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February 2022

Expansion Joints

page 30

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Critical Applications Require Expert Solutions

Vibra Screw Feeder Technology

VersiFeeder comes in three different trough sizes and screw sizes from 1/4" to 6".

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VersiFeeder with 100 ft^3 capacity **Live Bottom Bin.**

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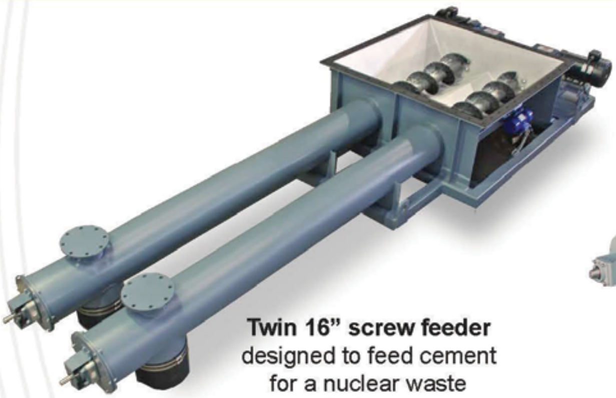
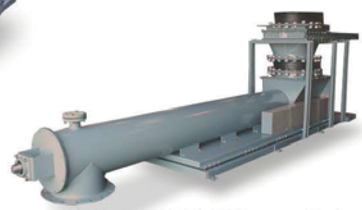


Twin 16" screw feeder designed to feed cement for a nuclear waste remediation system.



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February 2022 Volume 129 | no. 2

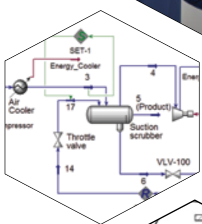
Cover Story

30

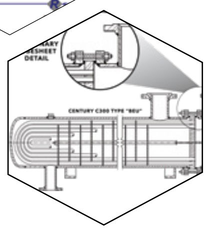
In the News

12

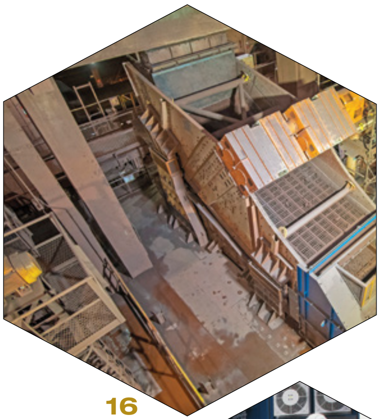
Technical and Practical



36



42


16


18


25

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Cover design: Tara Bekman

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Editor's Page

Spotlight on hydrogen

Driven by climate-related concerns, interest in hydrogen for its potential to play a significant role in decarbonization is surging. An increased urgency to get on track with decarbonization targets set by governments and corporations for the next few decades has sparked investments in technologies for low- and no-carbon hydrogen production, infrastructure and broader application areas.

Moving toward a hydrogen economy

Last month, the International Renewable Energy Agency (IRENA; www. irena.org) issued its new report, titled "Geopolitics of the Energy Transformation: The Hydrogen Factor." In brief, the report analyzes how a global hydrogen economy could reshape geoeconomics and geopolitics. For example, countries with low-cost renewable energy could become centers for "green" hydrogen supply and export, since green hydrogen is produced by electrolysis, using renewable energy sources. While IRENA affirms that there are many uncertainties in how the hydrogen market will develop, it estimates that hydrogen could contribute up to 12% of global energy consumption by 2050. During this decade, it is expected that there will be a focus on gaining technology leadership, while hydrogen demand is expected to increase in the 2030s, as the cost of green hydrogen becomes competitive with fossil-fuel-based production.

As of November, there were over 520 large-scale hydrogen-related projects announced worldwide in 2021, representing about $160 billion of direct investments, according to the Hydrogen Council (www. hydrogencouncil.com) and McKinsey & Company (www.mckinsey. com) in their co-authored report "Hydrogen for Net Zero." While this is a significant investment, the report estimates that it is only about 25% of the amount that will be needed by 2030 in order to reach the 2050 net-zero emission targets.

Applications and advances

Currently, the main applications for hydrogen are in petroleum refining and chemical (ammonia) production. Hydrogen use can, however, be expanded to reduce emissions in additional industrial applications, such as in steel production, as well as in aviation, shipping and trucking, thus greatly increasing its demand.

Steam methane reforming (SMR) is currently the main production route for hydrogen. Advances in hydrogen production are focused on two routes: 1) producing green hydrogen by electrolysis of water using renewable energy sources; and 2) reducing emissions from SMR to produce a low-carbon, or "blue" hydrogen, by capturing the produced carbon dioxide. In addition to making green hydrogen cost-competitive with the fossil-fuel-based route, additional challenges to advancing the hydrogen economy include transportation and distribution of the product.

For recent news on hydrogen in this issue, see "Advanced amine-scrubbing solvent offers carbon-capture advantages" on p. 6, and "Demonstration plant will convert waste biomass into emissions-free hydrogen" on p. 8. In addition to our magazine and website, the latest news on hydrogen can also be found in our e-letters that are specificallly dedicated to this topic, as well as our newest event, HydrogeNext (www.experience-power.com/hydrogen-next). ■

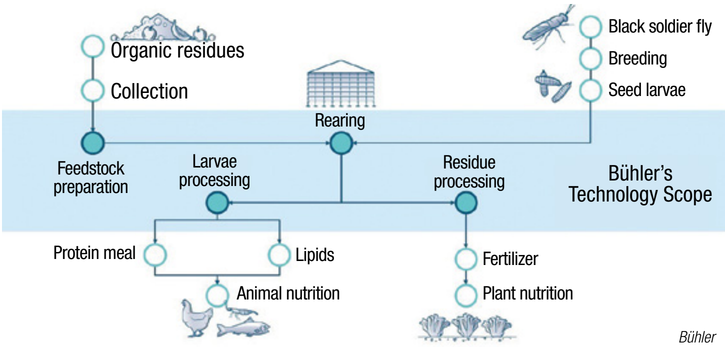
Dorothy Lozowski, Editorial Director

Large-scale production of insect proteins from waste

Agronutris (Saint Orens de Gameville, France; www.agronutris.com) has selected Bühler AG (Uzwil, Switzerland; www.buhlergroup.com) as its process-solution provider for its first commercial-scale black-soldier-fly plant. Bühler will deliver a full-scope solution for the facility, which will be built in Rethel, France. The plant is planned to go into operation in 2023, and when operating at full capacity, will process up to 70,000 ton/yr of organic residues and produce high-quality protein for the aquaculture and pet-food markets.

Bühler's scope for Agronutris will cover the entire supply chain (diagram). This includes feedstock preparation to provide safe, palatable and nourishing feed to the larvae and a fully automated larvae-growth system with sophisticated climate control. Bühler will also deliver the processing line to efficiently transform the grown larvae into protein meal and lipids with consistent quality, as well as the frass (excrement) handling system for a secure offtake of the rearing residues. Bühler will also be responsible for the entire automation and the timely project execution (engineering, procurement, manufacturing, supply, installation and commissioning).

The objective of the processing is to gently defat the larvae to get protein meals and lipids ready to use in pet food and animal-feed applications. After they have reached their harvesting size in the rearing area, the larvae are sent to the processing area of the plant. As a first step, the larvae are carefully sieved from the rearing residue. Then they are washed to remove any residual frass on the surface. A live-larvae storage solution, which can be added optionally to the process, allows the decoupling of processing from harvesting schedule, which leads to a high operational flexibility. Afterwards, the larvae are turned into a puree in a micro-cutter mill, which quickly inactivates the larvae and efficiently releases the lipids from the cells. After puree pasteurization in a heat exchanger, the lipids are separated in a decanter and further purified in a high-speed separator. Besides the lipids, the decanter step also results in a solid and stick water fraction. The stick water fraction is concentrated in an evaporator and then recombined with the solid fraction. Subsequently, the mixture is dried to achieve a shelf-stable, protein-meal product. The protein meal can be further ground in a mill to the final particle size, before it is packaged in the desired lot size.



Bühler

Renewable dimethyl ether plant planned

Engineering design is underway for a new plant for making renewable dimethyl ether (rDME) from biogas produced by agricultural digesters or derived from landfills. Project developer Oberon Fuels (San Diego, Calif.; www.oberonfuels.com) is basing the new plant on its existing reactive distillation technology for making DME from methanol.

In the process, raw biogas (methane and CO_2) is first reformed to obtain synthesis gas (syngas; CO and H_2). The syngas is catalytically converted into MeOH, which then enters the company's reactive distillation column to produce renewably sourced DME. Central to the process are Oberon's proprietary skid-mounted, modular production units, each capable of producing 10,000 gal/d of DME from waste products.

Elliot Hicks, Oberon co-founder, says the company's rDME will initially be sold into the propane market. "When blended with propane, the rDME reduces the carbon intensity of the propane, helping to meet renewable-fuel requirements in places like California," Hicks says.

In the future, rDME may have applications in the hydrogen economy, and as a renewable diesel-fuel substitute. "rDME is useful as a hydrogen storage agent," says Hicks, and as engines for burning DME are further developed, rDME will be a renewable substitute for diesel fuel in off-road, heavy-duty agricultural vehicles and others, Hicks says.

Edited by:
Gerald Ondrey

DRIVE & CHARGE

The R&D teams from Holcim Ltd. (Zug, Switzerland; www.holcim.com) and Magment GmbH (Oberhaching, Germany; www.magment.co) have developed a unique concrete with high magnetic permeability, which enables electric vehicles to recharge wirelessly while in motion. Known as inductive charging, this breakthrough concrete-based solution reduces the need for charging stations, while also saving time. The technology is currently being tested by researchers at Purdue University (West Lafayette, Ind.; www.purdue.edu). Other applications under development include the electrification of industrial floors to recharge robots and forklifts as they work.

NANOLIPIDS

Wacker Chemie AG (Munich, Germany; www.wacker.com) and CordenPharma (Luxembourg; www.cordenpharma.com) have signed a development partnership to jointly develop know-how and processes for the manufacturing of lipid nanoparticles (LNPs). LNPs are drug-delivery systems for nucleic-acid therapeutics consisting of special fats, which ensure that actives can safely enter the body in order to exert their biological effect. The protective capsules are an essential component of advanced medicines, such as messenger ribonucleic acid (mRNA)-based drugs, protein replacement therapeutics and antibody therapeutics.

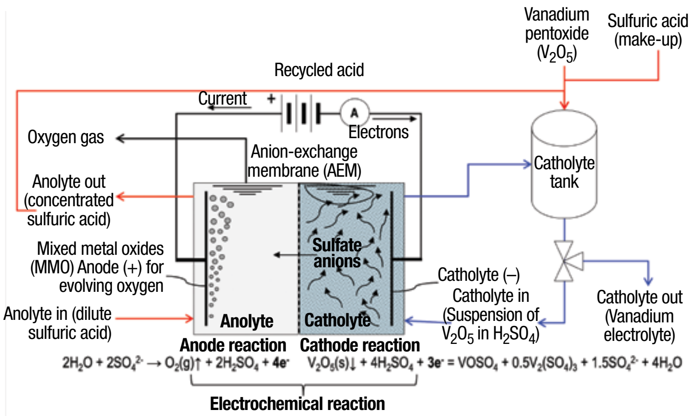
Both companies will first jointly build up R&D capacities for developing solutions in the field of LNP formulation at their respective manufactur-

(Continues on p. 6)

An electrochemical process for producing and recycling VRFB electrolytes

Electrochem Technologies & Materials Inc. (Montreal, Canada; www.electrochem-technologies.com) has recently patented its process for the production and recycling of all vanadium electrolytes (VE) used in vanadium redox flow batteries (VRFBs). This electrochemical technology offers a sound and profitable alternative to the chemical production of electrolyte, says company president, François Cardarelli.

Industrially, all vanadium sulfates electrolyte solutions are prepared chemically by reacting high-purity vanadium pentoxide (V_2O_5) as starting material with high-purity sulfuric acid. However, the chemical process requires the use of a reducing agent that allows the reduction of the barely soluble peroxovanadium (VO_2^+) cation into highly soluble vanadyl (VO^{2+}) cation and, to a lesser extent, V^{3+} cation to reach the targeted molarities. The proper reducing agent used is either an organic compound, such as oxalic acid, or an inorganic reagent, such as vanadium (III) oxide (V_2O_3), sulfur or gaseous SO_2. During the chemical processes, the dissolution reaction kinetics are driven by temperature and the concentrations of both H_2SO_4 and the reducing agent. As a result, the production rate is not easily adjustable, Cardarelli says.



Electrochem

By contrast, the single-step electrochemical process is only driven by the amount of electricity supplied — no additional chemicals are required, because the reduction is only performed by the electrons provided at the cathode, explains Cardarelli. In Electrochem's process (flowsheet), the suspension (slurry) made of solid V_2O_5 with H_2SO_4 is electrolyzed inside the cathode compartment of a divided electrolyzer with a plate-and-frame configuration and separated with an anion-exchange membrane (AEM). The electrolysis is conducted until the catholyte — made of equimolar acidic solution of vanadium (III) and vanadium (IV) sulfates — is finally produced. Meanwhile, in the anode compartment, the anolyte (dilute H_2SO_4) is concentrated until the maximum H_2SO_4 concentration is reached and it can be recycled with make-up H_2SO_4 for producing a new batch of catholyte.

The process is also used to recycle end-of-life spent vanadium electrolytes, because the process removes deleterious impurities. The process is currently performed commercially at Electrochem's facilities in Boucherville to produce tradenamed electrolyte formulations Vanalyte and SuperVanalyte, and to recycle used electrolytes. Ongoing discussions with users and constructors are underway to build skid-mounted or containerized modular units that can be deployed on-site, with nameplate capacities ranging from 5,000 to 25,000 L/d.

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ing sites — Wacker Biotech in Amsterdam, the Netherlands, and CordenPharma in Caponago, Italy. The aim is to offer a broad spectrum of LNP formulations, which the companies plan to produce as contract manufacturers according to good manufacturing practice (GMP) guidelines.

BIOTIN

In January, Wacker also signed a contract with Biosynthia ApS (Copenhagen, Denmark; www.biosynthia.com) to develop a large-scale fermentation-based process for the production of biotin (vitamin B7) — a coenzyme for the metabolism of proteins, fats and carbohydrates. The companies are dedicating "considerable" R&D resources in a multi-year program, which will build on Biosyntia's biotin technology. Only plant-based raw materials will be used in fermentative production.

Biotin has a wide range of appli-

(Continues on p. 8)

Advanced amine-scrubbing solvent offers carbon-capture advantages

Honeywell UOP (Des Plaines, Ill.; www.honeywell.com/uop) recently began offering a post-combustion carbon-capture system based on new advanced solvent technology that allows for improved carbon-capture economics for hard-to-abate industries, such as steelmaking, rotary kiln operations (such as cement-making) and natural-gas power production. The advanced solvent technology has been licensed by Honeywell UOP from the University of Texas at Austin (www.utexas.edu), where the technology was developed at the Texas Carbon Management Program, led by chemical engineering professor Gary Rochelle.

The proprietary amine solvent developed by Rochelle's group has two distinct advantages over conventional amine solvents used to capture CO_2 from fluegas. First, it absorbs CO_2 more quickly than other current-generation solvents, allowing for a shorter absorber for the capture phase, which saves capital costs. Second, the solvent is more thermally stable, so the stripper (for solvent recovery and CO_2 collection) can be operated at higher temperatures and pressures. This lowers the energy requirements for compressing the captured CO_2, explains Rochelle. Beyond the solvent, the advanced carbon-capture system has an enhanced heat-recovery system that allows improved utilization of heat energy. Taken together, the system has improved process economics for carbon capture, making it more viable for CO_2 abatement at industrial facilities.

The commercially available technology works at a wide range of CO_2 concentrations, but 4–20% CO_2 in fluegas is the projected operating range, Rochelle says, and it is available for installation at new facilities or to be retrofitted onto existing ones. Ben Owens, vice president and general manager, Honeywell Sustainable Technology Solutions, says the company has begun dialogues with several potential customers, but has not yet announced the first CO_2-capture project using the advanced solvent technology.


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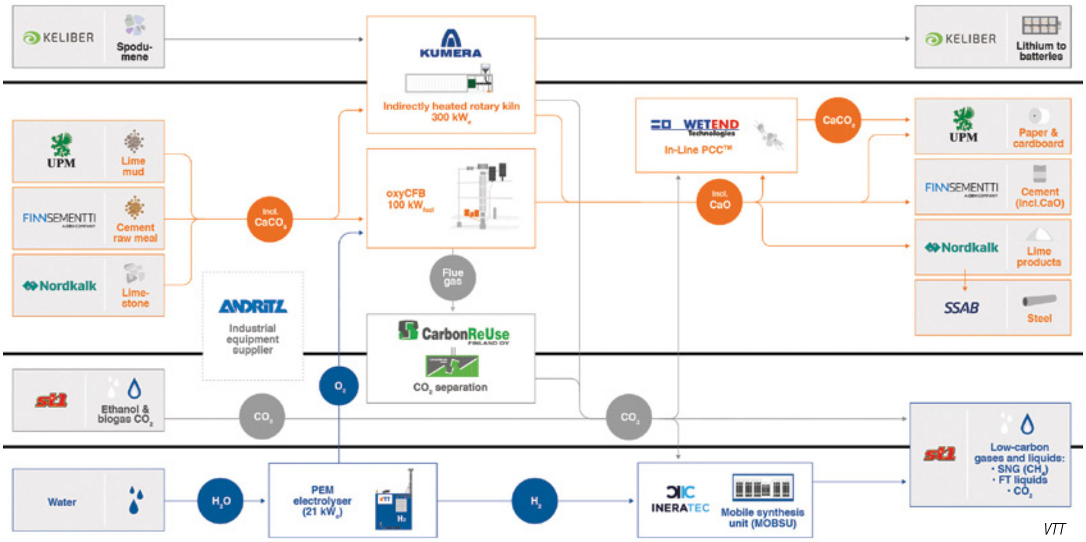
Reducing the carbon footprint of quicklime production

Decomposing limestone ($CaCO_3$) into quicklime (burnt limestone; CaO) releases significant CO_2 emissions, both from the combustion of fuel needed to heat the kiln to temperatures over 1,000°C, and by the release of CO_2 from the reaction itself ($CaCO_3 \rightarrow CaO + CO_2$). Because quicklime is a key ingredient in the production of cement, as well as being used in steel, pulp-and-paper and other industries, efforts are underway to reduce the carbon footprint of this operation.

One such effort is the 30-month Decarbonate project that is scheduled to be completed in March. Led by the Technical Research Center of Finland (VTT; Espoo, Finland; www.vttresearch.com) with nearly a dozen industrial partners (see diagram), the Decarbonate project involves the construction of a 12-m, 300-kWe electrically heated rotary kiln to perform precalcination of raw powders for cement, and the production of both quicklime and "lime mud" that is used in pulp mills. Because the kiln is gas-tight, the CO_2 released from limestone is nearly pure, so it can either be stored or utilized to make other products. For example, one part of the project will study the conversion of CO_2 and H_2 into low-carbon gases and Fischer-Tropsch (F-T) liquids. For this step, the H_2 is supplied from a 21 kW PEM electrolyzer. The O_2 co-product from the electrolyzer supplies an oxygen-enhanced circulating fluidized-bed (oxyCFB) calcinator.

By using low-emission electricity instead of combustion for decomposing $CaCO_3$ — a central part of cement production — and by capturing the CO_2 produced in the production process, it is possible to run a cement plant with close to zero CO_2 emissions, says VTT.

In the E.U., emissions trading is steering the industry towards reducing emissions. At the current price level, a decrease of 1 metric ton in CO_2 emissions means a savings of €60 for the company. For a medium-sized cement plant, for example, a one-third reduction in emissions would mean savings of several million euros per year, says VTT.



VTT

A more sustainable alternative for producing egg-white protein

Egg white is one of the most important protein ingredients for the food industry, with a market of 1.6-million ton/yr in 2020 and projected to grow in the future. Searching for sustainable alternatives to animal-based proteins has been of growing interest within the food industry. One alternative is so-called cellular agriculture, also called precision fermentation when used for recombinant ingredient production. Such biotechnology-based methods decouple the production of animal proteins from animal farming by instead using a microbial production system to produce a specific protein.

In a recent study published in *Nature Food*, researchers from the Future Sustainable Food Systems research group at the University of Helsinki together with the Technical Research Center of Finland (VTT; Helsinki; www.vttresearch.com) show that fungus-produced ovalbumin — the main protein of egg white — could have the potential to mitigate part of the environmental burden associated with chicken egg-white powder. This is especially true when using low-carbon energy sources in the production. Compared to its chicken-based counterpart, ovalbumin produced by precision fermentation reduced land-use requirements by almost 90% and greenhouse-gas emissions by 31–55%, according to the study.

"VTT has succeeded in producing ovalbumin with the help of the filamentous ascomycete fungus *Trichoderma reesei*," explains Emilia Nordlund, research manager at VTT. "The gene carrying the blueprints for ovalbumin is inserted by modern biotechnological tools into the fungus, which then produces and secretes the same protein that chickens produce. The ovalbumin protein is then separated from the cells, concentrated and dried to create a final functional product," she says.

cations in food and beverages, infant nutrition, nutraceuticals, pet food, animal feed, pharmaceuticals and cosmetics.

FUNCTIONAL GLASS

An international research team, led by scientists from the Nanyang Technological University (NTU) Singapore (www.ntu.edu.sg), has developed a material that, when coated on a glass window panel, can effectively self-adapt to heat or cool rooms across different climate zones in the world, helping to cut energy usage. Developed by NTU researchers and reported in a recent issue of *Science*, the first-of-its-kind glass au-

(Continues on p. 9)

tomatically responds to changing temperatures by switching between heating and cooling.

The self-adaptive glass is developed using layers of vanadium dioxide nanoparticles composite, poly(methyl methacrylate), and a low-emissivity coating to form a unique structure that could modulate heating and cooling simultaneously. The newly developed glass, which has no electrical components, works by exploiting the spectrums of light responsible for heating and cooling. During summer, the glass suppresses solar heating (near infrared (NIR) light), while boosting radiative cooling (long-wavelength IR) to cool the room. In the winter, it does the opposite to warm up the room.

CYBERSECURITY

In January, the International Society of Automation (ISA; Research Triangle Park, N.C.; www.isa.org) and the ISA Global Cybersecurity Alliance (www.isa.org/isagca), with contributing author Gary Rathwell, released a new white paper entitled, "Implementing an Industrial Cybersecurity Program for Your Enterprise."

The ISA/IEC 62443 standard provides powerful tools to reduce the risk of financial, reputational, human and environmental impact from cyber-attacks on industrial automation and control systems (IACS). Any specific company is likely to find that while most of the standard applies to their IACS, parts of it may not. It is therefore recommended that each company establishes their own IACS Cybersecurity Program to manage cybersecurity risks, and ISA/IEC 62443 2-1 provides guidance on how to establish such a security program for IACS asset owners. This whitepaper provides the guidance on how to do this. ❐

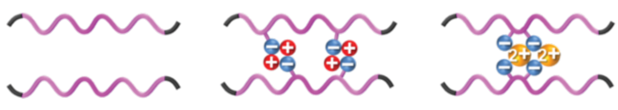
Demonstration plant will convert waste biomass into emissions-free hydrogen

A new demonstration plant near Bakersfield, Calif. will produce carbon-negative "green" H_2 from woody biomass waste, such as agricultural residues from orchard trees and walnut shells. Developed by Mote, Inc. (Los Angeles, Calif.; www.motehydrogen.com), with engineering partners Fluor Corp. (Irving, Tex.; www.fluor.com) and SunGas Renewables (Houston; www.sungasrenewables.com), the plant will be designed for 7,000 metric tons per year (m.t./yr) of H_2 production, alongside 150,000 m.t./yr of carbon capture and storage (CCS) capacity, with startup expected by 2024.

"The plant is demonstrating the first-ever system integration of biomass gasification, CO_2 geologic storage, a syngas water-gas shift (WGS) reaction and H_2 purification. "Using waste biomass as our feedstock gives us an incredible value stream of taking CO_2 out of the air and producing clean H_2 for the transportation market at the same time," explains Joshuah Stolaroff, Mote co-founder and chief technology officer.

Adapting the principles of coal gasification for biomass, the process gasifier acts as a pressurized, fluidized bed that is oxygen-fired, wherein woodchips are converted to a synthesis gas (syngas) stream consisting of mainly CO and H_2 — unlike in coal gasification, there is little sulfur or N_2 to deal with. "When we get the syngas that comes out of the gasifier, we purify it for the subsequent WGS reaction. There, we react the CO with water to make more H_2 and CO_2. That is one approach that sets us apart from other biomass gasification projects that have been proposed," adds Stolaroff. Several H_2-purification steps follow to separate the CO_2 and to remove particulate and tar impurities before the H_2 is compressed to 700 bars for transportation. The CCS portion of the process will employ Fluor's proprietary system based on a propylene carbonate solvent. According to Stolaroff, the demonstration plant is one-third the scale of Mote's proposed full-scale plant. In the future, the company is planning to fine-tune the WGS catalyst for specific biomass compositions and evaluate other CCS schemes, including cryogenic and membrane-based technologies.

This new thermoplastic elastomer has a large impact resistance



Astuchi Noro/Nagoya University

Thermoplastic elastomers (TPEs) are typically copolymers of a plastic and a rubber that have both thermoplastic and elastomeric properties. The best-known TPEs include styrenic block polymers, which contain molecular blocks of polystyrene (which is hard) and polydiene (which is rubbery). Two important examples are polystyrene-b-polyisoprene-b-polystyrene (SIS) and polystyrene-b-polybutadiene-b-polystyrene (SBS).

To improve the mechanical properties of styrenic block polymers, researchers from Nagoya University (www.en.nagoya-u.ac.jp) and the Zeon Corp. (Tokyo, both Japan; www.zeon.co.jp) have developed an industry-friendly synthesis of chemically modified SIS, such as hydrogen-bonded SIS (h-SIS) and ionically functionalized SIS (i-SIS), which is SIS with positive ions such as sodium bonded in it (diagram). These results were reported last March in *Science Direct*. Since then, the partners have recently reported, in *ACS Omega*, the first study to evaluate the impact resistance of the new elastomeric materials based on i-SIS, and compare them to the impact resistance of a typical high-strength material based on glass-fiber-reinforced plastic (GFRP), which has a tensile strength of 330 MPa. Drop-weight impact tests demonstrated that i-SIS with monovalent or divalent cations is 3 to 4 times more impact resistant than chemically unmodified SIS. Moreover, i-SIS with divalent cations is found to be 1.2 times more impact resistant than typical high-strength GFRP. In summary, i-SIS, especially with divalent ions, was found to be highly impact resistant, even though inorganic fillers (hardening additives) are not incorporated into the polymer and the molecular structure of the polymer is not chemically cross-linked.

These properties give the new material a great potential to become a next-generation elastomeric material for use not only in interior and exterior automobile parts, but also for automobile bodies, and even the outer panels of automobiles, trains and other vehicles that require light-weight structural materials with high impact resistance, as well as ease of manufacture. ■

Business News

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Plant Watch

Ascend to build HMD plant in China's Jiangsu province

January 12, 2022 — Ascend Performance Materials (Houston; www.ascendmaterials.com) signed an investment agreement to construct a new hexamethylene diamine (HMD) and specialty chemicals plant in Lianyungang, China in the Xuwei New Area Park. The new plant will be Ascend's largest investment outside of the U.S.

LG Chem to construct world's largest battery-cathode materials plant

January 11, 2022 — LG Chem Ltd. (Seoul, South Korea; www.lgchem.com) plans to construct the world's largest plant dedicated exclusively to manufacturing battery cathode materials. LG Chem plans to invest approximately KRW500 billion ($420 million) on a site at the Gumi National Industrial Complex 5 by 2025 to procure cathode-material production capacity of 60,000 metric tons per year (m.t./yr).

Veolia to build EV-battery recycling plant in the U.K.

January 11, 2022 — Veolia (Paris, France; www.veolia.com) has announced plans for its first electric vehicle (EV) battery-recycling facility in the U.K., which will have the capacity to process 20% of the U.K.'s end-of-life EV batteries by 2024. Veolia's new facility in Minworth, West Midlands marks the first step in developing its recycling technology and treatment capacity within the U.K.

SK Geo Centric and PureCycle to build recycled PP plant in Ulsan

January 10, 2022 — SK Geo Centric (SKGC; Seoul, South Korea; eng.skgeocentric.com) and PureCycle Technologies, Inc. (Orlando, Fla.; www.purecycletech.com) signed an agreement to open Asia's first recycled-polypropylene (PP) plant in Ulsan, South Korea. The facility is expected to have a production capacity of 60,000 m.t./yr, with completion expected in 2024.

Röhm announces PMMA capacity expansion in Shanghai

January 3, 2022 — Röhm GmbH (Darmstadt, Germany; www.roehm.com) has invested in the expansion of a production plant for polymethyl methacrylate (PMMA) molding compounds in Shanghai, China. The expanded molding-compounds plant will go into operation in 2023.

Merck to construct membrane production plant in Wisconsin

December 29, 2022 — Merck KGaA (Darmstadt, Germany; www.merckgroup.com) announced that its Life Science business sector has been awarded a €121-million contract for the construction of a lateral-flow-membrane production facility over a three-year period at the company's U.S. site in Sheboygan, Wis. The contract award from the U.S. Department of Defense, on behalf of the U.S. Department of Health and Human Services, is part of an effort to ensure secure local supply and production of critical products for pandemic preparedness.

Hexion to expand epichlorohydrin production capacity in the Netherlands

December 21, 2022 — Hexion Corp. (Columbus, Ohio) announced plans to expand production of epichlorohydrin (ECH) at its manufacturing site in Pernis, the Netherlands. The planned expansion will add 25,000 m.t./yr of ECH capacity and utilize bio-based renewable feedstocks by leveraging glycerin-to-ECH production technology. The planned expansion will occur over the next three years with production startup anticipated in late 2024.

Perstorp expands capacity for trimethylolpropane

December 21, 2022 — Perstorp AB (Malmö, Sweden; www.perstorp.com) has ramped up production capacity for trimethylolpropane (TMP) at its site in Vercelli, Italy to meet growing demand from the European market. Common applications for TMP include use in saturated polyesters for coil coatings, polyurethanes for coatings and elastomers, acrylic acid esters for radiation curing, esters for synthetic lubricants and for surface treatment of pigments. Perstorp also operates TMP production sites in China, Sweden and the U.S.

OMV scales up ReOil advanced recycling process for new demonstration plant

December 20, 2022 — OMV AG (Vienna, Austria; www.omv.com) plans to build a chemical-recycling demonstration plant based on its proprietary ReOil technology, which converts waste plastics into synthetic feedstock. With a design capacity of 16,000 m.t./yr at the OMV site in Schwechat, Austria, plant startup is planned for early 2023. A ReOil pilot plant has been operating at the site since 2018, and an industrial-scale plant is planned for 2026.

Mergers & Acquitisions

Perstorp acquires GEO's di-methylolpropionic acid business

January 11, 2022 — Perstorp has acquired the di-methylolpropionic acid (DMPA) business of GEO Specialty Chemicals (Ambler, Pa.; www.geosc.com). This acquisition further accentuates the company's strategic presence in polyurethane and alkyd dispersions for waterborne coatings applications. GEO will continue to produce DMPA exclusively for Perstorp at a plant in Allentown, Pa.

Thermo Fisher Scientific acquires protein manufacturer PeproTech

January 6, 2022 — Thermo Fisher Scientific Inc. (Waltham, Mass.; www.thermofisher.com) completed its acquisition of PeproTech, a developer and manufacturer of recombinant proteins, for a total cash purchase price of approximately $1.85 billion. PeproTech will become part of Thermo Fisher's biosciences business.

Clariant acquires BASF's U.S.-based Attapulgite business assets

December 28, 2022 — Clariant AG (Muttenz, Switzerland; www.clariant.com) agreed to acquire BASF SE's (Ludwigshafen, Germany; www.basf.com) U.S. Attapulgite business for $60 million. BASF's Attapulgite business is one of the largest attapulgite businesses in North America, with mining operations in Georgia and Florida and processing operations in Quincy, Florida.

Cargill to acquire industrial chemicals portfolio from Croda

December 22, 2022 — Cargill, Inc. (Minneapolis, Minn.; www.cargill.com) reached an agreement with Croda International Plc (Snaith, U.K.; www.croda.com) to acquire the majority of its performance technologies and industrial chemicals business for €915 million ($1.03 billion). Expected to close in summer 2022, the Croda acquisition will greatly expand Cargill's bioindustrial market presence, especially in Europe, the U.S. and Asia.

SK Geo Centric and Tokuyama form isopropyl alcohol JV

December 22, 2022 — SK Geo Centric and Tokuyama Corp. (Tokyo; www.tokuyama.co.jp) plan to invest roughly KRW120 billion (around $100 million) in a 50-50 joint venture (JV), which will produce and sell high-purity isopropyl alcohol (IPA) for semiconductors. The JV will construct a manufacturing plant to produce 30,000 m.t./yr of IPA. The plant will begin pilot operations in 2023 before being commercialized in 2024.

Cummins and Sinopec launch JV to produce electrolyzers in China

December 21, 2022 — Cummins Inc. (Indianapolis, Ind.; www.cummins.com) and China Petrochemical Corp. (Sinopec Group; www.sinpecgroup.com) formed a 50-50 JV located in Guangdong Province, China. The JV will initially invest $47 million for a manufacturing plant to produce proton-exchange membrane (PEM) electrolyzers. The plant will initially have a manufacturing capacity of 500 MW/yr of electrolyzers upon completion in 2023, which will be gradually increased over the next five years to reach 1 GW of manufacturing capacity per year.

Entegris to acquire CMC Materials for $6.5 billion

December 16, 2021 — Entegris, Inc. (Billerica, Mass.; www.entegris.com) and CMC Materials, Inc. (Aurora, Ill.; www.cmcmaterials.com) announced a merger agreement under which Entegris will acquire CMC Materials in a cash and stock transaction with an enterprise value of around $6.5 billion. CMC Materials is a leading supplier of advanced materials, primarily for the semiconductor industry. ■

Mary Page Bailey

PAT Framework Provides Benefits in the CPI

Beyond product quality, process analytical technology (PAT) strategies optimize processes and efficiency in the chemical process industries

IN BRIEF

BENEFITS OF PAT

TOOLS OF THE TRADE

DIGITALIZING PAT DATA

NEW APPLICATIONS FOR PAT

The process analytical technology (PAT) initiative was started by the U.S. Food and Drug Administration (FDA) in 2003 to ensure quality of product in the pharmaceutical industry; however, many sectors of the chemical process industries (CPI) had already been incorporating similar strategies. Today's advancements in analytical technologies and digitalization have taken these practices further, providing benefits in efficiency and optimization, as well as product quality and consistency.

PAT provides an integrated framework that enables real-time measurement of the quality attributes of a product during the manufacturing process. Companies can steer and optimize these quality measurements via multivariate control of critical process parameters. While the framework reflects the concept that quality cannot be tested into a product but must be deployed throughout the life of the product, adopters found that, in addition to generating actionable insight into processes to enhance product quality and consistency, the in-depth understanding that this framework provides can create additional benefits.

Benefits of PAT

According to Merilee Whitney, head of the BioContinuum platform, Millipore Sigma, the U.S. and Canada Life Science business of Merck KGaA (Darmstadt, Germany; www.emdmillipore.com), employing PAT helps processors in key aspects, including:

- Process improvement — monitoring, in real time, process parameters and quality attributes for greater process understanding and optimization, control and reproducibility during development phases
- Process automation — reducing off-line sampling and manual feeding via an automated nutrient control-loop strategy and decreasing the risk of contamination and minimizing the risk of batch failures
- Product yield and quality — understanding real-time process knowledge through PAT to help increase product yield and product quality

Mettler Toledo

FIGURE 1. Shown here is a PAT-equipped Synthesis Workstation for Process Development and Optimization. For accelerated process knowledge, Easymax automated reactor is equipped with ReactIR in situ FTIR and ParticleTrack particle characterization PAT. Used in conjunction with Dynochem process modeling, the technology facilitates rapid development, optimization and scale-up of chemical reactions and crystallization processes

Further, PAT frameworks can help lower manufacturing and development costs and processing times, as well as improve productivity and efficiency, says Martin Gadsby, CEO at Optimal Industrial Technologies (Bristol, U.K.; www.optimal-ltd.co.uk). "These frameworks can also enhance capability and sustainability, facilitating the reduction in the footprint of existing facilities. In effect, the comprehensive overview offered by PAT enables companies to clearly pinpoint where and how processes can be improved from both quality and commercial perspectives."

PAT has been successfully applied to both process development and manufacturing activities. "In process development, PAT is used for defining critical process parameters, quality attributes and design space in which the process operates in a manner that ensures optimal yield, quality and safety and minimizes byproducts that require additional workup and waste disposal," says Ulrich Schacht, principal technology and application consultant with Mettler-Toledo (Columbus, Ohio; www.mt.com). "Defining the space employs PAT, often orthogonally, to measure and understand the relationship between frequently competing reaction variables and overall reaction performance. In manufacturing, PAT is used to ensure that the process is stable and is operating within the prescribed design space. PAT solutions enable processors to build quality into the process instead of ensuring quality by extensive testing during production."

Schacht continues: "The net result of applying PAT is the enhancement of process understanding. PAT provides the measurement data required to fully understand a reaction or process and then to ensure that the process is operating as expected. The result of this process knowledge is higher chemical product quality, less waste and greater safety."

Optimal's Gadsby adds that the benefits of PAT cover multiple aspects of a business that ultimately make chemical processing facilities more agile and lean. "By enabling real-time, quality-centric measurement and control, it is possible to reduce or eliminate waste and reworks, improve energy and resource utilization, maximize throughput and reduce cycle times," he says. "This improved capability in material processing allows for the use of more widely sourced, possibly lower-cost raw materials, greatly improving business sustainability. By consistently delivering high-quality products with lower final quality variability, chemical manufacturers can improve customer satisfaction and market value while lowering product giveaway."

PAT can also help chemical processors shorten downtime and reduce activities associated with traditional "after-the-fact" quality control activities performed at the end of the manufacturing process by enabling real-time quality assurance strategies and reducing processing times and costs. "Furthermore," says Gadsby, "By adopting similar automated strategies in analytical laboratories, any such necessary testing can be performed faster and more efficiently. As a result, manufacturers can boost the productivity of existing facilities and reduce time-to-market, not only with faster development times, but also by adopting real-time release-testing strategies. They can also leverage their PAT capability to increase the throughput and capacity of existing facilities without increasing the main manufacturing infrastructure."

Tools of the trade

Successful implementation of PAT framework requires multiple components. At its core, PAT utilizes a variety of instruments, such as spectroscopic and chromatographic compositional analyzers and fixed-purpose sensors. The most-used instruments include single-purpose sensors for measuring a specific variable such as pH, turbidity or dissolved oxygen, says Calum Welsh, product manager, reaction analysis, with Mettler-Toledo. "In-situ spectroscopic monitors such as FTIR [Fourier-transform infrared], Raman, UV/VIS [ultraviolet/visible], NIR [near infrared], NMR [nuclear magnetic resonance] and mass spectroscopy provide large data volume," he says. "In addition, on-line chromatography is used for identifying/tracking reaction species and for impurity profiling. Particle characterization probes such as FBRM [focused-beam reflectance measurement] and in-situ imaging systems provide information about crystallizations and emulsions and allow real-time visualization of particles" (Figure 1).

Additionally, there are constant improvements to ensure precision and accuracy of instrumentation, with precision having the utmost importance when it comes to effective process control, says Michael Kester, senior chemical product manager with Endress+Hauser Optical Analysis, Inc. (Greenwood, Ind.; www.us.endress.com). "Another key ingredient to a successful technique is a high degree of reliability, where a system can run unattended 24/7, indefinitely, before maintenance is required. Finally, it is also vital for the technique to be unaffected by sample conditions, negating the use of a sample conditioning system. Approximately 80% of the time that a process analyzer fails, it is due to an issue with the sample handling system."

Martin Hornshaw, director of Enterprise, Science and Innovation with Thermo Fisher Scientific (Waltham, Mass.; www.thermofisher.com) agrees that improvements in sampling are important for the continued advancement of PAT techniques. "For PAT to really make a difference in supporting the development and implementation of a new process, an approach that is 100% reliable in aseptically taking a sample for analysis is critical," he says. "In addition, and particularly in process development, the PAT solution should include the ability to acquire multiple measurements from the same sample, aseptically taken from a bioreactor (or multiple bioreactors) with multiple analytical technologies (Figure 2) to acquire a vast amount of data in real time. Technologies that remove sample aseptically and can then send them to analytical devices are growing in popularity and there are several such technologies available."

For the greatest benefits, PAT instruments are embedded into the process, says Alfred Kania, busi-

Thermo Fisher

FIGURE 2. Double throughput or deepen sample knowledge using the Thermo Scientific Vanquish Duo UHPLC System for Dual LC, featuring a dual split sampler and two pumps, either as separate modules or combined in the dual pump. The dual liquid chromatography system has the same footprint as a single instrument, but contains two flow paths, allowing users to run the same method on both flow paths or run two different methods simultaneously on the same instrument

FIGURE 3. Optimal's software for PAT-driven manufacturing, synTQ, provides a regulatory-compliant, scalable and modular central platform that supports total quality management activities. The software solution generates immediate actionable insight into R&D and manufacturing processes by creating a single interconnected network of instruments, analyzers, management software and automation systems

ness development manager with Siemens (Houston; www.siemens.com) "A PAT strategy should consist of embedding one or more PAT analyzers in the process for continuous monitoring. PAT analyzers provide data which needs to be interpreted as they provide both chemical and physiochemical information about the process. The biggest benefit is to combine these measured data with process data and quality data of the consumed raw materials and to time-align all the data in a consistent way. The aligned data can then be used in statistical models to predict product quality in real time and initiate changes in the process to keep or get the process back on track."

Additionally, says Rudi Spinner, product manager with Siemens (Karlsruhe, Germany), fast measurement is, for many processes, a very important requirement. "Manually taking lab samples and analyzing them is by far too slow, especially when results of this untimely analysis can result in detrimental effects such as an explosion in the process. With fast, online monitoring, the operators know exactly what is going on in their processes in real time."

To get the most from a PAT framework, additional components are needed, often including industrial automation devices such as distributed control systems (DCS), programmable logic controllers (PLCs) and supervisory control and data acquisition (SCADA) systems. MVA (chemometric modeling) platforms are also necessary. Other systems, such as historians, laboratory information management systems (LIMS), manufacturing execution systems (MES) and business platforms, such as enterprise resource planning (ERP) tools may also be included in large-scale PAT frameworks. And, PAT knowledge management software often serves as a central hub, connecting disparate elements and combining data to generate holistic process understanding. This platform also stores, filters, processes and visualizes key information and generates reports for quality auditing purposes.

"A PAT knowledge-management platform provides the ability to seamlessly connect to all other components of a PAT framework," explains Optimal's Gadsby. "In particular, agnostic, multivendor solutions that can support connections with different instruments, MVA packages and control systems are extremely useful, as they enable chemical manufacturers to integrate the products that best address their needs within their PAT strategies without compatibility issues" (Figure 3).

Digitalizing PAT data

"PAT contributes to the digitalization of chemical plants by creating continuous data streams that reveal what the plant process is doing at a particular point in time. This continuous stream of data feeds into databases, either on premises or in the cloud and can be mined like any other process data to find the most optimal process operating conditions," says Endress + Hauser's Kester.

Christiane Jaeckle, manager of technology and concepts for the chemical industry with Siemens (Erlangen, Germany), says: "PAT and digitalization are a perfect match because PAT enhances technologies such as artificial intelligence and digital twins. Also, digital capturing of the process can be performed 24/7 with results being shared across the company. Embedding PAT in the process means you are bringing more data and knowledge into the process, which is the goal of digitalization."

While data analytics come into play when there is a deeper understanding of the chemical process and can be used to troubleshoot the process or find optimal process conditions for producing the best product as efficiently as possible, data complexity can become a challenge when multivariate data are collected using analytical techniques," says Endress+Hauser's Kester.

"Multivariate calibrations must be done to ensure an appropriate measurement from a technique," he explains. "Creating a chemometric model that ties together the complex process data to the measured property of interest often requires sophisticated spectroscopy and chemometric techniques. Software packages that perform these calculations and manipulations are getting easier to use all the time (Figure 4).

Kester continues: "What we are seeing today is software that can actually do much of the work that chemometricians previously did themselves. Plus, this new software can be configured to automatically generate new models as necessary to accommodate process variations such as recipe changes or different operating conditions such as changes in temperature or pressure."

Optimal's Gadsby agrees that data complexity does need to be addressed in PAT frameworks due to the nature of the processes involved. "Firstly, it is important to carefully design the systems, not only by determining key analyzers and data

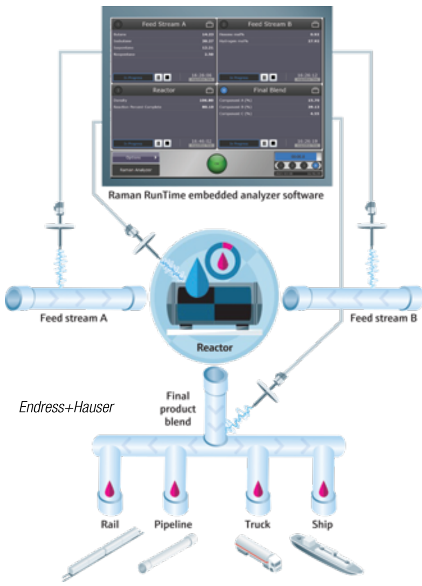


FIGURE 4. Embedded analyzer software simplifies data interpretation and delivers actionable information quickly

NEW APPLICATIONS FOR PAT

As PAT initiatives find their way into many sectors of the CPI, processors are finding new applications and reaping the benefits of PAT strategies.

According to Thermo Fisher's Hornshaw, PAT is underutilized in bioproduction. "Although a number of biopharma and biotech companies are currently exploring the implementation of more sophisticated multiplexed PAT tools in process development up to pilot scale, it has not advanced further for most," he says.

In biopharma, particularly for process development and pilot scale, for protein therapeutics and viral vectors for gene and cell therapies, many of the same analytical technologies and approaches would have relevance, says Hornshaw. For example, mass spectrometry, ultra-high performance liquid chromatography, liquid chromatography-MS and spectroscopic techniques such as Raman spectroscopy would have relevance. "These different technologies measure different process parameters and product quality attributes," he explains. "Multiplexed analysis, which captures information on a range of process parameters and/or product quality attributes at the same time is a particularly exciting area for the development of analytical approaches to support the rapid development of optimized processes. These may also be relevant to the final process applied at commercial manufacturing scale in particular circumstances."

Millipore Sigma's Whitney agrees that as technologies expand, especially those designed for the bioprocessing industry, there are many more potential applications in bioprocessing: "Integration of PAT for the bioprocessing industry in bioprocess manufacturing is currently evolving from the offline paradigm to at-line and in-line analytics. Technologies to actively monitor critical quality attributes, such as aggregation, glycosylation, residual host cell protein (HCP) and bioburden, to name a few, would advance biomanufacturing towards real time" (Figure 5).

FIGURE 5. MilliporeSigma's ProCellics Raman Analyzer probe is immersed into the bioreactor, protected from external straylight with a light-proof fabric. The instrument is controlled by Bio4C PAT Raman software

FIGURE 6. The EZ Series Online Analyzers include new and unique parameters, numerous measurement ranges and provide data 24/7. With continuous monitoring from EZ Series analyzers, trends and potential issues can be identified before they become problems

In a different vein, chemical processors are employing PAT frameworks into water quality analysis, both upstream and downstream of the process, to better manage the water cycle. "In the CPI, it's important to analyze and monitor source water, process water and effluent water. Instrumentation and analysis are integral here not only to improve product quality and yield, but also to meet regulatory compliance, enhance safety, protect downstream equipment and minimize waste, all of which greatly impact the bottom line," says Denton Slovacek, principal of application development with Hach (Loveland, Colo.; www.hach.com).

He says PAT framework is being applied to continuously monitor turbidity, suspended solids, chlorine, pH, conductivity, total organic carbon and other measurements necessary for the water coming into, going through and leaving the process. The ease of use of today's monitoring tools, the ability to present and trend relevant data to the user via simplified software platforms and employ that knowledge for real-time control of the process to optimize water usage is what engages PAT strategies for the water cycle, says Slovacek (Figure 6).

Similarly, PAT strategies are being applied to enhance safety, says Charu Pandey, senior global technical and application solutions specialist, with Emerson (Shakopee, Minn.; www.emerson.com). "Combustion safety, for example, is a great application for these technologies. Combustion probes can be installed in flue ducts of boilers to continuously measure the CO and oxygen concentration in the duct. Onsite boilers are used to generate steam for process heat around the plant. Flue duct walls, as well as the combustion probes themselves, are hot surfaces where combustibles can ignite. For this reason, boiler operators establish controls around CO and/or oxygen concentration measurements if the increase in CO concentration or decrease in oxygen concentration is too great, the boiler can be shut down."

He adds that pH and conductivity analytical instruments can also be used for combustion measurement in chemical process control. "In-situ and close-coupled extractive combustion probes are often installed in flue ducts of boilers that provide process heat for reboilers, reactors and heat exchangers" (Figure 7). ❒

FIGURE 7. Accurate and reliable measurements are critical in a wide range of chemical processing facilities to protect capital assets, ensure product quality, increase process uptime, enhance safety and reduce energy costs

points, but also by defining highly effective computational strategies.

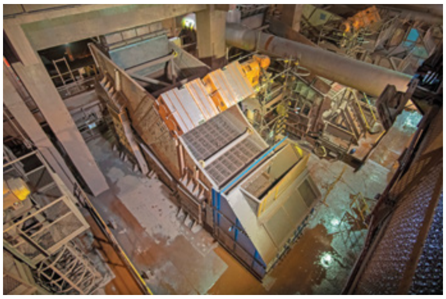
"Moving on, it is essential to adopt and continuously optimize advanced analytical methods for modeling and simulating manufacturing processes based on Big Data," he continues. "In this way, it is possible to reduce any inherent complexity and inaccuracy of data. The use of increasingly sophisticated and accurate automated intelligent control (AIC), quality and track-and-trace predictive models is extremely helpful to address these challenges. Even more, the near unlimited power of the cloud is ideal to help overcome data complexity as it enables businesses to process large volumes of data. Using the power of analytics in a PAT knowledge manager helps to make sense of the complex."

As for future goals, Thermo Fisher's Hornshaw sums it up: "I envisage a future where a process is fully automated, routinely needing no human intervention. This would include appropriate PAT technologies placed up and down the process, with data flowing into the digitally automated control system, enabling automated real-time decision making that reliably and reproducibly produces a product at maximum yield and quality in the shortest time possible. Every facility would take this approach and that process analytical data would be an essential element of the control of this futuristic, fully automated process and the monitoring of it remotely." ■

Joy LePree

Focus on Particle Sizing


Malvern Panalytical


Haver & Boecker Niagara


Flexicon


Gericke USA

Learn more than just particle size with this imaging unit

The Hydro Insight (photo) is a dynamic-imaging accessory for this company's Mastersizer 3000 particle-sizing instrument. Through real-time particle imaging, this tool helps users to see beyond particle size — powering more in-depth materials research and exciting scientific advances. Sitting alongside the Mastersizer 3000 laser-diffraction system, the Hydro Insight provides live particle images by combining Vision Analytical's dynamic imaging expertise with this company's flow-cell technology. Based on these images, it also generates quantitative data on particle shape, alongside particle-size data from the Mastersizer 3000. The combination of high-resolution imaging with high-range laser-diffraction data provides a more comprehensive overview of materials than laser diffraction alone, says the company. — *Malvern Panalytical B.V., Almelo, the Netherlands*
www.malvernpanalytical.com

Elliptical movement for high-moisture screening

This company has engineered a new, elliptical-motion Niagara XL-Class vibrating screen (photo) for a Brazilian iron-ore producer. The new technology handles screening applications with high-moisture content, and can easily handle capacities up to 3,500 ton/h while minimizing water usage. The XL-Class runs in an elliptical motion of up to 6 × *g* in a high-moisture iron-ore screening application to ensure stratification in all phases of screening. The new vibrating screen also features a robust elliptical exciter drive that offers a bearing life up to 75,000 h. Iron ore contains up to 15% moisture, and often behaves like a pasty, clay-like material, prone to blinding on a screen deck. The elliptical motion and increased acceleration of the XL-Class ensures that the material is stratifying without blinding or contamination. The elliptical-motion XL-Class vibrating screen is available in a wide range of sizes, in either a single module or tandem design. —*Haver & Boecker Niagara, St. Catharines, Ont., Canada*
www.haverniagara.com

Sizing-dispensing system for abrasive bulk materials

A newly introduced sizing-dispensing system (photo) for abrasive materials receives, scalps, stores and dispenses sand, rutile, zircon and other dense, abrasive materials on-demand, free of dust. Fed by a pneumatic conveying line, the system is equipped with an integral cyclone that separates incoming solids from the air stream. A rotary airlock isolates the pneumatic system from atmospheric pressure and meters material into a vibratory sifter that discharges on-size particles into a surge hopper. With extended vertical sides, the surge hopper stores up to 19 ft^3 (540 L) of material, enabling the system's flexible screw conveyor to dispense material when needed, while reducing the number of on-off cycles required for the independent pneumatic-delivery system to replenish the hopper with material. The enclosed 10-ft (3-m) conveyor, with curved, rigid carbon-steel tubing and heavy-duty round-wire screw, can handle a broad range of free-flowing and non-free-flowing bulk materials, from large particles to fine powders, including products that pack and seize, with no separation of blends. — *Flexicon Corp., Bethlehem, Pa.*
www.flexicon.com

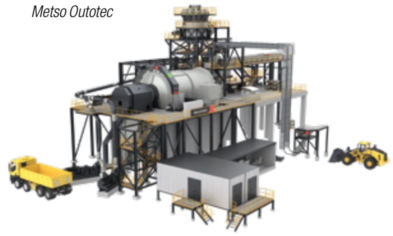
Centrifugal sifters achieve high throughput

GS centrifugal sifters (photo) automatically separate powders, granules and other dry, bulk materials into two product streams at a throughput rate up to 300% higher than common flat-deck sieves on the same footprint using identical screens, materials and cut points, says the company. Featuring a proprietary design with a rotating paddle assembly, the sifters direct fine particles through a mesh screen and divert oversized particles to the discharge using only centrifugal force and gravity. The centrifugal sifters typically achieve 99.9% efficiency, versus 85% efficiency for flat-deck

sieves given the same inputs without requiring the vibration, shaking or gyration that sieves typically require to process the material. The rotary sieve comes in a choice of carbon-steel or stainless-steel construction, with screen mesh sizes from 100 to 4,000 μm and throughput rates up to 120 ton/h. Four standard models and custom designs are available to suit sanitary, non-hazardous and hazardous ATEX environments. — *Gericke USA, Inc., Somerset, N.J.*
www.gerickegroup.com

Modular units for simple circuit selection in grinding

Metso Outotec



This company's horizontal mill plant units (photo) are pre-engineered plant units that provide optimized grinding performance and simplify project management through easy circuit selection and flowsheet implementation. At the same time, they ensure safe operability and maintainability thanks to their state-of-the-art design. The scope of the unit can be tailored according to project requirements (brownfield or greenfield, open or closed circuit). The horizontal mill plant units combine the company's horizontal mills, classification, pumping and automation technologies with a wide range of services and operation support. Benefits include: grinding and classification expertise to support flowsheet implementation; pre-engineered modules for simple and rapid execution; easy process optimization, thanks to comprehensive automation and digitalization features; and more. — *Metso Outotec Corp., Helsinki, Finland*
www.mogroup.com

Analyze particle shape and size in suspensions and emulsions

The Analysette 28 ImageSizer, in combination with the new automatic wet dispersion unit, is especially suitable for analyzing fine particles, poorly flowing, fine-agglomerating or sticky materials that do not react in water or other liquids. For perfect dispersion, the sample material is fed into a closed liquid-circulation system and is pumped with high power through the measuring cell between a camera and an LED strobe light. The continuously

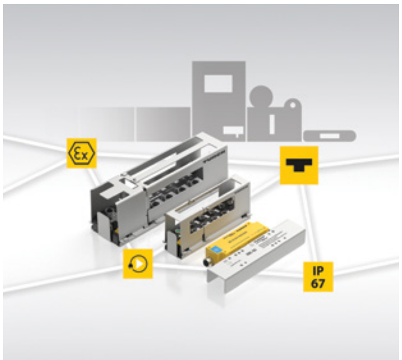
Fritsch

obtained images are the basis for the analysis with a variety of evaluation possibilities. For wet measurement, three different bi-telecentric lenses are available for optimum adaptation of the total measuring range from 5 μm to 3 mm. In combination with the powerful industrial camera, they guarantee the highest accuracy of the imaging of each individual particle at the same imaging scale and the highest shape accuracy with the greatest possible depth of field. — *Fritsch GmbH, Idar-Oberstein, Germany*
www.fritsch.de ■

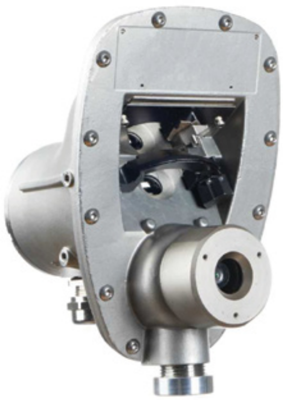
Gerald Ondrey

New Products

Blue-White Industries



Hans Turck



Dräger

Siemens

This chemical metering pump can handle long-chain polymers

The Flexflo A3 peristaltic metering pump (photo) is designed to deliver smooth and gentle chemical feed for industrial water treatment without damaging long-chain polymers. In chemical treatment applications for industrial wastewater, the pump will accurately and consistently dose off-gassing chemicals, such as peracetic acid (PAA) and sodium hypochlorite (NaClO) with no vapor lock and no loss of prime. Additional A3 features include a 5-in. intuitive touchscreen display, which will respond even when the operator is wearing work gloves. The extra-large icons are easily recognizable and highly responsive. Because of the A3's broad feed range and turndown ratio, users may be able to standardize operations on just one feed pump for all chemical dosing needs. Control methods for the pumps include manual, remote analog/digital, EtherNet/IP, Modbus TCP/IP and Profibus. — *Blue-White Industries, Ltd., Huntington Beach, Calif.*
www.blue-white.com

Decentralized I/O solutions for the Ex area

This company has approved its IP67 block input/output (I/O) modules (photo) for the TBEN-S and TBEN-L versions for use in Zone 2 areas. The company is said to be the first supplier to enable cabinet-free decentralized automation solutions with ATEX and IEC Ex approval, which can considerably reduce required mechanical labor, wiring and commissioning times. In conjunction with the devices of the IP67-rated IMC interface series, it is possible to implement the cabinet-free connection of intrinsically safe signals from Zone 0 or 1. Users can also implement cabinet-free safety, RFID, IO-Link, controller or cloud solutions directly in Zone 2, since virtually the entire IIoT ecosystem is offered in these designs. Users must also install the TBSG-L, TBSG-S or IMC-SG protective housings when implementing the I/O solutions in Zone 2. — *Hans Turck GmbH & Co. KG, Mülheim an der Ruhr, Germany*
www.turck.com

Use this optical gas-detection camera for methane leaks

The MetCam optical gas-detection camera (photo) automatically identifies and quantifies methane leaks, even under challenging conditions. Potential hazards from escaping gases can thus be assessed more quickly and more precisely. Methane gas leaks are invisible, but even the smallest leaks can endanger the safety of an industrial plant and damage the environment, and there are often dense facility areas that are difficult to access with many potential leak sources. For such areas, MetCam complements conventional point gas-detection systems with area monitoring. In contrast to point detectors, the gas source does not have to be in the immediate vicinity of the gas camera. Its field of view is already sufficient to detect the escaping gas. This means that detection is independent of wind or other influences. The gas cloud is visualized as a colored overlay on a black and white video image. In addition, the MetCam automatically quantifies the concentration of the escaping gas. — *Dräger, Inc., Houston*
www.draeger.com

A maintenance app with integrated AR function

Comos Mobile Worker (photo) is a new software application (app) for mobile data management with integrated augmented reality (AR) functionalities. It was developed in cooperation with Augmensys GmbH, a specialist in the field of mobile data management and AR. For the fast and safe maintenance of process plants, the Comos Mobile Worker app visualizes and processes all required data — from enterprise resource planning (ERP) systems, engineering data and also live data from the process control system — in an easy-to-use interface. Thanks to a direct connection to Comos engineering software, all engineering data can be linked to enable a holistic view of the plant. Changes or annotations can be securely transferred through the bidirectional exchange between the systems. The integration of location data also supports on-site navigation. — *Siemens AG, Munich, Germany*
www.siemens.com

A dosing system for automated contact-angle measurements

The success of coating and bonding, as well as other surface processes, depends on wettability. The relevant parameters are contact angle and surface free energy (SFE), which are measured with drops of one or more liquids that are dispensed onto the material. Automation of dosing devices has advanced to simplify serial testing of materials. However, the often-cumbersome change of liquids and slow positioning and dosing can lead to time losses. The Dosing Hub (photo) is a system for contact angle measurements that is designed for automatic dosing sequences with up to three different dosing units. With high-speed and precise positioning, the system enables reliable wetting analyses with up to four liquids. — *Krüss GmbH, Hamburg, Germany*
www.kruss.de


Krüss

Proprietary control technology for pneumatic conveying units

The ET line of advanced controllers are designed to automatically manage operation of this company's pneumatic vacuum-conveying systems (photo). Applying proprietary technology, ET conveyor controllers feature a sensor-based design that monitors material levels in the feed hopper, vacuum conveyor or receiving vessel via a choice of three operating modes, automatically controlling material transfer at every step, avoiding the potential for human error. Suitable for managing the transfer of powders, pellets, granules and other bulk materials, the ET line of electronic controllers comprises the ET-Advance for monitoring up to four level sensors at the same time, and the ET3 and ET4 for monitoring individual sensor locations. The controllers may be adjusted to change the vacuum-pump suction time, material discharge time, line clearing time and other parameters to quickly accommodate different materials and recipes. ET controllers may be integrated into existing programmable logic controller (PLC) environments or operated as standalone units. — *Volkmann USA, Inc., Bristol, Pa.*
www.volkmannusa.com


Volkmann USA

A module that grants functional safety to drive systems

The SK TU4-PNS, known as the PROFIsafe module, provides comprehensive safety for the reliable operation of this company's drive systems (photo). This PROFIsafe module is a drive-integrated solution for decentralized variable-frequency drives (VFDs) that implements functional safety within the system to stop operation and avoid potential injuries or component damage. In addition to the standard functions — STO (safe torque off) and SS1 (safe stop 1) — PROFIsafe includes additional safety features, with functions such

NORD Gear

as SLS (safely limited speed), SSR (safe speed range) and SSM (safe speed monitor) incorporated into the drive units. These functions, as well as SDI (safe direction) and SOS (safe operation stop), achieve SIL 3 (safety integrity level 3) or PLe (Performance Level 3) Category 4. — *NORD Gear Corp. Waunakee, Wis.*
www.nord.com

Electrical pressure generator for portable automatic calibrations

The ePG (photo) is a new electrical pressure pump for industrial pressure-calibration applications. The ePG is a robust, portable, battery-operated pressure pump that enables easy and quick pressure generation from near vacuum up to 20 bars (300 psi). With a field-replaceable, long-lasting battery pack, users can perform a large number of pressure calibrations on a single charge. The ePG can be used together with any existing pressure calibrator, meaning users

do not need to buy a new calibrator but can simply replace their manual hand pump with the ePG. It is very intuitive to operate, with coarse and fine adjustment buttons to easily generate the required pressure. When the ePG is used together with the MC6 family of calibrators, it enables fully automatic pressure calibration. — *Beamex, Inc., Marietta, Ga.*
www.beamex.com

This tool simplifies lubricant application

The Model 1154 Lincoln dual-piston lever-action grease gun (photo) features a thumb-operated switch that allows users to toggle between high-volume and high-pressure lubricant application modes. This makes it easier for technicians working on a wide range of equipment to quickly adjust the tool to match changing lubrication requirements as they work. For high-volume applications, the Model 1154 requires just one-third the number of strokes, compared to standard grease guns, to

apply the same amount of lubricant. The high-volume position allows efficient greasing of all lubrication points with fewer strokes. Large joints, bushings and bearings can be filled quickly. It is also suitable for lubricating large surface areas. If high pressure is needed, such as when a fitting is blocked, it can be difficult for an operator to clear, but in Model 1154's standard pressure position, the tool can more easily open the fitting without an operator having to apply excessive force. — *SKF, Inc., Lansdale, Pa.*
www.skf.com

A new member added to this family of rental compressors

This company has added a new air compressor for the 10-bars range to its portfolio of rental solutions. The TVS2500 (photo) is the largest air compressor made for rental packages to date and is characterized by a robust design, efficient technology, particularly quiet operation and high-temperature resistance. Thanks to a frequency inverter, assemblies can


Aerzener Maschinenfabrik

be optimally controlled, so that the required pressure and volume flow is always achieved. The variable speed control also enables a gentle start with low starting current. This reduces the load on the power grid during startup by a factor of 2.5. — *Aerzener Maschinenfabrik GmbH, Aerzen, Germany*
www.aerzen.com

Use these filter cartridges for treating chemical contamination

This company has expanded its water-treatment product portfolio with three new filter cartridges, including carbon block, pleated and melt-blown (spun) media. The new cartridges will enhance sediment-removal capabilities and widen applications to address chemical contamination concerns. The new spun and pleated filter cartridges improve sediment removal efficiency to as low as one micron through advancements in composition, surface area and pore size. The activated carbon units, which operate at a rate of 10 microns, address areas not covered by the company's existing products, including: taste and odor; lead and chlorine; and volatile organic compounds (VOCs). — *Rusco, Inc., Brooksville, Fla.*
www.rusco.com


Rusco

Hemco

A balance enclosure for critical weighing procedures

The VSE balance enclosure (photo) is offered in widths of 24, 36 and 48 in., in order to accommodate an analytical balance and other small-scale laboratory processes. Constructed of chemical-resistant metal framing and 1/4-in. thick clear acrylic side panels and viewing sash. Efficient airflow design with airfoil and bypass directs contaminants to baffled exhaust, thereby providing superior airflow and containment performance for user protection. The viewing sash is angled 15 deg for ease of viewing, with 8-in. reach-in opening height. The sash swings upward to provide 20 in. of access opening. Two service ports are located in lower-right and left-rear wall. — *Hemco Corp., Independence, Mo.*

www.hemcocorp.com

Bühler

A new volume for this family of bead mills

The Cenomic Optima bead mill (photo) has a range of technological improvements that result in higher flowrates, higher power inputs and improved cooling to deliver up to 25% higher productivity than previous mills of the Cenomic family. The Cenomic Optima is said to offer 37.5% more grinding-disc surface for more efficient bead activation. The 30-kW drive unit allows users to increase power input and thus more rapidly reach the required specific energy for optimal grinding. This can improve productivity by up to 25% without increasing the footprint, says the company. A ceramic inner liner ensures the products stay cooler during grinding and allows the usage of the higher power input without breaching the product's temperature limit. A larger screen diameter reduces pressure within the chamber and delivers at least 25% higher flowrates. This speeds up the process and avoids unwanted hydraulic packing. —*Bühler AG, Uzwil, Switzerland*

www.buhlergroup.com

Alfa Laval

Leveraging digitalization to optimize hygienic processing

The new CM Connect (photo) is a subscription-based condition monitor and cloud gateway. It enables plant operators to access rotating-equipment data on processing lines from a remote location. With data on actual runtime, trend analysis and time to next service close at hand, plant operators can make informed maintenance decisions using their personal computers and mobile devices. This protects process continuity and critical assets, improves workplace safety, saves time and money, and delivers competitive advantage. Acting as a gateway communicating via Bluetooth, the CM Connect can link up to 10 of this company's CM wireless vibration monitors. It then transmits the data over a 4G cellular network to the cloud for review and analysis on an intuitive, user-friendly dashboard. Besides linking CM wireless vibration monitors, the CM Connect can also act as a sensor. It measures vibration, inboard temperature and total runtime when mounted on LKH, SRU, SX and DuraCirc pumps, or other rotating machines, such as agitators or mixers. — *Alfa Laval AB, Lund, Sweden*

www.alfalaval.com

WIKA Alexander Wiegand

This DP transmitter has SIL 2 certification

The new model DPT-20 differential pressure (DP) transmitter (photo) is suitable for many industrial processes. As a SIL-2 certified instrument, it meets the highest safety requirements. The compact transmitter operates with an accuracy of <±0.065% of span. Due to a three-dimensional temperature compensation on adjustment, it provides a reliable measuring result, even under unfavorable ambient conditions. The DPT-20 is available with measuring ranges between –10 and 10 mbars, and –16 and +16 bars, and is designed for a static pressure of up to 400 bars. There are three communication protocols available for integration into existing systems. — *WIKA Alexander Wiegand SE & Co. KG, Klingenberg, Germany*

www.wika.de

Tuf-Lok International

Self-aligning pipe and tube couplings

This company's ring-grip pipe and tube couplings (photo) are heavy-duty, self-aligning couplings for either high pressure (up to 150 psig) or full-vacuum-rated applications. These

couplings can be installed quickly and easily, reducing costs. They are available in 2- through 10-in. pipe sizes and are made for use on plain-end pipes or tubes, regardless of pipe- or tube-wall thickness. Other features include self-grounding, vibration resistance and externally leak-proof, with an extremely high end pull for difficult applications. No machining or grooving is required to maintain pipe or tube integrity. Every coupling becomes a union, providing easy and low-cost maintenance when piping components need replacement. Numerous standard gasket materials are available to meet special design conditions, such as food-grade requirements, higher temperatures or special chemical-resistant applications. — *Tuf-Lok International, Madison, Wis.*
www.tuflok.com

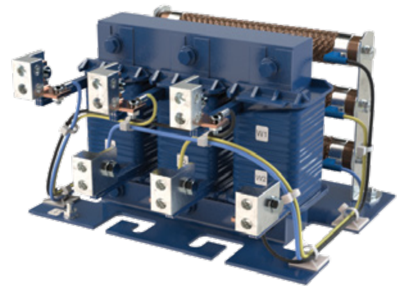
Optimize technology scouting and investing with this platform

This company has significantly revamped its Scout software (photo) for open-innovation and technology scouting with new features, including a redesigned visual user experience that helps identify and assess early-stage technologies for innovation investment. Until now, most or-

ganizations have defined their future-leaning innovation priorities based on technology readiness levels (TRLs), an approach first developed in the 1970s. But such methods require a pre-existing sense of where to look, which, for early-stage technologies, can be notoriously difficult to discern. The new analytics tools in Scout fill this gap by helping companies discover strategic innovation opportunities proactively. The new Scout analytics suite is an integrated toolkit that leverages the latest in machine learning technology, along with an easy-to-use, drag-and-drop visual interface. It allows users to identify technologies poised for disruptive growth and assess research programs primed for breakthrough results. Scout also now provides in-depth analytics tools to help innovation teams assess and prepare for key technology trends looming on the horizon. — *Wellspring Worldwide, Chicago, Ill.*
www.wellspring.com

These enclosures now feature enhanced gasket protection

The PolyStar series of electrical and industrial polycarbonate enclosures (photo) now features new foam-in-place gaskets. These gaskets provide full, secure contact to the mating cover surface with a continuous overlapping seal that ensures no air gaps, no glue joints and no shrinking of gasket size due to stretching of the material. The result is maximum sealing integrity and reliable protection of all wiring, connections, instrumentation and controls housed by PolyStar enclosures. Enclosures are available with matching polycarbonate latches for a fully nonmetallic enclosure, or with stainless-steel latches. Latches can be swapped easily without any tools, making retrofitting the enclosures in the field accessible to all users. Cover options include hinged or screw; with either opaque or smoked finish. Select Polystar models are listed as cULus Type 4X; or Type 6P for the U.S. and Canada; or are certified as IEC IP66 with select sizes IP68. A total of 13 sizes are available. — *Stahlin, Belding, Mich.*
www.stahlin.com



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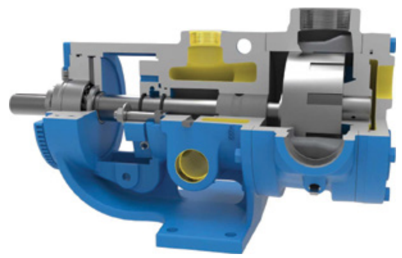

Michael Smith Engineers

Protect motors with this new dV/dt filter

The dV E-Series motor-protection filter (photo) mitigates reflective waves, reduces rise time and limits peak voltage, resulting in reduced motor heating, longer cable and motor life, and a significant reduction in downtime and total ownership cost. Using a d*V*/d*t* filter enables uptime and protects a.c. motors from the destructive effects of the variable-frequency drive (VFD) pulse-width modulated voltage that can damage cables and motors. The dV E-series offers up to 60% lower wattage loss versus competitive d*V*/d*t* filters, enabling more efficiency and savings, and ensuring longer life and protection for equipment around the filter, according to the manufacturer. It features a compact design that is said to be up to 73% lighter and 35% smaller than other commercial products for easier installation in crowded cabinets. — *MTE Corp., Menomonee Falls, Wis.*
www.mtecorp.com

Use these gear pumps with asphalt and bitumen

The ASP Series of internal gear pumps has added two new pumps, the ASP1 and ASP2 (photo), which can handle abrasive media. When pumping asphalt, bitumen and other similar abrasives that solidify at ambient temperatures, pumps have traditionally been sealed with packing that must continually leak to stay lubricated. The new ASP pumps are supplied with this company's O-Pro cartridge seal, which uses O-rings in combination with a lubricating grease. This means that the seal does not need periodic repacking or re-tensioning of the seal gland, which eliminates leaks and prevents loss of product and the associated clean-up costs. The pumps are designed to melt ambient-temperature solids to a liquid state prior to pump startup by using integral jacketing for steam or hot oil. — *Michael Smith Engineers, Ltd., Woking, U.K.*
www.michael-smith-engineers.co.uk

Mary Page Bailey and Gerald Ondrey

Connecting Research and Production Data to Deliver Chemical Innovation

Enhancing data management using LIMS software provides enhanced product-development opportunities

Frank Wahl
Covestro AG
Christian Mueller
Thermo Fisher Scientific Inc.

Accurate and efficient data management is key to productive and collaborative working practices, yet recording, storing and analyzing large quantities of laboratory data can be challenging. With many laboratories using disconnected systems and data often stored in siloed locations, numerous organizations face inefficiencies in their processes, a lack of collaboration and manual data transcription, increasing the risk of errors.

Implementing laboratory information-management system (LIMS) software, as part of a digital transformation strategy, can overcome data management challenges and bring many other benefits. Data output from instruments can be recorded directly, improving accuracy and increasing process automation (Figure 1). These high-quality data are stored centrally allowing easier collaboration between stakeholders. And the availability of data for further analysis means crucial insights can be more readily identified. Potential benefits include increasing productivity, reducing costs and driving optimization and research through improved connectivity and collaboration.

Covestro AG (Leverkusen, Germany; www.covestro.com), a global producer of high-performance materials, has successfully introduced Thermo Scientific SampleManager LIMS software (Thermo Fisher Scientific; Waltham Mass.; www.thermofisher.com) in 21 laboratories over 10 sites, involving around 1,700 people. We examine how their data management approach has changed, their experience of implementing SampleManager LIMS and the benefits they have observed.

Data management challenges

Collection of data is important across both Covestro's research and development (R&D) and production environments, and data need to be shared between these groups. Before the implementation of a LIMS, data were input manually, often into shared spreadsheets, an error-prone, labor-intensive process that resulted in data siloes. Information was then communicated by phone from the laboratory to the production line. Subsequent analysis occurred only on a small scale, and data for an entire process were not considered holistically or retrospectively, so trends and potential opportunities for optimization could be missed.

FIGURE 1. With a laboratory information management system, data outputs from instruments can be recorded directly, improving process automation

The potential of a LIMS

After much consideration, Covestro identified a LIMS to streamline data management as a crucial part of their digitalization strategy. By integrating instruments with the software, data entry and storage would be automated, bringing improvements in efficiency and accuracy.

LIMS allow data to be standardized and harmonized. No matter what its source, the underlying database remains the same, so meaningful comparisons and extrapolations can be made. This enables easier collaboration and analysis, with the data able to be used and reused to inform current and future projects. For example, data can be used to monitor processes and identify trends to inform optimization, and act as feed for R&D projects. Ideas "hidden" in these data could be the key to the new products or processes of the future. As Frank Wahl, project manager R&D Solutions at Covestro, who was responsible for the implementation of SampleManager LIMS, says, "The data of today are the raw materials of tomorrow."

Practical implementation

Introducing any new technology, including a LIMS, requires effective change management and company-wide participation to smooth the process. Wahl explains, "Involving different teams in discussions throughout the implementation process reduces the time taken for staff to go from opponents to proponents of the new system."

Thermo Fisher's professional services team was instrumental in guiding the process, working closely with stakeholders at Covestro to suggest the best path forward for the implementation. Taking a consultative approach, the team looked at all processes within the scope of the project to determine the best way to configure the LIMS to fit Covestro's laboratory workflows. Their focus was on configuration over customization to achieve a more future-proofed solution that would be easier and less costly to support and maintain.

Wahl explains, "The significant experience of Thermo Fisher's team with interfaces to SAP's Enterprise Resource Planning and other third-party systems helped us integrate SampleManager LIMS tightly into the existing Covestro infrastructure, easing the transformation process and ensuring that existing best practice was maintained. We were able to incorporate the specific requirements of individual laboratories with relatively low effort."

During the initial phase of implementation, there were some hurdles and, according to Wahl, "It took time for this 'activation energy' to be overcome." However, as staff learned about the new system, they could see how it positively impacted their roles and confidence grew. For example, the removal of manual data input and transfer reduced their administrative workload, allowing more time for scientific tasks. Any concerns disappeared within a few months, and they began sharing and discussing suggestions for optimizations. Later, the broader benefits to the company, including increased productivity, were also clearly recognized and their contribution to this reinforced the team's positive experience.

By the end of the implementation process, Wahl noted, "You have a great product placed in the laboratory and our scientists now rely on it." At Covestro, there is now full confidence in the system and staff consider SampleManager LIMS to be integral to their work.

Benefits of LIMS for Covestro

After the implementation, Covestro realized a number of benefits, including time and cost savings. As a direct result of integrating the LIMS with instrumentation, skilled laboratory staff no longer spend time inputting and sharing data (Figure 2). Instead, data collation is automated in a central database that is readily accessible to all who need it. And when decision-making is required, this is better informed by all the available data.

When data are needed for a project or to develop an idea or process, this may already exist and be stored in the system so time and effort is not spent on duplication. As researchers can see all available data, they can focus on areas where there are gaps, meaning research efforts are better focused. The availability of high-quality "big data" alongside advanced analytics allows trends to be studied — for example, the effect of weather on processes. The synergy between different parts of the business, such as R&D and production, is maximized.

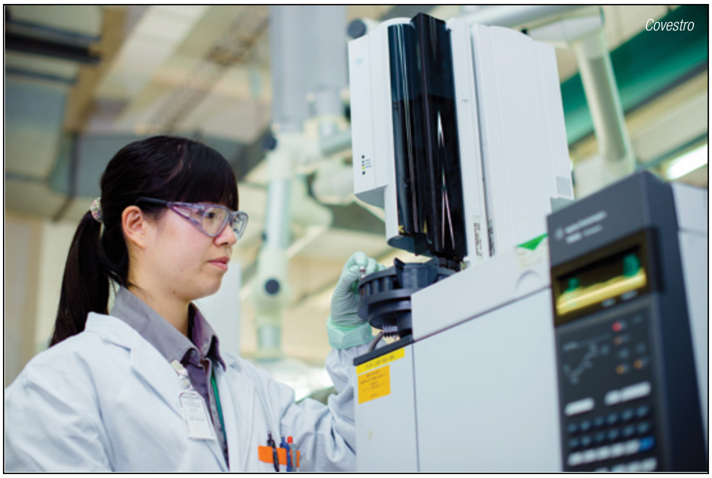

FIGURE 2. After integrating the LIMS with instrumentation, skilled laboratory staff no longer spend time inputting and sharing data

The benefits of the SampleManager LIMS introduction have been felt throughout the company. Wahl comments, "Thermo Fisher's configuration-over-customization approach has allowed us to standardize and harmonize our LIMS landscape, as SampleManager LIMS is introduced into more laboratories." And those without SampleManager software are now requesting it, with implementation in more sites scheduled to begin in 2022–2023.

Concluding remarks

The implementation of an integrated LIMS is pivotal to any digital-transformation strategy. With vendor support and stakeholder involvement, the best configuration of the LIMS can be built to standardize and streamline processes, reduce manual interactions and connect instruments to provide a complete flow of information from research through to production.

This automated digital data management saves time and improves accuracy, which benefits laboratory staff and drives process optimization while increasing productivity. What's more, due to the standardized format of the data, maximum value benefits can be obtained through its analysis, across the company. Scientists can now use existing data in new projects rather than collecting it again, avoiding redundancy. Further study using advanced analytics can help generate new ideas or uncover potential product development routes that before might have stayed "hidden" in existing data. The introduction of LIMS software has led to long-term gains for Covestro and demonstrates how LIMS can be implemented to bring companywide benefits. ■

Edited by Gerald Ondrey

Authors

Frank Wahl started his career working as a laboratory technician for almost 17 years at Bayer AG, which later transformed into Covestro AG (Kaiser-Wilhelm-Allee 60, Leverkusen, Germany, 51373; Email: frank.wahl@covestro.com). Following his interests, Wahl moved into a position as R&D IT project manager, taking over as project lead of several local and global IT projects. One of these projects was the first Thermo Scientific SampleManager LIMS implementation for Bayer in 2008, which then developed into a companywide implementation program, including the implementation of more than 20 instances of SampleManager LIMS globally. In his current role as R&D Solutions Manager, Frank continues to manage the LIMS as well as other digitalization projects within Covestro.

Christian Mueller joined Thermo Fisher Scientific Inc. (168 Third Avenue, Waltham, MA 02451; Email: christian.mueller@thermofisher.com) in 1998 and has since held various responsibilities within the Digital Science business unit as a project manager and a services manager for the Germany region. In 2020, Mueller was promoted to the director, Service and Support, for the EMEA (Europe, the Middle East and Africa) region. Prior to joining Thermo Fisher Scientific, Mueller worked as a laboratory lead for an environmental laboratory. Mueller is a chemist with a doctorate from the University of Essen, Germany.


ARKEMA
FOR THE WORLD TO CHANGE, WE MUST CHANGE THE MATERIALS WE USE.
If we are to make the world more sustainable, we must also change our daily lives, and welcome innovative materials into our homes. At Arkema, we develop materials that combine comfort with performance, such as supply coatings that insulate while protecting, and adhesives that provide both simplicity and well-being. Arkema makes housing better by ensuring innovation and responsibility always go hand in hand.
Arkema. Innovative materials for a sustainable world.
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Process Hazard Identification Methods

Department Editor: Scott Jenkins

Process hazards analyses (PHAs) are structured reviews during the engineering design process intended to detect potential hazards that were not addressed by the design team. This one-page reference describes commonly employed PHA methods.

PHA methods

PHAs are often conducted or moderated by a specialist, with participation by the design team, owner's employees or experienced operators. Several PHA methodologies exist, each suitable for specific purposes and for certain phases of project development and plant lifecycle (Figure 1).

Consequence analysis. This method quantitatively assesses the consequences of hazardous material releases. Release rates are calculated for the worst-case and alternative scenarios. Toxic points are defined and release duration is determined.

Hazard identification analysis (HAZID). HAZID is a preliminary study performed in early project stages when hazardous material, process information, flow diagrams and plant location are known. It is generally used later on to design the preliminary piping and instrumentation diagrams (P&IDs).

What-if. This is a brainstorming method that uses questions starting with "What if . . . ?," such as "What if the pump stops running?" or "What if the operator opens or closes a certain valve?" Participation by experienced staff is important to foresee possible failures and identify design alternatives to avoid them.

Hazard and operability study (HAZOP). This technique has been a standard since the 1960s in the chemical process industries. It is based on the assumption that there will be no hazard if the plant is operated within design parameters, and analyzes deviations of the design variables that might lead to undesirable consequences for people, equipment, environment, plant operations or company image. If a deviation is plausible, its consequences and probability of occurrence are then studied by the HAZOP team. Usually, an external company is hired to interact with the operator company and the engineering company performs this study. Evaluating risk involves multiplying the consequence level by the frequency of occurrence.

Layer-of-protection analysis (LOPA). This method analyzes the probability of failure of independent protection layers in the event of a scenario previously studied in a quantitative hazard evaluation like HAZOP. It is used when a plant uses instrumentation independent from operation (safety instrumented systems to assure a certain safety integrity level (SIL)). The study uses a fault tree to study the probability of failure on demand (PFD) and assigns a required SIL to a specific instrumentation node. For example in petroleum refineries, most companies will maintain a SIL equal to or less than 2 (average PFD $\geq 10^{-3}$ to $<10^{-2}$), and a nuclear plant will tolerate a SIL 4 (average PFD $\geq 10^{-5}$ to $<10^{-4}$).

Fault-tree analysis. Fault-tree analysis is a deductive technique that uses Boolean logic symbols (that is, AND or OR gates) to break down the causes of a top event into basic equipment failures or human errors. The immediate causes of the top event are called "fault causes." The resulting fault-tree model displays the logical relationship between the underlying basic events and the selected top event.

Quantitative risk assessment (QRA). QRA is the systematic development of numerical estimates of the expected frequency and consequence of potential accidents based on engineering evaluation and mathematical techniques. The numerical estimates can vary from simple values of probability or frequency of an event occurring (based on relevant historical data), to very detailed frequency modeling techniques. The events studied are the release of hazardous or toxic materials, explosions or boiling liquid expanded vapor explosion (BLEVE). The results of this study are usually shown on top of the plot plan.

Failure mode and effects analysis (FMEA). This method evaluates the ways in which equipment fails and the system's response to the failure. The focus of the FMEA is on single equipment failures and system failures.

Timing

Methods have more impact in some design phases than others. For example, if a consequence analysis is not performed in a conceptual or pre-FEED (front-end engineering and design) phase, important plot-plan considerations can be missed. Others, like HAZOP, cannot be developed without a control philosophy or P&IDs, and are performed at the end of FEED or detailed engineering (or both) to define and validate pressure safety valve locations and other process controls and instrument safety requirements. QRA or LOPA (or both) are done after HAZOP to validate siting and define SIL levels and meet the level required by the plant. ■

Editor's note: This column was adapted from the following article: Giardinella, S., Baumeister A. and Marchetti, M. Engineering for Plant Safety, *Chem. Eng.* August 2015, pp. 50–58.

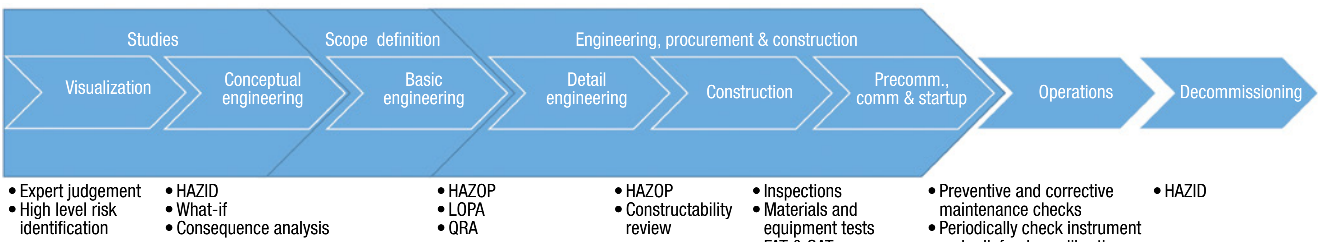


FIGURE 1. Typical hazards analyses that are used throughout a CPI project lifecycle

Allyl chloride production

By Intratec Solutions

Allyl chloride (3-chloropropene; Figure 1) is primarily used almost exclusively as a chemical intermediate in the production of epichlorohydrin. A three-carbon epoxide, epichlorohydrin is used in the manufacture of epoxy resins prevalent in coatings, adhesives, and plastics. Epichlorohydrin is also used in the manufacture of synthetic glycerine, textiles, paper, inks and dyes, solvents and surfactants. Additionally, allyl chloride is a common alkylating agent relevant to the manufacture of pharmaceuticals and pesticides

The vast majority of allyl chloride produced on commercial scale is made from chlorine and propylene, via high-temperature chlorination processes. The uses and applications of allyl chloride may vary according to the product grade. The main form of allyl chloride is commercial grade, with 99 wt.% minimum purity.

Production process

The process for making allyl chloride from propylene and chloride comprises three major sections: (1) chlorination; (2) propylene recovery; and (3) product treatment (Figure 2).

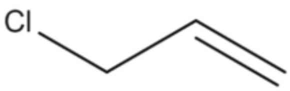
Chlorination. Liquid propylene is sent to an evaporator, and is vaporized and preheated to the chlorination reaction temperature. It is then fed, along with chlorine, to an adiabatic reactor, where the chlorination reaction is carried out, producing allyl chloride and byproducts.

Propylene recovery. The reactor effluent is cooled and routed to the prefractionator, where HCl and unreacted propylene are separated from chloropropenes, dichloropropenes, chloropropanes and heavier compounds. The pre-fractionator overhead stream, containing HCl and propylene, is passed in countercurrent with demineralized water in the HCl absorber, forming a hydrochloric acid solution with 32% purity that is stored. The off-gas, mostly propylene, is sent to a caustic wash step, which removes residual HCl. The washed propylene is compressed and routed to a decanter and dried by adsorption for water removal. Part of dried propylene is returned to the feed, and the remainder is recycled to the pre-fractionator.

Product treatment. The bottom stream from the pre-fractionator, rich in allyl chloride, is directed to the light-ends column, which strips components lighter than allyl chloride. These light components are burned as fuel. The bottom product of this column is sent to the purification column, where allyl chloride is removed from the top, condensed and routed to storage vessels, while the bottoms are sent to the dichloropropene column. This last distillation step separates dichlorides, which are collected from the top and sent to storage, from heavy components, which are burned for fuel.

Production pathways

While the main commercial production pathway for allyl chloride is the direct high-temperature chlorination of propylene, examples of other pathways include thermal dehydrochlorination (cracking) of dichloropropane and oxychlorination using hydrogen chloride and propylene (Figure 3). While based on cheaply available feedstocks (dichloropropane and hydrogen chloride), such processes are either less used or of no commercial interest due to low allyl chloride selectivity and the generation of byproducts with no significant commercial use. Allyl chloride can be safely transported and stored in carbon-steel vessels. ■



Allyl Chloride

FIGURE 1. Allyl chloride is an intermediate in the production of epichlorohydrin

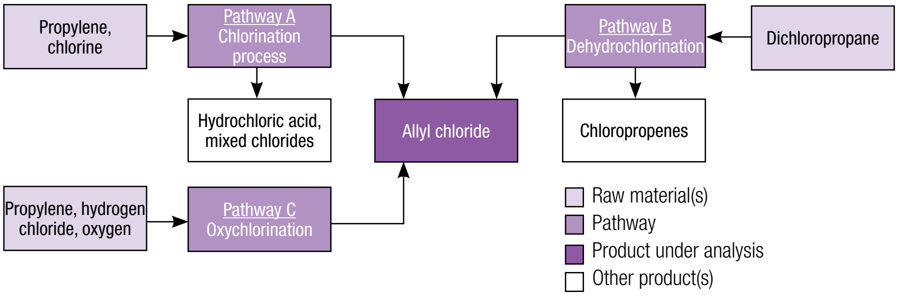


FIGURE 3. Several pathways exist for the production of allyl chloride

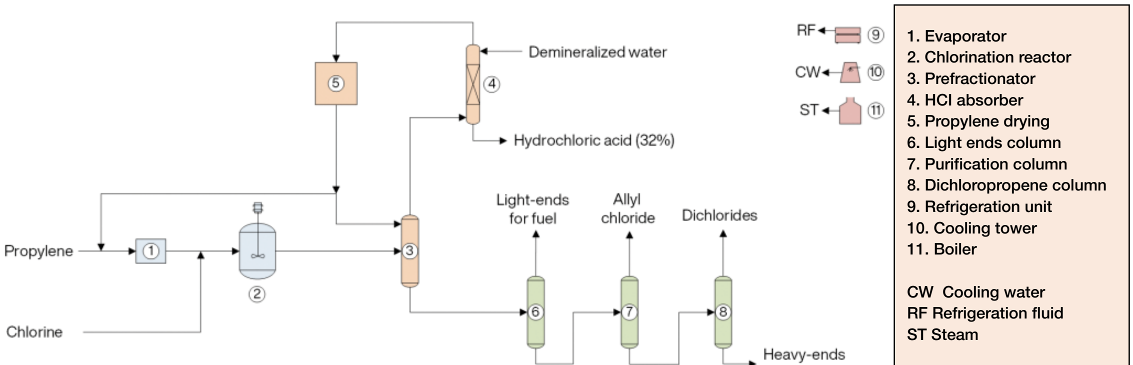


FIGURE 2. The diagram shows the production of allyl chloride

Editor's note: The content for this column is developed by Intratec Solutions LLC (Houston; www.intratec.us) and edited by *Chemical Engineering*. The analyses and models presented are based on publicly available and non-confidential information. The content represents the opinions of Intratec only.

Selecting Expansion Joints in CPI Applications

In order to maximize longevity and minimize process downtime, it is imperative to understand the factors that determine the proper selection of expansion joints. The following guidelines can help with selection decisions for expansion joints

Eric Blazej
Proco Products Inc.

IN BRIEF

EXPANSION JOINT TYPES

FACTORS FOR JOINT SELECTION

SELECTION RECOMMENDATIONS

Although sometimes overlooked or treated as an afterthought in a piping system, expansion joints are critical elements in chemical process industries (CPI) operations for providing flexibility and stress relief to piping systems. Failures in expansion joints can result in leaks of process fluids, with implications for personnel safety, environmental protection and operational uptime. Selecting the correct type of expansion joint for the process conditions will maximize the lifetime of the joint. By considering a full set of process characteristics when selecting expansion joints, plants can maximize production and operational uptime while still maintaining safety and environmental stewardship.

Expansion joint types

Expansion joints can be split into three general categories: rubber expansion joints, polytetrafluoroethylene (PTFE) expansion joints and stainless-steel expansion joints (Figure 1). Each type has its own advantages and disadvantages. In addition, there are multiple design variations for each type, with different joint geometries that help their performance in specific applications.

The vast majority (~95%) of rubber and PTFE expansion joints are found off the suction and discharge of process pumps. Installing expansion joints where pumps and piping connect, for example, can extend the longevity of the pump. The mechanical seals and bearings inside the pump will operate longer without needing to be replaced. Other common locations include boilers, heat exchangers, tanks and cooling towers. Stainless-steel expansion joints are usually found in the middle of pipe runs to help with movements in the piping system from thermal expansion and contraction. They can also assist with seismic activity.

Rubber expansion joints. Rubber expansion joints are generally more versatile than other types of expansion joints. They effectively handle compression (movement inward), extension (movement outward), as well as lateral offset, vibration and sound dampening in a shorter overall length compared to other expansion joints. Over the years, rubber expansion-joint manufacturers have standardized a specific overall length for each pipe size. This makes finding a replacement easier should a failure occur. Rubber expansion joints are a standard, stock item as opposed to stainless-steel expansion joints that are manufactured specific to each application.

For rubber expansion joints, the most

FIGURE 1. Expansion joints are generally categorized by their materials of construction: rubber (left), stainless steel (right) or polytetrafluoroethylene (PTFE; center)

common elastomers are ethylene propylene diene monomer (EPDM) rubber, polychloroprene (also known as Neoprene), nitrile rubber, butyl rubber (Figure 2) and natural rubber. Table 1 contains specific uses and properties for each elastomer type. Chemical compatibility, pressure and temperature may preclude them from being used under some process conditions. The table can be referenced for additional design characteristics that may need to be taken into consideration.

The two most common types of rubber expansion joints used are the spherical style and spool type. Spherical expansion joints are a molded design allowing for higher pressure rating and a flowing arch. They also come with floating flanges for easy installation. Spool-type expansion joints are hand-built and are more of a "heavy duty" option. Spool-type joints offer more movement than a spherical style due to the wider profile arch. They can also be manufactured with a filled arch for slurry applications with solids. Both expansion joints are offered with multiple arches for additional movement. Multiple arches will always mean a longer overall length (Figure 3). This should be taken into consideration when designing the piping system.

Additional types of rubber expansion joints include reducing concentric and eccentric, wide arch low spring rate for plastic piping, large lateral offset for settlement, straight spool pieces to help mitigate excess sound and vibration, and finally ducting joints.

PTFE expansion joints. For applications that handle caustic, basic or acidic process media, PTFE expansion joints may be used (Figure 4). PTFE expansion joints also handle compression, extension, lateral, vibration and sometimes sound dampening. There are two common types of PTFE expansion joints. The first is a molded design, which is good for low-pressure applications and offers a low spring rate. Low spring rates are ideal for polyvinyl chloride (PVC), chlorinated PVC (CPVC), high-density polyethylene (HDPE), fiber-reinforced polymer (FRP) piping systems, as well as tanks. The second is a PTFE-lined rubber expansion joint. This type of expansion joint is used for tough, demanding applications and has the ability to resist corrosive attack at elevated temperatures. These types of expansion joints are most commonly found on the chemical process side for pulp-and-paper operations.

Stainless-steel expansion joints. Stainless-steel expansion joints are used in applications where rubber and PTFE cannot handle the operating conditions for the given application. These types of joints are available in several variants, such as 304, 316 and 321 stainless-steel grades (Figure 5). They can also be made from other specialty metals, such as titanium, Hastelloy and Inconel. Stainless-steel expansion joints are good for handling compression, extension, lateral and sometimes vibration. As long as a piping system is properly guided and anchored, the expansion joint will function properly. The Expansion Joint Manufacturers Association Inc.'s (Tarrytown, N.Y.; www.ejma.org) website offers further details on this topic that should be considered when designing the piping system.

Most of the time, stainless-steel expansion joints will exert a larger overall force on the piping system and also require a longer overall length than a rubber expansion joint, which can be a major drawback. This can be avoided only if multiple-ply bellows construction is utilized. Stainless-steel expansion joints traditionally have a higher cost, as well as longer lead time spent due to specification and engineering.

There are many styles for stainless-steel expansion joints, including: internally pressurized, externally pressurized, flexible loops, gimbal, hinged, universal and pressure-balanced. Once again, all will be custom-engineered specific to each application.

Stainless-steel expansion joints are highly engineered products compared to rubber expansion joints. Should an application arise that requires stainless steel to be used,

FIGURE 2. Butyl rubber, used in the joint shown here, is a common elastomer

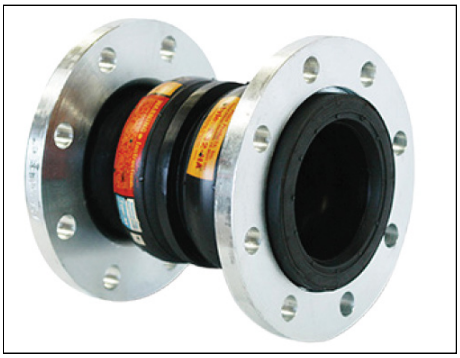


FIGURE 3. Multiple arches can provide additional movement, but increase length

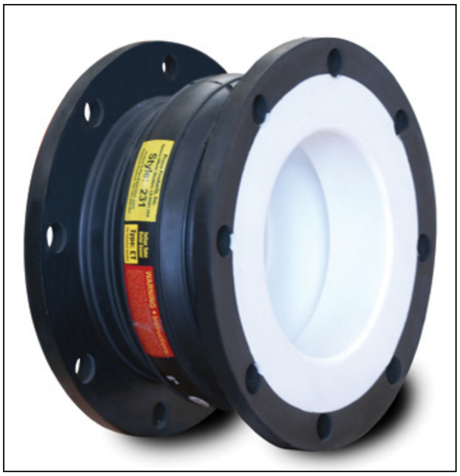


FIGURE 4. For applications involving caustic, acidic or basic process media, PTFE can be used

FIGURE 5. Stainless-steel expansion joints can be made from 304, 316 or 321 steels

plant personnel should consult an industry specialist.

An important note to remember is that stainless-steel expansion joints should not be confused with stainless-steel flex connectors, which are made from stainless-steel hose and braid (Figure 6). Stainless-steel hose and braid is only intended to address lateral movement in a single plane, whereas an expansion joint can move in multiple planes.

Factors for joint selection

When selecting expansion joints for process pipes and equipment, engineers should begin by following a set of criteria for determining relevant information. The set of criteria agreed upon by the industry is known by the acronym "STAMPED." By gathering information according to this set of factors, one is able to determine a basis for which expansion joints should be used. The components of the acronym are defined here:

• ***S size.*** What are the diameter and pipe thickness? Determining the size of piping can be accomplished by measuring the outer diameter of the pipe, looking for an engraving in the flange, or noting the size of the flange on the equipment it is mated to. You can also determine the pipe size by looking on the side of the bellows. A size (in millimeters, rubber expansion joint only) may be designated. Metal expansion joints may also have tagging. Are the size of the equipment mating flange and piping system flange the same size? If not, you may need a reducer.

• ***T temperature.*** What is the process temperature? Is the temperature variable? Will the process temperatures stay below the temperature rating for the material of the expansion joint in all situations? Will the expansion joint be located outdoors? If so, what is the potential differential between winter- and summer-month temperatures? What is the install temperature versus the process operating temperature?

• ***A application.*** What are the details of the application? What type of equipment is being connected? What are the characteristics of the process media? Is the process media acidic, basic or neutral? Is the process media abrasive (for example, a solids-containing slurry) or aggressive? Is the expansion joint exposed to weather conditions? Is there a chemical that can attack from the outside? If the process medium is a solution, what is the percent concentration of the solute? Is there a material safety data sheet (MSDS) available for the chemicals under consideration?

• ***M movement.*** What type of movement will the joint experience? Compression, extension, lateral? Are their multiple movements at once (con-current versus non-concurrent)? Has the piping system shifted over time? Are multiple arches (rubber expansion joints) or more convolutions (stainless-steel expansion joints) required? Increased the number of arches, convolutions or overall length of the expansion joint allows greater movement capabilities.

• ***P pressure.*** What is the pressure inside the pipeline? Does the pressure vary, and if so, what is the range of pressure experienced? Will the system be tested at 1.5x operating pressure? Is there a burst pressure rating required?

• ***E end fittings.*** What type of equipment is the expansion joint mated to?

FIGURE 6. Stainless-steel hose-and-braid connectors, like those shown here, address lateral movement in a single plane

TABLE 1. MATERIALS AND PROPERTIES OF ELASTOMERS COMMONLY USED FOR EXPANSION JOINTS

Property/ performance	Elastomer types					
Common name	Chlorobutyl	EPDM/EPT	Hypalon	Neoprene	Buna-N	Natural rubber
Chemical name	Chloro-isobutyl-ene-isoprene	Ethylene-propylene-diene monomer	Chlorosulfonated polyethylene	Poly-chloroprene	Butadiene acrylonitrile	Polyisoprene
ASTM 1418 designation	CIIR	EPDM	CSM	CR	NBR	NR/IR
Hardness range (durometer)	40–75	40–90	40–95	40–95	40–95	30–90
Low temperature (min. service), °F	–60 to –10	–60 to –20	–60 to –30	–50 to –10	–40 to +30	–20 to 65
High temperature (max. service), °F	250 to 300	300	275	220	240	185
Abrasion	Good	Good to excellent	Excellent	Excellent	Good	Excellent
Cold	Good	Excellent	Good	Good	Good	Excellent
Heat	Very good	Excellent	Excellent	Very good	Good	Good
Acid (dilute)	Excellent	Excellent	Excellent	Excellent	Good	Fair to good
Acid (concentrated)	Good	Excellent	Very good	Good	Good	Fair to good
Chemicals	Excellent	Excellent	Excellent	Fair to good	Fair to good	Fair to good
Impermeability	Very low	Fairly low	Low to very low	Low	Low	Fairly low
Ozone	Excellent	Outstanding	Outstanding	Very good to excellent	Fair	Poor to fair
Sunlight	Very good	Outstanding	Outstanding	Very good	Poor	Poor
Solvents	Fair to good	Poor to failr	Poor	Poor	Fair	Poor
Water	Good	Excellent	Fair	Good	Fair to good	Fair to good
Weather	Good to excellent	Excellent	Excellent	Excellent	Fair	Fair
Generally resistant to the following:	Animal and vegetable oils; fats; greases; air; water, oxidizing chemicals; ozone	Vegetable and animal fats, oils, ozone; many strong and oxidizing chemicals, ketones, alcohols	Strong acids and bases; freons; hydroxides; ozone; alcohols; and etching, alkaline and hypochlorite solutions	Moderate acids and chemical, ozone, oils, fats, many solvents, oily abrasive applications	Most hydrocarbons, fats, oils, greases, hydraulic fluids, chemicals and solvents	Water, air, average-concentration acids, bases, alcohols, salts, ketones, best abrasion resistance
Generally attacked by the following:	Oil; solvents; aromatic hydrocarbons	Mineral oils, solvents, aromatic hydrocarbons	Ketones, esters; certain chlorinated, nitro and aromatic hydrocarbons	Oxidizing acids; esters and ketones, aromatic, chlorinated and nitro hydrocarbons	Ozone, ketones, esters, aldehydes, nitro and chlorinated, hydrocarbons, polar solvents, methyl ethyl ketone	Ozone, strong acids, bases, oils, solvents, most hydrocarbons

These can include threaded, flanged, weld, grooved and so on. Also, from what material do the end fittings need to be composed?

• ***D — delivery.*** Is this item time sensitive? If so, is rush delivery required? Can a different type of expansion joint be used temporarily or permanently? Air freight may be required versus ocean or truck freight.

The STAMPED criteria can go a long way toward narrowing down the choices in expansion joints, but there are still a variety of choices within each of those categories, and different designs are available for particular conditions and applications. Contacting an expansion-joint vendor can be a valuable resource for selecting the appropriate type of expansion joint.

Selection recommendations

STAMPED is a valuable tool for selecting the appropriate type of expansion joint. This acronym will get you well on your way to selecting the proper expansion joint for your application, however, it is not the "end-all, be-all." Some additional design criteria, as well as common knowledge to have in your back pocket, include the following:

Rule of 250. The "Rule of 250" concerns pressure and temperature of the media. If the pressure is lower than 250 psi and temperature lower than 250°F, then rubber expansion joints should be used. For applications above 250 psi and temperatures over 250°F stainless steel should be used. It is highly advised to use stainless-steel expansion joints for all steam and condensate applications.

TABLE 2. TEMPERATURE CORRECTION FACTORS FOR STAINLESS-STEEL EXPANSION JOINTS

Temperature, °F	Material	
	304 stainless steel	321 stainless steel
Ambient	1.00	1.00
150	0.96	0.97
200	0.92	0.94
250	0.91	0.92
300	0.86	0.88
350	0.85	0.86
400	0.82	0.83
450	0.80	0.81
500	0.77	0.78
600	0.73	0.74
700	0.69	0.70
800	0.64	0.66
900	0.58	0.62
1,000	-	0.60
1,100	-	0.58
1,200	-	0.55
1,300	-	0.50
1,400	-	0.44
1,500	-	0.40

Pressure-temperature relationship. It is important to note that *all* types of expansion joints are unable to operate at the maximum operating pressure and temperature at the same time. For example, consider a 6-in. 321 stainless-steel expansion joint with a pressure per square inch (psi) rating of 150. This means the expansion joint can operate up to 150 psi at 70°F. If we increase the temperature rating to 200°F, we can conclude that the psi rating must be multiplied by a factor of 0.92. Therefore, the expansion joint is now rated for 138 psi at 200°F. Table 2 contains temperature correction factors for two types of stainless-steel expansion joints.

Specific temperature requirements. Beyond the so-called Rule of 250, the selection of expansion joint material should get more specific. EPDM and butyl rubber expansion joints are suitable up to 250°F, but Neoprene is only good to 225°F and nitrile rubber up to 212°F. Different types of stainless steel (the most common being 321, 304 and 316) each have their own limitations as well.

MSDS. Material safety data sheets provide details on various compounds that might be present in process media. The information can include details about the potential health and environmental hazards of the components, as well as chemical compatibility. It is highly recommended that users consult MSDS before selecting an expansion joint. Two similar compounds used in a process, such as ethylene glycol and propylene glycol, could require different expansion joints at elevated temperatures. Ethylene glycol is suitable for EPDM expansion joints, while propylene glycol works with nitrile rubber. The degree of specificity that users can have for the type of media that the expansion joint will encounter can have a huge impact on the type of elastomer selected.

Control rods. All types of expansion joints can be offered or manufactured with control rods (Figure 8). This is a preventative measure and should be considered for all expansion joints. The natural reaction of a piping system is to extend outwards once pressurized. Without proper restraints or anchors, the expansion joint may extend past its capabilities. This could lead to an immediate or premature failure. Not only can control rods be used to prevent overextension, but they can also be used to prevent over compression. If an expansion joint is in the vertical position, and a heavy piece of equipment sits on top of the expansion joint, or if a pipe hanger is not properly installed, the weight of the pipe may "pop" the expansion joint.

Brochures, submittals, CAD drawings and so on. Almost every expansion joint manufacturer offers detailed submittals, brochures or computer-assisted design (CAD) drawings. Brochures cover basic information about the expansion joint, such as overall length (OAL), movement and weight. Submittals are a bit more technical and may include bill of materials, spring rates and so on. CAD, building information modeling (BIM) and Revit drawings are the most in-depth and can also be used in engineering programs, such as the pipe-stress-analysis software CAESER or CAEPIPE, to ensure that the piping system will work effectively with reduced stress points once the expansion joint is installed.

Sound. If the pipe operation results in high-frequency sound (high-pitched squealing traveling through the piping), rubber expansion joints are the best solution and will help mitigate this issue.

Concentrations. Beyond the identity of the process media that is present, concentrations of various components within the media are also important. For example, a 5% solution of a caustic substance might be suitable for a particular type of elastomer, but if the concentration of the same caustic material is increased to 20% the rubber may not be compatible. In these cases, PTFE or stainless-steel expansion joints might be required.

Gas handling. For processes involving gases, the material should be considered carefully also, since rubber expansion joints are somewhat permeable to gases. Cases where gas escape would be a problem might also require the use of stainless-steel expansion joints.

Life expectancy. It can be useful to identify factors that might reduce or extend the lifetime of an expansion joint. The average lifespan of a rubber expansion joint is roughly 7–10 years. Depending on the particulars of an application, however, expansion joints might only last a matter of 2–3 months, while other joints might function well for 25 years or more. Some of the factors that can contribute to a shorter life expectancy are high pressure, high temperature, aggressive or abrasive media, exposure to outdoor weather and extensive levels of movement. This is also a similar case for stainless-steel expansion joints and hose and braid. Traditionally, however, stainless-steel expansion joints will last much longer than rubber expansion joints.

Cycle life. This can be defined as the life expectancy of an expansion joint. If an expansion joint were to fully extend or compress from its initial position through a complete range of motion, we can conclude that is has experienced one cycle. We call this a "full load cycle." Rubber expansion joints will typically wear and tear before they reach their point of failure due to life cycle. In some cases, high-amplitude cycles will in fact wear down rubber expansion joints. Stainless-steel expansion joints, on the other hand, will typically require this information up front during the design phase. Higher life cycle will lead to specialized engineering of the expansion joint.

Safety of plant personnel. The majority of expansion-joint manufacturers offer sleeves, jackets or some other sort of protective shield that can be wrapped around the expansion joint. This simple procedure can help prevent a catastrophic failure from causing damage to nearby equipment or plant personnel.

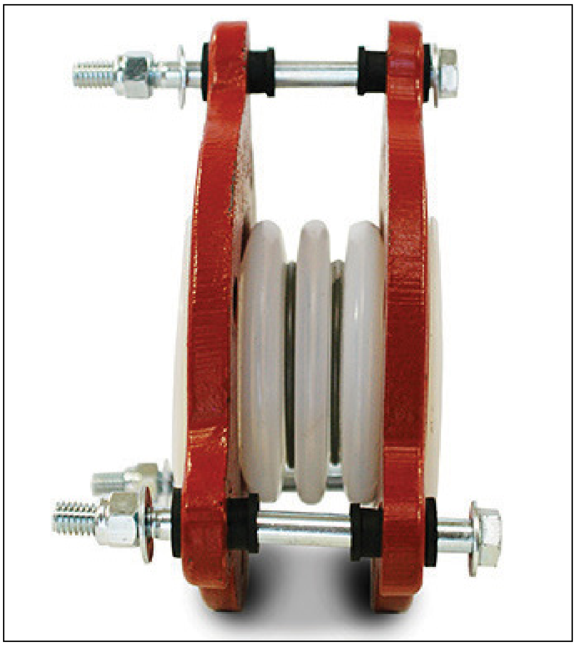


FIGURE 8. Control rods prevent the expansion joint from extending beyond its capabilities

Expansion joint surveys. Expansion joints do not last forever. Manufacturers provide expansion joints based on STAMPED criteria to maximize longevity. However, a definitive method for determining exactly when to replace expansion joints or to identify the exact moment when they will fail does not exist. The best way to prepare for an expansion joint failure, and to limit downtime in the event of a failure, is an expansion joint survey. This is offered as a completely free service by most member companies of the Fluid Sealing Association (FSA; Wayne, Pa.; www.fluidsealing.com). This process is proactive as opposed to reactive, catches failures before they happen, streamlines ordering replacements and leads to stocking recommendations. Surveys can be critical for plant maintenance, especially with plants that are trying to maximize productivity and profits while also limiting downtime. Surveys have the potential to help a plant avoid environmental concerns associated with expansion joint failures as well.

No matter what process details are found in a process, expansion-joint manufacturing companies will be able to guide plant personnel toward the correct type of expansion joint for given operational conditions. ■

Edited by Scott Jenkins

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Feature Report

Optimizing Vapor Recovery from Storage Tanks

Light hydrocarbons in storage tanks can vaporize and vent to the atmosphere, creating harmful emissions. An optimized vapor-recovery unit can effectively and economically reduce such emissions

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University of Nottingham Malaysia
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NGLTech Sdn Bhd

IN BRIEF

BASE-CASE SIMULATION

PARAMETRIC STUDIES

HYDRATE FORMATION STUDY

OPTIMIZATION MODEL

COMPARISON OF RESULTS

SENSITIVITY ANALYSIS

In the chemicals, petroleum refining and natural gas industries, storage vessels are used to contain various liquids, such as condensates, crude oil and produced water. Condensate and crude oil are usually kept in fixed-roof, atmospheric-pressure tanks between production wells and pipelines or truck transportation. In offshore fields, the storage vessels usually contain crude oil and condensate produced from connected wells, or from nearby platforms [*1*].

In most cases, light hydrocarbons, such as methane, volatile organic compounds (VOCs), natural gas liquids (NGLs) and hazardous air pollutants (HAPs), in the crude oil tend to vaporize and collect within the space between the fixed roof and liquid level of the tank [*2*]. Ambient temperature changes cause the fluctuation of liquid level in the tank, leading to the escape of vapors into the atmosphere. These escaped vapors cause income losses due to reduction in hydrocarbon volume and changes in the American Petroleum Institute (API) gravity measure of the oil. Apart from potential fire hazards, they also contribute to environmental pollution, because methane (C1) and carbon dioxide (CO_2) are greenhouse gases that contribute to global warming [*3*].

Flash gases may be flared or vented directly to the atmosphere — the latter results in an environmental emissions impact [*4*]. Therefore, a commonly accepted option to simultaneously reduce light hydrocarbon emissions and realize significant economic savings is to install vapor-recovery units (VRUs) on storage vessels. VRUs are relatively simple systems that can capture approximately 95% of the light hydrocarbon vapors for sale, or for onsite usage — for instance, as fuel. Ref. 2 reported the generation of savings from recovering light hydrocarbons, while at the same time reducing the volume of HAPs and methane emissions.

TABLE 1. FEED COMPOSITION FOR STUDY [*5*]

Components	Composition, mol %
Oxygen (O_2)	0.80
Water (H_2O)	9.28
Hydrogen sulfide (H_2S)	0.00
Carbon dioxide (CO_2)	6.69
Nitrogen (N_2)	13.80
Methane (C_1)	31.68
Ethane (C_2)	6.73
Propane (C_3)	13.41
i-Butane (i-C_4)	3.29
n-Butane (n-C_4)	7.41
i-Pentane (i-C_5)	2.38
n-Pentane (n-C_5)	1.76
Hexanes (C_6)	1.20
Heptanes (C_7)	0.91
Octanes (C_8)	0.47
Nonanes (C_9)	0.12
Decanes (C_{10})	0.04
Undecanes (C_{11})	0.01
Dodecanes (C_{12})	0.01
Totals	**100**

For this article, simulation and optimization were performed on a VRU for the recovery of light hydrocarbons. The process parameters that affect profitability were identified and optimized in order to achieve higher profitability for the VRU.

Base-case simulation

A base-case simulation model (Figure 1) was developed using the commercial process simulation software Aspen Hysys v8.8, using a thermodynamic package employing the Peng-Robinson equation of state, which is frequently used to evaluate natural gas systems in industry. The feedstream composition is taken from a literature case study reported for a floating production

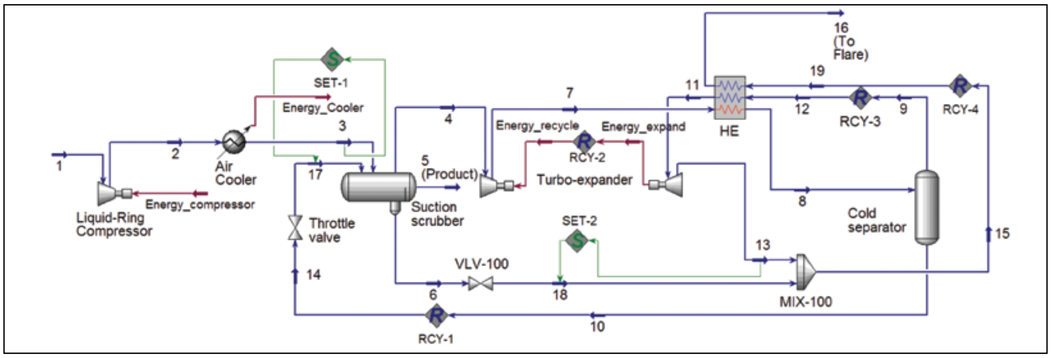

FIGURE 1. The simulation model for this optimization exercise was developed using Aspen HYSYS software

storage and offloading (FPSO) unit [*5*], as shown in Table 1.

As shown in Figure 1, light hydrocarbon feed (Stream 1) that is vented or flared from a storage vessel is fed at atmospheric conditions (1 atm and 40°C) to a liquid ring compressor. The feed is compressed to a pressure that corresponds to the maximum temperature (150°C) at the outlet of the compressor (in order to prevent damage to the compressor). The compressed gases then pass through an air cooler (with a pressure drop of 0.3 barg), where ambient air at 35°C is used for cooling. Next, a suction scrubber (a three-phase separator) is used to separate the gas phase (Stream 4) and aqueous layer (Stream 6) from the product (Stream 5), which is the organic phase.

The separated organic phase in the product stream is delivered into a surge vessel for sale, or for further processing. The aqueous phase in Stream 6, which mostly consists of water, is mixed with the expanded gas (Stream 13) with a small amount of hydrocarbon before entering the heat exchanger (HE) as the cooling medium. Upon exiting the HE, this stream is then flared or vented.

The gas phase from the suction scrubber (Stream 4), which mostly consists of light hydrocarbons and some unwanted gases, is sent to the compressor section of a turbo-expander. The latter is used to convert energy from expanding the high-pressure gases to drive the compressor or generator [*6*]. The compressed hydrocarbon gases next enter the HE (with a pressure drop of 0.3 barg), which is being cooled to partially condense its hydrocarbon gases. The hydrocarbon gases next enter a cold separator where the unwanted gases are separated and sent to the HE as cooling medium. The unwanted gases, with a pressure of 19 barg, next enter the expander section of the turbo-expander, to recover their pressure. The condensate from the cold separator is recycled to the suction scrubber in order to recover the uncaptured hydrocarbon.

Note that the temperature of the entire system should be maintained in order to prevent icing and hydrate formation in the pipelines. The expanded gas (Stream 13) is the only potential stream where hydrate may be formed. Hence, the pressure of the expanded gas is to be controlled to avoid the expanded gases stream from reaching hydrate formation temperatures. Furthermore, the outlet of the compressor should not reach temperatures higher than 150°C to avoid damaging the compressor. It is also worth noting that the maximum pressure of the system

TABLE 2. RECOVERY BASED ON COMPRESSION RATIO OF LIQUID RING COMPRESSOR

Case	Compression ratio of liquid ring compressor	Temperature of Stream 2,˚C	Pressure of Stream 2, barg	Energy required, kW	Propane recovery, %	*i*-Butane recovery, %	*n*-Butane recovery, %	C5+ recovery, %	Total recovery, %	Greenhouse gases reduction, %
1	5.00	126.81	4.07	42.02	6.91	19.53	27.89	54.63	21.81	0.39
2	5.50	132.07	4.57	44.74	8.03	22.17	31.43	56.77	23.47	0.48
3	6.00	136.88	5.08	47.25	9.48	25.57	35.87	60.07	25.72	0.59
4	6.50	141.31	5.59	49.57	10.69	27.89	38.30	59.34	26.48	0.67
5	7.00	145.43	6.09	51.73	12.09	30.61	41.32	60.13	27.81	0.77
6	7.50	149.27	6.60	53.76	13.52	33.24	44.16	60.84	29.09	0.88
7	8.00	152.88	7.11	55.67	15.01	35.84	46.90	61.50	30.36	1.00

TABLE 3. RECOVERY BASED ON OUTLET TEMPERATURE OF AIR COOLER

Case	Temperature of Stream 3,˚C	Duty required, kW	Mass flowrate of air, kg/h	Propane recovery, %	*i*-Butane recovery, %	*n*-Butane recovery, %	C5+ recovery, %	Total recovery, %	Greenhouse gases reduction, %
1	45.00	74.38	26,777.29	17.70	41.97	54.09	63.83	33.38	1.10
2	46.00	73.28	26,380.66	16.81	40.19	52.14	63.32	32.53	1.06
3	47.00	72.18	25,985.83	15.95	38.43	50.17	62.76	31.68	1.01
4	48.00	71.09	25,592.47	15.11	36.68	48.18	62.16	30.82	0.97
5	49.00	70.00	25,200.23	14.30	34.95	46.17	61.53	29.96	0.92
6	50.00	68.91	24,808.79	13.52	33.24	44.17	60.85	29.10	0.88

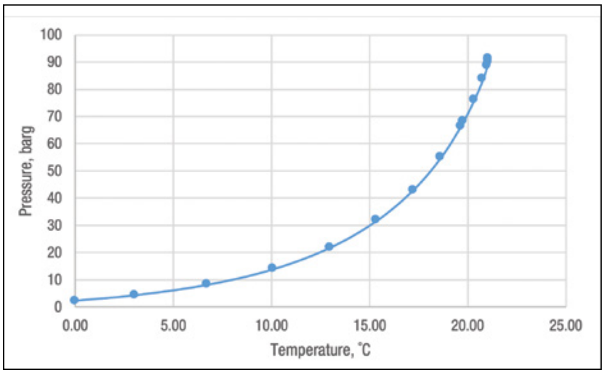

FIGURE 2. This chart shows the conditions where hydrate will form in stream 15

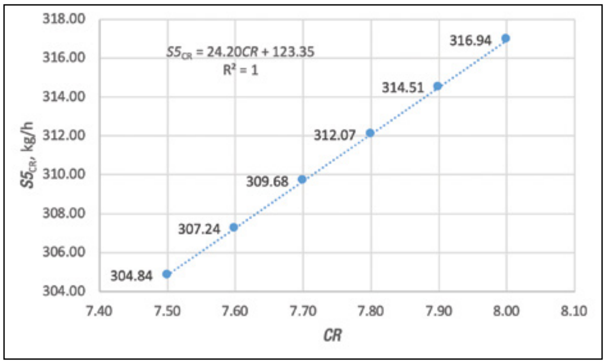

FIGURE 3. This chart displays the relationship between the product stream yield and compression ratio (*CR*)

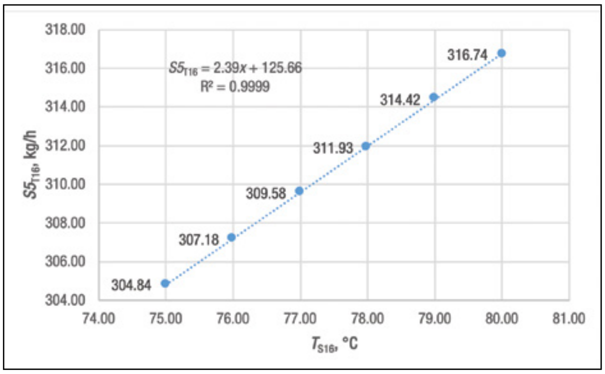

FIGURE 4. The relationship between the product stream yield and the Stream 16 temperature is nearly linear

is to be maintained below 20 barg for safety and maintenance purposes. Within the simulation, two set operation models were used to maintain the pressure of the streams to avoid backflow.

Parametric studies

The purpose of parametric studies is to examine the effect of operating parameters, such as compression ratio (*CR*) of the liquid ring compressor, temperature at air cooler outlet (Stream 3), pressure of expanded gas (Stream 13) and temperature of Stream 16, on the recovery of hydrocarbon in the product stream. Note that the latter also corresponds to the reduction of greenhouse gases (C1 and CO_2).

Parameter 1: Compression ratio of liquid ring compressor. In Figure 1, temperature and pressure of the feedstream are set to 40°C and 0.01 barg (1 atm), respectively. In this study, the liquid ring compressor *CR* is the parameter being analyzed. The temperature of the air cooler outlet (Stream 3) is kept constant at 50°C, while that for Stream 16 is kept at 75°C, and the expanded pressure of Stream 13 is set at 0.4 barg. The simulation results are summarized in Table 2. As shown, the total recovery of hydrocarbon in the product stream increases when the compression ratio is increased. To maximize the recovery of hydrocarbon and yet remain bound to the above-mentioned constraints, the optimum *CR* should be 7.5, in order to maintain the outlet temperature of the liquid ring compressor lower than 150°C.

Parameter 2: Temperature at air cooler outlet (Stream 3). For this case, the *CR* of the liquid ring compressor is set to 7.5, the temperature of Stream 16 is set at 75°C and the expanded pressure of Stream 13 at 0.4 barg. The temperature of the ambient air, which is used as coolant for the air cooler, is set to 35°C, to allow a minimum temperature difference (ΔT) of 10°C. Hence, the lowest exit temperature of Stream 3 is at 45°C. The simulation results are summarized in Table 3. As shown, the recovery of hydrocarbon is inversely proportional to the increase in temperature. Hence, the lowest temperature of Stream 3 (45°C) should be chosen as the optimum condition, as it recovers the most hydrocarbon, which also leads to the highest greenhouse gases reduction.

Parameter 3: Expanded pressure at Stream 13. For this case, the compression ratio of the liquid ring compressor is fixed at 7.5, and the temperatures of Streams 3 and 16 are fixed at 45°C and 75°C, respectively. Additionally, the pressure of Stream 7 is also observed to ensure the pressure will not go beyond 20 barg. At these conditions, the expanded pressure at Stream 13 is being manipulated, aiming to keep it near atmospheric pressure. Note that the temperature of Stream 15 is being observed because this stream has the highest possibility of forming hydrate.

The results of changing this parameter are summarized in Table 4. Based on these findings, neither C5+ recovery nor greenhouse gases reduction are significantly affected by the expanded pressure of Stream 13. The highest total recovery is observed at 0.2 barg. However, the corresponding temperature of Stream 15 is very low at –9.5°C, while the pressure of Stream 7 is higher than 20 barg. Hence, a pressure of 0.3 barg at Stream 13 is chosen.

Parameter 4: Temperature of Stream 16. For this case, the CR of the liquid ring compressor is set to 7.5, the temperature of Stream 3 is set to 45°C and the expanded pressure of Stream 13 is set to 0.3 barg. The temperature of Stream 16 is manipulated to find the optimal temperature that could increase total hydrocarbon recovery, while meeting the minimum approach temperature of 3°C (by comparing with the temperature of Stream 7). The temperature of Stream 15 is also observed, due to the potential for hydrate formation, as mentioned earlier.

Table 5 shows that the highest total recovery and greenhouse gases reduction is observed at 80°C. Therefore, this is set as the optimum temperature for Stream 16. After these parametric studies,

TABLE 4. RECOVERY BASED ON PRESSURE OF EXPANDED GAS

Case	Pressure of Stream 13, barg	Temperature of Stream 15, ˚C	Pressure of Stream 7, barg	C5+ recovery, %	Total recovery, %	Greenhouse gases reduction, %
1	0.20	–9.50	20.71	63.76	33.41	1.10
2	0.30	–8.05	19.92	63.80	33.40	1.10
3	0.40	–6.70	19.19	63.83	33.38	1.10
4	0.50	–6.03	18.46	63.87	33.36	1.10
5	0.60	–7.26	17.54	63.92	33.35	1.10
6	0.70	–8.38	16.75	63.96	33.33	1.10

TABLE 5. RECOVERY BASED ON TEMPERATURE OF STREAM 16

Case	Temperature of Stream 16, ˚C	Temperature of Stream 15 ˚C	Temperature of Stream 7, ˚C	C5+ recovery, %	Total recovery, %	Greenhouse gases reduction, %
1	50.00	0.35	102.95	57.43	26.03	0.79
2	55.00	–1.51	99.60	59.10	27.62	0.86
3	60.00	–3.30	96.42	60.56	29.16	0.92
4	65.00	–4.95	93.60	61.80	30.62	0.98
5	70.00	–6.54	90.89	62.88	32.04	1.04
6	75.00	–8.05	88.39	63.80	33.40	1.10
7	80.00	–13.05	84.68	64.63	34.71	1.16

TABLE 6. COST ANALYSIS OF OPTIMUM CONDITIONS

CR of liquid ring compressor	7.5
Temperature of Stream 3, ˚C	45
Expanded pressure at Stream 13, barg	0.3
Temperature of Stream 16,˚C	80
C5+ recovery, %	64.63
Total recovery, %	34.71
Greenhouse gases reduction, %	1.16
Mass flowrate of condensate, kg/h	316.8
Gross profit, $/h	226.2

cost analysis is performed to maximize the profit gain from the VRU. The cost of the condensate recovered from the feed is taken as $50/barrel, while the unit cost of electricity (for compression) is set to $0.02/kWh. Cost analysis results are shown in Table 6.

Hydrate formation study

According to the parametric studies, the pressure of the expanded gas at Stream 13 and the temperature of Stream 16 affect the temperature of Stream 15. In this study, a simulation is done to determine the conditions under which hydrates will form at Stream 15 when Stream 13 is mixed with Stream 6 (which consists mostly of water).

Stream analysis has been carried out using the "envelope" tool in Aspen Hysys in order to identify the conditions for hydrate formation. A hydrate formation graph with pressure versus temperature is shown in Figure 2. Hydrate formation in Stream 15 can occur when there is high pressure and low temperature. In the simulation model, the pressure of the expanded gas in Stream 13 is close to 0.01 barg, which requires very low temperature to form hydrate.

Furthermore, the "hydrate formation" stream analysis tool was also carried out for specific temperatures and pressures to determine the conditions of hydrate formation. The optimum conditions from the four parameter studies were analyzed for hydrate formation. For the optimum conditions of Stream 15 at –13.05ºC and 0.3 barg (see Table 5), hydrate formation does not occur. At 0.3 barg, hydrate formation occurs at a temperature of –18.71ºC; while at –13.05ºC, hydrate will form at 0.75 barg.

From the above analysis, it can be concluded that potential hydrate problems are not significant in this case.

Optimization model

Optimization is next carried out for the VRU, based on the base-case model built earlier. The model was solved using MS Excel Solver, and verified with Lingo commercial software. In this optimization model, the objective was set to maximize the hydrocarbon in the product stream (Δm_{prod}), while the *CR* of the liquid ring compressor and the temperature of Stream 16 are the manipulated variables. Note that the temperature of Stream 3 is kept at 45ºC, while the expanded gas pressure (Stream 13) is kept at 8ºC, since those are the optimum conditions that lead to maximum total hydrocarbon recovery. The base-case data for the optimization model are shown in Table 7. The objective of the optimization is given in Equation (1) below:

$$max\Delta m_{prod} = \Delta m_{CR} + \Delta m_{S16} + m_{base} \quad (1)$$

where Δm_{CR} is the additional hydrocarbon recovery from the base case (in kg/h) achieved by manipulating the CR value; Δm_{S16} is additional hydrocarbon recovery from the base-case (in kg/h) by manipu-

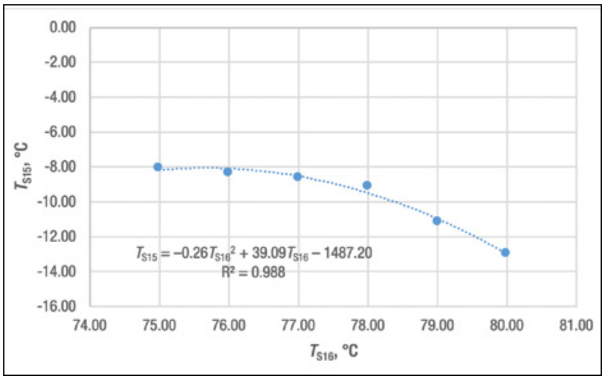

FIGURE 5. The temperatures of Streams 15 and 16 are correlated here

lating the temperature of Stream 16; and m_{base} is the base case product flowrate of the product stream (304.84 kg/h).

Three scenarios are analyzed in the optimization model. Scenario 1's goal is to maximize the product flowrate based on the constraints outlined in the base-case section. Scenario 2 explores the possibility of increasing the boundary range of constraint (outlet temperature of the liquid ring compressor), in order to maximize the increment of its gross profit. In Scenario 3, a new constraint is added to reduce the risk of hydrate formation.

Scenario 1. To maximize mass flowrate of the product stream (Δm_{prod}), the relationships between Δm_{S5} and its manipulating variables (CR and T_{S16}) are first determined. Their relationships are first determined independently. By running the simulation model in Aspen Hysys, the flowrate of the product stream as a result of manipulating the variables is shown in Figures 3 and 4, respectively. As shown in Figures 3 and 4, the relationships of these variables show a linear trend. The linear relations are then deducted from the base values, and result in the revised form that is shown in Equations (2) and (3).

$$\Delta m_{CR} = S5_{CR} - m_{base} = 24.2CR - 181.49 \quad (2)$$

$$\Delta m_{S16} = S5_{T16} - m_{base} = 2.39T_{S16} - 179.18 \quad (3)$$

Additionally, the temperature of Stream 2 (T_{S2}) is dependent on the compression ratio, as shown in Equation (4). On the other hand, the temperature difference between Streams 16 and 7 (ΔT) is given in Equation (5).

$$T_{S2} = 7.21CR + 95.23 \quad (4)$$

$$\Delta T = -0.098(T_{S16})^2 + 13.44T_{S16} - 444.28 \quad (5)$$

The constraints are given below in boundary Equations (6) and (7):

$$T_{S2} \leq 150°C \quad (6)$$

$$\Delta T \geq 3°C \quad (7)$$

The objective in Equation (1) is solved, subject to the constraints in Equations (2) through (7), resulting in a product flowrate of 320.8 kg/h. The optimization results were re-simulated and verified with Aspen Hysys. The optimal results for CR (7.6) and T_{S16} (80.74°C) obtained from the optimization model are also verified by re-running the simulation model in Aspen Hysys. The difference between the optimization and simulation models is determined as approximately 0.04%, which is negligible.

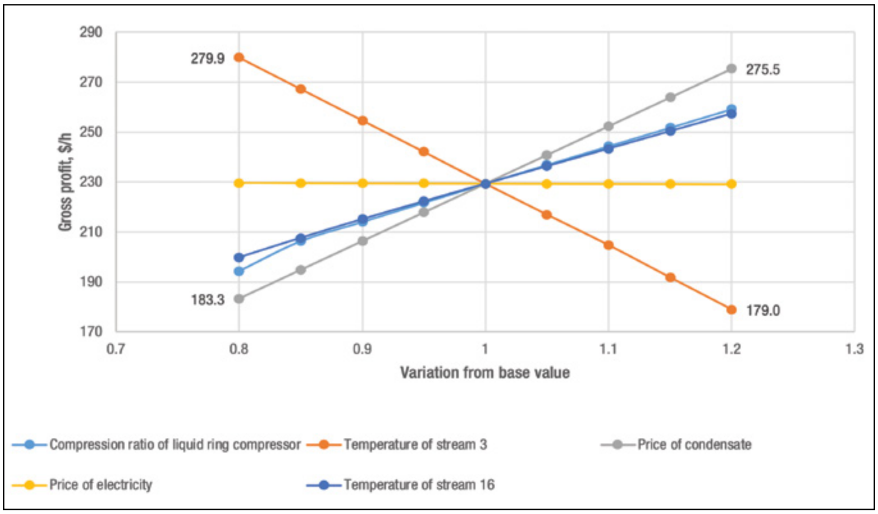

FIGURE 6. Sensitivity analysis shows that most parameters are actually quite sensitive

TABLE 7. BASE CASE DATA FOR OPTIMIZATION.

Compression ratio of liquid ring compressor, CR	7.5
Temperature of Stream 16 (T_{S16}), (°C)	75
Mass flowrate of product stream (m_{base}), kg/h	304.84

Scenario 2. In this scenario, the objective remains the same as in Scenario 1. However, temperature for Stream 2 (T_{S2}) is set to be 5°C above the actual restriction, which is 155°C. This is because the increase of CR values increases the product mass flowrate of Stream 5 (see Figure 5), which generates higher income. Therefore, a new constraint is added as in Equation (8):

$$T_{S2} \leq 155°C \quad (8)$$

Note that all the other constraints remain the same as in Scenario 1. Solving for the objective in Equation (1), subject to the constraints in Equations (2) through (5) and Equations (7) and (8), resulted in a product flowrate of 337.2 kg/h. The optimization results were verified with Aspen Hysys. Rerunning the simulation model in Aspen Hysys shows 0.15% difference from the optimization model, which can be neglected.

Scenario 3. In this scenario, the objective is the same as Scenario 1, but a new constraint is added for Stream 15 temperature (T_{S15}) to prevent hydrate formation. Hydrate formation could reduce the hydrocarbon recovery, as well as the profit. Although the hydrate formation study indicated that the formation temperature is much lower at –18.71°C (0.3 barg), to reduce the risk of hydrate formation, T_{S15} is set to be higher than –10°C in Equation (9) :

$$T_{S15} \geq -10°C \quad (9)$$

TABLE 8. COMPARISON OF BASE-CASE AND OPTIMIZATION RESULTS

	Before optimization	Scenario 1	Scenario 2	Scenario 3
Compression ratio	7.50	7.60	8.29	7.60
Temperature of Stream 16, °C	80.00	80.74	80.74	78.53
Mass flowrate, kg/h	316.8	320.8	337.2	313.2
C5+ recovery, %	64.63	64.81	65.34	64.38
Total recovery, %	34.71	35.15	36.95	34.32
Greenhouse gases reduction, kg CO_2e/h	30.45	31.46	37.16	30.77
Gross profit, $/h	226.2	229.4	243.0	223.5
Increment of gross profit, %	-	1.41	7.43	–1.19
Payback period, yr		0.69	0.65	0.71

Note also that T_{S15} depends on the Stream 16 temperature (TS16), as shown in Figure 5. The simulation results indicate that their correlation may be given as in Equation (10):

$$T_{S15} = -0.26(T_{S16})^2 + 39.09T_{S16} - 1{,}487.2 \quad (\mathbf{10})$$

Solving the objective in Equation (1), subject to the constraints in Equations (2) through (7) and Equations (9) and (10), yields a product flowrate of 313.2 kg/h. Similar to earlier scenarios, the differences between the Lingo and Hysys models are negligible.

Comparison of results

The results from the base-case model and those from the optimization scenarios are shown in Table 8. As shown, there are increments of gross profit increase for both Scenarios 1 and 2, as compared to the base-case model. Scenario 3, however, shows a decrease in gross profit. The reason for reduced gross profit is due to the additional constraint set for T_{S15}, which causes T_{S16} to have lower value, and leads to lower gross profit.

The economic evaluation tool in Aspen Hysys was used to evaluate the economics of the VRU system, resulting in capital cost of $1,263,500 (operating cost is negligible). The payback period of each scenario is shown in Table 8, calculated assuming an annual operating time of 8,000 h. The last row of Table 8 shows that the three scenarios are comparable for their payback period, with Scenario 2 slightly outperforming the others, with the highest greenhouse gas reduction of 37.16 kg of emissions per hour (CO_2e/h). Note that the latter is calculated based on the differences of methane and CO_2 flowrates in the feed (Stream 1) and Stream 16, which is sent to flare. Note also that methane is generally regarded as a greenhouse gas that is 25 times more powerful than CO_2, in terms of global warming potential.

Sensitivity analysis

Sensitivity analysis was next performed to identify the parameters that have significant influence on the gross profit of the project. In the analysis, several parameters, including compression ratio, price of condensate, outlet temperature of Stream 3, temperature of Stream 16 and the price of electricity, were studied to evaluate the gross profit. Each of the parameters is set to have ±20% variation in their values compared to the base-case model.

Based on Figure 6, it can be seen that apart from the price of electricity, all other parameters are very sensitive. The most sensitive parameter is the cooler outlet temperature (Stream 3), which will lead to the biggest difference of gross profit of approximately $100/h. Additionally, the price of condensate will also lead to significant gross profit difference of approximately $90/h.

These analyses confirm that implementation of VRUs on storage vessels reduces pollution while also generating extra profit. The optimization results showed that increased recovery of hydrocarbon leads to increased profit, with a payback period of approximately 0.7 years, coupled with greenhouse gas reduction of more than 30 kg CO_2e/h. Sensitivity analysis shows that careful control of Stream 3 temperature is required, because it is the most influential parameter among all those analyzed. ■

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References

1. Climate & Clean Air Coalition (CCAC), Technical Guidance Document Number 6: Unstabilized Hydrocarbon Liquid Storage Tanks, 2017.
2. U.S. Environmental Protection Agency, Lessons Learned from Natural Gas STAR Partners, Installing Vapor Recovery Units on Storage Tanks, 2006.
3. Abdel-Aal, H. K., Aggour, M. and Fahim, M. A., "Petroleum and Gas Field Processing," CRC Press, July 2003.
4. Schneider, G. W., Boyer, B. E. and Goodyear, M. A.. Recovery of flash gas from storage tanks at an offshore production platform using scroll compression technology, Society of Petroleum Engineers — SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, April 2010.
5. De Vos, D., Duddy, M. and Bronneburg, J.. The problem of inert-gas venting on FPSOs and a straightforward solution, Offshore Technology Conference 2006: New Depths. New Horizons, May 2006.
6. Bloch, H.P., Soares, C., "Turboexpanders and Process Applications," Gulf Professional Publishing, June 2001.
7. AspenTech, "Aspen HYSYS V8 Highlights, Resources, IT Support For V8," www.aspentech.com, 2015.
8. Blackwell, B., Vapor recovery systems for tank farms or upstream process separators, Gardner Denver Garo, 2019.
9. Sinnott, R. K. and Towler, G., "Chemical Engineering Design," Elsevier, 2013.

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Specification Tips to Maximize Heat Transfer

Presented here are some practical points to help in the selection of a shell-and-tube heat-exchanger design for various applications

John Boyer and Jim Klimek
Xylem Inc.

Heat exchangers are widely used in various sectors of the chemical process industries (CPI), including: chemical; oil and gas; power generation; food and beverages; heating, ventilation and air conditioning (HVAC) and refrigeration; pulp and paper to name a few. Their use is expecting strong growth over the coming years, driven, in part, by a rising focus on environmental impact and improving efficiency standards.

Although used for varied applications, a heat exchanger's primary role is to transfer heat from one fluid or gas to another in order to control the temperature of a system and manage waste heat. Growing environmental concerns and regulations are motivating energy-intensive industries to look at ways to improve heat exchanger performance and maximize energy efficiency use.

Choosing the right heat exchanger to fit the needs of specific applications and systems is critical in achieving optimal efficiency.

Operating conditions, ease of access for inspection and maintenance, and compatibility with process fluids are just some of the variables to be considered when assessing heat exchanger options. Other factors include the following:

- Maximum design pressure and temperature
- Heating or cooling applications
- Maintenance requirements
- Material compatibility with process fluids
- Gasket compatibility with process fluids
- Cleanliness of the streams
- Temperature approach

A properly selected, installed and maintained heat exchanger can help enhance the reliability and efficiency of a fluid system by optimizing energy consumption and reducing associated operating costs.

In this article, we look at the specification tips to maximize heat transfer in shell-and-tube (S&T) heat exchangers in order to boost heat exchanger performance and increase efficiency.

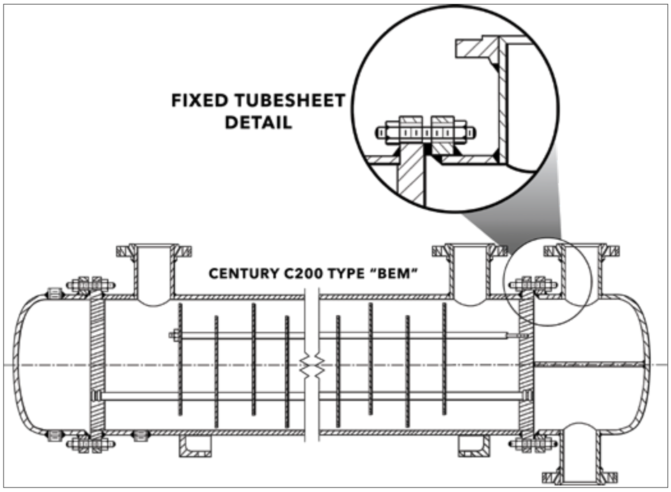

FIGURE 1. In a fixed tubesheet exchanger, straight runs of tubing are attached to two perforated tubesheets. The design has no shell-side gasket or packed joints. This minimizes the potential for leakage, and makes this exchanger ideal for high-pressure operations, or those handling potentially lethal fluids

S&T exchangers

The shell-and-tube heat exchanger's flexible design, high pressure and temperature capabilities, and its ability to handle high levels of particulate material make it the most common heat exchanger type used. Mechanically simple in design and a proven technology, the shell-and-tube design offers a low-cost method of heat exchange for many process operations. The following is a brief description of each of the most common shell-and-tube configurations:

Straight-tube, fixed-tubesheet exchangers. The fixed-tubesheet exchanger is the most common, and typically has the lowest capital cost per square foot of heat-transfer surface area. Fixed tubesheet exchangers consist of a series of straight tubes sealed between flat, perforated metal tubesheets (Figure 1).

Because there are no packed or gasketed joints on the shell side, potential leak points are eliminated, making the design suitable for higher pressure or potentially lethal service. However, because the tube bundle cannot be removed, the shell side of the exchanger (outside the tubes) can only be cleaned by chemical means. The inside surfaces of the individual tubes can be cleaned mechanically, after the channel covers have been removed. The fixed tubesheet exchanger is limited to applications where the shellside fluid is non-fouling; fouling fluids must be routed through the tubes.

In line with the Tubular Exchanger Manufacturers Association (TEMA) heat exchanger standards and nomenclature, shell-and-tube heat-exchanger types have a three-letter designation which refers to the specific type of stationary head at the front end, the shell type, and the rear-end head type, respectively.

Common TEMA designations for the straight-tube, fixed-tubesheet exchangers are BEM, AEM, NEN. Common applications include the following:

- Vapor condensers
- Liquid-liquid exchangers
- Reboilers
- Gas coolers

Removable-bundle, externally sealed, floating-head exchangers. Floating-head heat exchangers are so named because they have one tubesheet that is fixed relative to the shell, and another that is attached to the tubes, but not to the shell, so it is allowed to "float" within the shell. Unlike fixed tubesheet designs, whose dimensions are fixed at a given dimension relative to the shell wall, floating-head exchangers are able to compensate for differential expansion and contraction between the shell and the tubes.

Since the entire tube bundle can be removed, maintenance is easy and inexpensive. The shell-side surface can be cleaned by either steam or by mechanical means. In addition to accommodating differential expansion between the shell and tubes, the floating tubesheet keeps shell-side and tube-side process fluids from intermixing.

Although the externally sealed, floating-head design is less costly than the full, internal floating-head exchanger, it has some design limitations due to it being a serviceable joint exposed to the atmosphere: both shell-side and tube-side fluids must be non-volatile or non-toxic, and the tube-side arrangements are limited to one or two passes. In addition, the packing used in this exchanger limits design pressure and temperature to 300 psig and 300°F.

Common TEMA designations are AEW and BEW. Applications include exchangers handling the following:
- Inter- and after-coolers
- Oil coolers
- Jacket water coolers

Removable-bundle, outside-packed, floating-head exchangers. This design is especially suited for applications where corrosive liquids, gases or vapors are circulated through the tubes, and for air, gases or vapors in the shell. Its design also allows for easy inspection, cleaning and tube replacement, and provides large bundle entrance areas without the need for domes or vapor belts (Figure 2).

Unlike the previous design, only shell-side fluids are exposed to packing, allowing high-pressure, volatile or toxic fluids to be used inside the tubes. The packing in the head does, however, limit design pressure and temperatures.

Common TEMA designations are BEP and AEP. Typical applications include the following:
- Oxygen coolers
- Volatile or toxic fluids
- Gas processing

Removable-bundle, internal clamp ring, floating-head exchangers. This design is useful for applications where high-fouling fluids require frequent inspection and cleaning. And, because the exchanger allows for differential thermal expansion between the shell and tubes, it readily accommodates large temperature differentials between the shell-side and the tube-side fluids.

This design has added versatility since multi-pass arrangements are possible. However, since the shell cover, clamp ring and floating-head cover must be removed before the tube bundle can be removed, service and maintenance costs are higher than in "pull through" designs (discussed next).

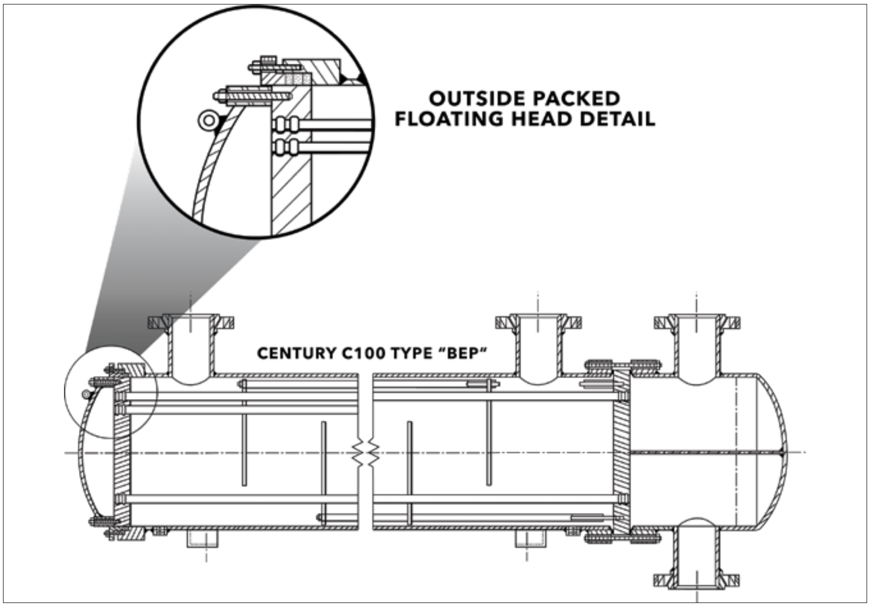

FIGURE 2. In a removable bundle, outside packed floating head exchanger, straight runs of pipe are attached to one fixed (or stationary) head, and one floating head, which allows the entire assembly to be removed for cleaning and repair. Also, the floating head accommodates differential thermal expansion during operation

Common TEMA designations are AES and BES. Typical applications include the following:
- Process plant condensers
- Inter- and after-cooler designs
- Gas coolers and heaters
- General purpose industrial heat exchangers

Removable-bundle, pull-through, floating-head exchangers. In the pull-through, floating-head design, the floating-head cover is bolted directly to the floating tubesheet. This allows the bundle to be removed from the shell without removing the shell or floating-head covers, which eases inspection and maintenance.

This is ideal for applications that require frequent cleaning. However, it is among the most expensive designs. And, the pull-through design accommodates a smaller number of tubes in a given shell diameter, so it offers less surface area than other removable bundle exchangers.

Common TEMA designations are AET and BET, and typical applications include the following:
- Exchangers handling chemical fluids
- Hydrocarbon fluid condensers
- Air or gas compressors
- Inter- and after-coolers

Removable-bundle, U-tube exchangers. In the U-tube exchanger, a bundle of nested tubes, each bent in a series of concentrically tighter U-shapes, is attached to a single tubesheet (Figure 3). Each tube is free to move relative to the shell, and relative to one another, so the design is ideal for situations that accommodate large differential temperatures between the shell-side and the tube-side fluids during service. Such flexibility makes the U-tube exchanger ideal for applications that are prone to thermal shock or intermittent service.

As with other removable bundle exchangers, the U-tube bundle can be withdrawn to provide access to the inside of the shell, and to the outside of the tubes. However, unlike the straight-tube exchanger, whose tube internals can be mechanically cleaned, there is no way to physically access the U-bend region inside each tube, so chemical methods are required for tube-side maintenance. As a rule of thumb, non-fouling fluids should be routed through the tubes, while fouling fluids should be reserved for shell-side duty.

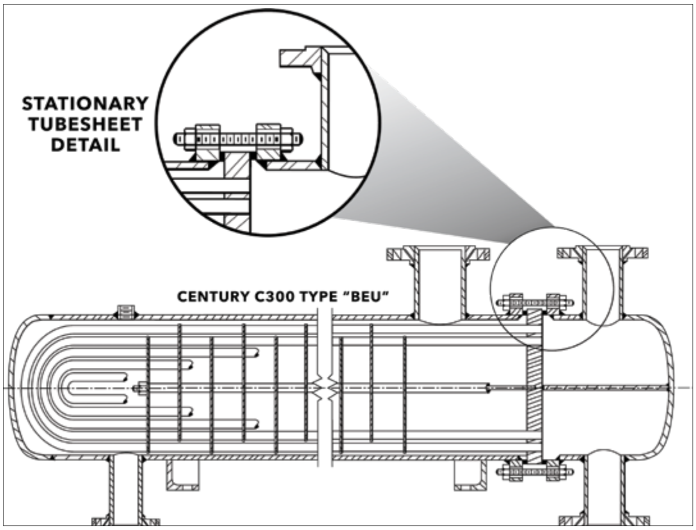

FIGURE 3. Removable bundle U-tube exchangers have only one tubesheet, which allows for maximum differential expansion between the shell and the tubes during operation

This inexpensive exchanger allows for multi-tube pass arrangements. However, because the U-tube cannot be made single pass on the tube side, true countercurrent flow is not possible.

Common TEMA designations are BEU and AEU, and typical applications include the following:

- Oil cooling
- Chemical condensing
- Steam heating

Special designs

For applications with high vapor flow and high-pressure conditions, a specially designed shell-and-tube exchanger is often the only viable solution. Special designs may also be called for when applications have temperature crossing, meaning the outlet temperature of the warmed fluid exceeds that of the cooled fluid. The following are several examples:

- TEMA K-type shells, which allow for proper liquid disengagement for reboilers
- TEMA J-type shells, which accommodate high vapor flows by allowing for divided flow in the shellside
- Two-pass TEMA F-type shells, which can be used for applications when a temperature cross exists
- TEMA D-type front head designs, which are often the answer for high-pressure tubeside applications

While these specially designed heat exchangers may be the solution to a process problem, construction costs tend to be higher than those of "standard" engineered shell-and-tube equipment.

Common TEMA designations include BKU, BJM, BFM and DED. Specially designed exchangers are often called for in the following applications:

- Reboilers
- Steam heaters
- Vapor condensers
- Feedwater heaters

Pre-engineered exchangers

Fixed-tubesheet and U-tube shell-and-tube heat exchangers are the most common types of pre-engineered heat exchangers available today. Such models are often used as components in vapor condensers, liquid-liquid exchangers, reboilers and gas coolers for smaller capacity applications such as pilot plants.

Standard fixed-tubesheet units, the most common pre-engineered shell-and-tube heat exchangers, range in size from 2 to 8 in. in diameter. Materials of construction include brass or copper, carbon steel and stainless steel. Even though this exchanger is one of the least expensive available, it is still generally constructed to standards specified by the manufacturer and not to TEMA specifications. If the user desires, pre-engineered exchangers can be constructed to American Society of Mechanical Engineers (ASME) codes.

U-tube heat exchangers are commonly used in steam-heating applications, or heating and cooling applications that handle chemical fluids as opposed to water. While the U-tube is generally the lowest-priced heat exchanger available, service and maintenance costs tend to be higher than other exchangers, since the nested, U-bend design makes individual tube replacement difficult.

Custom-designed heat exchangers, though more expensive than the pre-engineered counterparts, are generally made to higher design standards than pre-engineered exchangers. Many manufacturers follow the TEMA standards for design, and fabrication following the TEMA industry classifications:

- TEMA B is the most common TEMA designation, and provides design specifications for exchangers used in chemical process service
- TEMA C guidelines provide specifications for units used in commercial and general process applications
- TEMA R guidelines provide specifications for exchangers used in petroleum refining and related process operations

Each of these classes are applicable to shell-and-tube heat exchangers with the following limitations:

- Shell diameter does not exceed 100 in.
- Pressure does not exceed 3,000 psi
- The product of shell diameter (in.) times pressure (psi) does not exceed 100,000

Standards set by the American Petroleum Institute (API) are also generally accepted throughout the heat exchanger industry.

While there are obvious advantages to purchasing a custom-designed exchanger that meets either TEMA or API manufacturing guidelines, these specifications add to the cost of the exchanger and may have a longer manufacturing cycle. ■

Edited by Gerald Ondrey

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Economic Indicators

2019 ▬ 2020 ▬ 2021 ▬

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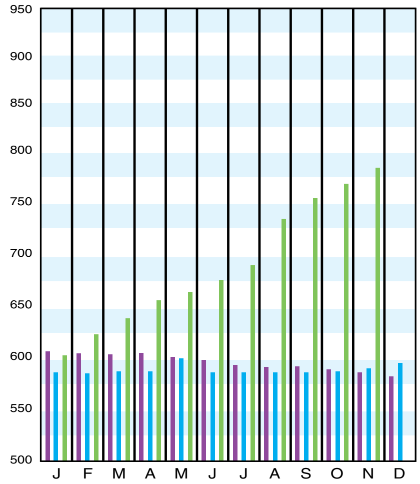
CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	Nov. '21 Prelim.	Oct. '21 Final	Nov. '20 Final
CE Index	772.5	761.4	600.2
Equipment	972.8	956.4	728.1
Heat exchangers & tanks	828.5	816.7	614.8
Process machinery	976.6	962.6	724.6
Pipe, valves & fittings	1385.2	1361.0	979.2
Process instruments	569.8	559.8	423.2
Pumps & compressors	1178.3	1178.1	1084.0
Electrical equipment	671.5	644.5	569.5
Structural supports & misc.	1064.1	1044.6	768.5
Construction labor	348.7	350.4	336.4
Buildings	796.8	782.0	612.7
Engineering & supervision	310.7	310.8	309.6

Annual Index:
2013 = 567.3
2014 = 576.1
2015 = 556.8
2016 = 541.7
2017 = 567.5
2018 = 603.1
2019 = 607.5
2020 = 596.2

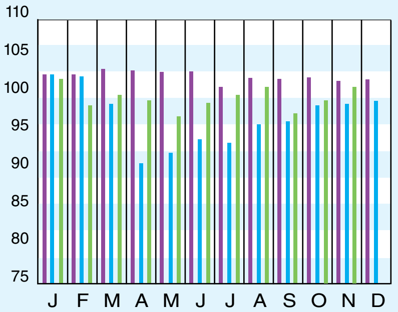
Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)



CURRENT BUSINESS INDICATORS

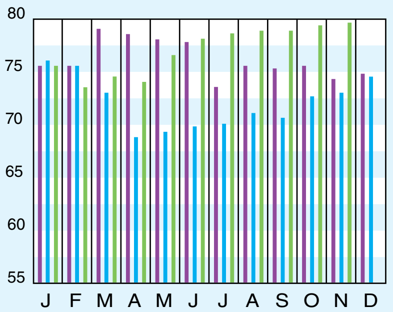
	LATEST			PREVIOUS						YEAR AGO		
CPI output index (2017 = 100)	Nov. '21	=	99.7	Oct. '21	=	98.9	Sept. '21	=	97.6	Nov. '20	=	94.3
CPI value of output, $ billions	Oct. '21	=	2,093.1	Sept. '21	=	2,020.8	Aug. '21	=	1,984.9	Oct. '20	=	1,684.4
CPI operating rate, %	Nov. '21	=	79.5	Oct. '21	=	78.9	Sept. '21	=	77.8	Nov. '20	=	74.9
Producer prices, industrial chemicals (1982 = 100)	Nov. '21	=	343.7	Oct. '21	=	334.7	Sept. '21	=	328.2	Nov. '20	=	232.4
Industrial Production in Manufacturing (2017 =100)*	Nov. '21	=	100.6	Oct. '21	=	99.9	Sept. '21	=	98.6	Nov. '20	=	96.2
Hourly earnings index, chemical & allied products (1992 = 100)	Nov. '21	=	194.8	Oct. '21	=	195.0	Sept. '21	=	197.5	Nov. '20	=	189.5
Productivity index, chemicals & allied products (1992 = 100)	Nov. '21	=	96.8	Oct. '21	=	96.4	Sept. '21	=	357.0	Nov. '20	=	92.3

CPI OUTPUT INDEX (2017 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)

CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2012 to 2017
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the *CE* Plant Cost Index (CEPCI; top) for November 2021 (the most recent available) is once again higher than the previous month, continuing the upward trend that dominated 2021. The increase for November is driven by two of the subindices in particular — the Equipment and Buildings subindices — which both saw increases that offset smaller decreases in the Construction Labor and Engineering & Supervision subindices. The current CEPCI value now sits at 28.7% higher than the corresponding value from November 2020. Meanwhile, the Current Business Indicators (middle) show increases in the CPI output index for November and for the CPI output of value for October.

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