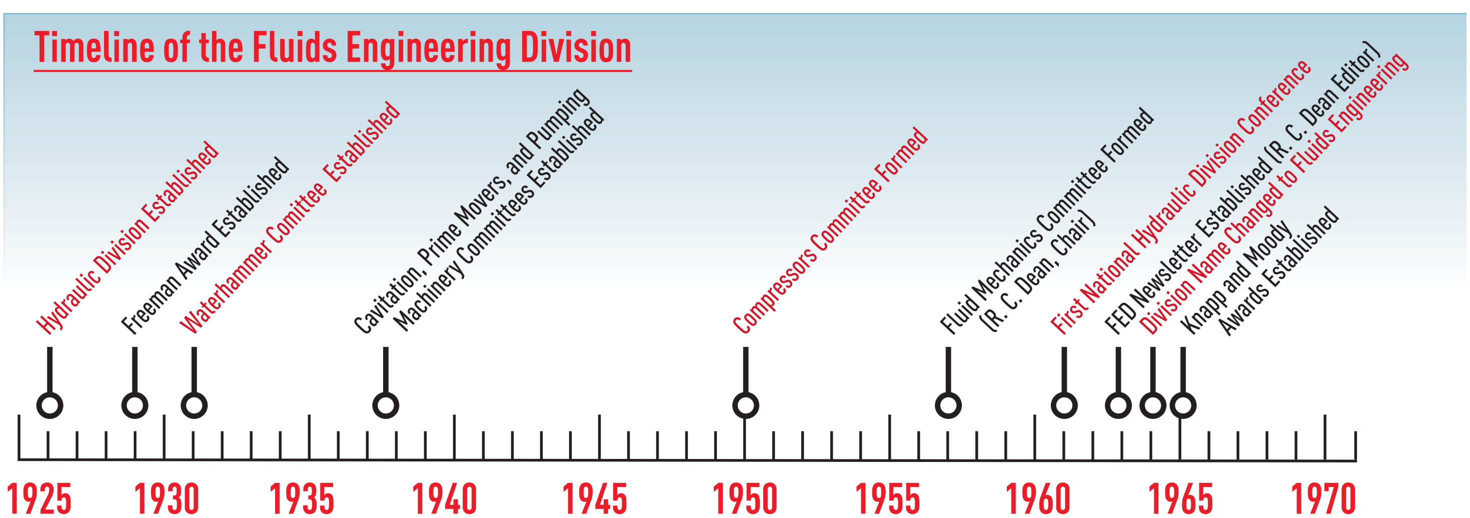
The Pumping Machinery Committee also formed in 1938 and was chaired by Robert L. Daugherty for its first ten years. The list of members of PMC is a roll call of academicians and engineers who were involved with some of the most important pumps and pump research and technology of their day, including Lewis Kessler, Fred Antunes, Alexander Agostinelli, and Sankaraiyer Gopalakrishnan.


Lewis F. Moody, who helped create the Hydraulic Division, chaired the Waterhammer and Cavitation Committees.

The Compressors Committee appears to have been spun off from the PMC (several pump engineers were members of both). It was first chaired in 1950 by A.M.G. Moody. Government and academic researchers such as Joseph Hamrick and George Serovy also served as chairs, and the committee had vice chairs who were responsible for centrifugal, turbomachinery, and reciprocating compressors.

During the late 1940s and 1950s, a couple of additional short-lived committees were formed. The Positive Displacement Hydraulic Machinery was spun off from the PMC in 1948 and chaired by W.E. Wilson for the three years of its existence. The Fluid Power Systems Subcommittee, formed in 1957, was chaired by O. S. Carliss during its five-year existence. The area of interest for those two committees were merged with the Hydraulic Prime Movers Committee, the Pumping Machinery Committee, and the Compressors Committee to form the Fluid Machinery Committee in 1968.

Finally, Murrough O'Brien and others saw the need for research into the fluid dynamical principles of hydraulic machinery and installations being developed at



the time. In 1938, they formed the Committee on General Hydraulics, chaired by O'Brien. The committee, which lasted three years, established a precedent for a separate committee dedicated to fluid mechanics. That precedent—plus a general blossoming of the field that later prompted a writer to call the decade "the Rise of Fluid Mechanics"—may have been a factor in the establishment in 1957 of the Fluid Mechanics Committee, under the chairmanship of Robert C. Dean of the Massachusetts Institute of Technology. What is indisputable is that Dean was passionate about the many applications and possibilities that were arising for applying the science of fluid mechanics, knowing that progress in this area also required advancement in the science itself. Dean's vision was for the Hydraulic Division to meet this challenge in three ways, the first of which was to establish a dedicated and focused Fluid Mechanics Committee within the division.

That move led inevitably to a second, which was to change the name of the division in 1964.

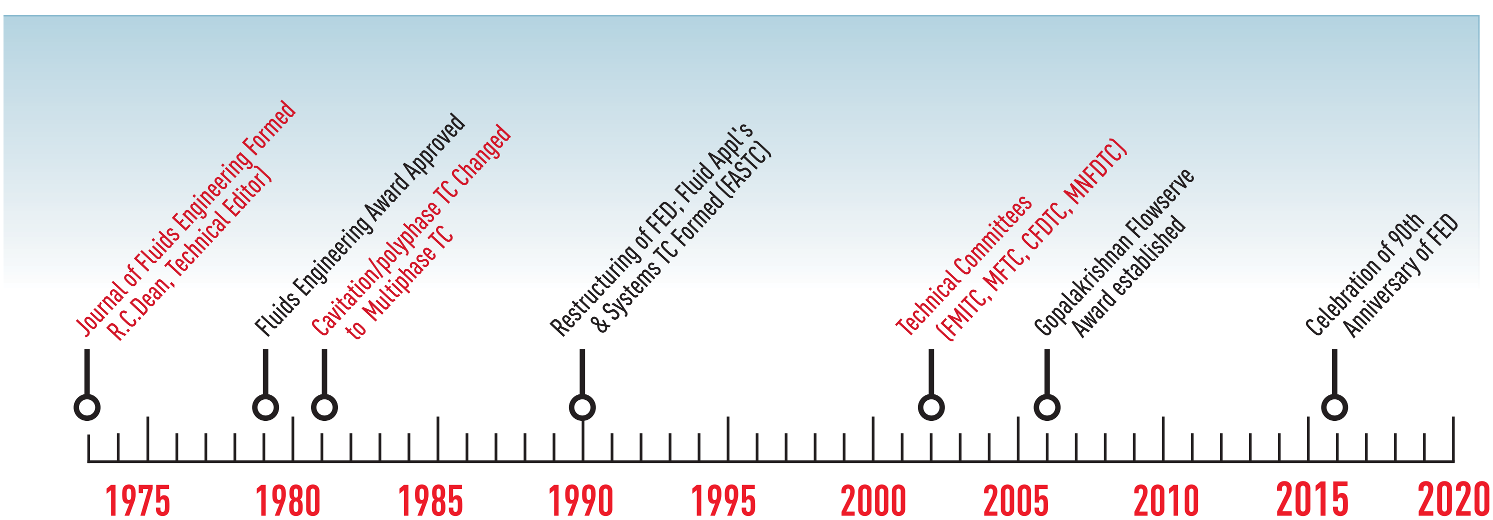
Finally, in 1973, Dean created and became the first editor of the new *Journal of Fluids Engineering*—a part of ASME's *Transactions*. The Fluid Mechanics Committee was therefore an essential element in the total transformation that Dean brought about by driving this rebirth of the division to serve the evolving fluids engineering reality that he saw so clearly.

Robert L. Daugherty was the first chair of the Pumping Machinery Committee.

Division Re-alignment and Renaming

By the late 1950s, research work opportunities in fluid mechanics existed in both industry and university settings—in many cases this was a continuation of defense-related R&D that started in World War II. The first specialty conference on hydraulics was held at the University of Michigan in 1959. Of the 20 papers presented, seven could be classified as fluid mechanics papers. Major research-oriented universities became active in the field, with elite universities in New England and California leading the way.

There was also a groundswell of activity and interest in renaming the Hydraulics Division to more accurately reflect the interest and focus of subcommittee members. Dean led the charge to rename



At the Borg-Warner research center, from 2nd from left: S. Gopalakrishnan and center: John Tuzson.

the division, and was supported by Stephen Kline of Stanford, Howard Emmons of Harvard University, and A.H. Shapiro of MIT. There was, however, a cadre of subcommittee members from water hammer and hydraulic prime movers who strongly supported the name "Hydraulic Division," as it suited their activities.

George Wislicenus, the well-respected chair of the Cavitation Committee, brought the hydraulic and fluid mechanics members together for a vote—53 to 23—that changed the name to the Fluids Engineering Division in 1964.

The name change also brought re-alignment, coalescence, and emergence within the committee structure. The Water Hammer Committee changed its name in 1965 to the more general Fluid Transients Committee. In addition to traditional water hammer, the scope was expanded to include unsteady flow, fluid-structure interaction, and vibrations.

Another realignment followed with the merging of Hydraulic Prime Movers, Pumping Machinery and Compressors committees into the Fluid Machinery Committee in 1968. And the Cavitation Committee evolved to the Polyphase Committee and what is known today as the Multiphase Committee.

Lastly, the Fluidics Committee, with Forbes Brown as chair, was jointly formed in 1967 by the FED and the Automatic Controls Division. It had a series of chairs that ended with Milton Franke in 1976, after which the committee was transferred to the Automatic Controls Division.

Two groups—the Coordinating Group for Fluid Measurements and the Coordinating Group for Computational Fluid Dynamics—were formed in the 1980s to address the growing emphasis on flow metrology and computational fluid dynamics that emerged within the areas represented by the technical committees. CGFM was charged with working in areas such as fluid meters, laser Doppler anemometry and other optical flow measurement and visualization techniques, pressure and temperature measurements, and experimental uncertainty. The CGCFD was charged with applying computational fluid dynamics techniques to the solution of fluids engineering problems. Program areas included numerical uncertainty, identification of benchmark cases, and cooperation with similar groups from other technical societies. Both groups were to coordinate with the technical committees in their respective areas.

The 1990 Restructuring

By the late 1980s, the fluids engineering landscape had changed sufficiently to affect the technical committees and the other functions of the division. The Fluids Engineering Division Executive Committee, at its meeting in late 1989, proposed a review that would ensure better coordination of its committees and would increase participation of the division's industrial members in its technical programs.

The goal of the review was to address three trends that characterized the new landscape: The increase in fluids engineering industrial applications in addition to traditional fluid machinery, such as pumps and turbines; a fusion of the disciplines in the traditional fluid machinery area; and the increased research in basic flows in the fluid mechanics discipline. Under the direction of chair Tom Morel, the FEDEC solicited input from the technical committee and coordinating group chairs, and subsequently developed a suggested structure.

Paul Cooper and Sam Martin chaired an open meeting of the Division on June 4, 1990, at the ASME Spring Fluids Engineering Conference that was held jointly with the CSME Mechanical Engineering Forum in Toronto. The purpose of the meeting was for the attendees to examine the operation, structure, and mission of the FED and to consider improvements that would maintain and increase the effectiveness of the Division. Tom Morel presented the FEDEC report, and after discussion the members authorized the proposed new committee structure.

The major change was the formation of two new technical committees, namely the Fluid Applications and Systems Technical Committee and a Fluid Mechanics Technical Committee. The Fluid Mechanics Committee originally addressed both the applied and basic subject areas of fluid mechanics. Over the following years, however, it took on so much in so many subject areas that the applied areas had to be spun off in 1990 into the Fluid Applications and Systems Technical Committee, which also absorbed the Fluid Transients and the Fluid Machinery committees. The balance of the original committee became the Fluid Mechanics Technical Committee.

In addition, a newly created Advisory Board to the FEDEC was created. The board consisted of resource persons such as past FEDEC members, past technical committee and coordinating group chairs, senior members of the Division, and others familiar with the programs of FED and fluids engineering. Their role is to advise the FEDEC on future technical programs, industry, government, and university cooperation, the FED Student Papers Contest, and agendas for special programs and other topics.

Evolvement to Present Day

The idea behind founding the Coordinating Group for Fluid Measurements and the Coordinating Group for Computational Fluid Dynamics was that they would represent their technologies across the research and application space of the existing technical committees. In time, however, the coordinating groups had evolved to operate as technical committees in everything but name: They organized sessions, reported to the FEDEC, and held a variety of other responsibilities.

C. Samuel Martin is an authority on fluid transients and FED history.

As a result, it was announced at the FEDSM 2002 that the coordinating groups were becoming technical committees in their own right. The Coordinating Group on Computational Fluid Dynamics became the Computational Fluid Dynamics Technical Committee and the Coordinating Group on Fluid Measurements became the Fluid Measurements and Instrumentation Technical Committee.

In addition, the Coordinating Group on Industry Technology was converted to an advisory committee called the Industry Technology Committee.

The most recent addition to the FED committee structure was formed in response to the significant international interest and high level of activity in both basic and applied micro- and nano-fluid dynamics. The earliest FED efforts in this area were supported by the FMTC, from which the first symposium on the topic, Application of Microfabrication to Fluid Mechanics (IMECE 1994), was organized by Promode R. Bandyopadhyay. Additional symposia followed at the IMECE in 1996 and 1998, becoming an annual event in 1999. At the 2001 IMECE, the FEDEC approved a proposal to form the Micro and Nano Fluid Dynamics Technical Committee. The scope of the MNFDTC was to coordinate, primarily at IMECE but also at FEDSM, strong participation between numerous ASME divisions organizing sessions devoted to all aspects of microelectromechanical systems (MEMS). Fred K. Forster served as the first chair of the MNFDTC, which held its initial meeting at FEDSM 2002 in Montreal.

Honors & Awards

In addition to the six technical committees, the FED Executive Committee oversees the Honors and Awards Committee, the Graduate Student Steering Committee, and the Young Engineer Paper contest.

The HAC solicits candidates and evaluates FED-sponsored award programs. ASME has two categories of awards: Society Awards and Division Awards. The society as a whole can nominate an individual for the highest level of award, or an existing Division Awards can be elevated to society level, after being recommended by the FED Honors and Awards Committee.

The following table lists all the awards that have and continue to serve the FED community towards recognizing exceptional achievements and contributions in the field of fluids engineering:

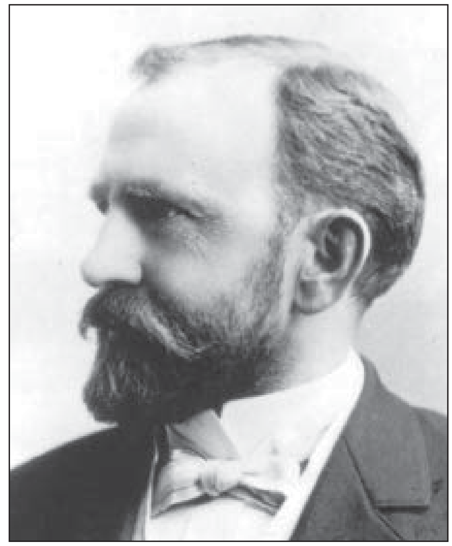
AWARD	CATEGORY	DESCRIPTION
ASME Medal	Society	The highest award the society bestows recognizing "eminently distinguished engineering achievement." Five FED members have been recipients: John R. Freeman, Charles T. Main, Theodore von Karman, William F. Durand, and Robert C. Dean Jr.
Honorary Member	Society	A level of recognition awarded to a person who has made "distinctive contributions" to engineering, science, industry, research, or public service. Sixteen ASME members with FED affiliation have received honorary membership.
Fluids Engineering Award	Society	Initially a division-level award started in 1968, it was later approved by the FED Honors and Awards Committee and the Society of Honors Committee to be a Society-level award, with the first recipient in 1979 being Robert C. Dean. To be considered for this award a person needs to have made "Outstanding contributions over a period of years to the engineering profession -- especially in the field of fluids engineering through research, practice, and/or teaching."
Freeman Scholar	Society	A biennial award to a person of significant expertise to review a coherent topic in their specialty, resulting in a review article for the JFE and a plenary lecture at the IMECE.
Thurston Lecture	Society	Given annually by an outstanding leader in pure or applied science that stimulates thinking on a subject of broad technical interest to engineers. Eight engineers with FED affiliation have been Thurston lecturers.
Worthington Medal	Society	This Society-level award is administered by the Petroleum Division for eminent achievement in the field of pumping machinery. Nine medalists have FED affiliation.
Fluid Machinery Design Award	Division	Given to a recipient that has excelled in the design of fluid machinery involving significant fluid mechanics principles.
Gopalakrishnan Flowserve Award	Division	Given to a recipient that has at least five years of experience in the field of pumps, documented through publications and testimonials of peers and co-workers and shows promise in the field.
Knapp and Moody Awards	Division	Given for an outstanding original paper resulting directly from analytical or laboratory research and of usefulness to the practice of fluids mechanical engineering.

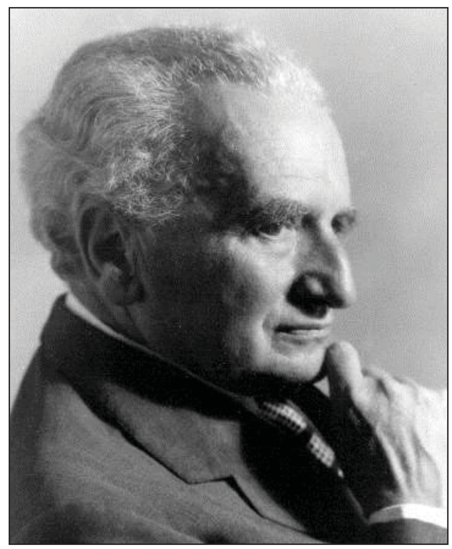
2012 Young Engineer Paper Award recipients, flanked by Malcom Andrews (left) and Terry Beck (right).

The Graduate Student Steering Committee was formed by J. Bayandor in 2013, with the objective of encouraging and rewarding quality graduate students in the area of fluids engineering who are expected to become the future members and leaders of FED. Selected from the FEDSM student paper track, honorees receive the title of ASME FED Graduate Scholar of the Year and are invited to join one of the six FED technical committees aligned with the area of their research. The technical committees provide mentorship and involve students in a range of professional and technical activities, including organizing symposia and ambassador programs. Student winners are offered a travel grant to assist them to attend FEDSM and present their papers. They also have an opportunity, as returning scholars, to participate in FEDSM one year after their initial selections. To date, the GSSC has awarded over 40 exceptional graduate students from both U.S. and international colleges.

The FED also sponsors the Young Engineer Paper contest at IMECE with the participation of undergraduate students, recent baccalaureate engineers, and beginning graduate students. Coordinated by B. T. Beck, contest participants compete their fluids research papers for top awards. Their papers are reviewed by the FED Young Engineer Paper Contest Committee.

Recipients of the Graduate Student Scholarship Program in 2014 with Javid Bayandor.





ASME Medalists John R. Freeman, Theodore von Karman, and Robert C. Dean, Jr., were visionaries and leaders in the field and the "Rise of Fluid Mechanics" within ASME.

The ASME *Journal of Fluids Engineering*: Past, Present, and Future

ASME split its single research journal, ASME *Transactions*, in 1959, creating the *Journal of Heat Transfer* and the *Journal of Basic Engineering*, which carried fluids engineering papers. Soon, Fluids Engineering Division colleagues such as Robert Dean, Stephen Kline, and George Wislicenus urged the formation of a specialized journal. In 1973, the Society authorized a new publication, the *Journal of Fluids Engineering*, with Robert Dean as Technical Editor. The first issue launched in March 1973.

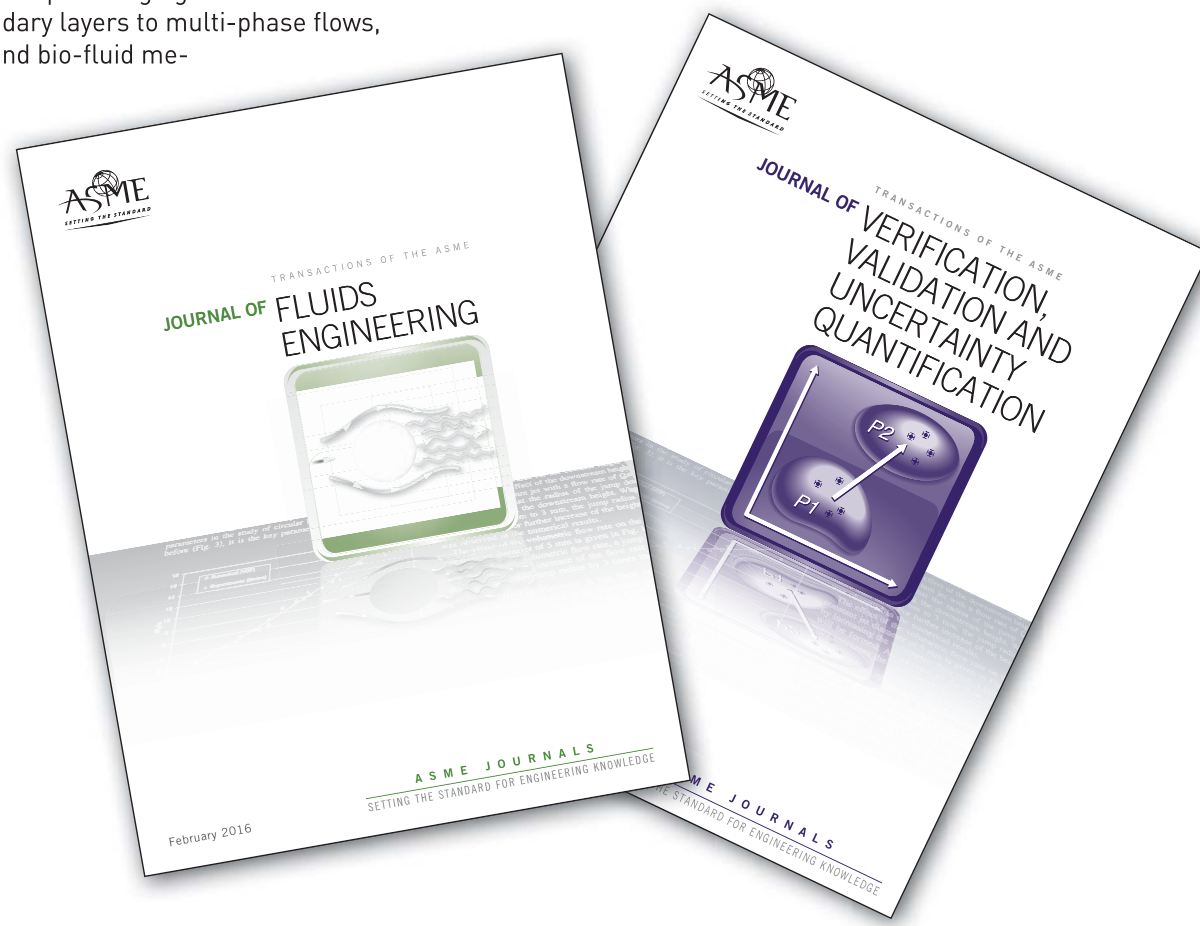
After Robert Dean, the *JFE* had three editors with ten-year terms: Frank White, Demetri Telionis, and Joseph Katz. The present editor, Malcolm Andrews, took office in 2010.

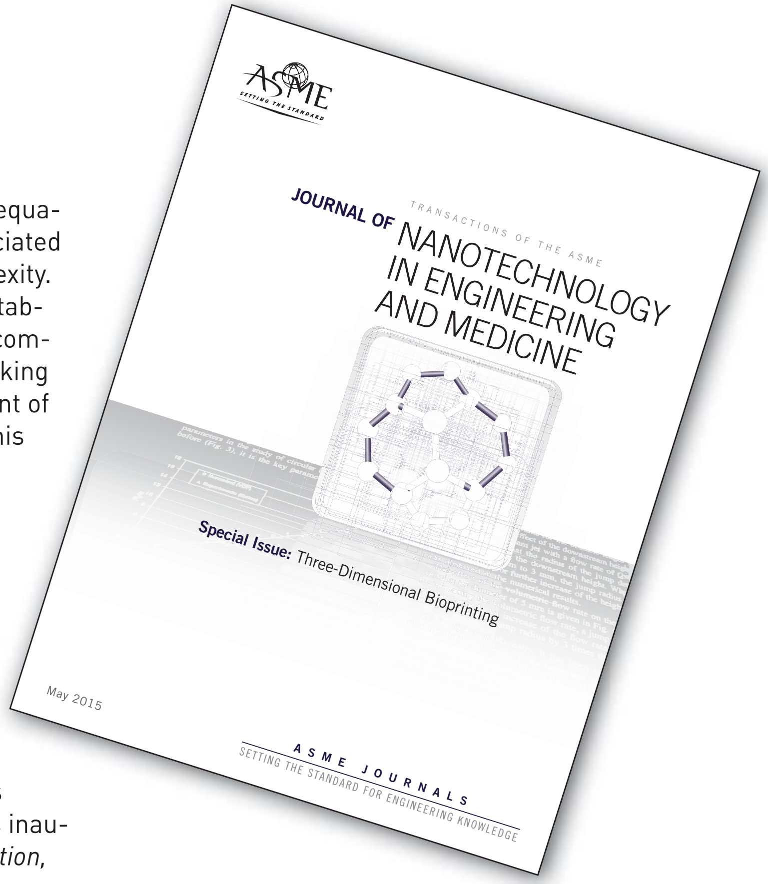
In a rapidly expanding field, the *JFE* has maintained a strong interest in fundamental and applied fluids research of interest to ASME members. *JFE* publishes both archival manuscripts and review articles on topics ranging from micro-fluidics and boundary layers to multi-phase flows, pumps, and bio-fluid mechanics.

In recent years, *JFE* has thrived as a monthly publication that produces more than 1,800 pages per year while maintaining a submission-to-publication ratio of 4-to-1 out of close to 1,000 submissions in 2015. With an average submission-to-decision time of five months, *JFE* is selective and responsive to manuscripts. In spite of a heavy workload, all associate editors are dedicated volunteers, and their hard work is the basis for the continued success of the *JFE*.

ASME *Journal of Verification, Validation, and Uncertainty Quantification*

Numerical simulation of complex systems has grown from simple and straightforward numerical





solutions of ordinary and partial differential equations to massive parallel computations associated with systems of hitherto unbelievable complexity. Increasingly, emphasis is being placed on establishing the credibility and accuracy of these computational models as a basis for decision making and scientific insight. The field of development of the tools and methods needed to establish this credibility is verification and validation, and validation based on experimental results is only possible if the uncertainties of the data are evaluated.

Many of the concepts, tools, and methods applicable to verification, validation, and uncertainty quantification, or VV&UQ, are independent of their area of application, and practitioners are often immersed in their narrow area of interest.

ASME, under the sponsorship of the Fluids Engineering and Heat Transfer divisions, has inaugurated the new *Journal of Verification, Validation, and Uncertainty Quantification* to provide a source where practitioners of VV&UQ from all disciplines can find peer reviewed articles describing best practices, illustrative successes, and high quality validation and datasets in all areas of engineering and applied science. The interpolation or extrapolation of the results to the simulation model are of interest.

ASME *Journal of Nanotechnology in Engineering and Medicine*

Unlike other nanoscience related journals, the ASME *Journal of Nanotechnology in Engineering and Medicine* provides an interdisciplinary forum uniquely focused on new frontiers of nanoscience—including nanofluidics, nanostructures, and nanomaterials. The journal consists of original research reports addressing nanoscale phenomena, synthesis, analysis and applications of devices and materials; reviews of emerging nanotechnology topics and research needs to impact engineering and medicine; and opinion pieces on the developments and potential applications of nanoscience in engineering and technology.

Special issues have covered such topics ranging from the design and fabrication of microscale and nanoscale devices for applications in energy, environment, and medicine to 3-D bioprinting ,nanoscale materials, devices, and systems for biosensing, biomanipulation, and biofabrication.

JNEM is supported by ASME's Fluids Engineering Division, Bioengineering Division, Heat Transfer Division, and Materials Division. The *JNEM* Advisory Board includes members of the supporting divisions.

Fluid Engineering: Trends in Industry and Technology

The field of fluids engineering has evolved over the past 90 years, and the Fluids Engineering Division is well positioned to address new trends and emerging focus areas in the field. Specifically, the Division's technical committees offer the means to support member interests in all aspects of fluids engineering applications and research and thus provide valuable intelligence about important future developments.

The FED Executive Committee and technical committees' chairs and co-chairs meet twice annually during FEDSM and IMECE to exchange ideas regarding the Division's operation for current and future conference programs. This process ensures healthy future programs, which cover both industry and academia interests in fluids engineering.

Here's what the technical committees are reporting today:

Fluids Applications and Systems Technical Committee

J. A. Bamberger, chair; G. Chamoun, co-chair.

FASTC is the primary technical committee for examining industrial flow applications and needs. Specific industrial applications being addressed by the committee include blowers, compressors, pumps, reciprocating engines, and turbines. Under its purview are also applications in alternative energy systems, atmospheric and oceanic flows, contaminant transport, groundwater flows, planetary mantle dynamics, solar convection and rotation, solar heating and cooling systems, and wastewater treatment. Some recent topics for FASTC symposia, which presented both works in progress, as well as new concepts, have featured industrial and environmental applications of fluid mechanics, fluid machinery, turbomachinery flow predictions and optimization, and wind turbine aerodynamics and control.

Fluid Mechanics Technical Committee

D. Davis, chair; S. aus der Wiesche, co-chair.

FMTC promotes fundamental and applied fluid mechanics related to primarily academic research. The FMTC encourages investigations of turbulent shear flows and turbulence modeling, flow transition and separation, Newtonian and non-Newtonian flows, and flow mixing and wakes. Symposia organized by FMTC inform participants on the aspects of fundamental and applied fluid mechanics important to the fluid engineering community. These form the core of fluid mechanics research and as such will continue to be an important element for the future.

Multiphase Flow Technical Committee

D. Pence, chair; J. Katz, co-chair.

MFTC is focused on the study of multiphase fluids—those involving various combinations of gas, solid, and/or liquid. The committee continues to support a wide range of industries with applications ranging from drug delivery, water treatment, waste management, to hydraulic fracturing. Areas of future development in multiphase flow include research into delivering of nanoscale particles to the alveoli in the lung for cancer treatments and the behavior of minuscule liquid droplets in vapors used for delivering asthma medication. The future management of nuclear waste nitrification is also of considerable interest for the MFTC. Further out, many aspects of the life-support systems for long-duration manned space missions will require sophisticated waste management incorporating multiphase flow systems.

Micro and Nano Fluid Dynamics Technical Committee

S. Mitra, chair; J. Zhe, co-chair.

MNFDTC works with engineers to better understand how fluids behave at very small scales, from water drops rolling on a lotus leaf to underwater oil repellency of fish scales. Fluid transport in confinements ranging from micrometer to nanometer/sub-nanometer sizes is critical to a number of cutting-edge applications such as 3-D printing, micro-pumps, lab-on-chip devices, micro-thrusters, nanofiltration devices, and optofluidic devices. In the future, it is likely that miniaturization will be the norm for mechanical systems in order to reduce cost and increase efficiency and portability. As a result, this technical committee will play a significant role by facilitating further innovation with both economic and social impacts.

Computational Fluid Dynamics Technical Committee

N. Zhang, chair; E. Merzari, co-chair.

CFDTC focuses on the field of computational fluid dynamics, especially integrating CFD tools with industrial design optimization. To that end, the technical committee addresses such topics as the development of CFD algorithms, advanced techniques for the numerical representation of fluid flow, quantification of numerical error, verification and validation, uncertainty of CFD, best practices and procedures for the accurate application of CFD, turbulence modeling and simulation, and other computational issues. CFD will continue to serve as a tool for industrial design optimization and as a powerful method for discovering new flow physics. Continuously increasing computational power brings us closer to achieving the goal of attaining high-fidelity simulations with optimal resolution.

The welcoming ceremony at the first joint ASME-JSME-KSME conference held at Hamamatsu, Japan, in July 2011.

Fluid Measurement & Instrumentation Technical Committee

F. Diez, chair; M. Woznik, co-chair.

Instrumentation and measurements in fluid mechanics are used to verify new theories and concepts, certify performance of fluid machinery, and obtain information on processes to guide and validate analytical and numerical models. With an emphasis on experimentation, FMITC focuses on issues related to flow measurements in both laboratory and field. While instrumentation technology and data processing capability have significantly improved in recent years, enabling time-resolved three-dimensional velocity measurements, there is no single tool to fit all processes. Industry is gradually moving towards flow based simulations and high performance computing, which means that over time the technical committee will place greater emphasis on carefully designed and conducted benchmark measurements for verification and validation of numerical models.

Going forward, FED will enjoy greater opportunities to engage with engineers worldwide through ASME's growing networks. On social media alone, ASME reaches more than 400,000 people globally via its Facebook and LinkedIn groups. The Division is looking forward to growing its community not only through conferences, journals, and training, but also via multimedia content including webinars, podcasts, and video. With greater engagement and increased knowledge dissemination, FED is poised to play a key role as ASME strives to advance technology in such areas as energy, healthcare, manufacturing, and transportation. Indeed, the fluids discipline lies at the crux of each of these fields.

LINEAR POSITIONING

PI, L.P., AUBURN, MASS.

The L-509 is a new compact linear stage positioning system designed to handle payloads of more than 20 lbs. Available with travel ranges of 26 mm (1 in.), 52 mm (2 in.), and 102 mm (4 in.) and a velocity of up to 20 mm/s, the L-509 is intended to provide unidirectional repeatability down to 0.1 microns. The stage is driven by a compact dc servo motor with a gearhead for high torques and resolution, while a two-phase direct-drive stepper motor is used for higher velocity. Encoder options include an integrated rotary sensor mounted on the motor shaft and an integrated linear version that provides direct position measurement not influenced by mechanical play or hysteresis in the drive train. The L-509 is designed for applications such as beamline systems, microscopy, semiconductor manufacturing, and photonics instrumentation.

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AUTUMN 2016

ASME TRAINING COURSES FOR ENGINEERS AND TECHNICAL PROFESSIONALS

JULY 2016 – NEW YORK, NY USA

PD395 API 579-1/ASME FFS-1 Fitness for Service 25-27 July

PD643 B31.3 Process Piping Code **ASME STANDARDS COURSE** 25-28 July

Visit: go.asme.org/newyork1

AUGUST 2016 – NEW YORK, NY USA

PD570 Geometric Dimensioning and Tolerancing Fundamentals 1 **ASME STANDARDS COURSE** 22-23 Aug

PD442 BPV Code, Section VIII, Division 1: Design and Fabrication of Pressure Vessels **ASME STANDARDS COURSE / TOP SELLER** 22-24 Aug

PD603 GD&T Combo Course *(combines PD570 and PD561)* **SAVE UP TO $825!** 22-25 Aug

PD443 BPV Code, Section VIII, Division 1 Combo Course **ASME STANDARDS COURSE** *(combines PD441 and PD442)* **SAVE UP TO $680!** **TOP SELLER** 22-26 Aug

PD561 Geometric Tolerancing Applications and Tolerance Stacks **TOP SELLER** 24-25 Aug

PD441 Inspections, Repairs and Alterations of Pressure Equipment **ASME STANDARDS COURSE** 25-26 Aug

Visit: go.asme.org/newyork2

SEPTEMBER 2016 – LAS VEGAS, NEVADA USA

PD100 Introduction to the Maintenance and Inspection of Elevators and Escalators 26-27 Sep

PD382 How to Predict Thermal-Hydraulic Loads on Pressure Vessels and Piping 26-27 Sep

PD475 The Engineering Manager: Engaging Today's Workforce 26-27 Sep

PD539 Bolted Joints and Gasket Behavior 26-27 Sep

PD561 Geometric Tolerancing Applications and Tolerance Stacks 26-27 Sep

PD769 Boiler Operation and Maintenance **ASME STANDARDS COURSE** 26-27 Sep

PD027 Heating, Ventilating and Air-Conditioning Systems: Sizing and Design 26-28 Sep

PD077 Failure Prevention, Repair and Life Extension of Piping, Vessels and Tanks **ASME STANDARDS COURSE** 26-28 Sep

PD190 ASME BPV Code, Section III, Division 1: Rules for Construction of Nuclear Facility Components **ASME STANDARDS COURSE** 26-28 Sep

PD389 Nondestructive Examination – Applying ASME Code Requirements (Section V) **ASME STANDARDS COURSE** 26-28 Sep

PD395 API 579-1/ASME FFS-1 Fitness-for-Service 26-28 Sep

PD506 Effective Management of Research and Development Teams and Organizations 26-28 Sep

PD513 TRIZ: The Theory of Inventive Problem Solving 26-28 Sep

PD618 Root Cause Analysis Fundamentals 26-28 Sep

PD635 ASME NQA-1 Quality Assurance Requirements for Nuclear Facility Applications **ASME STANDARDS COURSE** 26-28 Sep

PD685 Today's Workforce and Strategic Thinking Combo Course *(combines PD475 and PD676)* **SAVE UP TO $450!** 26-28 Sep

PD720 Layout of Process Piping Systems 26-28 Sep

PD763 Centrifugal Pumps: Testing, Design and Analysis 26-28 Sep

PD014 ASME B31.3 Process Piping Design **ASME STANDARDS COURSE / TOP SELLER** 26-29 Sep

PD184 BPV Code, Section III, Division 1: Rules for Construction of Nuclear Facility Components **ASME STANDARDS COURSE / TOP SELLER** 26-29 Sep

PD448 BPV Code, Section VIII, Division 2: Pressure Vessels **ASME STANDARDS COURSE** 26-29 Sep

PD603 GD&T Combo Course *(combines PD570 and PD561)* **SAVE UP TO $825!** 26-29 Sep

PD657 HVAC Systems and Chiller Performance Combo Course *(combines PD027 and PD387)* **SAVE UP TO $440!** 26-29 Sep

PD771 Boiler Operation and Maintenance with Inspection, Repairs and Alterations Combo Course **ASME STANDARDS COURSE** *(combines PD769 and PD770)* **SAVE UP TO $575!** 26-29 Sep

PD192 BPV Code, Section XI: Inservice Inspection of Nuclear Power Plant Components **ASME STANDARDS COURSE** 26-30 Sep

PD581 B31.3 Process Piping Design, Materials, Fabrication, Examination and Testing Combo Course **SAVE UP TO $575!** **TOP SELLER** 26-30 Sep

PD601 Bolting Combo Course *(combines PD539, PD386 and PD577)* **SAVE UP TO $1,275!** 26-30 Sep

PD602 Elevator and Escalator Combo Course *(combines PD100 and PD102)* 26-30 Sep

PD686 Layout of Process Piping Systems and Plant Design Using 3D CAD/CAE and Laser Scanning Technology Combo Course *(combines PD720 and PD721)* **SAVE UP TO $650!** 26-30 Sep

PD386 Design of Bolted Flange Joints 28 Sep

PD676 Strategic Thinking 28 Sep

PD570 Geometric Dimensioning and Tolerancing Fundamentals 1 **ASME STANDARDS COURSE** 28-29 Sep

PD766 Post Weld Heat Treatments in ASME Codes 28-29 Sep

PD770 Inspection, Repairs and Alterations of Boilers **ASME STANDARDS COURSE** 28-29 Sep

PD102 A17.1 Safety Code and A17.2 Inspection Requirements **ASME STANDARDS COURSE** 28-30 Sep

PD387 Understanding Chiller Performance, Operation and Economics 29 Sep

PD577 Bolted Joint Assembly Principles Per PCC-1-2013 **ASME STANDARDS COURSE** 29-30 Sep

PD591 Developing Conflict Resolution Best Practices 29-30 Sep

PD721 Plant Design and Project Design Using 3D CAD/CAE and Laser Scanning Technology 29-30 Sep

PD457 ASME B31.1 Process Piping Materials, Fabrication, Examination and Testing **ASME STANDARDS COURSE** 30 Sep

Visit: go.asme.org/lasvegas3

OCTOBER 2016 – ATLANTA, GEORGIA USA

PD107	Elevator Maintenance Evaluation	10-11 Oct
PD445	ASME B31 Piping Fabrication and Examination	10-11 Oct
PD692	Communication Essentials for Engineers	10-11 Oct
PD706	Inline Inspections for Pipelines	10-11 Oct
PD268	Fracture Mechanics Approach to Life Predictions	10-12 Oct
PD370	ASME B31.8 Gas Transmission and Distribution Piping Systems **ASME STANDARDS COURSE**	10-12 Oct
PD584	Centrifugal Compressor Performance Analysis	10-12 Oct
PD683	Probabilistic Structural Analysis, Design and Reliability-Risk Assessment	10-12 Oct
PD711	ASME NQA-1 and DOE Quality Assurance Rule 10 CFR 830 **ASME STANDARDS COURSE**	10-12 Oct
PD765	Gas Turbine Engines – Controlling Pollutants	10-12 Oct
PD359	Practical Welding Technology	10-13 Oct
PD394	Seismic Design and Retrofit of Equipment and Piping	10-13 Oct
PD777	Pipe Sizing, Pump Selection and Water Hammer **NEW!**	10-13 Oct
PD621	Grade 91 and Other Creep Strength Enhanced Ferritic Steels **ASME STANDARDS COURSE**	12-14 Oct
PD449	Mechanical Tolerancing for Six Sigma	13-14 Oct

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OCTOBER 2016 – BARCELONA, SPAIN

MasterClass Courses – Pressure Tech and Piping

MC113	Techniques and Methods Used in API 579-1/ASME FFS-1 for Advanced Fitness-for-Service (FFS) Assessments *	17-18 Oct
MC147	Advanced Application of ASME Boiler and Pressure Vessel Code, Section VIII, Division 1: Construction Requirements * **NEW!**	17-18 Oct
MC127	Bases and Application of Design Requirements for High Pressure Vessels in ASME Code, Section VIII, Division 3 *	17-18 Oct
MC110	Bases and Application of Piping Flexibility Analysis to ASME B31 Codes *	17-18 Oct
MC142	Integrity Management of Natural Gas Pipelines Using ASME B31.8S Standard *	17-18 Oct
MC141	Pipeline Stress Corrosion Cracking Management	17-18 Oct
MC132	Run-or-Repair Operability Decisions for Pressure Equipment and Piping Systems *	18-19 Oct
MC125	Impact Testing and Toughness Requirements for Pressure Vessels: ASME Section VIII, Divisions 1&2 * **NEW!**	19 Oct
MC121	Design by Analysis Requirements in ASME Boiler and Pressure Vessel Code, Section VIII, Division 2: Alternative Rules *	19-20 Oct
MC140	Pipeline Defect Assessment	19-20 Oct
MC143	Pipeline Integrity Issues, Migration, Prevention and Repair Using ASME B31.8S Standard *	19-20 Oct
MC111	Piping Vibration Causes and Remedies – A Practical Approach *	19-20 Oct
MC144	Integrity Assessment and Repair of Process Piping and Tanks *	20-21 Oct
MC112	Materials and Design for High Temperatures *	20-21 Oct
MC123	Fatigue Analysis Requirements in ASME BPV Code, Section VIII, Division 2 – Alternative Rules * **NEW!**	21 Oct
MC117	Piping Failures – Causes and Prevention *	21 Oct

Public Courses Also Available

PD723	ASME B31.4 & B31.8, Liquids and Gas Pipelines	17-19 Oct
PD577	Bolted Joint Assembly Principles per PCC-1-2013	19-20 Oct
PD706	Inline Inspections for Pipelines	19-20 Oct

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OCTOBER 2016 – HOUSTON, TEXAS USA

PD391	ASME B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids **ASME STANDARDS COURSE**	24-25 Oct
PD624	Two-Phase Flow and Heat Transfer	24-25 Oct
PD146	Flow-Induced Vibration with Applications to Failure Analysis	24-26 Oct
PD410	Detail Engineering of Piping Systems	24-26 Oct
PD442	BPV Code, Section VIII, Division 1: Design and Fabrication of Pressure Vessels **ASME STANDARDS COURSE / TOP SELLER**	24-26 Oct
PD583	Pressure Relief Devices: Design, Sizing, Construction, Inspection and Maintenance **ASME STANDARDS COURSE**	24-26 Oct
PD778	Microbiologically Influenced Corrosion (MIC) in Engineering Terms **NEW!**	24-26 Oct
PD764	Introduction to Hydraulic Systems for Industry Professionals	24-27 Oct
PD013	ASME B31.1 Power Piping Code **ASME STANDARDS COURSE**	24-28 Oct
PD432	Turbo Machinery Dynamics: Design and Operation	24-28 Oct
PD443	BPV Code, Section VIII, Division 1 Combo Course **ASME STANDARDS COURSE** *(combines PD441 and PD442)* **SAVE UP TO $680!** **TOP SELLER**	24-28 Oct
PD665	BPV Code, Section I: Power Boilers **ASME STANDARDS COURSE**	24-28 Oct
PD115	The Gas Turbine: Principles and Applications	27-28 Oct
PD606	ASME NQA-1 Requirements for Computer Software Used in Nuclear Facilities **ASME STANDARDS COURSE**	27-28 Oct
PD441	Inspections, Repairs and Alterations of Pressure Equipment **ASME STANDARDS COURSE**	27-28 Oct
PD679	Selection of Pumps and Valves for Optimum System Performance	24-27 Oct

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Pressure Technology Series – HOUSTON, TEXAS USA

MasterClass Series

MC110	Bases and Application of Piping Flexibility Analysis to ASME B31 Codes	31 Oct-1 Nov
MC113	Techniques and Methods Used in API 579-1/ASME FFS-1 for Advanced Fitness-For-Service Assessments	31 Oct-1 Nov
MC127	Bases & Application of Design Requirements for High Pressure Vessels in ASME Code, Section VIII, Div. 3	31 Oct-1 Nov
MC147	Advanced Application of ASME Boiler and Pressure Vessel Code Section VIII Division 1 Construction Requirements **NEW!**	31 Oct-1 Nov
MC150	Fracture Mechanics and other Methods for Fatigue and Fracture Analysis of Pressure Equipment **NEW!**	31 Oct-1 Nov
MC132	Run-or-Repair Operability Decisions for Pressure Equipment and Piping Systems	1-2 Nov
MC125	Impact Testing and Toughness Requirements for Pressure Vessels; ASME Section VIII, Divisions 1&2 **NEW!**	2-Nov
MC111	Piping Vibration Causes and Remedies – A Practical Approach	2-3 Nov
MC121	Design by Analysis Requirements in ASME Boiler and Pressure Vessel Code Section VIII, Division 2 – Alternative Rules	2-3 Nov
MC112	Materials and Design for High Temperatures	3-4 Nov
MC117	Piping Failures - Causes and Prevention	4-Nov
MC123	Fatigue Analysis Requirements in ASME BPV Code Section VIII, Division 2 – Alternative Rules **NEW!**	4-Nov

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Pipeline Technology & Standards Training Week – HOUSTON, TEXAS USA

MasterClass Series

MC139	Onshore Pipeline Design and Construction – A Practical Approach	31 Oct-1 Nov
MC141	Pipeline Stress Corrosion Cracking Management **NEW!**	31 Oct-1 Nov
MC142	Integrity Management of Natural Gas Pipelines Using ASME B31.8S Standard **NEW!**	31 Oct-1 Nov
MC140	Pipeline Defect Assessment	2-3 Nov
MC143	Pipeline Integrity Issues, Mitigation, Prevention and Repair using ASME B31.8S Standard **NEW!**	2-3 Nov
MC144	Integrity Assessment and Repair of Process Piping and Tanks **NEW!**	3-4 Nov

Public Courses Also Available

PD359	Practical Welding Technology	31 Oct-3 Nov
PD643	ASME B31.3 Process Piping Code	31 Oct-3 Nov
PD723	ASME B31.4 & B31.8, Liquids and Gas Pipelines	31 Oct-2 Nov
PD706	Inline Inspections for Pipelines	2-3 Nov
PD577	Bolted Joint Assembly Principles per PCC-1-2013	3-4 Nov

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NOVEMBER 2016 – SAN DIEGO, CALIFORNIA USA

PD539	Bolted Joints and Gasket Behavior	14-15 Nov
PD231	Shock and Vibration Analysis	14-16 Nov
PD389	Nondestructive Examination – Applying ASME Code Requirements (Section VI) **ASME STANDARDS COURSE**	14-16 Nov
PD506	Effective Management of Research and Development Teams and Organizations	14-16 Nov
PD571	The Taguchi Design of Experiments for Robust Product and Process Designs	14-16 Nov
PD619	Risk and Reliability Strategies for Optimizing Performance	14-16 Nov
PD394	Seismic Design and Retrofit of Equipment and Piping	14-17 Nov
PD448	ASME BPV Code, Section VIII, Division 2: Alternative Rules – Design and Fabrication of Pressure Vessels **ASME STANDARDS COURSE**	14-17 Nov
PD603	GD&T Combo Course *(combines PD570 and PD561)* **SAVE UP TO $825!**	14-17 Nov
PD622	ASME BPV Code: Plant Equipment Requirements **ASME STANDARDS COURSE**	14-17 Nov
PD691	Fluid Mechanics, Piping Design, Fluid Transients and Dynamics	14-17 Nov
PD601	Bolting Combo Course *(combines PD539, PD386 and PD577)* **SAVE UP TO $1,275!**	14-18 Nov
PD570	Geometric Dimensioning and Tolerancing Fundamentals 1 **ASME STANDARDS COURSE**	14-15 Nov
PD386	Design of Bolted Flange Joints	16 Nov
PD561	Geometric Tolerancing Applications and Tolerance Stacks	16-17 Nov
PD575	Comprehensive Negotiating Strategies®: Engineers and Technical Professionals	17-18 Nov
PD577	Bolted Joint Assembly Principles Per PCC-1-2013 **ASME STANDARDS COURSE**	17-18 Nov

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NOVEMBER 2016 – ORLANDO, FLORIDA USA

PD100	Introduction to the Maintenance and Inspection of Elevators and Escalators	28-29 Nov
PD475	The Engineering Manager: Engaging Today's Workplace	28-29 Nov
PD531	Leadership and Organizational Management	28-29 Nov
PD567	Design, Analysis and Fabrication of Composite Structure, Energy and Machine Applications	28-29 Nov
PD673	ASME BPV Code, Section 1: Power Boilers	28-29 Nov
PD467	Project Management for Engineers and Technical Professionals	28-30 Nov
PD513	TRIZ: The Theory of Inventive Problem Solving	28-30 Nov
PD515	Dimensioning and Tolerancing Principles for Gages and Fixtures	28-30 Nov
PD596	Developing a 10-Year Valve Inservice Testing Program	28-30 Nov
PD685	The Engineering Manager: Engaging Today's Workforce and Strategic Thinking Combo Course *(combines PD475 and PD676)* **SAVE UP TO $450!**	28-30 Nov
PD702	Process Safety and Risk Management for Engineers and Supervisors	28-30 Nov
PD620	Core Engineering Management	28 Nov - 1 Dec
PD632	Design in Codes, Standards and Regulations for Nuclear Power Plant Construction **ASME STANDARDS COURSE**	28 Nov – 1 Dec
PD675	ASME NQA-1 Lead Auditor Training	28 Nov - 1 Dec
PD602	Elevator and Escalator Combo Course *(combines PD100 and PD102)*	28 Nov – 2 Dec
PD629	Project Management Combo Course *(combines PD467 and PD496)* **SAVE UP TO $650!**	28 Nov - 2 Dec
PD676	Strategic Thinking	30 Nov
PD690	Economics of Pipe Sizing and Pump Selection	30 Nov – 1 Dec
PD102	A17.1 Safety Code and A17.2 Inspection Requirements **ASME STANDARDS COURSE**	30 Nov – 2 Dec
PD496	Preparing for the Project Management Professional Certification Exam	1-2 Dec
PD595	Developing a 10-Year Pump Inservice Testing Program	1-2 Dec

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DECEMBER 2016 – AMSTERDAM, THE NETHERLANDS

PD634	Comparison of Global Quality Assurance and Management Systems Standards Used for Nuclear Application **ASME STANDARDS COURSE**	12-13 Dec
PD442	ASME BPV Code, Section VIII, Division 1: Design and Fabrication of Pressure Vessels **ASME STANDARDS COURSE**	12-14 Dec
PD615	ASME BPV Code, Section III, Division 1: Class 1, 2 & 3 Piping Designs **ASME STANDARDS COURSE**	12-14 Dec
PD635	ASME NQA-1 Quality Assurance Requirements for Nuclear Facility Applications **ASME STANDARDS COURSE**	12-14 Dec
PD645	ASME BPV Code, Section IX: Welding, Brazing and Fusing Qualifications **ASME STANDARDS COURSE**	12-14 Dec
PD714	ASME BPV Code, Section VIII, Division 2: Alternative Rules – Design and Fabrication of Pressure Vessels **ASME STANDARDS COURSE**	12-14 Dec
PD616	API 579-1/ASME FFS-1 Fitness-for-Service Evaluation	12-15 Dec
PD642	ASME B31.1 Power Piping Code **ASME STANDARDS COURSE**	12-15 Dec
PD643	ASME B31.1 Process Piping Code **ASME STANDARDS COURSE**	12-15 Dec
PD675	ASME NQA-1 Lead Auditor Training	12-15 Dec

PD716	ASME BPV Code, Section 1: Power Boilers **ASME STANDARDS COURSE**	12-15 Dec
PD443	ASME BPV Code, Section VIII, Division 1 Combo Course *(combines PD441 and PD442)* **SAVE UP TO €680!** **ASME STANDARDS COURSE**	12-16 Dec
PD684	ASME BPV Code, Section III, Division 1: Rules for Construction of Nuclear Facility Components	12-16 Dec
PD441	Inspections, Repairs and Alterations of Pressure Equipment	15-16 Dec

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DECEMBER 2016 – AMSTERDAM, THE NETHERLANDS

MasterClass Course

MC135	Using ASME Codes to Meet the EU Pressure Equipment Directive (PED)	14-16 Dec

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DECEMBER 2016 – NEW ORLEANS, LOUISIANA USA

PD769	Boiler Operation and Maintenance	12-13 Dec
PD539	Bolted Joints and Gasket Behavior	12-13 Dec
PD382	How to Predict Thermal-Hydraulic Loads on Pressure Vessels and Piping	12-13 Dec
PD395	API 579-1/ASME FFS-1 Fitness-for-Service Evaluation	12-14 Dec
PD370	ASME B31.8 Gas Transmission and Distribution Piping Systems	12-14 Dec
PD615	ASME BPV Code, Section III, Division 1: Class 1, 2 & 3 Piping Design	12-14 Dec
PD190	ASME BPV Code, Section III, Division 1: Rules for Construction of Nuclear Facility Components	12-14 Dec
PD442	ASME BPV Code, Section VIII, Division 1: Design and Fabrication of Pressure Vessels	12-14 Dec
PD410	Detail Engineering of Piping Systems	12-14 Dec
PD077	Failure Prevention, Repair and Life Extension of Piping, Vessels and Tanks	12-14 Dec
PD146	Flow-Induced Vibration with Applications to Failure Analysis	12-14 Dec
PD633	Overview of Nuclear Codes and Standards for Nuclear Power Plants	12-14 Dec
PD644	Advanced Design and Construction of Nuclear Facility Components Per BPV Code, Section III	12-15 Dec
PD771	Boiler Operation and Maintenance with Inspection, Repairs and Alterations Combo Course *(combines PD769 and PD770)*	12-15 Dec
PD184	BPV Code, Section III, Division 1: Construction of Nuclear Facility Components	12-15 Dec
PD679	Selection of Pumps and Valves for Optimum System Performance	12-15 Dec
PD772	Electrohydraulic Components and Systems	12-15 Dec
PD013	ASME B31.1 Power Piping Code	12-16 Dec
PD443	BPV Code, Section VIII, Division 1 Combo Course **ASME STANDARDS COURSE** *(combines PD441 and PD442)* **SAVE UP TO $680!** **TOP SELLER**	12-16 Dec
PD441	Inspections, Repairs and Alterations of Pressure Equipment	15-16 Dec
PD601	Bolting Combo Course *(combines PD539, PD386 and PD577)*	12-16 Dec
PD766	Post Weld Heat Treatments in ASME Codes	13-14 Dec
PD386	Design of Bolted Flange Joints	14-Dec
PD770	Inspection, Repairs and Alterations of Boilers	14-15 Dec
PD577	Bolted Joint Assembly Principles Per PCC-1-2013	15-16 Dec

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ASME Pressure Vessels, Piping and GDT Training Events

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AVAILABLE THIS JULY 2016

API 579-1/ASME FFS-1 Fitness-for-Service Evaluation (PD395)	25-27 July
B31.1 Process Piping Code (PD643)	25-28 July

Visit: go.asme.org/newyork1

AVAILABLE THIS AUGUST 2016

Geometric Dimensioning and Tolerancing Fundamentals 1 (PD570)	22-23 August
BPV Code, Section VIII, Division 1: Design & Fabrication of Pressure Vessels (PD442)	22-24 August
Geometric Dimensioning & Tolerancing Combo Course *(combines PD570 and PD561)* (PD603)	22-25 August
BPV Code, Section VIII, Division 1 Combo Course *(combines PD441 and PD442)* (PD443)	22-25 August
Geometric Tolerancing Applications and Tolerance Stacks (PD561)	24-25 August
Inspections, Repairs and Alterations of Pressure Equipment (PD441)	25-26 August

Visit: go.asme.org/newyork2

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PINCH VALVE

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The NPV series miniature pinch valve is a solenoid-operated device designed to control the flow of fluids in a tube. By energizing the solenoid, the plunger within the valve is extended or retracted, which closes or opens the tube. The valve returns to its original state when the solenoid is de-energized. The valve is offered in four sizes and in pressure ranges up to 30 psig. Each valve comes with a 12-inch length of medical/laboratory grade silicone tubing. The NPV series miniature pinch valve is intended for applications such as waste water, medical devices, chemical, food and beverage equipment, ceramic/glass/plastic, and bulk and solids handling.

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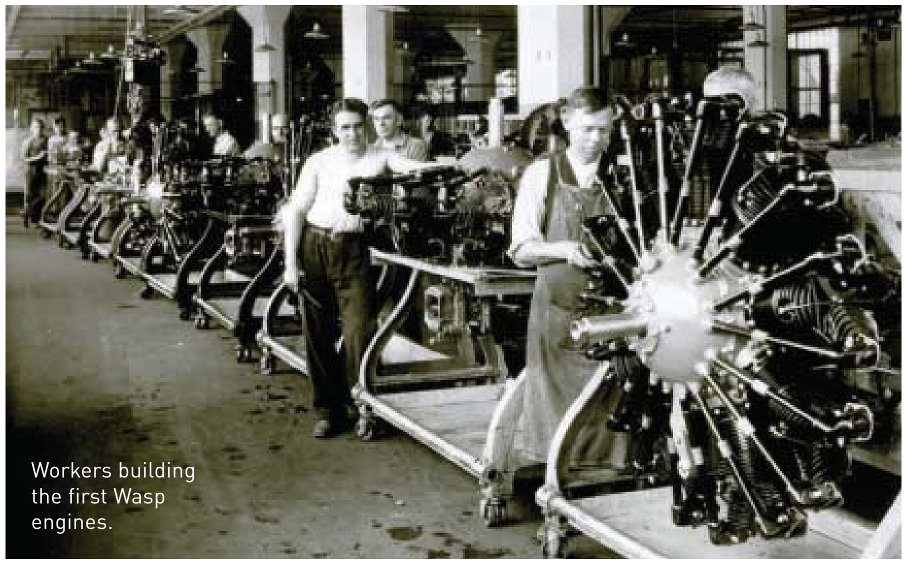
PRATT & WHITNEY WASP ENGINE NAMED LATEST ASME LANDMARK

Pratt & Whitney's R-1340 Wasp radial engine was recognized by ASME for its technical significance in engineering and aviation on May 4 when the Society designated it as a Historic Mechanical Engineering Landmark at a ceremony held at the New England Air Museum in Windsor Locks, Conn.

The designation ceremony drew a crowd of approximately 100 people, including Pratt & Whitney executives, members of the ASME Hartford Section executive committee, Lee Langston of the ASME History and Heritage Committee, and ASME President Julio Guerrero, who presented the ASME landmark plaque to Pratt & Whitney President Bob Leduc.



Workers building the first Wasp engines.

Photo: Pratt & Whitney

The Wasp engine is one of nearly 260 technological innovations from around the world to be designated as an ASME landmark.

The Pratt & Whitney Wasp R-1340 engine, which was the first engine designed and built by the company after it was founded in 1925, was a significant improvement to the radial aircraft engine design. The engine helped make commercial aviation economically viable and was used to power U.S. military aircraft during World War II.

The R-1340 Wasp was the first in a series of Wasp engines, which included the Twin Wasp, the Wasp Junior, the Double Wasp, and the Wasp Major. Between 1926 and 1960, Pratt & Whitney produced nearly 35,000 R-1340 Wasp A radial engines for approximately 100 different aircraft models. Each engine generated between 425 and 600 hp.

"The Wasp engine is a most deserving addition to ASME's roster of mechanical engineering landmarks," Guerrero said. "The Wasp engine is an integral part of the proud legacy of one of the world's leading technology firms, while also playing a role in the progress of commercial aviation."

For more information on the ASME Historic Mechanical Engineering Landmarks Program, and to see the complete list of ASME landmarks, visit www.asme.org/about-asme/who-we-are/engineering-history/landmarks. ME

CAL STATE NORTHRIDGE TRIUMPHS AT ASME

A student team from California State University, Northridge took top honors at the Human Powered Vehicle Challenge West in April. Cal State Northridge beat out 31 other teams, including squads from perennial HPVC heavyweights such as the Rose-Hulman Institute of Technology and Franklin W. Olin College of Engineering.

This entry from the University of Akron won the men's speed event at HPVC West.

The three-day ASME competition was sponsored by the Santa Clara Valley Section and held at three locations in Santa Clara, Calif. The design event was held on April 22 at Santa Clara University, and the male and female drag races were held the following day at San Jose State University. The final event, a two-and-a-half hour endurance race, took place April 24 at the Santa Clara Valley Fairgrounds.

In addition to placing first in the overall competition, Cal State Northridge's entry took first place in the design, innovation and women's speed race categories, as well as second place in the men's speed race and third place in the

ASME TEAMS WITH MANCEF FOR NANO CONFERENCE

ASME is partnering with the Micro and Nano Technology Commercialization Education Foundation to stage the Commercialization of Micro, Nano and Emerging Technologies conference, to be held from Aug. 28 to 31 at the JW Marriott Houston in Houston, Tex.

The COMS conference is intended to help entrepreneurs bring their research to market, find new customers, and interact with investors, suppliers and other business people. MANCEF has been holding the COMS conference for more than 20 years.

COMS 2016 is intended to be a hands-on, practical meeting that will provide researchers with insight on how to bring their products to market and identify customers and development partners. The conference series is regarded as being among the leading global events focusing on the scale-up of micro, nano, and emerging technologies.

Panelists and speakers currently scheduled to appear at COMS 2016 include Mauro Ferrari, CEO and president of the Houston Methodist Research Institute; Michael Gaitan from the National Institute of Standards and Technology's Physical Measurement Laboratory; Michael Meador, director of the National Science and Technology Council; and Mark Zdeblick, chief technology officer for Proteus.

Rainer Harms of the Netherlands Institute for Knowledge Intensive Entrepreneurship at the University of Twente is also scheduled to speak.

The conference will feature two special competitions.

The Young Technology Award Contest and Boot Camp will provide an informal setting for attendees involved in early-stage, high-tech entrepreneurial startups to pitch their ideas to experts and receive practical advice and feedback. The Student Poster Competition will give students the chance to present their nanoscience and emerging technology research to an audience of business and technology leaders.

For more information on COMS 2016, or to register for the conference, visit www.asme.org/events/coms. ME

HPVC WEST

endurance event.

Other big winners at this year's HPVC West included the team from the University of Akron, which placed second overall and first in the men's speed category, and Utah State University, which placed third overall, first in the endurance race and second in the innovation category.

To see the complete list of winners at the HPVC West event, visit the Human Powered Vehicle Challenge Community page on ASME.org. ME

RING ON

A high school student's science project is now helping people with Parkinson's disease find better treatment

Utkarsh Tandon is a Silicon Valley executive who has created a marketable invention that has met its first-round funding goals. Tandon is also a sophomore at Cupertino High School.

Tandon's youth might be extraordinary for an inventor, but the challenges he faces are similar to those confronted by many engineers working to take their research or product to the next level.

His product, called OneRing, is intended to assist patients suffering from Parkinson's disease. The ring captures information on tremors and other motor symptoms, algorithmically classifies the movement patterns by severity, and sends the information to a server. From there it's sent to a mobile device in the form of a daily report that features time-stamped analytics of the patient's movements. A doctor can use the data to fine-tune a patient's medication and choose other treatments.

Tandon is preparing 15 rings for patients at the Parkinson's Institute and Clinical Center in Sunnyvale, Calif., where he had worked as a volunteer. Feedback from doctors and patients will enable him refine the device.

"When I'm done it will be cheaper, it will be faster, and it will look a lot better," Tandon said. "To do that, I have to overcome some roadblocks with mechanical engineering."

Tandon became interested in Parkinson's when he was 10 and happened upon a YouTube clip of Muhammad Ali lighting the torch at the 1996 Summer Olympics. "It made me want to know how someone can go through the entire day with that type of shaking," he said. "That started the fire in me."

By the time he entered high school, Tandon was proficient in programming, website design, artificial intelligence, machine learning, and app development. He looked for as much information as he could find on Parkinson's disease and came across a comprehensive data set the Michael J. Fox Foundation had compiled.

"That gave me the benchmark for my experiment," he said.

The project, a machine learning algorithm model for collecting and classifying data of Parkinson's disease patients, went on to win awards at the Synopsys Science and Technology Championship, a county science fair, and the California State Science Fair.

Tandon's first prototypes were clunky plastic devices manufactured via a mail-order 3-D printing company. For the trial at the Parkinson's Institute, he redesigned the device as a sleek metal ring with an adjustable band that sports an accelerometer for monitoring the shaking hand of a Parkinson's patient. Tandon also created a smarter and more powerful algorithm for modeling the patient's motor symptoms. A low-energy Bluetooth transmitter wirelessly relays the data, while a USB cable charges the device. He's also designing a smaller circuit board and researching new integrated circuit chips for processing and packaging the data.

To pay for the new rings, Tandon will use the $3,590 he raised through a Kickstarter campaign, which he launched shortly after giving a presentation and participating in a press conference before 700 people at this year's Consumer Electronics Show.

"Based on the number of people in the audience, I had a feeling the Kickstarter campaign was going to do well," he said. ME

JEFF O'HEIR

Tandon used Kickstarter funds to replace this prototype with a sleeker one-size-fits-all design.

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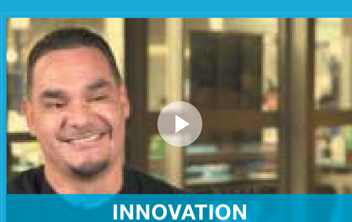

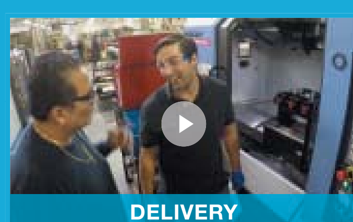

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