The University of Iowa

EDITOR: Christine Czarnecki

AIChE Fall 2018

Advisor's Corner

By: Prof. David Murhammer, Professor and AIChE Student Chapter Advisor

Greetings to Hawkeye Chemical Engineers!! This Fall 2018 issue of our AIChE Student Chapter Newsletter begins with an article about our student chapter's attendance at the AIChE Annual Student Conference held in Pittsburgh, PA. At this conference our students competed in the ChemE Jeopardy Competition and gave design-related and research presentations. Furthermore, our student chapter and students received many awards as noted in the article. It was definitely a great year for University of Iowa Chemical Engineering students!

This issue also contains articles about our ChemE Car, the fall Halloween-themed Kids Day Camp, a student co-op at Cargill and an internship at NASA. The remainder of this newsletter contains two topical papers written by students in the sophomore-level Process Calculations course and five articles written by students in the junior-level Chemical Process Safety course. The Process Calculations articles discuss a sustainable alternative to nitrogen fertilizers and the use of noble gases by frigid water divers. The Chemical Process Safety papers include three papers related to chemical plant security and two articles about chemical regulation that were course requirements. Note that this was the first time that the safety course was taken in the fall semester of the junior year under our new curriculum; this course was previously taken during the spring semester of the junior year.

Any comments about the newsletter contact can be sent to me at david-murhammer@uiowa.edu.

University of Iowa American Institute of Chemical Engineers

INSIDE THIS ISSUE:

AIChE
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National AIChE Student Conference

On the weekend of October 28th—November 2nd, the University of Iowa student chapter of the American Institute of Chemical Engineers took a trip to Pittsburgh, PA for the National Student Conference. The conference featured several events, including graduate school seminars, professional development seminars, student research presentations, etc. Numerous students from the University of Iowa participated in the poster and paper presentations. The conference also held an award ceremony, where we won several awards. Following is a list of the national awards received by the University of Iowa:

- 2017-18 AIChE Outstanding Student Chapter Award (14th consecutive year and 25th of the last 26 years)
- 2018-19 Donald F. & Mildred Topp Othmer National Scholarship Award ($1000): Ojas Pradhan
- 2017-18 Donald F. Othmer Sophomore Academic Excellence Award: Michael Leyden
- Chem-E Jeopardy Competition Megan Jones, Zachary Kazmer, Madison Murhammer, Elizabeth Zimmerman - won preliminary round and lost in the semi-final round.
- 2018 Safety & Health Division National Design Competition Award for Inherently Safer Design: Madison Murhammer, Jackie Ricke, Rachel Seibel, Elizabeth Zimmerman
- 2018 Jack Wehman SAChE Team Design Award (SAChE Team Award for Overall Safety): Madison Murhammer, Jackie Ricke, Rachel Seibel, Elizabeth Zimmerman
- 2018 AIChE Student Design Competition – Team Category: Madison Murhammer, Jackie Ricke, Rachel Seibel, Elizabeth Zimmerman (Honorable Mention)
- 2018 AIChE Student Design Competition – Individual Category: Bjorn Blomquist (First Place)
- 2018 AIChE Undergraduate Student Poster Competition, General Engineering and Engineering Education Category: Andrew Textor (2nd place)

ChemE Car—Michael Leyden

ChemE Car is a student organization dedicated to constructing a moving car powered by a chemical reaction. It is comprised of sophomores, juniors and seniors majoring in chemical engineering. This semester ChemE Car has made great strides; the goal for this year is to produce a functioning car to compete at the regional AIChE conference at the Missouri University of Science and Technology. At the competition, each car is allowed two attempts to travel a specified distance while carrying a required amount of water. This year's car will be powered by a lead acid battery and utilize an iodine clock reaction as a stopping mechanism.

Like standard car batteries, electricity will be generated by submersing a lead and a lead oxide electrode in a dilute sulfuric solution. An oxidation reaction occurs at the lead electrode forming lead (II) sulfate. The electrons travel towards the lead oxide plate, powering the motor, and leading to the reduction of lead (IV) oxide to lead sulfate.

The purpose of the iodine clock is to make the car stop at the specified distance. In an iodine clock reaction, a clear solution is initially created, but after a set amount of time the solution turns black. This will prevent light from hitting a photoresistor and shut down the motor. For the iodine clock, two separate reactions are being tested. Each reaction is better suited for a specific time range. The first reaction utilizes potassium iodate reacting with sodium metabisulfite and corn starch; this is well suited for times between 10 to 60 seconds. The second reaction utilizes hydrogen peroxide, potassium iodide, corn starch, sodium thiosulfate and sulfuric acid. This second mechanism is better suited for longer times between 60 to 120 seconds. To vary the times, trials were conducted varying the reactant concentrations. From the data gathered, a standard curve can be created to be used to determine the exact combination to yield the time needed to complete the task.

The group is experimenting more with 3D printing this year. The battery cell and iodine clock vessel are all being 3D printed. There are also discussions of 3D printing the chassis for the car entirely. Overall, the group has made progress this semester. If you would like to join ChemE car, feel free to contact Michael Leyden.

Fall 2018 Kids Day Camp—Annemarie Weber, Mackenzie Cady, Hannah Wasserkrug

On Sunday, October 21st, the University of Iowa's AIChE student chapter hosted their semi-annual Kid's Day Camp for kids from Kindergarten through fifth grade. The camp's focus is to give a basic level introduction of chemical engineering by doing simple chemistry and science experiments. The children were able to participate in seven different activities that went along with the Halloween theme. Four of those activities involved science/engineering skills that the children began to build. The first experiment consisted of figuring their way through a haunted maze. The participants were able to use problem solving skills to help them get through the life-size maze that was made out of masking tape on the floor. The next activity that the children participated in was making a catapult. Each participant received 7 popsicle sticks, a handful of rubber bands and a plastic spoon to build their catapults. After finishing their designs, the kids were able to test it out by flinging plastic spiders at a spider web to try to make them stay. This activity allowed them to learn how every action has an equal and opposite reaction. By pulling back the spoon and releasing it, the spoon would quickly go back to its original position, flinging the spider into the air. Following the Halloween catapult, it was finally snack time. For snack the children were allowed to make dirt cups, which consisted of chocolate pudding, vanilla pudding dyed green, crushed Oreo crackers, gummy worms, and pumpkin candy corn. The alternating layers of chocolate pudding and crushed Oreo crackers allowed the children to create their own grave yards, with the gummy worms and the candy corn pumpkins adding an extra touch to them. Then, the green vanilla pudding was used to re-create Frankenstein's head, with brown sprinkles as his hair, the pumpkin candy corn as his eyes, and the gummy worm as his mouth. After snack time, the participants spend the majority of the left-over time making slime. The slime was made using Elmer's glue, contact solution, baking soda, and water. This activity allowed the kids to learn how different ingredients can come together to make something really cool. We look forward to the next Kid's Day Camp, which will take place in the Spring of 2019, with an Earth Day theme.

Co-op at Cargill—Andrea Birtles

This fall, I had to opportunity to work with Cargill as a Production Management Engineer Co-op. I worked at a global edible oils solutions facility located in Sidney, Ohio. We are a full process facility, with 3 different departments. Soybeans are shipped into our Crush department, where they undergo a full crush and extraction process to get the oil from the bean. The Refinery is where the oil gets cleaned, and different blends of different kinds of oils are created. The refinery also receives shipments of different oil types to create the blends (Soy Salad, Corn, Vegetable, Canola, Sunflower, and different types of Shortening). The last department is the Packaging, where I have been working over my 7-month experience. We package oil among our 6 production lines and send it out. We are attached to our fully automated warehouse, which has capacity of over 22,000 pallets of products.

I had the opportunity to work on a few different projects during my time with Cargill. One of my biggest projects focuses on performance loss for our Jug-In-a- Box (JIB) production lines. When the line goes down for over 45 seconds, operators are prompted to identify what the issue was. If the line is down for less than 45 seconds, it is grouped as Performance Loss. After performance loss spiked in June, I spent about an hour a day for 2 months observing the two lines and identifying what exactly is causing these micro stops. I identified issues I saw on the line and communicated my findings to supervisors, leads and operators. The biggest issue I found was that the capper was waiting on JIBs to finish filling, which didn't allow us to reach our output goal of 23 JIBs/ minute. I am now in the second phase of this project, where I am using Pi Process Book and PI Data Link to track all of the cycle times at the filler during every run for all of our different products. Before the end of my co-op, I will identify standard cycle times that the line should be running at for all 5 of the different oil types that run on the JIB line.

Another big project I have been working on is compiling data for the packaging department's weekly metrics. For each production line, I look at different factors, including global efficiencies, equipment breakdown hours, overfill levels, top downtimes, and how much flush is used (to clear out the line of one product before running a different one). I talk with supervisors daily and find out what exactly is causing issues if we did not reach our goal efficiency that week and create trends that allow us to look at the different factors over a long period of time.

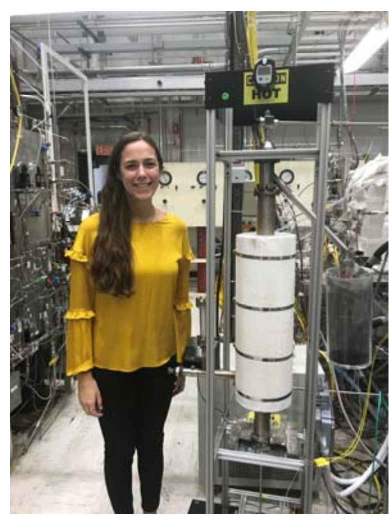
Other day to day tasks I have includes leading our 8 am production meeting, pulling and distributing reports for all leads and supervisors, updating one-point-lessons, and other various projects. Cargill has given me the opportunity to learn how to work with different departments of people, be an independent worker, and taking initiative during all different situations. I truly have enjoyed my time in Ohio and thank Cargill for my wonderful experience!

NASA Academy Internship—Emmy Moore

In April 2018, I received a call from the Iowa Space Grant Consortium offering me an internship with NASA in Huntsville, Alabama. I couldn't believe it – I was going to work for NASA! It was a dream come true. At the end of May, I packed up and made the drive to Huntsville and moved into the dorms at the University of Alabama – Huntsville, about a twenty-minute drive from the Marshall Space Flight Center on Redstone Arsenal, where I would be working.

I was a part of the NASA Academy, which meant I would have to participate and engage in various activities outside of my 8 – 5 project work. The Academy is meant to be an immersive and intense summer experience, and it certainly was. I attended lectures and lunches with notable NASA leaders and other leaders of the local aerospace companies, volunteered at the Space and Rocket Center, attended weekly academy meetings, and went on trips to three other NASA centers.

My project for the summer was in the Environmental Control and Life Support Systems Development Branch, where I worked on oxygen recovery for long-duration, manned exploration missions outside of low-Earth orbit. Currently, on the International Space Station (ISS), the Sabatier process is used to recycle metabolic carbon dioxide back into oxygen for the astronauts to breathe. This process uses CO_2 and H_2 to produce H_2O and CH_4; the methane is wasted to space, and therefore the hydrogen cannot be recycled back through the system. For that reason, the ISS requires resupply from Earth. Outside of low-Earth orbit, resupply is not an option. For that reason, for my project, I worked with the Bosch process, which has a 100% maximum theoretical O_2 recovery from CO_2. The system I tested was a Series-Bosch system, and included a reverse water-gas shift reactor (RWGSR), a carbon formation reactor (CFR), a water separation assembly (WSA), a carbon dioxide extraction membrane, and a hydrogen extraction membrane. My project centered on the CFR portion of the system, but it must be integrated with the other pieces of the system for performance testing. Specifically, my responsibility was to test a CFR from UMPQUA Research Company, determine its ability to create solid carbon and water vapor, and evaluate its overall performance. In doing so, I greatly strengthened my problem solving and trouble shooting skills, as we ran into many issues ranging from air leaks to lines clogged with solid carbon. It was an amazing experience in the research and development setting, and I was able to apply much of my chemical engineering background knowledge to the project. I loved every second of my summer at NASA, and I am forever grateful for such a once-in-a-lifetime experience and the opportunity to meet and work with so many amazing people.



Engineering Bacteria for a Sustainable Alternative to Nitrogen Fertilizers—Yuejia Gu

Among the numerous applications in which bacteria play a role, certain species could transform the way farmers cultivate their crops and provide economic and environmental benefits to communities worldwide. These developments come at an opportune time as the worldwide demand for nitrogen fertilizer and projected population growth are increasing each year, while the effects of climate change demonstrate the need for less energy-intensive agricultural practices. By enhancing and editing DNA of nitrogen-fixing bacteria, researchers are developing a means, which if properly incorporated, will eliminate the need for energy intensive chemical fertilizers.

In the world of agriculture, nitrogen is essential for plant growth. The nitrogen in the air, however, is not readily usable by plants, excepting certain legumes which form a symbiotic relationship with nitrogen-fixing bacteria. Once derived from application of animal byproducts to soil, farmers have since utilized ammonia synthesized via the Haber-Bosch process. Developed in the 20th century, this process combines air, an iron catalyst, and hydrogen, often from natural gas, under extremely high pressures and moderate temperatures to “fix” the nitrogen in the air into ammonia, a more usable form. (Jefferson, 2018)

Ammonia is the second most important chemical in the United States. However, its widespread use has had many adverse effects on public health, ecological systems, and the overall environment. Given that plants can only absorb up to 40 percent of applied fertilizer, most remain in the soil unused. Heavy rains can generate nitrogen runoff into water sources and prompt an abundance of algae growths which consume dissolved oxygen as they decompose, creating hypoxic zones and killing off the local plants and wildlife. (United States Geological Survey, 2017) High levels of nitrates in drinking water also pose a health hazard, especially for young children. Additionally, the Haber-Bosch process is a key driver of climate change, as the production of ammonia fertilizer releases massive amounts of carbon dioxide into the atmosphere and uses 1-2 percent of all energy in the world. (Coss, 2015) In order to keep up with the demand for nitrogen and alleviate the extreme effects of climate change on growth conditions, the development of engineered nitrogen-fixing bacteria would benefit agriculture and people worldwide.

The most recent science concerning these bacteria come from groups of researchers at the Washington University in St. Louis and from the University of Minnesota-Twin Cities. The team of researchers at Minnesota genetically engineered bacteria which naturally produce nitrogen, called diazotrophs, to ramp up production to a level beneficial to most crops like corn and wheat. At Minnesota, the researchers isolated genes that regulate the buildup of ammonium and worked to edit them out of the bacterial genome, resulting in an excess of the nitrogen compound to be released. (Barney, 2017)

At Washington University in St. Louis, the group of researchers worked with cyanobacteria, specifically a strain called Cyanothece. The Cyanothece photosynthesizes during the day, fixes nitrogen at night, and is the only bacteria which has a circadian rhythm. The team isolated 35 genes which became active only at night, and attempted to insert them into another cyanobacteria, Synechocystis, in hopes that it would also be able to convert nitrogen from the air. One researcher found that removing some of the genes improved the nitrogen fixing rate drastically, although it was hindered when oxygen was reintroduced back into Synechocystis. The researchers are working to define the genes responsible for nitrogen fixation more clearly and, with help from plant scientists, extend this ability to the nutrient-hungry plants themselves. (Jefferson, 2018)

The experiments conducted so far show a strong possibility for the bacteria to be introduced into regular practice, although with any new technology there are hurdles to be found. The bacteria must be evaluated in varying types of soil, oxygen content, and how well the different species perform at their tasks. Given that researchers at Minnesota are also changing the bacteria to produce nitrogen compounds with low solubility, the best method and frequency of application of these bacterial fertilizers are yet to be determined. (Coss, 2015) Public perception of genetic engineering is also an issue. Consumers might be wary of changing the genetic code of bacteria and plants that are so prevalent, but it can also be said that engineering genetic changes is no different than selective breeding of plant and animal species, except on a faster time scale.

The vast benefits of commercial nitrogen fertilizer has not come without its costs. While boosting the world population and increasing crop yield, the side effects of its use—rampant energy use, water pollution, and soon enough irreversible climate change—demonstrate the need for a safer alternative. By utilizing the nitrogen-fixing genes already present in certain bacteria, researchers could provide plants the same amounts of nutrients for less energy and work. The advent of engineered bacteria could also open up possibilities for self-fertilizing plants, which would eliminate the need to apply any fertilizers. Although the technology will take time and effort to integrate into regular practice, it is imperative that it be done, for the sake of not only human health, but the health of the entire planet.

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Ensuring Chemical Plant Safety—Nathan Ashley

In early August of 2012, Chevron's Richmond oil refinery caught fire, killing more than a dozen people. The fire created a plume over the San Francisco area that caused approximately 15,000 people to seek medical attention for breathing issues. Chevron was only charged $2 million for fines and restitution for their accident. Since then, Chevron's same refinery has exhibited two non-lethal incidents. To prevent catastrophic events like this, the Environmental Protection Agency (EPA) has an outdated Risk Management Plan (RMP) to regulate chemical storage and operations in facilities that are deemed hazardous to the population and the environment. Unfortunately, the current RMP only rules over 77 toxic and 63 flammable substances. These do not include chemicals such as methanol, phenol, sulfuric acid, xylene and more (Hess & Johnson, 2014). Chemical manufacturers are also governed by the Department of Homeland Security (DHS). The Occupational Safety and Health Administration (OSHA) also governs chemical safety with the Process Safety Management (PSM) program that regulates management of processes using highly hazardous chemicals. Despite these standard-setting regulatory agencies, deadly chemical plant accidents still happen in the United States today. These accidents kill their employees, cost millions of dollars, and endanger their communities. The United States government needs to implement higher standards to prevent catastrophic chemical facility accidents by regulating companies to include ISD technologies wherever deemed necessary.

The debate of installing inherently safer design (ISD) and inherently safer technology (IST) has been proceeding for decades. In 2002, the EPA's administrator, Christine Todd Whitman, proposed regulations for ISD implications in processes of high-risk chemicals. The United States government is facing backlash from global companies because of the high cost of ISD and IST implementation. These companies have already integrated ISD under similar regulations in Europe and are lobbying to inhibit new U.S. regulations. The trade association represents the nation's largest chemical companies; they contend that mandatory consideration or adoption of safer alternatives would be counterproductive. These opposing international companies argue that the cost of ISD implementation would cost too much to manufacture their products. They also argue that catastrophic incidents have only occurred at facilities that were in violations of the RMP program (Hess, 2014). But according to insurance data, the losses from refinery accidents in Europe are one-third that of the United States (Moure-Eraso, 2014). The insurance data clearly shows that Europe's regulations are effective towards chemical safety and should be considered in North America. As European regulations for chemical safety have been introduced, the number of accidents has greatly declined. Therefore, companies under European regulation are still making money while experiencing less accidents, contradicting their argument of counter productivity.

Industrial officials also argue that under the DHS's regulated CFATS (Chemical Facility Anti-Terrorism Standards), companies are required to make substantial financial investments to address a range of security concerns. According to the American Chemistry Council, the industry has spent almost $13 billion on security enhancements over the past decade. The chemical production industry's revenue is over $700 billion per year. Considering this enormous revenue, $13 billion over the span of ten years does not seem to impact the industry at a concerning rate. The battle for safety does not have to be settled with governmental law suits and fines; more than 3,000 facilities have voluntarily changed production processes or reduced hazardous chemical inventory, enabling them to avoid expensive requirements and exit the program (Hess & Johnson, 2014). If thousands of facilities have the capabilities to change their production and business model, thousands more can change their designs and technologies to create a safer work environment.

In response to President Barack Obama's directive, an interagency task force reports that the government should not require the adoption of IST. Rather, the report recommends the agencies should require companies to analyze and document whether alternative measures and safety techniques could reduce the risk of their operations (Hess, 2014). The problem with this recommendation is that it only allows companies to become self-informed about what improvements they should make, but it does not require any company possessing hazardous inventory to make any accident-preventing changes. The report's requirement does not actually reduce the risk of accidents within a company. It may inform companies of the potential hazards within their facilities, but it seems that companies do not make safety measures unless it seems to benefit their revenues or, when it is too late. The Chevron facility in Richmond, California experienced pipe failure from sulfidation corrosion in 2007 (Gerard, 2017). The refinery did not replace the pipes nor inspect other pipes. This corrosion was the same root cause for Chevron's infamous accident in 2012. Chemical production companies will not improve safety measures unless mandated by governing regulations and standards.

Counties that contain chemical facilities that are regulated under the RMP should train every member of emergency response with knowledge of chemical industrial hazards. In April of 2013, West Fertilizer company exploded from an unknown ignition source with tons of ammonium nitrate. The explosion killed 15 and wounded another 226 people. First responders arrived at the scene to battle the fire

Ensuring Chemical Plant Safety—Nathan Ashley (continued)

30 minutes before the fertilizer exploded. Only two of the emergency responders were knowledgeable of the hazardous chemicals in the plant (McLaughlin, 2014). Furthermore, the fertilizer plant explosion destroyed nearby schools and homes. Federal government needs to implement zoning laws for chemical plants mandated under the RMP to protect schools, residences and commercial businesses.

The United States government needs to take steps that will mitigate risk, not manage it. The EPA has the power to act now to require ISD for chemicals with hazardous processes and inventory. The continuum of chemical accidents proves that without extensive mandated standards, chemical companies yet to implement ISD will continue to practice unsafe design. The hazardous chemical manufacturers oppose the integration of ISD and IST because it increases their operating costs, but companies volunteering to meet CFATS is a prime example showing that companies will find ways to change their processes or inventories to meet their revenue goals. BASF, the world's largest chemical production company, told the House of Representatives, "CFATS has helped make our industry and communities more secure" (Hess, 2018). BASF's statement disproves the allegations of counterproductivity because BASF leads the chemical industry in revenues every year, and they voluntarily implement sustainable and ISD in their facilities. If other companies do not follow their lead under the current chemical safety standards, future lethal accidents are imminent in the United States.

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Noble Gases: A Thermal Wonder for Frigid Water Divers—Elijah Parr

A staple of mankind has always been our aptitude to push boundaries. Accomplishments like sailing to the new world, journeying to the south pole, and even putting a man on the moon are a testament to our determined nature as a species. However, by its definition, these boundaries are the things that set the limits to what we can achieve. One such realm we have not been able to fully conquer has been underwater exploration. A combination of freezing temperatures, high pressure, and an obvious lack of oxygen has placed heavy limitations on our abilities to explore underwater. However, recently engineers have developed a new wetsuit that uses noble gases as a thermal insulator to greatly increase our survivability in frigid waters. This breakthrough has opened many new possibilities in the areas of exploration, recreation, and military operation.

The previous standard wetsuit was made from a material called foam neoprene which is a layered rubber material with air occupying the middle (2). While this material holds up fine under normal aquatic temperatures, in temperatures below 10°C divers can only remain underwater for a little under an hour, and the entire duration is quite painful as well (3). While divers can alternatively use a more thermally equipped dry suit, a suit that has a layer of air between the skin and suit for insulation, this design is severely hampered by its reliance on a hose and pump connection (1). The pump functions as a method to ensure that the pressure and volume within the suit are steady as the diver changes altitude underwater (1). Not only does this greatly reduce maneuverability, but if the pump were to be damaged during a dive, it could prove catastrophic. Damage to the lower part of the suit could cause flooding within the air insulation creating a danger of hypothermia, while damage to the upper portion would throw off the pressure and buoyancy balance in the suit (1). Without the pressure and buoyancy in balance, the diver could get stuck underwater from the weight of the suit or suffer pressure sicknesses, both of which can prove fatal (1). All in all, there was a prevalent need for an innovation in the cold- water wet suit design. Hence, this prompted groups such as the Navy SEALs, that must carry out operations and rescue missions in freezing waters, to see if there was a way to increase survivability under these conditions while maintaining maneuverability. As such, the Navy contacted chemical engineering researchers at MIT to see if they could help them out, and as a result, a two-year long study was launched (2).

Researchers began the study by examining various ways animals in the wild retained heat in polar waters. Three main methods were observed: air pockets stored in fur and feathers, such as with penguins, internally generated heat, like in sharks, and insulating blubber utilized by walruses and whales (1). Combining the air pocket and insulation tactics, it was discovered that small air pockets of noble

Noble Gases: A Thermal Wonder for Frigid Water Divers—Elijah Parr (continued)

gases such as argon, xenon, or krypton, could be added to the suit as a method of insulation (1). As mentioned before, standard neoprene suits have lots of air in them. The air, which compromises about 2/3 of the total volume, also accounts for most of the heat loss within the suit. (2). The way that the gas insulation works is that the suit is put in a pressure chamber with one of the gases, usually xenon. Then, the gases occupy what was previously just air pockets in the suit, the only difference is the noble gases have an extremely low heat transfer which means almost no heat from your body is lost to the cold-water surroundings (1). In fact, this newly developed xenon-insulated wetsuit has the lowest heat transfer of any garment ever made (1). In addition to all of this, the wetsuit still maintains its flexibility and low weight while increasing survivability underwater in cold conditions by a factor of 3 (3).

It used to be a lesser of two evils situation when choosing a cold-water wet suit. Do you want to have a cold and painful experience but be mobile, or do you want a big, warm, bulky suit that's a bit dangerous? However, with the discovery of the noble gas infused wet suit, you can have the best of both worlds. The layer of noble gas provides a layer of insulation that prevents heat loss and allows the diver to spend a longer time under water, while its low weight properties also make the suit comfortable and maneuverable. All in all, this new suit has greatly benefited many cold-water divers of all sorts from long-distance swimmers to pearl miners. However, nothing can truly be perfected, so the question remains, what more can be improved?

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Legislation Regarding Inherently Safer Design—Michael Leyden

The manufacturing of chemicals is one of the largest industries in the United States, producing everything from gasoline to dish soap. To produce such a variety of products, thousands of different chemical processes are utilized. Each process has specific hazards such as the use of high pressures and the presence of flammable solvents. Every hazard must be analyzed to ensure the safety of employees and the surrounding population. Much capital is spent on safety systems; these include sprinkler systems, relief valves and advanced process control equipment. Over the past few decades, the concept of inherently safer design (ISD) has become a prominent topic in process safety. The goal of ISD is to reduce or eliminate hazards. Legislation should be passed in the United States requiring companies to conduct a safety analysis, specifically addressing the concepts of inherently safer design, for all processes and submit a report to an appropriate government agency, such as the Occupational Safety and Health Administration, for evaluation. This should be performed to help reduce the frequency of accidents in the chemical industry.

Inherently safer design is increasingly being incorporated in process development. The concept of ISD was created by Trevor Kletz following the 1974 Fixborough, England chemical plant disaster (Hendershot, 2011). Substitution, moderation, minimization and simplification are the four main components of ISD. These mean that companies should attempt to reduce the amount of hazardous materials on site, use less toxic or flammable substances, run operations at moderate conditions, and make the overall process simple and easy for operators to understand. By applying these four concepts to a chemical process, the number of hazards can be lowered dramatically. For example, in 2010 a fire occurred at the Tesoro refinery in Anacortes, Washington. It was determined that the accident was caused by the rupture of a heat exchanger (McClary, 2011). It was determined that the piping used was carbon steel, which corroded. If a proper analysis of the system was initially performed, a proper maintenance schedule could have been developed or corrosion resistant stainless steel could have alternatively been used. (Hess & Johnson, Another Look at Plant Safety, 2014). The Chemical Safety Board determined that the design would have been inherently safer if high chromium content steel was used in the exchanger (Chemical Safety Board, 2010). By performing a safety analysis based on the concepts of inherently safer design, lives can be saved.

On the other hand, numerous chemical engineers believe that introducing more legislation would be a waste of time. Industry claims that the Occupational Safety and Health Administration (OSHA) Process Management Act and the Environmental Protection Agency's (EPA) Clean Air Act are substantial enough. Unfortunately, even though these laws were passed to improve the safety of chemical plants, accidents are still far too frequent. In addition, businesses believe that reducing the amount of chemicals on site would prevent them from filling customer orders. It is also stated that businesses would be forced to transport excess chemicals, thus just shifting the hazard to a different area in the supply chain (Hess & Johnson, Another Look at Plant Safety, 2014). This does not mean that an analysis should not still be conducted. The purpose of an analysis is to document possible hazards or ways to improve safety. The compa-

Legislation Regarding Inherently Safer Design—Michael Leyden (continued)

nies would have the opportunity to state whether it is reasonable to adopt certain practices, such as lowering the amounts of chemicals on site.

The proposed solution would only require companies to perform an assessment and submit a report regarding the process. It is understandable that every process is unique, and it would not be practical to develop only one set of standards to apply to every company. The purpose of performing a safety analysis is too make sure companies, and its employees, are aware of potential hazards. It would provide them an opportunity to scrutinize every element of a process and evaluate areas where safety could be improved. Obviously, not every element of ISD can be applied in every situation. For example, the best way to never die in a car crash is to never get in a car; this is an unpractical solution since driving is a necessary activity to function in society. This situation parallels the predicament a chemical company is in. Some safety enhancements may not be practical, and companies can explain this in the report. A government agency will evaluate the report and decide if a company's decisions are reasonable. Businesses may claim that such an agency would never seriously consider the concerns of a business in rendering a decision. If a business feels their interests are not considered in the agency's evaluation, they could submit their grievances with the decision directly to the decision-making body or submit a court case.

Finally, many businesses claim they have spent enough money on safety to comply with the Chemical Facility Anti-Terrorism Standards program. CFATS requires companies with substantial amounts of hazardous materials develop security plans and utilize equipment such as guards and surveillance cameras (Hess, Chemical Plants Improve Security, 2015). These only prevent accidents caused by external threats such as terrorists. All the security equipment in the world would not prevent an internally caused accident such as the one in Tesoro. The only way to limit these accidents is to perform a safety analysis

Legislation should be passed requiring companies to perform a safety analysis based on the concepts of inherently safer design. This analysis will force companies to review every piece of a chemical process and evaluate hazards that may be present. Many may believe this is a tedious process that places a large burden on industry, but it is necessary to ensure a safe work environment. This legislation would not create a set of standards but would establish a more involved form of government oversight in process safety. This process would improve a company's awareness of hazards, thus improving the overall safety of a plant.

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Improving Safety in US Chemical Facilities—Lisa Eischens

The United States Government has made progressive moves by outlining policies to ensure that safety is a priority in industries where potentially dangerous chemicals are used and other hazards are present. It is not reasonable, however, for the government to enforce a single set of regulations for inherently safer design across all chemical industries due to the diversity of the industries, availability of materials, and variety of techniques. Instead, in 2019, updates should be made to the current regulations to encourage widespread implementation of inherently safer design and to make it easier for companies to access resources and follow these guidelines.

In 2007, The Department of Homeland Security (DHS) launched a national program aiming to enhance security at facilities storing and using what are defined as "high-risk" chemicals. This program was given the name Chemical Facility Anti-Terrorism Standards (CFATS) and it was updated in 2014. Through this legislation, facilities are called upon to take action if they possess a specified amount of a chemical that is listed in the CFATS Chemicals of Interest (COI). Any company in possession of the specified amount of one of the more than 300 COIs is required to work with DHS to complete a screening process and submit security plans, after which the facility will be inspected by members of the Infrastructure Security Compliance Division (ISCD) of DHS. The ISCD continues to perform inspections to ensure that plans are properly implemented and that safety measures are maintained, and they can also impose fines and/or take further action when facilities are in violation of CFATS. There are currently about 3,500 facilities listed as high-risk under the CFATS regulation (Department of Homeland Security, 2018).

The majority of accidents in the chemical industry are preventable by following the principles of inherently safer design (ISD), a concept introduced by Trevor Keltz. The DHS has their own definition of this concept, which they call Inherently Safer Technology (IST).

Improving Safety in US Chemical Facilities—Lisa Eischens (continued)

Definitions of this idea vary slightly, but they all focus on the same principle that processes should be made safer on a foundational and preventative level, and not just by adding safety features to compensate for existing hazards. Kletz defines four categories for ISD measures: Intensification, substitution, attenuation, and limitation. Intensification, also known as minimization, means using smaller amounts of hazardous chemicals at a time. Substitution means switching out hazardous materials for lower-risk alternatives that can achieve the same product. Attenuation means using chemicals under conditions that make them less hazardous, for example, reduced operating temperature and pressure. Finally, limitation means simplifying process design to eliminate unnecessary complexity that involves extra hazards (Kletz, 2009). It is crucial that all chemical facilities constantly evaluate their processes and procedures to ensure that inherently safer design principles are followed, and to minimize risks associated with their equipment and materials. However, ISD is not something that the DHS or the EPA can impose on all industries by a generalized set of regulations.

Each chemical process is different, and operators at each facility handle management of change in different ways. It is simply not feasible to apply one set of laws regarding ISD across all industries. For example, the substitution principle of inherently safer design could apply to any chemical process using a solvent-based reaction. One way to make those reactions safer would be by switching from the solvent-based process to one that uses water or is solvent-less. While these alternatives exist for some processes, it may be a lot more expensive, the solvent-less materials may not be as easily accessible, and altering the process may require expensive equipment changes as well. While this is an example of something that manufacturers should be actively researching, it cannot be required that they make these large changes to their processes on a specified timeline. Instead, what the government should do is provide copious resources such as recommendations and inspections to ensure that ISD is a priority in all facilities, whether they handle chemicals from the COI list, or not. In this case, the company may have been unaware that the solvent-less process was an option, but now they could consider it with suggestions and collaboration with the DHS. With this increased guidance, companies will be able to educate their employees and implement safer design with greater ease.

Presently, companies may be overlooking some of the potential hazards in their plants. For example, a safety feature in a plant that has a history of false alarms may become accepted as the norm by operators, but it could cause a big problem if triggered by a real incident and if no one responds with urgency. Adjusting operating procedures and performing inspections is important in situations like this, and it will minimize economic, property, and personnel losses for the company. It should be a priority to educate employers and employees, to learn from past incidents, and to consistently support safer alternatives and procedures.

While there cannot be one regulation across all industries, there is one area that needs stricter regulations due to a larger number of incidents in the past few years, and that is the oil refining industry. Recent incidents include two sulfuric acid spills at the Tesoro Martinez Refinery in California in 2014, a vapor release and explosion at the Chevron Refinery in California in 2012, and the Macondo explosion in the Gulf of Mexico in 2010, which killed 11 people and resulted in a massive oil spill (CSB, 2016). Site Security Plans should be required for all refining operations - even if they are not using any Chemicals of Interest - and inspections performed to ensure that safer design is implemented. With more resources available, this will be a less arduous task for those oil companies, and it will greatly reduce the risks involved in refining operations, creating a safer industry as a whole.

If all of these updates are added to CFATS in 2019, the result will be safer environments for workers and citizens, and changes will be in the best interest of both the chemical companies and the safety advocates. By increasing resources and putting out clear information about inherently safer design, companies will see the ways in which they can update their processes to minimize risks, and they will be able to implement changes more easily over time with the help of the EPA and the DHS.

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Chemical Regulation: What is the Best Approach for the US? —Alaa Othman

On the 22nd of June, 2016, president Obama signed into law a bill called Frank R. Lautenberg Chemical Safety for the 21st Century Act, commonly known as New TSCA (Grossman, 2016). The Old TSCA (Toxic Substances Control Act) was the legislation that regulated chemical substance use in the US for the last 40 years. Despite passing unanimously in the senate, chemical production firms and the environmentalist organizations voiced concerns over the new statute (Herszenhorn & Schwartz, 2015). The chemical production firms worry the new law will exacerbate pro-

Chemical Regulation: What is the Best Approach for the US? —Alaa Othman (continued)

duction cost, preferring an updated, yet less restrictive version of the Old TSCA (Hogue, 2106). Environmentalists, on the other hand, criticize the new law as providing inadequate protection to humans and the environment, preferring an analogue to the more rigorous European law known as REACH (Regulation, Registration, Evaluation, Authorization and Restriction of Chemicals). They even tried to overturn the new law in court (Franklin, 2018). The objective of this paper is to extrapolate which of the three acts, Old TSCA, New TSCA or REACH would be the best vehicle for regulating chemical substances in the US by delineating their differences on conceptualizing the authorities granted to the governmental oversight body entrusted with upholding the law.

According to the Old and New TSCA, the EPA (Environment Protection Agency) is the government body entrusted with reviewing the safety of commercial chemicals to ensure the protection of human health and the environment (Hogue, 2106). However, the Old TSCA only gave the EPA nominal powers, inhibiting its ability to regulate the industry. The major dilemma facing EPA under the Old TSCA was having to prove that a chemical substance poses a threat before it can order the manufacturer to provide data about that substance. Paradoxically, the EPA needed this data to be able to conduct the required safety tests. Also, without proving that a chemical substance perils, EPA cannot order the chemical manufacturer to conduct toxicity and hazard of exposure tests (Hogue, 2106, p. 19). Furthermore, the Old TSCA allowed chemical firms to force the EPA to withhold important information about the safety of their products from the public based on proprietary rights and for the protection of trade secrets. Chemicals firms prodigiously misused this right to avert examination of their products (Hogue, 2106, p. 20). Hence, the Old TSCA completely impaired the EPA to the extent that from 1991 to 2016, the agency was not able to ban the use of asbestos (Reinstein, 2015), a known human carcinogen (National Cancer Institute). In 1991 the court overturned the EPA's decision to ban the substance although the court acknowledged that exposure to asbestos can cause cancer., The court argued that according to the Old TSCA, the EPA failed to prove that banning asbestos was the least burdensome alternative (Driesen, Adler, & Engel, 2016). All this provides support to the argument that the Old TSCA was an inadequate statute that crippled the federal agency endowed with protecting humans and the environment, leading to the conviction that a New TSCA was an exigent necessity.

The New TSCA was designed to ameliorate the Old TSCA by addressing its most consequential deficiencies (Herszenhorn & Schwartz, 2015). According to the New TSCA if the EPA suspects that a chemical substance poses a risk to humans or the environment, it has the right to order the manufacturers of the substance in question to conduct a safety review and provide the EPA with safety data and other information about the product (Hogue, 2106, p. 19). Furthermore, the New TSCA empowers the EPA to acquire information from chemical manufacturers through an administrative order instead of going through the formal federal regulations which usually took years to process (Hogue, 2106, p. 19). Moreover, the New TSCA limited the ability of chemical manufacturers to use trade secrets as justification to force the EPA to withhold information about the safety of their products from the public (Hogue, 2106, p. 20). All these changes mean the New TSCA will enhance the EPA's ability to perform its job, and to better protect humans and the environment. Still, some environmentalists argue the New TSCA is not satisfactory, demanding a legislation similar to the EU's chemical regulation REACH.

REACH is considered by many to be better than the New TSCA, yet this assumption lacks corroboration. Advocates of a REACH-like statute argue that one of the New TSCA's shortcomings is not requiring the EPA to check and acquire data on all chemical substances in the market (Scott, 2016). According to the New TSCA, suspecting that a chemical substance may pose a threat to human health or environment is sufficient for EPA to start taking action. Yet, the EPA must have reasonable suspicion to doubt that a specific chemical is hazard to humans or the environment, not mere speculations (Bergkamp & Uyesato, 2017). REACH, on the other hand, requires toxicological and eco-toxicological data for all chemicals (Jones Day, 2017, p. 6). Nevertheless, REACH ubiquity does not automatically make it better than the New TSCA, such an assumption would be a spurious correlation. On the other hand, the New TSCA has an advantage over REACH, by avoiding the authorization list complexity (Bergkamp & Uyesato, 2017). Chemicals on this list are banned. However, companies can request permission to continue to produce or import them. This provision creates a legal loophole that undermines REACH's efficacy in limiting the public exposure to harmful chemicals, making it an analogue to the Old TSCA. Conversely, the New TSCA, despite being slower, diminishes the prospect that a harmful chemical stay in the market once it is banned. Which makes the New TSCA a more practical and pragmatic statute (Scott, 2016).

In conclusion, every statute has its strengths and flaws, and no single piece of legislation would ever satisfy all segments of the society, producers, consumers, environmentalists...etc. Hence, an optimal law would be one that serves the most vital interests of the largest number of people, by protecting their health and environment, without incapacitating the, economically significant, chemical industry with folios of tedious intricacies. The New TSCA does just that, it is not lenient as the Old TSCA, allowing the industry to avoid supervision, nor convoluted and overwrought like REACH. Therefore, the New TSCA is the best approach, of the three discussed options, for regulating the chemical industry in the US.

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Chemical Process Safety—Maggie Norland

With the recent update to the Toxic Substances Control Act (TSCA), the United States took a vital step forward in the journey to improving chemical safety. However, there are concerns with the TSCA that were not addressed in the revision, and it still lacks some valuable aspects of chemical safety regulation that are present in the European Union's Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) program. While the passage of the New TSCA is promising, its implementation requires resources and awareness that are not readily available. To reduce costs and efforts, the United States and the European Union need to adopt a system of mutual recognition concerning the evaluation of potentially dangerous chemicals (Jones Day, 2017).

The New TSCA poses various obstacles to the protection of people and the environment from the effects of harmful chemicals. Because it is only an update to existing legislation, the New TSCA makes it challenging to review substances that were already evaluated under the original act; as many as 62,000 chemicals were grandfathered in and presumed to be safe (National Academy of Sciences, 2014). It requires a considerable amount of time and evidence to prove that a chemical is harmful enough for the Environmental Protection Agency (EPA) to revisit and regulate the previously reviewed chemicals. The EPA's power to test and regulate new chemicals is quite limited under the New TSCA. It still does not give the EPA power to control the use of new substances without sufficient data supporting their concerns. This creates a difficult situation because the EPA also must supply data indicative of harmfulness to require proper testing of a new chemical.

Despite the shortcomings of the New TSCA, several steps should be taken to facilitate its implementation and improve chemical safety practices in general. Prevention and risk management measures are vital to the reduction of chemical accidents. First and foremost, it is critical those involved in the industrial use or production of potentially dangerous chemicals be made aware of the risks and potential consequences involved. This awareness results in an increased understanding of safety measures and the importance of testing the effectiveness of safety features with adequate frequency. Some critical resources that must be funded and provided to industries at the national level are inventory management systems, hazard and risk assessment tools, and chemical safety and security guidance documents and training (OPCW, 2016). These measures would improve chemical safety practices in general and help to reduce the negative impacts caused by the shortcomings of the TSCA. The European Union has implemented many of these through its REACH program, which serves as an exemplary model of attainable safety standards in the current industrial market.

Several aspects of REACH can be used to improve standards in the United States. Though the European system has shortcomings of its own that may produce similar issues in the United States (Molly Jacobs, 2016), it holds many advantages over the New TSCA. REACH requires toxicological and eco-toxicological data be provided for all chemicals, and if there is a lack of data, new experiments are conducted (Jones Day, 2017). The EPA does have the power to request new data, but it must be justified so this power is utilized much less in the United States than it is in Europe. Moreover, there is significant pushback from American chemical companies claiming these regulations hinder their ability to do business and make profits. Though European companies initially protested REACH, they recently came out in support as they believe bolstering chemical safety laws will be good for competitiveness (Scott, 2018). If the United States approved the use of chemical data from REACH, much of the effort and cost concerns would be alleviated.

The New TSCA is a marked improvement from the original legislation, but there is still plenty of room for the advancement of chemical safety regulations and practices in the United States. Because the EPA is limited in its power to regulate harmful substances, it is essential for the chemical industry to be provided with resources geared toward preventing accidents and reducing consequences. One major obstacle in implementing these improvements is the reluctance of American companies to adopt stricter rules due to their costs. Lawmakers in the United States are heavily influenced by large corporations concerned that an increase in safety regulations will lessen their profits. However, an agreement between the United States and the European Union would significantly increase available resources and information while decreasing the amount of money and effort required for both entities. The European program has shown positive results while garnering the support of large chemical companies, and the United States needs to follow their example and make immediate changes.

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4133 SEAMENS CENTER OF
ENGINEERING ARTS AND SCIENCES
IOWA CITY, IOWA 52242

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