Cybercrime Surge: How Controls Vendors Are Responding

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VIRTUAL VERSUS LIVE EVENTS

I’ve been attending some virtual events of late. They are a poor substitute for the real thing. One-hour webinars are fine, but several-day affairs can be rough.

Case in point: One conference failed to send me the log-in details. As a result, I missed the entire first morning. The platform being used took a while to load, then needed an update. When it loaded, it took me to an information screen to add some personal information. Once entered, various security measures had to be negotiated. Finally, I was in. But no! It asked for a password to the specific session and I didn’t have one. I gave up and wrote the entire day off. The good news is that this conference went to great pains to provide me with links to some of the sessions from the day before. The following days were smoother.

Another recent show was a little better. Yet it was deeply unsatisfying to view one face on a screen giving a talk followed by no applause and a delay before the MC came back on to introduce another speaker. Connection issues happened occasionally, too. But better than nothing.

An earlier event suffered from low attendance. One discussion group had me, one user, and four panelists. That almost never happens at a live event. Even badly attended sessions have a dozen or so attendees to keep the panelists and moderator company.

All in all, I am ready to get back to live shows. Industry events are all about the crowds, the interaction, meeting old friends you haven’t seen for ages, the networking, the exhibits, the press conferences, the hospitality gatherings … it’s been 18 months since I attended one. They are sorely missed.

That said, some statistics provided by Mark Axford and Tony Brough give a sobering view of the short term. Our market trends article on gas turbine orders shows that it has been a lean few years. The next few may not be much better. But the article highlights opportunities for turbomachinery in oil & gas, the aftermarket, and the areas of the power generation space most likely to favor gas turbines. It also provides food for thought on the proposed hydrogen economy, the shortcomings of battery technology, and predictions for the future.

Our cover story was supposed to be a general overview of turbomachinery controls. But events such as the Colonial Pipeline hack swayed its focus towards cybersecurity. We cover the general state of industrial cybersecurity (see also a lengthy piece in our news pages), what controls vendors are doing about it, and provide details of the latest controls features available in the marketplace.

On the topic of maintenance & repair, we offer several technical articles: One on how to troubleshoot pipeline steam condensate issues, one on combating noise levels in plants, and another on deep compression repair for steam turbine compressors. Additionally, you can read about the proposed Infrastructure Bill and how it might impact the turbomachinery sector, as well as a new approach to hydrogen combustion.

Our regular columns serve up a vendor showcase about Waukesha Bearings, a Q & A from Regal, and show reports from the Turbomachinery Expo and Western Turbine Users. Meanwhile, our Myth Busters tackle air filtration effectiveness and our Turbo Tips column delves into the many factors impacting compressor surge.

THE LATEST ISSUE

With so much propaganda around about the elimination of fossil fuels, some have the idea that the end is nigh. It really isn’t. Consider this: In 2019, gas turbines transported 4.5 billion people by air, and generated nearly 6300 terawatt-hours of power. They are an integral part of modern life and will continue to be so for a long time to come.
**INDUSTRY NEWS**

**REPORT REVEALS THE RISE OF RANSOMWARE AND THE IMPORTANCE OF THE HUMAN ELEMENT**

The Verizon Data Breach Investigations Report (DBIR) provides a window into the world of global trends in security. This year’s analysis looked into 79,635 incidents around the world, of which 5,258 were confirmed data breaches.

Social engineering (primarily phishing — whereby the assailant sends scam emails in order to trick someone into clicking on a malicious link or attachment) came up as the top avenue of incursion used in breaches. More than 30% of incidents stemmed from it, while web application attacks accounted for around 25% and system intrusions scored almost 20%. Not surprisingly, 85% of breaches included a human element with 61% involving credentials, and 13% containing ransomware. About 10% of the ransomware attacks cost organizations an average of about $1 million — whether from forking over the cash, remediation, or lost revenue.

The manufacturing industry, of which turbomachinery is a subset, is beset by phishing and other social engineering schemes. The same holds true for oil & gas, power generation, and utilities. These industries suffered heavily from social engineering attacks this year. Credentials, personal and internal data are the most commonly lost data varieties. Ransomware is also a major threat. Verizon noted sustained phishing campaigns against many organizations. This indicates that these companies are viewed as lucrative targets.

The sector witnessed a marked rise in ransomware-related breaches. Overall, these kinds of attacks accounted for the bulk of breaches. Internal threats stemming from a rogue employee only accounted for 19% of the total.

In almost all cases, the motive was financial. However, there is a small percentage of industrial espionage impacting manufacturing. The primary tactic is to compromise log in credentials. If someone clicks on a malicious link, the bad guys can take over their email account, and gain entry to other parts of the network. Threat actors were more likely to use a social engineering attack (75.4% were phishing) or a hacking attack (79.5% were via the use of stolen credentials) to gain an initial foothold. From there, cybercriminals seek out additional credentials such as those with administrative privileges of those related to financial accounts. They also install malware, sometimes letting it lurk unseen for months while they study the opportunities available.

**ATLAS COPCO ACQUISITIONS**

Atlas Copco has agreed to acquire Arpuma, a specialized vacuum systems and solutions provider for the chemical and pharmaceutical industry. Arpuma is based in Germany. It will become part of the Industrial Vacuum Division within the Vacuum Technique Business Area.

Atlas Copco also acquired a majority share of Eco Steam and Heating Solutions, a Dutch industrial steam and hot water boiler company. Eco Steam and Heating Solutions develops, rents, and sells customized industrial boiler assemblies. It will become part of the Speciality Rental division within the Power Technique business area.

Finally, Atlas Copco has acquired the operating assets of Compressed Air Systems (CAS), a distributor of compressors located in North Carolina in the US. CAS is a privately owned company located in Salisbury, North Carolina. It will become part of the service division within the Compressor Technique Business Area.

**PIPELINES MORE POPULAR THAN EXPECTED**

Nearly 90% of Americans believe the United States should reduce its reliance on foreign energy sources and nearly three-quarters support oil and natural gas transport via pipeline, according to a recent nationwide poll commissioned by the GAIN Coalition. This show of support for American energy and infrastructure appears to hold true regardless of political affiliation. By a margin of more than 3-to-1, Americans believe pipelines are the best option to transport oil and gas compared to the alternatives of truck and train.

The Dakota Access Pipeline (DAPL) transports up to 570,000 bpd of Bakken crude from North Dakota to Illinois. The survey showed that 64% agree DAPL should continue serving American energy consumers.

**LM6000 MAINTENANCE AGREEMENT**

MTU Power and Amazonas GT have signed a ten-year agreement for the maintenance, repair, and overhaul of the company’s five LM6000 turbines. Based in Manaus, Northern Brazil, Amazonas GT is a subsidiary of utility Eletrobras. On-site technicians are dispatched from MTU’s Brazilian base in São Paulo, whenever the customer requires. The Brazilian facility is certified up to level II.

**TEXAS BLACKOUT AFTERMATH**

Texas has more work to do to prevent the kinds of weather-driven blackouts that devastated the state in February 2021. That is the conclusion of Never Again: How to Prevent Another Major Texas Electricity Failure. It offers recommendations to avoid future grid failures, including: Power plant and natural gas system weatherization; definition of price gouging for natural gas; higher energy efficiency standards; and backup power systems.
**DOOSAN ŠKODA POWER DIGEST**

Doosan Škoda Power is supplying a one-core DST-S20 steam turbine with accessories for a waste-to-energy plant in Olsztyn, Poland. The new plant, scheduled to be completed in 2023, will be capable of processing up to 110,000 tons of refuse derived fuel (RDF). The plant will be covering roughly 30% of the district heating demand in the city by replacing old coal fired sources of heat.

**CARBON CAPTURE PLANNED FOR LNG**

Venture Global LNG announced plans for carbon capture, utilization, and sequestration (CCUS) at its Calcasieu Pass and Plaquemines LNG facilities. The goal is to compress CO₂, transport and inject it deep into subsurface saline aquifers. An estimated 500,000 tons of carbon per year is planned from its two liquefaction sites.

**SIEMENS ENERGY DIGEST**

Siemens Energy will supply a gas and steam turbine to a 390 MW combined cycle power plant in Côte d’Ivoire as part of an agreement with Spanish EPC contractor TSK for a plant scheduled to begin operations in late 2022. The company will supply one SGT5-4000F gas turbine and one SST5-3000 steam turbine, each along with a generator, condenser and an SPPA-T3000 control system. Additionally, a long-term service agreement has been signed.

Siemens Energy is to build a turnkey gas-fired power plant purely as grid-related equipment in Leipheim, Bavaria, in a contract with LEAG. The plant will be used at the request of the transmission grid operator Amprion to ensure grid stability in an emergency. It can supply 300 MW in 30 minutes. Siemens Energy’s scope of supply includes construction, an O&M agreement, an SGT3-4000F gas turbine, an SGen-2000P generator, and the SPPA-T3000 control system. The company will also provide a system for cooling the intake air and a system for injecting fully desalinated water into the gas turbine.

Leveraging Siemens Energy’s Eos.ii software, energy companies can turn cyber threat intelligence targeting operational technology (OT) and information technology (IT) networks — connected to physical energy assets — into an actionable response through the ServiceNow OT Management product. This enables plant operators to act with Precision Defense, a response method to deploy measures to correct and recover from cyber incidents. Siemens Energy’s MDR system provides a unified picture of anomalous behavior for defenders with insights to stop attacks. The service goes beyond conventional monitoring by achieving understanding of how digital systems relate to the real world. With its unified OT and IT data stream, MDR’s Eos.ii technology platform uses AI and digital twin technology to compare billions of real-time data points against a correctly functioning asset.

**AERODERIVATIVE ORDER FOR MITSUBISHI POWER AERO**

Mitsubishi Power Aero and Mitsubishi Power de Mexico executed a contract to install and commission five 30 MW FT8 MobilePac aeroderivative, dual-fuel gas turbines for CFEN, a subsidiary of Mexico’s CFE. The project, located in Mexicali, Baja California, delivers power in time for peak season. A sixth gas turbine will be added later to expand capacity and support next summer’s requirements.

**MAN DIGEST**

MAN Energy Solutions’ paper-industry vacuum systems registered 11 orders in the tissue sector in the first quarter of 2021. ABC Tissue Paper in Sydney recently marked a first for Australia with an order for a vacuum blower type RT 56-1.

MAN Energy Solutions and the thyssenkrupp business unit Uhde are partnering to drive forward the development, testing and marketing of autonomous turbomachinery systems operation for the nitric acid production industry. They will use artificial intelligence (AI) to aid decision-making. It will involve taking real-time account of data such as product price, yield, efficiency, emissions, energy costs, process stability, and forecast maintenance requirements.

**MITSUBISHI POWER DIGEST**

Bakken Energy and Mitsubishi Power Americas have signed a partnership agreement to create a hydrogen hub in North Dakota. It will be composed of facilities that produce, store, transport, and consume hydrogen. It will be connected by pipeline to other such hubs being developed throughout North America. The hub in North Dakota will focus on blue hydrogen production.

Mitsubishi Heavy Industries America has appointed Michael Sicker as president of its Oil & Gas Division. He succeeds Hiroaki Osaki, who has retired but continues to serve as chairman of Mitsubishi Heavy Industries Compressor Corporation, Japan. Sicker will continue to serve as MHIA’s global account manager for ExxonMobil.

Mitsubishi Power and Texas Brine Company signed an agreement to develop large-scale long-duration hydrogen storage systems. Texas Brine and its affiliates have salt positions in New York, Virginia, Texas and Louisiana.

**INDUSTRY NEWS**
INDUSTRY NEWS

EXERGY TO SUPPLY BRINE RECOVERY GEOThERMAL PLANT
Exergy, a provider of geothermal binary power plants signed a contract with EDC for the supply of an ORC binary system. It will consist of a single pressure level bottoming cycle equipped with a Radial Outflow Turbine that will recover the thermal energy to produce 3.6 MWe of power before the brine is reinjected into the reservoir. Located in the Philippines, the Mindanao 3 unit will be EDC’s first geothermal brine recovery plant to go online in 2022. It will help generate an additional 3.6 MW of power from an existing geothermal field that utilizes the waste geothermal brine available from Mindanao 1 and 2 steam power plants.

GE GAS POWER DIGEST
Qatalum of Qatar signed an agreement with GE to provide five Advanced Gas Path (AGP) upgrade units, maintenance services for a period of 15 years for equipment at its 1,080 MW power plant, and a suite of cybersecurity solutions. Four of the AGP upgrades will be installed on 9F gas turbines, and one unit will be kept as a spare. It is expected to: enhance power output by up to 96.7 MW with improved plant efficiency; increase the availability of its gas turbines; lower operational expenses by increasing the interval between their planned maintenance cycles from 24,000 factored fired hours (FFH) to up to 32,000 FFH; and to reduce carbon dioxide emissions by up to 67,000 tons annually. Qatalum is the only aluminum smelter in Qatar. GE will provide maintenance works for four 9F gas turbines, four generators, and other equipment.

Summit of Bangladesh received delivery of a GE 9HA.01 gas turbine at its upcoming Summit Meghnaghat II power plant located near Dhaka. It has been placed on the foundation at the site, which is expected to be commissioned in 2022. Under the EPC contract, the equipment to be provided includes: one 9HA.01, one three-pressure level with reheater (RH) drum type Heat Recovery Steam Generator (HRSG), one steam turbine, one gas turbine generator, one steam turbine generator, one condenser and associated systems, along with balance of plant (BOP) solutions. Additionally, GE will be providing maintenance and repair services for 22 years.

POLYMER FOR CORROSIVE APPLICATIONS
CDI Energy Products achieved API 610 recognition for its dures 200 polymer under extremely corrosive sulfuric acid conditions. This thermoplastic polymer was the foundation for components developed for an API 610 Vertical Single Casing Diffuser Pump (VS1) for a high-production sulfuric acid plant. Suction bell eye case rings, bowl eye case rings, and bowl bushings were developed to sustain differential pressures of over 200psi, coupled with an extreme temperature profile of -20°F to 105°F (-28.8°C to 40.55°C).

HYDROGEN COLLABORATION
Baker Hughes and Bloom Energy will work together to commercialize and deploy integrated, low-carbon power generation and hydrogen solutions. They will begin on pilot projects. Bloom Energy’s solid oxide fuel cell technology (SOFC) and Baker Hughes’ gas turbines will be combined to create cleaner energy generation, waste heat recovery, grid independent power and microgrids. In addition, the companies will pair Bloom’s solid oxide electrolyzer cells (SOEC) that can produce green hydrogen with Baker Hughes’ compression technology for production, compression, transport, and delivery of hydrogen. In addition, other avenues of development may include carbon capture and emissions monitoring technologies, digital solutions, and additive manufacturing capabilities.

VIKING ENGINEERING OPENS NEW LABORATORY
Viking Engineering has opened the Viking Engineering Laboratory located in Houston, Texas. It will provide failure investigation and forensic services, metallurgical evaluations, material testing services, fit-for-service evaluations, microstructural characterization, finite element analysis (FEA), fracture surface evaluation (SEM/EDS fractography evaluations), mechanical testing (tensile, hardness, CVN), fracture mechanics analysis and fracture mechanics testing (KIC, JIC, J-R) for evaluating complex downhole and pipeline failures. For midstream and downstream clients, the Viking Laboratory offers pipeline failure investigations and forensic services. In addition, the Viking Laboratory provides services to the renewables energy sector.

3D PRINTERS IN DEMAND
Velo has received a couple of recent orders. The first is an aluminum F357 metal Advanced Manufacturing (AM) solution to Wagner Machine, a precision machine shop. Founded in 1982, its capabilities include 3- and 5-axis CNC mill, CNC lathe, CNC swiss, wire EDM, abrasive waterjet, and a variety of precision grinding and other support processes. Adding Velo3D metal AM expands the company’s ability to serve aerospace and defense customers who need mission-critical parts. The second order is from ADDMAN Engineering. It is for a full-stack laser powder bed fusion 3D printing solution to serve the spacecraft and turbomachinery fields.
API 617 Integral Gear Unit

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FACTORS IMPACTING COMPRESSOR SURGE

BY AMIN ALMASI

Surge can be a major challenge for turbo-compressors. Operation in the surge area will result in an instability, exposing the machine to destructive stresses and forces, high vibration, and even serious damage.

Surge during shutdown (trip) has been reported for many turbocompressors. This is particularly possible if the machine operates at high head and low flow, immediately before the trip, when the operating point can move toward the surge line and even pass it during coast-down (when the turbo-compressor reduces flowrate). When a turbo-compressor experiences a serious alarm, an emergency shutdown is usually initiated. But an immediate shutdown could result in a surge. In this case, the surge happens shortly after the shutdown (trip) and at a high energy level. This could be a surge at a high head (operating point could pass the surge line at high head).

In many cases, there are advantages to not removing the driving power from the turbocompressor (tripping) immediately by delaying for a few seconds so the anti-surge valve can be opened and the discharge pressure (head) can be sufficiently reduced. As soon as the trip is intended, the anti-surge is opened, and the compressor shutdown is implemented with a second or two delay.

Many alarms and malfunctions do not require an instantaneous shutdown. For example, a high bearing temperature and a high vibration (unless it reaches more than 10 times allowable levels). An exception is loss of lubrication oil where it could potentially be worse than a full load surge. A safety study helps determine if such a delay is allowable.

RATE OF SPEED REDUCTION

Another critical parameter is the rate of speed reduction (coast-down time) during trip/shutdown. For many turbocompressors, rapid speed reduction can cause surge to be reached sooner and at a higher head condition. This results in a high energy surge event.

Great care should be taken for gas turbine-driven compressors. As soon as the fuel supply to the gas turbine driver is cut-off, the power is eliminated to the driven turbo-compressor and the speed drops rapidly. Some installations maintain the fuel flow to the gas turbine driver for up to two seconds, while the anti-surge valve (turbo-compressor recycle valve) opens. This delay may generate a safety hazard.

High-pressure gas trapped in the discharge system plays a major role in surge.

The head-making capability of a turbocompressor is reduced typically by the square of its running speed, while the pressure ratio is imposed by the upstream and downstream piping and facilities system. Therefore, the unit will surge if the anti-surge valve cannot provide fast pressure relief at the discharge system. The deceleration rate as a result of train inertia and energy dissipation is a decisive factor. The rate of pressure relief at discharge not only depends on the reaction time of the anti-surge valve, but also on the volume of gas enclosed in piping and other systems between the compressor and anti-surge valve.

Speed reduction is fast in aeroderivative gas turbines. An emergency shutdown of a two-shaft or aeroderivative gas turbine-driven compressor can be problematic since train inertia is low and train speed decreases rapidly in a trip. Roughly 20-30% speed reduction can be expected for an aeroderivative-driven machine in the first second after the shutdown. This results in around 50% reduction in head generation capability. An anti-surge valve for such a compressor should be able to reduce the pressure across the turbo-compressor by about half during the same period. The worst-case scenario for an anti-surge system is an emergency shutdown of the gas turbine while the turbocompressor is operating at high pressure and close to surge.
Similar scenarios may be applicable for an electric motor trip. However, the inertia of a typical electric motor-driven train is much higher. A typical rotor assembly for an electric motor-driven turbo-compressor has three to seven times higher inertia compared to a two-shaft or aeroderivative train.

High-pressure gas trapped in the discharge system plays a major role in surge. Large volumes of pressurized gas need time to depressurize. The volume of pressurized, high-energy gas to be dissipated can be reduced by discharge check valve(s) located upstream of large headers or vessels that store significant amounts of high-pressure gas. Fast-closing check valves are generally specified.

Challenging situations have been reported when the anti-surge valve loop is taken downstream of the aftercooler(s). Usually in these cases, the discharge gas volume in the cooler and piping is too large and the anti-surge valve (recycle valve) cannot avoid a surge. An additional hot gas bypass valve is often required. This is a short recycle loop without any cooler that only operates for a very short time during trip or emergency.

Vent valves on the discharge piping can effectively reduce discharge pressure and stored energy that contributes to the severity of the surge. This is particularly useful in multi-section turbo-compressor installations where recycling around the 2nd stage, for example, results in high-pressure gas being added to the 1st stage discharge energy. Venting can allow some gas from the 2nd stage to be removed. Such venting should only be used as the last resort. Most vent valves are small and can be opened rapidly.

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**Editors’ Series**

**Turbomachinery, Carbon Capture, Hydrogen, and Achieving a Net Zero Carbon Footprint**

**Event Overview**

This webinar discusses the various applications and technical challenges for the turbomachinery required for carbon capture. The presentations include discussions about hydrogen compression, hydrogen combustion in gas turbines, carbon dioxide compression separation and injection as well as associated infrastructure needs and impacts.

**Key Learning Objectives**

- How the reduction of the carbon footprint will require the capture of CO2 from combustion processes.
- The combustion of hydrogen or hydrogen-natural gas blend fuels in gas turbine combined cycle power plants has potential as a route to reduce greenhouse gas emissions in the electric power industry.
- Power plant post-combustion carbon separation turbomachinery will be required to compress, transport, and inject the carbon dioxide into permanent geological storage formations.

**Who Should Attend**

- Turbomachinery engineers, manufacturers, researchers, and designers
- Power plant, oil & gas, and industrial facility owners, operators, and maintenance personnel
- Turbomachinery supply chain and aftermarket partners

For questions or concerns, email kbarry@mjhlifesciences.com

Register for this free webinar at: www.turbomachinerymag.com/turbo_p/zero
First there was the Colonial Pipeline hack. The gasoline supply to the U.S. Eastern Seaboard shut down until a near $5 million ransom was paid to Eastern European criminals. Then came an alert that Siemens programmable logic controllers (PLCs) had a security hole that was being exploited by attackers.

Siemens AG released firmware updates to address this vulnerability in Simatic S7-1200 and S7-1500 PLCs. If exploited, malicious actors could remotely access protected areas of memory and achieve unrestricted and undetected code execution. This vulnerability means an unauthorized person could access the network and write arbitrary data and code to protected memory areas or read sensitive data to launch further attacks.

The ability to execute code on PLCs that might be running plant systems, power stations, or various items of turbomachinery is bad news. It represents another level of hacking sophistication beyond that seen in the Stuxnet exploits that caused trouble to Iranian nuclear facilities a few years ago. To make matters worse, such attacks can evade detection by security tools. All the attacker needs is a way to get onto the network, which entails little more than tricking a gullible employee to click on a malicious email link or attachment. This kind of incursion is very much on the rise in turbomachinery (See our lead news story: Report Reveals the Rise of Ransomware and the Importance of the Human Element, p. 8).

Despite the presence of the Siemens update, there is no guarantee that all users of the PLC will deploy it across their systems. Too often in cybersecurity, the bad guys use known vulnerabilities to access systems. The moral of the story is to keep systems current with the latest updates and patches.

With cybercriminals actively seeking potentially lucrative targets related to infrastructure, what are control systems OEMs and suppliers doing about such threats? What changes are they making to their offerings? And what else is new on the turbomachinery controls and software front? Let’s hear from the vendors.
**SIEMENS ENERGY**

Siemens Energy, as distinct from Siemens AG that provided the PLCs noted above, has placed plenty of emphasis on cybersecurity of late. Its Eos.ii software helps energy companies use cyber threat intelligence targeting operational technology (OT) and information technology (IT) networks connected to physical energy assets. Siemens Energy has partnered with IT software firm ServiceNow as part of this offering. Those impacted can use it to deploy appropriate, targeted and proportionate measures to correct and recover from cyber incidents.

Additionally, Siemens Energy’s MDR system provides a unified picture of anomalous behavior for defenders with insights to stop attacks. The service goes beyond conventional monitoring by achieving understanding of how digital systems relate to the real world. With its unified OT and IT data stream, the platform uses artificial intelligence (AI) and digital twin technology to compare billions of real-time data points against a correctly functioning asset. This provides context for analysts to determine not only which events are abnormal, but which are consequential.

Dieter Fluck, Vice President of Controls Systems & Innovation for Siemens Energy, noted that security has become more important of late as companies gain familiarity with remote monitoring. His company has been remotely monitoring its fleet for more than 10 years to provide faster support and to enact quality improvements.

“Questions around compliance with cyber security norms and regulations have been a constant feature of conversations about remote monitoring with customers,” said Fluck. “This hinges on finding a good balance between the benefits of cost and efficiency while ensuring long-term safety and security of critical customer assets.”

All Siemens Energy controls solutions offer remote connectivity. This ranges from basic connectivity to complete digital twin-based support through company Remote Expert Centers (RECs). RECs lets users tap into a network of in-house experts that address issues ranging from process know-how to software/hardware issues. Turbine experts can evaluate performance, analyze and diagnose changes in operational behavior and provide recommendations.

The SPPA-T3000 for turbine control of gas and steam turbines in power generation encompasses governor, protection, and auxiliary controls combined in one control cabinet. All devices are integrated into this control system. Independent SIL3 protection systems can be added, if desired.

Specific to oil and gas, the controls interface at the individual asset level as well as the plant (or enterprise) level. At the asset level, controls are available for turbine and electric motor-driven compressors and pumps. All Siemens Energy compressors are offered with process controls including modules for anti-surge and load sharing.

“In the larger controls, we are seeing strong interest in advanced cybersecurity, enhanced reliability, and integrated functional safety,” said Greg Marino, Woodward.

Fluck said the growing demand for data coupled with ease of communication and data transmission has driven several trends. Cloud-based controls, for example, are being used more to foster data consistency and availability for asset optimization. Companies are also seeking greater interoperability of assets across platforms. There is growing demand, too, for systems that support autonomous plant operation without the need for manpower onsite.

“In the power generation market, there are increasingly complex requirements targeted towards grid stability and security,” said Fluck. “In the industrial and oil & gas markets, customers have been looking for greater asset reliability and availability which often translates into demands to push the operational profile of our machines beyond established precedence while ensuring all applicable safety standards are still met.”

**WOODWARD**

Woodward Turbomachinery Systems also offers remote monitoring systems to enable its technicians to gain remote access to address service issues.

“A key aspect of any remote monitoring or access system is cybersecurity,” said Greg Marino, Product Line Manager, Woodward. “In today’s world, no one is going to allow you to connect remotely without a thorough security review.”

He added that each new hardware upgrade carries with it a greater degree of cybersecurity to ensure Woodward products meet or exceed security standards. The company also offers system-level security for Human Machine Interfaces (HMI), workstations, and networks in addition to controls to help users meet NERC/CIP, ISA 62443 and regional standards.
Woodward offers a line of turbomachinery controls that range from small hydro and mechanical-drive steam turbines through nuclear steam, gas turbines, combined cycle, and integrated gasification combined cycle. It also has SIL2/3 safety controls and matching electro-hydraulic and electric valve actuation products.

“Connectivity remains a challenge because of the large number of legacy systems in the plant,” said Jeff Schleis, EthosEnergy

Marino said the 505 product line is the most popular turbine control platform with approximately 28,000 installed worldwide. It’s preprogrammed and configurable via an onboard multi-language HMI or remotely from a workstation. It includes self-optimizing control loops and is available in single valve, extraction, and dual-redundant versions, and has multiple international and regional hazardous location certifications.

“In larger controls, we see interest in cybersecurity, reliability, and integrated functional safety,” said Marino. “The use of functional safety controls or integrated functional safety is expanding in the oil & gas market. Buyers of smaller controls are more focused on ease of use, reliability, and cost efficiency.”

The newest Woodward platforms and updates are being enhanced to support analytics and secure Industrial Internet of Things (IIoT) functions.

ETHOSENERGY

EthosEnergy’s approach as an integrator is to evolve its cybersecurity to match the needs of users. Its scope had increased to include balance of plant controls, and helping bridge IT and OT security. Basic historical methods of network segregation, firewalls, and hardening workstations are standard for the core control system.
Jeff Schleis, Product Manager, EthosEnergy, has observed greater built-in security in controls. While plant-wide issues remain, features like keyed software/firmware, encrypted communication methods, and networking hardware/software that is co-developed with the control system manufacturer are all methods that increasingly harden the equipment we integrate.

Schleis emphasized the benefits the entire industry has experienced due to the dramatic rise in the amount of processing power available to control systems.

"Whereas in the past, we required multiple processors to handle demanding sub-10ms systems or large balance of plant systems, we can now perform well in one CPU with room to spare," he said. "However, connectivity remains a challenge because of the large number of legacy systems in the plant."

EthosEnergy has a fleet of units that it operates for owners. Predictive data analysis is used to optimize maintenance efforts via the company’s PHD Advance solution. It leverages cloud computing to process large volumes of data received from a plant. It identifies issues and negative trends that are further investigated by EthosEnergy engineers to find root causes and target maintenance activities to reduce maintenance spend, maintain plant performance, and increase availability.

Additionally, the company provides Icon control system upgrades and retrofits on gas and steam turbines. With over 1,000 systems supplied, these encompass nearly every OEM and industry.

Take the case of an LM6000 gas turbine. The base icon system upgrade for this turbine includes the necessary sequencing, fuel control, and protections. Optional solutions are available to solve problems surrounding the package and plant. One of those includes the ability to improve on-vent fan diagnostics. Rather than utilize the original flow switches, technology has been added to the motor control center (MCC) to diagnose when a fan is running, or if an abnormal situation is present. This reduces the possibility of a failed start and improves availability. Other enhancements improve diagnostics, increase performance, and reduce downtime.

It has been a common theme for EthosEnergy to expand this same hardware into the balance of plant systems and reduce the number of platforms that the site supports. This has been primarily for independent power producers or small petrochemical plants where a Distributed Control System (DCS) may not be present or has similar obsolescence issues as the turbine control system.

"Customers have issued specifications that include both the turbine control and the balance of plant controls where we can modernize those systems for the HRSG, water treatment, inlet chilling, and other systems," said Schleis.

He noted other trends such as: adjusting controls to deal with cyclic operating profiles; increasing turndown and attempting to minimize stress on the unit; finding ways to peak fire and increase the plant’s usefulness to the power market; finding ways to improve availability and prevent downtime; redundancy requirements have increased as industrial customers have the budget to increase controller complexity, as well as instrumentation in the field to improve availability; and allocating funds for upgrades on older units that previously were not being considered.

"Larger projects to modify the unit to meet emissions and increase generating output are getting approved," said Schleis. “Having the ability to mechanically modify the unit and provide the necessary control system upgrades are key to being competitive.”

YOKOGAWA

Yokogawa has teamed up with Shell to develop the Platform for Advanced Control and Estimation R5.03 as part of the OpreX Asset Operations and Optimization family. This software suite brings together Shell’s plant process control technology and Yokogawa’s real-time controls to improve productivity by increasing product yield and reducing energy consumption.

It incorporates a new communication standard that enhances security: The Open Platform Communications Unified Architecture (OPC UA), which improves plant systems interoperability and security. OPC is an interoperability standard for the secure and reliable exchange of data in industrial automation.
The new Yokogawa platform is suited to facilities such as oil refineries, petrochemical plants, chemical plants, and LNG trains. It incorporates the control of multiple variables based on predictions made using models of the dynamic characteristics of plant responses, as well as sensing to estimate quality in real-time based on temperature, flow rate, pressure, and other process values.

**TRI-SEN**

Tri-Sen reports a rise in discussions relating to the IIoT and big data. The issue there is the vulnerabilities inherent with a higher level of connectivity.

“We’ve been investigating methodologies for identifying and reducing connectivity risk in the solutions we provide, and are excited about the possibilities related to the top-down systems approach posited in the ‘System Theoretic Process Analysis’ for security (STPA-Sec),” said Thomas Bailey, Director of Marketing, Tri-Sen.

The company has begun using the STPA-Sec methodology to identify, frame, model, and evaluate security vulnerabilities associated with system connectivity for a given integrated turbomachinery control application/solution. Tri-Sen uses this approach to assess system exposure, then makes specific recommendations for reducing and controlling the cybersecurity risk associated with the respective turbomachinery controls solution.

Tri-Sen provides configurable, stand-alone turbomachinery controls, custom PLC-based turbomachinery controls, turbine-safety products, as well as turbomachinery controls-related engineering services. Its standard configurable products include digital turbine governors, digital positioners, and ancillaries. Custom solutions are delivered on the PLC platforms such as Triconex, Allen Bradley, and Siemens, as well as on major DCS platforms. Turbine-safety products include a TUV SIL 3 certified hydraulic trip interface, and a couple of electronic overspeed detection system offerings. It also offers dynamic model-based studies for compression applications that include compressor startup and shutdown evaluation (associated with surge control), piping arrangement, valve sizing, and control system optimization.

Currently, the Elliott-Tri-Sen alliance team is developing a solution to provide Elliott’s users with an advanced compressor monitoring, diagnostics, and controls capability. The Alliance Compressor Performance Monitoring System (ACPMS) is a modularized software/hardware solution that provides a monitoring tool-kit with fleet monitoring functionality. Features include remote monitoring, fleet monitoring, analytics, surge control, vibration analysis, along with a digital twin (compressor model) that supports “what-if?” analyses.

As for the retrofit market, Bailey said such projects are getting easier because first and second-generation digital control platforms are being replaced due to hardware obsolescence issues and not so much because of performance issues.

“Challenges associated with retrofitting mechanical governors like speed measurement and the valve actuation interface are usually already resolved when replacing one digital control system with another,” he said.

**GE GAS POWER**

GE Gas Power Executive Product Manager for Controls & Digital, Chris Long has noticed major trends such as the increasing use of artificial intelligence (AI) in modeling and analytics to keep models current with evolving plant asset capability and degradation. To complement OT cyber solutions, the company is leveraging its OEM physics-based models augmented with AI to develop means for detecting, localizing, and neutralizing threats as part of a defense-in-depth strategy.

Supporting the changing needs of a grid with increasing renewables penetration is another area of focus. GE has controls for turbine combustion and electrical systems to support high rate of change of frequency (RoCoF) scenarios. Furthermore, generator controls leverage analytics in early event detection schemes to respond to frequency swings and voltage dips.
“There is greater interest in remote connectivity and control across all aspects of plant (remote operations, grid testing, monitoring, tuning) including centralized remote command centers,” said Long. The company recently introduced a Non-Optical Flame Detector (NOFD) leveraging digital twins of sensors to improve reliability and reduce maintenance costs.

Sanchez said Mitsubishi Power’s Tomoni can help facilities become digital power plants by adding automation and embedded intelligence. “Tomoni uses analytics, adaptive control, and AI to increase plant flexibility and provide profitable, clean power,” said Sanchez. “Plants utilizing it for remote monitoring and diagnostics operate with 1-2% higher reliability.”

INGERSOLL RAND
Ingersoll Rand (IR) has been building centrifugal compressors since the early 1960’s. This includes legacy Centac and Turbo-Air frames and the latest generation of Turbo-Air NX compressors ranging from 500 cfm to over 30,000 cfm with discharge pressures from 25 to 610 psig.

IR provides controls and automation equipment for its equipment to more easily manage compressor systems, enhance system reliability and improve efficiency. This includes flow and pressure controls, centrifugal compressor control systems, rotary compressor controllers, and compressor system automation products.

Its Xe-145F Series controllers (standard on MSG Centac) have a high-resolution color display. When it detects a problem, it can post information on the web or send email notifications. Maestro Universal is an equivalent air control system for managing centrifugal compressor performance, and is the standard controls for IR MSG Turbo-Air and MSG centrifugal compressors. The company can design a customized Maestro Universal controller upgrade for existing compressed air systems. Instrumentation packages and monitoring

MITSUBISHI POWER
Mitsubishi Power has also been active in cybersecurity. “There is a great need for control systems to strike a balance between openness and security in order to work with higher level systems and achieve optimum operation,” said Marco Sanchez, the company’s Vice President of Intelligent Solutions.

In response, Mitsubishi Power has developed cybersecurity solutions to meet the compliance requirements of the latest North American Electric Reliability Corporation Critical Infrastructure Protection (NERC CIP) standard. It consists of two components within the DIASYS Netmation 4S control system that enable flexible operations and meets functional safety standards as defined by IEC 61808:2010.

The first component is Virtualized Netmation that virtualizes HMI workstations on redundant servers. Virtualization creates a more secure environment by reducing exposure to outside threats and providing a framework to monitor continuously for malware and intrusion detection.

The second component is Netmation Protect Pack (NPP) that provides a framework for integrated threat management, risk management, application control and system health monitoring. NPP provides mechanisms to ensure that all software has up-to-date patches and a centralized portal to report, audit, and protect against intruders, malware, and ransomware.
functions are configured to optimize compressor performance. In many cases, equipment can be repurposed. With the newest generation of controllers, IR enables expanded connectivity and communication capability, as well as increased memory and processor speed.

“For flows over 500 cfm or under 600 psig centrifugal compressors tend to be a clear winner versus a reciprocating compressor,” said Sam Gooldy, Ingersoll Rand.

Maestro Universal controls are used on the Turbo-Air NX, which is built to operate in industrial applications, including the process air and air separation markets at often unmanned sites without backup for extended periods, years in some cases. It is rated for flows from 3000-7500 cfm and pressures from 35-210 psig discharge. An inlet guide vane and increased throttle range bring operating flexibility. Further models in this line include the NX 12000 and NX 8000.

“The Turbo-Air NX 5000 is applicable across markets demand a consistent supply of oil-free compressed air or nitrogen,” said Sam Gooldy, Senior Global Product Manager, Ingersoll Rand.

The company also makes reciprocating compressors. Gooldy says they are typically applied below 500 cfm or over 600 psig discharge pressure. “For flows over 500 cfm or under 600 psig centrifugal compressors tend to be a clear winner due to reliability and the higher maintenance associated with a reciprocating compressor.”

“Capabilities include site installation, and integration of site audible and visual annunciation for occupational safety and health global standards compliance.”

NEXUS CONTROLS, BAKER HUGHES

Nexus Controls, a Baker Hughes business, has provided unit control, DCS, excitation, mechanical, cybersecurity, services, and software in more than 11,000 projects globally. These included gas/steam turbine, hydroelectric, and compressors. “Cybersecurity is a fundamental part of managing the operating risks of pipelines and critical equipment,” said Terry Knight, Vice President, Nexus Controls, a Baker Hughes business.

The company’s offerings cover unit controls, generator excitation and protection, static starting systems, mechanical and instrumentation solutions along with BOP controls. Its turbine-driven compressor controls address operating efficiencies and surge. The Nexus OnCore Control System enables digitization through collecting, integrating, and analyzing data. The company is adding further analytic capabilities and remote monitoring offerings. “We have seen increased interest for remote monitoring and operation, primarily from those seeking to optimize maintenance and operations expenses,” said Knight.

“We have seen a significant increase in customer interest for remote monitoring and operation solutions,” said Terry Knight, Nexus Controls.

SCHNEIDER ELECTRIC

Schneider Electric provides control systems for steam/gas turbines, compressors, automatic voltage regulation, generator automatic synchronization, generator power management, turbine auxiliaries, mechanical retrofit, data analysis, and HMI interfaces. It offers site surveys, machine assessments, dynamic simulation, consultation, performance optimization, controls troubleshooting, mechanical retrofits, predictive analytics, and performance monitoring. Controllers range from simplex Modicon to TMR Triconex PLCs.

“Customers desire increased time between turnarounds and decreased turnaround times,” said Hector Buchelly, Schneider Electric.

“Customers desire increased time between turnarounds and decreased turnaround times,” said Hector Buchelly, Global Senior Director of Turbomachinery and Advanced Services, Industrial Automation Business, Schneider Electric. “The road to digitalization, which requires the ready availability of data, requires machinery to be upgraded and retrofitted so the digital solutions can have the value they represent.”

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The highlight of the annual Western Turbine Users Inc. (WTUI) show is the report on gas turbine trends by Tony Brough and Mark Axford. Tony Brough, President of Dora Partners, kicked things off by showing the latest trends. MW orders are down 3.2% in 2020 compared to the previous year, while unit orders are up 0.3%. Since 2012, however, MW orders are down 42% and unit orders are down 67%.

“Over the past five years, gas turbine capacity orders have dropped from about 50 GW per year to just less than 40 GW,” he said. “In 2020, the market was unexpectedly good in light of COVID-19, likely due to the fact that the process of contracting and purchasing industrial GT’s is a protracted process that may well have started in 2018 and 2019.”

Looking more closely at aeroderivative turbine trends, Brough commented on the resilience of the LM2500 and LM2500+. The LM2500+ accounted for 30% of the market over the past five years, by far the best selling aeroderivative. The various flavors of LM2500 also boast the largest aeroderivative gas turbine fleets followed by the LM6000.

Although sales could be better, the overhaul and repair market for existing aeroderivative fleets is valued at $2.3 billion per year.

Outside of Russia, sales of aeroderivatives are dominated by GE/Baker-Hughes. The jump in their share of the market in 2020 was largely driven by Baker-Hughes’ newest unit, the LM9000.

Brough provided an interesting point of comparison of the most recent seven year period compared to the previous seven years (i.e., a 14 year total period). In the electric power and utility (EPU) market, there has been a sharp drop in aeroderivative units orders in all regions except the Middle East and Africa. Asia Pacific is down 34%, Europe and North American down 80%, South America down 54%, and Russia down 83%. In oil & gas, the picture is a little different.

Aero Unit Orders were down 31% (excluding the Russian market) in 2020 With the GE/Baker-Hughes share jumping to 88%. Courtesy of Dora Partners.
North America experienced a 174% spike in aero unit orders compared to the earlier seven-year slot. Every other area was down – anywhere from 33% to 84%.

“Only the North American oil & gas industry has seen long-term growth for aeroderivative units,” said Brough. “This was mainly due to the need to power fracking sites, as well as for pipeline network expansion.”

During 2020, the worldwide market for aeroderivative gas turbines showed a 14% jump on the previous year, with MW orders up 7%. GE’s worldwide share was 67%. The LM9000 accounted for almost half of all worldwide orders, followed by the LM2500+ at around 30% with the LM6000 and Siemens SGT-A35RB (formerly RB211) sharing third spot. But North American aeroderivative unit orders and MW orders were both down 69% with GE grabbing 100% of U.S. business for the year.

LONG-TERM OUTLOOK
Brough turned his attention to the long-term outlook for industrial gas turbines. He said to expect wind and solar to grow dramatically over the next 20 years. Therefore, it is important to determine what role gas turbines will have, particularly aeroderivative units.

“Gas turbine utilization of hydrogen, methanol, ammonia, and other low-carbon fuels will gradually be introduced over the next 10-25 years, with a mix of these low-carbon fuels and natural gas initially,” he said.

Another big push will be for green hydrogen i.e., produced with only renewable sources. Green hydrogen is viewed as the battery of the future whereby you take excess renewable energy and use it via electrolysis to produce hydrogen.

“Gas turbines can be retrofitted for hydrogen mixes as well as to work on 100% hydrogen,” said Brough. “But getting the hydrogen to the point of demand is going to be a major challenge and implementation of this green hydrogen vision is going to take a long time.”

He pointed out that the economics currently are hard to justify, but regulatory requirements and government incentives will propel this change over time. To run an LM2500 for a year on 100% green hydrogen would require a massive amount of excess renewable energy. Thus, major technical, fuel delivery infrastructure, and economic hurdles must be overcome in any transition to low carbon fuels.

“There is a future for gas turbines with or without fossil fuels,” said Brough.

AXFORD’S INPUT
Mark Axford, President of Axford Turbine Consultants, showed a graphic of flat aeroderivative orders for 2020. He expected it to be worse. He outlined the three factors responsible for long-term stagnancy in the markets: regulation, mandates, and subsidies.

In the gas turbine business, the regulations started with pollutants. Limitations on NOx and CO were around 100 ppm when Axford started in
the business during the 1970s. But the limits are now as low as 2 PPM in some states (2 PPM typically exceeds the error factor inherent in measurement equipment). Additionally, Axford noted unnecessary limits on ammonia slip, and the requirement to treat CO2 as a pollutant rather than an emission.

As a result, renewable energy is the fastest growing component of U.S. electric supply. The Department of Energy’s Energy Information Administration (EIA) now predicts that in 2030, more electricity production will be from renewables than gas. The current 40% share of natural gas will drop to 36% by 2050.

“Solar is now growing so rapidly, it is forecast to be the largest component of renewable energy by 2040, surpassing wind,” said Axford. “But it remains to be seen if this will take place.”

LARGE TURBINES
Axford moved on to the advanced gas turbine market. GE accounts for 45% of advanced gas turbine MW orders since 2014 worldwide. Mitsubishi Power is in second place, followed by Siemens Energy and Ansaldo. His view on this market will largely be driven by combined cycle plants being used to replace coal and nuclear facilities forced into retirement. But the market for these massive gas turbines is constrained by grid requirements. Many areas don’t have a grid that can support an 800 MW to 1 GW combined cycle plant.

“This is too large for many countries with less developed grids,” said Axford. Meanwhile, the launch of the GE LM9000 aeroderivative gas turbine is off to a good start. Baker Hughes received an order for 20 units for the Novatek Arctic LNG project in Pacific Russia. This includes 12 LM9000s in mechanical drive and another eight gensets.

Axford also noted that Siemens Energy has ended production of its A45 and A65 (formerly Trent) engines due to factors such as cost and difficulty competing. Other engines in trouble include the LM6000 which has seen a sharp drop off of orders over the last decade, and several units with no orders in 2020: the LMS100, FT8 MobilePac, and FT4000.

“The LM6000 has a fleet of more than 1,100 units, but has been getting few orders for some years,” said Axford.

He added that part of the reason for this is competition from the Siemens Energy SGT-800, which now dominates the 50-60 MW segment. Axford said factors such as price and combined cycle performance favor the SGT-800. Another area where GE is losing out is in refurbished LM6000s. ProEnergy has delivered 52 of them over the last few years.

Turning to the electric vehicle (EV) market, Axford views the rise of the EV as good news for gas turbines.

“As battery storage is adopted, the market for mid-sized gas turbines will be the big loser,” he said. “But at higher levels of renewables, it could be risky to rely on expensive battery backup so there will a place in the market for gas turbines.”

He largely dismissed the concept of turbines running on 100% hydrogen provided from electrolysis. He said that steam reformation of methane is a far cheaper way to produce blue hydrogen. Further, the pipeline network is not built for hydrogen. Plastic distribution lines would embrittle, and there would need to be extensive rework done on 1,400 compressor stations in the U.S. to deal with hydrogen.

“Carbon capture of natural gas is probably a far more economical path than trying to convert everything to 100% hydrogen,” said Axford.

He ended with some advice for plant managers and a prediction for the year.

“As the supply chain has slowed down considerably, plant managers need to move away from just-in-time models to having parts at each site and suppliers in the home country even if it costs more,” said Axford. “2021 won’t see a recovery: I predict a 10% drop in MW orders.”
The Western Turbine Users, Inc. (WTUI) conference took place virtually this year. Instead of everything packed into a few days, the organizers decided to stagger it over several weeks. Hence this article only summarizes the first week.

John Hutson, WTUI President and Plant Manager at NAES Orange Grove Energy, welcomed everyone and provided an overview of the conference, which is the largest aeroderivative gas turbine user group in the world. The goal is to share information and best practices with fellow users to produce better operational outcomes for GE LM series turbines, he said.

He introduced the various session chairs for each turbine series. Dave Fink, I&C Technician for Onward Energy, Fountain Valley Power, headed up the LM6000 forum. Steve Worthington, Plant Manager, Arizona Public Service, Ocotillo Power Plant, was in charge of LMS100 sessions. Garry Grimwade, Utilities Generation Technician, Riverside Public Utilities, covered the end-of-lifed LM2500, and Perry Leslie, Plant Technician at Wellhead was responsible for the LM5000.

In subsequent days, attendees split up based on the engines they care for in their own plants. The conference tracks dedicated to each engine consisted of discussion groups, vendor presentations, and in-depth coverage of the various issues and remedies impacting their respective machines. This included meticulous coverage of Technical Bulletins from the OEM, as well as closed-door user-only meeting where they could voice their concerns, share remedies, and educate others on best practices.

To kick things off on day one, conference veteran Andrew Gundershaug, Plant Manager at Calpine, provided an LM engine refresher workshop. He oriented the audience on what was on offer at the conference, how to get the most out of it, and how everything is being organized. He also provided a description of the LM engines, defined the various components and systems, explained how they worked, and laid out the many acronyms being used at the show.

**AUTHORIZED SERVICE PROVIDERS (ASPS)**

WTUI has forged strong relationships with the authorized service shops for aeroderivative
turbines. Each year, they get to showcase their facilities and lead user sessions where they go over common problems and solutions for certain engines.

For example, MTU Power’s Vice President of Industrial Gas Turbine Sales Greg Stoecker, presented on behalf of his company. Despite ongoing COVID-19 pandemic challenges, he said his company saw around 25% growth in its industrial gas turbine and package business in 2020. MTU Power has been expanding its yearly capacity for LM engines and has just introduced hot section repairs for the newest LM variant, the LM6000PF+ TCT, ANZGT, and IHI provided similar briefings. The first day ended with a briefing by GE.

**FLEET PERFORMANCE**

Over the following weeks, the LM turbine leaders took their users through many hours of specialized coverage. Each track featured a breakdown by Tom Christiansen, Senior Vice President at Strategic Power Systems (SPS), on findings from the company’s ORAP system.

The Operational Reliability Analysis Program (ORAP) captures data from global operating power plants (gas, steam, wind, and solar) as well as reciprocating engines. It contains detailed reliability performance data that allows users to compare their performance against relevant peer groups and identify differences and opportunities for improvement. This is achieved by gathering operating, age, and event data from plants around the world. SPS offers contributing members access to a secure, cloud-based business intelligence portal.

Christiansen took the LM6000 users through a rundown of the top causes of forced outages. ORAP gathers data from 256 LM6000 units, representing 27% of the worldwide fleet.

The availability the turbine in simple cycle plants is more than 96%. The overall engine package has a slightly lower availability (94%). Over the past few years, the availability level has been improving.

Drilling down into forced outage incidents, ORAP findings show the primary causes of forced incidents in the LM6000, 25% come from balance of plant (BOP) issues, 28% from the aeroderivative engine itself, 37% from controls and accessories (package), and 10% from driven equipment. When studied based on outage hours rather than volume of forced incidents, the numbers are: BOP 28%, aero engine 38%, driven equipment 15%, and controls and accessories 19%.

Combustion issues were the top reason for forced outage incidents with 148 reported in 2020.

Christiansen then broke things down further. Combustion issues was the top reason for forced incidents with 148 reported in 2020, well up from 2019. He said that the detection of high CO or NOx emissions were the main cause for these outages, followed by issues related to non-optimum fuel flow, flameouts, failures to ignite, and acoustic issues.

The higher quantity of outage hours noted compared to the previous year was due to two specific sites where the combustor suffered damage and had to be replaced — the plant didn’t have a replacement on site.

After combustion issues in the top ten came lube oil pressure issues with almost half due to faulty switches. Other causes noted by SPS were low oil pressure incidents, filter pressure issues, and problems with the pressure relief valve, pressure sensor, and pressure transmitter.

The number three contributor to forced outages per ORAP was gas fuel control/shut off valve issues. These were traced primarily to calibration, driver, valve synching, or actuator problems.

Christiansen laid out the rest of the top ten for the LM6000. In subsequent days, he provided a similar analysis of the reasons for forced outages in the other GE LM machines.

Next year’s WTUI conference will be held in Long Beach, California in late March, 27-30, 2022. Conference registration opens January 1, 2022. For more information, visit www.WTUI.com.
A transformation of the energy market is ongoing. Renewable energy rose from 5,451 terawatt hours (TWh) in 2000 to 9,824 TWh in 2019. But there is a need for large-scale energy storage to satisfy power demands when solar and wind are offline.

Hydrogen is regarded by some as the green energy carrier of the future. But it faces technical and regulatory challenges. Gas turbines operating on some or 100% hydrogen will play a key role in the transition. They are a proven technology, provide electricity and process heat, and can be sized from kilowatts up to several hundred megawatts.

However, hydrogen combustion is not entirely straightforward, because of its extreme flammability range and flame speed that can lead to flashbacks. It also requires the right combustion technique to keep NOx production low. Wet NOx combustion is the current method used, where water or steam is injected into the combustion chamber to reduce the combustion temperature. The water/steam must be free from impurities. While reducing NOx emissions effectively, this approach is still not environmentally sound or efficient.

Dry low Emission (DLE) technology is likely to be the answer. But the combustion process means that engineers must think outside the typical lean combustion-low NOx box to develop new techniques.

To date, good progress has been made in achieving 30% volume H2 with only minor adjustments to the combustion chamber. But the pathway to 100% H2 is far from easy. 30% volume equates to 5% mass or 11% of energy when mixed with methane. Even 60% volume means around 15% mass. These fractions are acceptable for today when large amounts of H2 are anyway unavailable. But they are not sufficient for decentralized reconversion plants.

Another factor to consider is that at typical fuel-air ratios (e.g. Lambda 2.3) the turbulent flame speed starts to rapidly increase at around 35% to 40% volume H2 and reaches its maximum at around 70%. At that point, the danger of flashbacks for premixed combustors is extremely high. When the flame travels upstream and anchors in an undesired region such as a small step, it can quickly destroy parts of the burner structure.

Increasing the air cross flow velocity is also problematic. The pressure drop of the combustor section would increase, reducing overall machine efficiency. Additionally, burner geometries are not always perfectly smooth and typically feature small steps where flow can recirculate and autoignition can take place. This can trigger flashbacks and represents a random phenomenon. Therefore, it is difficult to detect in tests since all burners are slightly different and manufacturing process quality control plays an important role here, which also has an impact on component price. Finally, the flow velocity on the wall is zero by definition. In contrast to methane, hydrogen is more prone to boundary layer flashbacks due to the higher flammability range and flame speed.

THE REAL HYDROGEN CHALLENGE

The real challenge, therefore, is how to burn greater than 90% volume of hydrogen at low emissions, without a water/steam admixture, and to fulfill safety, emission, pressure drop, and lifetime requirements inside the gas turbine. The only technology on the market bringing these points together is called Micromix (MMX) combustion.

In research and development since the late 1980s by Aachen University of Applied Sciences (AcUAS, FH Aachen), it has been the subject of many collaborative projects. These have primarily involved B&B-AGEMA and Kawasaki Heavy Industries (KHI). The basic ideas behind the concept are:

• NOx suppression by residence time reduction.
• Jet-in-cross-flow mixing for flashback safety.
To suppress NOx formation, one can either lower the flame temperature or reduce the residence time of fuel/air inside the high temperature zone of the flame. NOx molecules can only form under certain fuel/air conditions and high temperatures. The best course is for N and O molecules to reach colder zones behind the flame before they undergo a chemical bond.

Pure hydrogen cannot burn. A diffusion flame is consequently flash-back safe whilst pre-mixed flames will always carry risk. By the jet-in-cross-flow mixing process, rapid premixing lowers the average flame temperature. If the flame travels towards the H2 injector, the mixture becomes too rich to burn and is forced to travel back to its intended position without damage to burner components.

Early designs proved out the general concept and highlighted issues to overcome. By incorporating computational fluid dynamics (CFD) through the help of AcUAS and Kawasaki, this combustor technology was introduced into the Kawasaki M1A-17 gas turbine (2 MW).

Reactive flow simulations were performed in Siemens Simcenter STAR-CCM+ to study aerodynamic flow parameters and the combustion structures (flame shapes). The aim was to find the optimal design and length of the flame to ensure low NOx combustion and reduce the number of injectors. Simulations included reactive chemistry to predict the flame shape, size, and temperature signature. Siemens Digital Industry Services provided model tuning.

As a result of this research, AcUAS and B&B-AGEMA developed the fourth and fifth generation MMX combustor. It includes a new flame shape with very low NOx properties, based on CFD simulation, which was never considered before. The team developed a prototype burner.

An air-cooled borescope was developed to visualize the MMX flames inside the can combustor under full pressure. This optical monitoring device is equipped with an infrared or white light endoscope which can be inserted into the combustor. The head is located downstream of the flames and exposed to the highest temperatures (>1300°C). This assisted in verifying combustor performance.

The overall target was to have less than 35 PPM NOx at 100% hydrogen from 50% to 100% load, with low NOx values at part-load operation as well. Additional requirements were stable ignition, no flash-back, and an acceptable pressure drop. With an intensive program of CFD simulation, design optimization and benchmark validation on low- and high-pressure test rigs, an MMX burner design successfully met these targets.

The recent focus has been on implementing this technology into industrial turbines. In 2020, the Japanese New Energy and Industrial Technology Development Organization (NEDO) and KHI announced a successful demonstration of the first DLE 100%-hydrogen-fuelled gas turbine under commercial operating conditions in the port of Kobe, Japan.

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Atsushi Horikawa is in the Thermal System Research Department of the Technical Institute of Kawasaki Heavy Industries. The combustor development projects done on behalf of NEDO were “Research and Developments of Hydrogen Gas Turbine Combustion Technology” and “Development and Demonstration Project for Low-NOx Hydrogen-Fueled Gas Turbine Combustion Technology.”

Prof. Dr.-Ing. H. H.-W. Funke is Head of the Institute for Gas Turbines and Aero Engines at Aachen University of Applied Sciences (AcUAS). His research topics include low nitric oxide hydrogen combustion as an alternative fuel in gas turbines and related gas turbine controls.
Steam turbines provide an efficient means of producing electricity. Improving the corrosion fatigue performance and damage tolerance of steam turbine blades can offer overhaul and maintenance cost savings, improved reliability, and reduced outages.

The application of surface residual compressive stress to components can enhance fatigue strength and reduces the effects of applied tensile stresses. Shot peening has been used for decades to reduce overall operating tensile stresses in steam turbine components. However, corrosion pits, erosion, fretting, and other damage can penetrate shot peening’s shallow layer of residual compression, providing a starting point for stress corrosion cracking and fatigue failures. Instead of settling for shallow compression, the introduction of a deep layer of compressive residual stress can extend service life.

To test the benefits of deep compression, high-cycle fatigue tests were done on Type 410 stainless steel, a common alloy widely used in steam turbine applications, to compare the corrosion fatigue benefits of Low Plasticity Burnishing (LPB) to shot peening.

LPB is also a mechanical surface treatment, but it imparts a controlled layer of compression that is deeper than most surface damage. LPB was developed in the 1990s to keep cold work low when introducing compressive residual stress. 20 years of studying residual stresses led to the conclusion that residual compression introduced using high levels of cold working could be wiped out from in-service thermal and mechanical loads.

The first step in the investigation was to obtain sample specimens of 410SS machine-finished by low stress grinding (LSG) to serve as a baseline. Compressive stress was introduced either by LPB or shot peening. The LPB process is performed on conventional CNC machine tools and robots. Shot peening was done using a conventional air blast peening system.

**Damage Tolerance Results**

Next to be tested was the fatigue strength of samples subjected to either mechanical damage or simulated corrosion and stress corrosion cracking. Mechanical damage simulates what can happen to the surface of the turbine blade from common fatigue damage mechanisms like foreign object damage, fretting, corrosion pitting, or erosion.

Mechanical damage was simulated through an electrical discharge machining (EDM) notch with a depth of 0.01 in. (0.25mm). For a portion of the LPB-treated samples, a deeper notch depth of 0.02 in. (0.51mm) also was investigated.

High cycle fatigue tests show that shot peening the 410 SS samples provided a modest improvement over the baseline condition with mechanical damage. Residual stress distributions revealed that the 0.01 in. (0.25 mm) notch completely penetrated
the compressive layer introduced by shot peening minimizing any fatigue life benefit from shallow compression.

However, the deep compression provided by LPB doubled the fatigue strength and improved fatigue life near the endurance limit by a factor of over 100 compared to the shot peen condition. Even with damage twice as deep, the LPB-processed samples outperformed those that had been shot-peened.

When subjected to corrosion damage and salt exposure, simulated by testing samples in an active corrosion medium of a 3.5% weight NaCl solution after first exposing them to stress corrosion cracking (SCC) in the same medium, the LPB-processed samples again demonstrated double the fatigue strength.

Surface roughness measurements indicated roughness values of 19.5 μin for the baseline sample, 157.1 μin for the shot peened sample, and 4.5 μin for the LPB-processed sample. The roughness value for the shot peened sample is nominally 35X higher than that of the LPB-processed sample. Shot peening dimples produce a rough surface that can adversely impact fluid flow at the blade surface.

Some steam turbine manufacturers are now implementing LPB on their blades upfront to reduce overhaul and maintenance issues. Others use LPB as a faster and more economical repair technique. Depending on the steam turbine, manufacturers can apply LPB with the turbine blades installed on the rotor. LPB as a surface treatment does not add material or change the blade’s balance like traditional welding repair methods.

Kyle Brandenburg is a Research Engineer at Lambda Technologies Group and has been supporting the research and development efforts of the company for over 10 years. He can be reached at 800.883.0851 or info@lambdatechs.com.
OPERATIONS & MAINTENANCE

NOISE LEVELS AT ENERGY PLANTS

The Energy Industry Has a Problem With High Decibel Work Environments

BY RICK FARRELL

Peter Drucker once said, “The most important thing in communication is hearing what isn’t said.” With all due respect to the founder of modern management theory, if Drucker had spent more time on the floor of an energy plant he may well have declared that the most important thing in communication is hearing what is said.

Energy plants are noisy places. The level of noise can vary by the plant’s source of power and one’s location relative to operating equipment. A sound level of 80 decibels (dB) is considered unpleasant, 85 is the threshold for loud, and 110 is categorized as extremely loud. The thresholds for pain and potential permanent hearing loss are 140 and 150 decibels, respectively.

The mean noise levels are somewhat similar for coal plants and gas plants, with both averaging between 80 and 85 dB. However, prolonged exposure to noise in a gas-powered plant tends to be greater, with a time-weighted average (TWA) of 78 dB versus 69 for coal.

Wind power is relatively quiet, despite the complaints made by some who are opposed to construction of turbines near their homes. 55 dB are produced immediately adjacent to the turbine itself. 300 meters away (the minimum distance to nearby homes) the sound only averages 43 dB. At 500 meters the noise level falls to 38 dB.

However, noise levels from individual pieces of equipment in any of these plant types can run as high as 155 dB when they run combustion turbines or diesel engines. That can lead to hearing-related safety issues and workers compensation claims. The Bureau of Reclamation, which oversees management of water resources including dams and hydroelectric plants, reports that one fourth to one fifth of its workers compensation costs related to hearing loss. Noise exposure over time, even at lower decibels, can have a cumulative effect. This can result in other health issues, including cardiovascular problems.

NOISE LEVELS AND COMMUNICATION

Despite noise abatement measures to protect people from hearing loss, the noise generated by the operation of equipment can make it hard to hear someone else speak. The human voice is typically measured at only 60 dB. This makes it susceptible to audio blurring even in a relatively quiet plant. A background noise level of 85 dB means that people have to raise their voices to be heard by someone standing three feet away.

85 dB may seem innocuous, but noise at that level can create more problems than those resulting from 150 dB. Why? At the higher level, it is obvious to all parties that communication is impossible. There is no chance of misinterpreting a message that can’t be heard at all. However, when people talk over background noise in the 85 dB range, a single word or phrase may be misunderstood without either party being aware of it. That can lead to poor decisions, inefficient performance, weakened collaboration, and accidents.

By equipping anyone who works in a noisy energy plant with a communication system consisting of a headset or earphone with a microphone, the speaker’s voice can be transmitted directly to a receiver that allows it to be heard through another set of earphones. Such systems, originally designed for tours of noisy factories, are hands-free when used with a head-worn microphone. With this system in place, there are no issues in hearing instructions, warnings, or sharing of information. The only remaining barrier to communication will be hearing what isn’t said.

Rick Farrell is President of Plant-Tours.com, a provider of headsets and audio systems for tours, training, and worker communication.

Photo courtesy of Plant-Tours.com
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Even the most ardent supporters of natural gas generation acknowledge that curbing emissions is a good thing. Many mainstream power and oil & gas executives are some of the loudest voices calling for improvements. And they have been joined by U.S. President, Joe Biden.

The Administration unveiled a several trillion-dollar infrastructure plan that set the goal of net-zero carbon emissions by 2050. The plan would require major changes in the energy sector. (At this time of writing, the bill has yet to negotiate its way through Congress, and the overall amount is being trimmed down).

At an Earth Day climate summit, Biden called for cutting U.S. greenhouse gas emissions by 50% to 52% from the baseline year of 2005. In comparison, Obama’s target was 26% to 28%. The power industry is under the microscope as part of these plans as electricity generation accounts for 25% of U.S. emissions. That said, the sector has a much better record of curtailing emissions over the past twenty years than the transportation, commercial, or agriculture sectors. This is largely due to the switch from coal to natural gas, increasing adoption of renewables, and the implementation of efficiency and emissions reduction measures.

The administration’s plan would establish an Energy Efficiency and Clean Electricity Standard (EECES) to incentivize “more efficient use of existing infrastructure and continuing to leverage the carbon pollution-free energy provided by existing sources like nuclear and hydropower.” What his ultimately means to natural gas generation is anyone’s guess. Opinions vary from it being a benign approach that will gradually phase out natural gas generation over many decades to a ploy to outlaw natural gas via extreme emissions requirements.

**SUBSIDIES BEGONE!**

A tax reform proposal is included that would eliminate billions of dollars’ worth of “subsidies, loopholes, and special foreign tax credits for the fossil fuel industry,” according to the White House website. It intends to reinstitute financial penalties for companies contributing to pollution.

The American Petroleum Institute (API) believes that ending the tax breaks would have a catastrophic effect on the economy. “Targeting specific industries with new taxes would only undermine the nation’s economic recovery and jeopardize good-paying jobs, including union jobs,” the API.

The American Gas Association (AGA) expressed support for the U.S. Department of Energy’s initiative to fund technologies designed to reduce methane emissions. “We continuously examine our 2.6 million miles of infrastructure for methane reduction opportunities and are investing in ways to help other industries reduce emissions by injecting their methane into our delivery system,” said AGA President and CEO Karen Harbert.
American natural gas utilities have delivered methane emission reductions of around 73%, according to the 2020 Inventory of U.S. Greenhouse Gas Emissions by the U.S. Environmental Protection Agency (EPA). Research recently published in the journal Environmental Research Letters calculated that existing technologies could cut methane emissions in half by 2030. These methods include reducing oil- and gas-related leaks and methane flaring, in addition to cleaning abandoned oil mines and expanding the use of feed supplements for cattle.

**RESILIENT TRANSMISSION**

While there are contrasting views on some proposed measures, one area receiving broad support is an investment tax credit to incentivize buildout of 20 GW of high-voltage capacity power lines. This will be overseen by a new Grid Deployment Authority at the Department of Energy. One of its duties will be to fast-track right-of-way approvals for new transmission lines. States have been advised to remove regulatory obstacles that may impede the progress of the network.

Hydrogen is also in the spotlight. The plan calls for pairing 15 hydrogen demonstration projects with a new renewable electricity production tax credit (PTC) to encourage carbon emission reductions. Pioneer facilities would test carbon capture systems on steel, cement, and chemical production plants. Power plants were omitted from this program.

Green hydrogen from renewable sources is the priority, but there is room for blue hydrogen, produced from natural gas and other fossil-fuel facilities. Such projects may be able to take advantage of a production tax credit.

The proposed Storing CO₂ and Lowering Emissions (SCALE) Act addresses the development of large-scale carbon sequestration technology. The plan encourages carbon capture, utilization, and storage (CCUS) through the expansion of a tax credit, intended to make the technology “easier to use for hard-to-decarbonize industrial applications, direct air capture, and retrofits of existing power plants.”

A10-year extension of the production tax credit and investment tax credit for renewable energy generation, high voltage transmission, and energy storage is another element of the plan. Biden also appears to be betting on LNG as a smart way to lower the U.S. carbon footprint. This is to be achieved by lowering the emissions profile of LNG while addressing methane venting, fugitive emissions, and flaring.

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**Plantwide Asset Reliability-Getting Easier?**

**Event Overview**

Is it getting easier to do more with plantwide reliability? This webinar will share 3 main ways we say the answer to this question is a resounding yes. 1- Technology costs have come down 2- Reliability of the main critical machines have gone up so you need to leverage that next layer of machines for continual improvement, and lastly 3- It is becoming easier to embed the intelligence of people into the systems and the mass acquired data.

**Key Learning Objectives**

- Expanding asset reliability with plantwide monitoring
- Taking that first step in the journey without regrets
- Learning the ropes from real industry examples

**Who Should Attend**

- Reliability Engineers, Operations and Maintenance Managers from O&G, Petrochemical, and Power Industries

Register today to watch a replay on-demand
One day an engineering lecturer at school discussed an accident at a nuclear power station. Seawater had entered the cooling pipes of the reactor. He asked the students what would happen in such a situation.

A Dean’s Honor-List student answered that neutron flux from the reactor would irradiate the sodium ions in the seawater salt molecules to create a short-lived isotope of sodium. This isotope would emit low-intensity alpha radiation which lodges in the interstices of the ferrous lattices of the steel alloys of the pipes, creating hot spots or fractures, leading to escape of radioactive seawater to the river.

No, the lecturer replied, the pipes will rust. In troubleshooting, then, it is best to first suspect the obvious. Why make things more complicated than they really are? Recognizing that there is an overflowing sink and turning off the water, for example, can save a lot of time that might otherwise be spent trying to mop up the floor. To troubleshoot problems, it is necessary to be aware of the various factors that may have a direct influence on the situation.

Here is an example:

Condensate samples were taken of steam that was being taken from six once through steam generators (OTSGs) and two heat recovery steam generators (HRSGs) to several dozen well pads each with dozens of individual well pads. Each HRSG turbomachine produced 90 MW so a combined 180 MW with some extra headroom reaching 202 MW for peak loading. The HRSGs of oil producing steam assisted gravity drainage (SAG-D) sites make high-temperature, high-pressure steam. But only high-temperature, low-pressure steam is needed to be injected into the ground to liquefy bitumen for extraction, so it makes financial sense to run the steam through turbogenerators.

Above ground pipelines carry steam to the pads and above ground pipelines carry the produced bitumen back to the plant. The bitumen is then treated to separate the oil from the water, gasses, and steam. The steam in a SAG-D site is injected into the ground; heat and pressures change the viscosity of the heavy oil that is trapped in the sand and it flows downward by gravity to collection pipes and is pumped out. The gasses are collected and burned in the steam generators to create heat to vaporize the recycled water from the wells and reuse it.

When samples of steam condensate samples were collected from the steam being injected below ground used to liquefy bitumen for extraction.
Many different tests were run in an attempt to find a statistical correlation between the changing shades. A volatile acid test was done, based on esterification of the carboxylic acids present. All volatile organic acids present are reported as their equivalent mg/L acetic acid. This led to the discovery that the darker the steam condensate, the higher the presence of carboxylic acids (an indication of potential corrosion). This results from this test can be statistically compared to steam generation parameters such as steam qualities, temperature, pressures, carryover, and amine additions for the set points of the steam engines.

This investigation led to further discoveries. This included the causes of scale taken from samples gathered from boiler pigging operations. X-ray diffraction (XRD) analysis done by an electron microscope scan of scale in an HRSG stream final pass going to a turbogenerator. Different kinds of scale have varying effects on heat transfer and metal expansion coefficients, as well as vibration.

Steam condensate samples showing different colors from week to week and well pad to well pad.

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XRD analysis of scale in a HRSG stream.
Waukesha Bearings provides custom-engineered hydrodynamic fluid film bearings, active magnetic bearings systems, and damper and seal technologies for turbomachinery across the oil & gas, power generation, marine, and industrial markets. Engineers apply design codes and predictive tools to tailor thrust, journal, or combination bearings to achieve optimum performance across the machine operating range.

The Waukesha Bearings Maxalign tilting pad journal bearing, for example, features a specialized ball and socket pivot, along with Directed Lubrication and trailing edge cooling to increase reliability and reduce power loss for rotating equipment with shaft diameters greater than 300 mm. Engineers optimize the bearing size and pad materials and tailor insulation, hydrostatic jacking, and instrumentation according to requirements.

“The controlled stiffness and damping of ISFD technology, and the precise placement of critical speeds and rotor modes that this allows, will help address potential destabilizing forces in the system and minimize unbalance response,” said Masala.

Stability can be enhanced further with the application of pocket damper seals. Based on bulk-flow analysis, they can cope with a range of speeds and gas conditions to counter seal-induced instabilities. Waukesha Bearings is also working on new pocket damper seals to further increase damping characteristics and lower leakage.

MAGNETIC BEARING SYSTEMS

Waukesha Magnetic Bearings has been involved in magnetic bearing technology development for more than 30 years. Challenging applications in high pressures and aggressive gas have driven the market towards a mechanical solution with controller architecture. High controller functionality is available for both low-power controllers (for applications below 1 MW) and high-power controllers (for applications above 25 MW).

Modularity is another element of Waukesha Magnetic Bearings systems. The Zephyr controller, for instance, allows enough flexibility to integrate software and hardware features within the same enclosure. Automated commissioning is also available. This is a repeatable process that provides commissioning and maintenance autonomy for OEMs and end users, with available training, remote support and field service from active magnetic bearing (AMB) specialists.

The skid-mounted magnetic bearing controller introduced by Waukesha Magnetic Bearings in 2019, reduces installation time and avoids the need for long field cables from the controller to the machine. Skid mounted AMB controllers can provide modularity for different size units, oil free operation, and the convenience of remote maintenance that fluid film bearings cannot. Skid mounted AMB’s primary application is in
turboexpanders for gas processing plants, but have also been applied in various industries and services.

**BRUSH SEALS**

Brush seals are commonly used in gas and steam turbines to minimize leakage and improve performance. They are also applied to increase the efficiency of compressors operating on fluid film or magnetic bearing systems.

The Waukesha Bearings’ brush seal is closely packed with alloy bristles that deflect with rotor movement and experience minimal wear. This brings about a smaller leakage gap between the sealing surface and rotor. The bristle strips can be replaced without throwing away the seal assembly.

On AMB-equipped compressors, brush seals protect and augment labyrinth seals. The gap between the levitated rotor and labyrinth seal must correspond to the distance from the rotor to the auxiliary bearings. Otherwise during coast down, the rotor would contact and roll the labyrinth seal teeth. Augmenting labyrinth seals with brush seals reduces sealing clearances and leakage during operation. Upon rotor delevitation, the bristles deflect in response to rotor weight, protecting the seal. The bristles return to their original state once the rotor is levitated.

**ROTORDYNAMIC ANALYSIS**

Custom-engineered solutions rely upon rotordynamic analysis. In AMB-equipped turbomachinery, the bearings, rotor, and process are deeply integrated in shaping machine dynamics. Waukesha Bearings’ engineers collaborate with OEM engineers throughout design and development to understand application needs and support rotor design optimization. Direct measurement of forces and displacement with magnetic bearings, and correlation with operating conditions, allows the characterization of mechanical and process interaction. Control algorithms address destabilizing seal effects and process upset conditions.

“In traditional power generation and oil & gas applications, we see OEMs and end users push equipment to produce more power from the same footprint, operate more efficiently and be more operationally flexible,” said Masala. “From a fluid film bearing perspective, that translates into requirements for power loss reduction, higher load capacity, highly tuned bearing dynamic characteristics, and the ability to handle higher temperatures, frequent starts and stops, and off-design conditions. These demands are being met with a combination of design elements, such as trailing edge cooling, ISFD technology and damper seals, and advanced bearing materials, such as polymer and aluminum tin.”

“Each application is unique so we design each bearing to meet performance requirements, whether they are tilt pad or fixed profile, babbitt, bronze, polymer or ceramic, and small, medium, or large,” said Andrea Masala, Waukesha Bearings.
The ASME’s Turbomachinery Expo 2021 normally alternates between a North American and a European/Asian location. This time it was wholly virtual. The overarching theme was “Sustainable energy – accelerating the transition by advancing turbine technology.” Keynotes and sessions reflected this, focusing on the ability to adapt turbine technology to carbon-neutral fuels, hybrid power systems, and alternate heat sources. Digital design tools, advanced manufacturing, integrated sensor technology, and machine learning with artificial intelligence (AI) were all embraced as part of this transition.

OPENING KEYNOTE
The conference kicked off on a bright note. Dr. Michael Webber, Chief Science & Technology Officer at Engie & Professor in Energy Resources, Mechanical Engineering at The University of Texas at Austin, surprised what is a largely academic audience by urging people to “just build stuff.”

“Don’t just focus on the science; let’s keep building things,” said Michael Webber, Engie.

He used the example of the development of the steam engine to make his point. Machines were developed over many decades including the famous engine design of Scotsman James Watt. The innovators and builders of equipment forged ahead, refining the design, and adding features. The science behind why it worked better that way followed far behind. It was the application that drove the science and not the other way around.

“Keep in mind that they built the original steam engines then figured out the science as to why they work,” said Webber. “Don’t just focus on the science; let’s keep building things.”

His talk outlined the history of energy production as a steady improvement in efficiency. This, he said, was a mega-trend. The first steam engines were reciprocating. Their back and forth motion proved to be less efficient than the continuous motion of turbomachinery. “Rotating machines with continuous motion are better overall,” said Webber. “Turbomachinery is part of the grand arc of humanity and can play a key role in a decarbonized future.”

He emphasized that change happens gradually, but even small improvements in turbine efficiency add up. A 1% gain in gas turbine efficiency within the existing fleet provides power for another 2.5 million homes.

Power density is another big plus for gas-fired power, Webber added. And the grid needs the rotational inertia of turbomachinery to firm up the system.
“You don’t get rotational inertia from wind and solar, so turbines add real value when kept on the grid,” he said.

Looking ahead, he believes turbines need to get smaller, lighter, and operate at higher temperatures and with a wider range of fuels. That means light-weight materials and the use of 3D printing to achieve better blade cooling.

Engie, he said, continues to operate a lot of gas turbines in its network. It is working on hydrogen blends, biomethane, and ammonia.

“There are a lot of naysayers that say turbomachinery has no place in the future,” said Webber. “They are probably wrong. If we create an energy future without turbines, we are going to miss their many benefits.”

FUTURE FUELS PANEL
A panel at the show delved into high-purity hydrogen, hydrogen/natural gas blends, ammonia, synthetic carbon-neutral natural gas, and biofuels. But what impact will these fuels have on gas turbine performance, components, ancillary equipment, and the fundamental mechanism effecting performance of these machines for stationary power and flight applications?

“Blue hydrogen produced from natural gas will be important in the energy transition,” said Geert Laagland.

Geert Laagland, Head of Engineering at electricity and district heat utility Vattenfall, said his company has wind, biomass, hydrogen, gas, coal, wind, and solar in its portfolio. His take on the future of the market is that hydrogen will certainly be needed in quantity for carbon-neutral dispatchable power, as well as district heat.

“But we still need gas-fired plants to ensure reliable power,” said Laagland.

He considers biomethane and biomass to lack viability as alternatives to natural gas. Nuclear power has poor public support. Fuel cells are expensive and too small scale. As for carbon capture, storage, and utilization (CCUS), he said high upfront costs means it is only going to be viable if a plant is going to run a lot of hours.

“Hydrogen and gas-fired plants are best, and over time we can transition to more hydrogen,” said Laagland. “This is a flexible approach and one that can be realized technically.”

His company has a facility in the Netherlands that is hydrogen-ready. The challenge is where the hydrogen is going to come from. The current idea is that it will be produced by wind farms and transported to where it is needed. But that requires major investment and regulatory support, as well as incentives and the establishment of the right legal framework.

This means that the green hydrogen concept (hydrogen produced by electrolysis using wind and solar power) has a tough roadmap toward viability. Laagland doesn’t believe the infrastructure will be in place in Europe until at least 2030.

“Green hydrogen development will happen slowly,” said Laagland. “Blue hydrogen produced from natural gas will be important in the transition.”

OEMS GOING GREEN
The major gas turbine OEMs have been quick to proclaim their green credentials of late. Mitsubishi Power, in particular, has made several acquisitions and internal product development moves to widen its green portfolio.

Brian Allen, Vice President, Product Line Management, Mitsubishi Power Americas, told conference attendees about the company’s path to decarbonized gas turbine operations operating on hydrogen and ammonia gas.

“The Mitsubishi J-series turbine, for example, needed some combustion component modifications to be able to run on hydrogen. Its diffusion combustor and multi-cluster DLN combustor can both operate with 100% hydrogen while its Pro-Mix DLN combustor can currently manage 30%.

Where there is a lack of excess renewable energy for the production of green hydrogen, he thought ammonia could fill the gap. The company’s H25 gas turbine is one that can serve this market.

“Challenges remain such as avoiding and detecting flashback and maintaining low emissions at low loads,” said Allen. “The operational profile of gas-fired power plants will change due to rapid ramping and the changing of blends.”
Solar Turbines, meanwhile, has turbines with DLE combustion systems that can operate with at least 20% hydrogen and has a roadmap to 100%. The company is meeting the challenges of hydrogen turbomachinery via additive manufacturing (AM) and by redesigning a new high-hydrogen DLE combustion system. Mason emphasized how natural gas turbines have already enabled a dramatic transition from coal that brought about a steady decline in CO₂ while providing stable base load and allowing a greater penetration of renewables onto the grid.

“This is a career-defining decade for our engineers to enable gas turbines to remain relevant in the power industry,” said John Mason, Solar Turbines.

“Oh this is a career-defining decade for our engineers to enable gas turbines to remain relevant in the power industry,” said John Mason, Director of Technology and New Product Development for Turbomachinery Products at Solar Turbines. “The emerging hydrogen economy will also open up energy storage and transportation opportunities in existing natural gas pipelines.”

The aviation industry, too, was well represented at the conference. That sector is committed to a 50% reduction of its carbon footprint relative to 2005 levels. Currently, aviation contributes about 2% of global CO₂ emissions. But that could rise to 18% if unmitigated.

Sean Bradshaw, Fellow, Sustainable Propulsion, Pratt & Whitney, said his company is working to raise fleet efficiency by switching to biofuels and other fuels that may be needed. He stressed that this must be done economically.

And it’s not just about new engines. Improvements can be made to existing machines. The Turbofan engine, for example, brought about a 16% fuel savings, a 75% reduction in noise, and a 50% reduction in regulated emissions compared to older engines.

“Fully electric engines have been proposed, but hybrid engines comprised of turbines and electric motors looks more promising,” said Bradshaw.

FUTURE WORKFORCE

Another panel at the show turned its attention to creating the workforce of the future. The next generation of engineers will probably need to be able to work at the intersection of turbine technology, integrated renewables, zero carbon fuels, electric propulsion systems, and cybersecurity systems.

“The new workforce needs to have strong familiarity with computer science, AI, as well as engineering, physics, and the material sciences,” said Barbara Esker, NASA.

Barbara Esker, Deputy Director, Advanced Air Vehicles Program. NASA Aeronautics Research Mission Directorate (ARMD) said technologies like automation, machine learning, AI, and other IT innovations will play an important role in engineering going forward. But they must be balanced by competence in traditional disciplines such as solid/fluid mechanics, thermodynamics, heat transfer and equipment controls.

“The new workforce needs to have strong familiarity with computer science, AI, as well as engineering, physics, and the material sciences,” said Esker. “They have to understand the value of these other technical disciplines since future systems are becoming more integrated.”

She stressed that engineers must become more conversant with soft skills such as teamwork, the value of multi-disciplinary cooperation, economics, business and finance, market forces, and politics.

“These added factors bring context to engineering work to help the person synthesize the big picture,” said Esker. “People should also be able to grasp emotional intelligence, self-awareness, empathy, and communication skills such as being able to really listen to others.”

Mark Jefferies, Chief of University Research Liaison, at Rolls-Royce Group, said children today are very computer savvy, a far cry from the days of his youth. When he started in industry, the office had one green-screen computer. He believes the future will not involve a complete return to the classroom. For a year, that traditional model has been turned on its head. Hybrid class/online learning for technical disciplines is likely to be the pattern that emerges.

“Employers are changing their thinking on what they want from their future workforce,” said Jefferies. “They will always need technical skills, but they are demanding a more flexible and agile workforce that can work creatively in teams. This raises the value of diversity of experience, thought, and continuous learning.”
He added that the technical world has perhaps placed too much emphasis on academic grades rather than the ability to do. The new wave of enrollees and graduates have grown up with laptops and tablets. This is a far cry from earlier generations that grew up building computers, tinkering with car engines, or fixing farm equipment.

“New workers often lack the skills to repair mechanical equipment,” said Jefferies. “We need more practical experience going ahead and apprenticeship programs could be the best way to provide that. New students have to understand that not everything can be learned on YouTube videos.”

Brian Monreale, Associate Lab Director at NETL’s Research and Innovation Center, said the computational sciences using high performance computing and analytics will play a key role in driving forward innovation.

“Computing, data science, AI, and machine learning have changed our lives,” he said. “They can move the energy ecosystem beyond the current average of 35% energy efficiency. Computing will play critical role in helping managers and engineers make informed decisions about efficiency, as well as bringing about more synergy between supply and demand.”

“He suggests that students be encouraged to spend one semester at college and the next working in a related industry as the best way to marry academic learning with practical experience.

The next Turbo Expo is scheduled to take place in Amsterdam, Netherlands in June of 2022.

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**EDITORS’ SERIES**

**Is Hydrogen the Answer to Low-Emission Turbomachinery?**

**Event Overview**

This webcast offers an overview of the various elements of the hydrogen economy, the different types of hydrogen (gray, blue, green), where turbomachinery fits into the hydrogen economy, the challenges involved (the design of combustors, pipelines etc.), and the economics of hydrogen. It answers questions such as:

- How likely is a truly hydrogen-based economy? How long will it be before it takes shape?
- How is it possible to achieve CO2 neutral flexible dispatchable power in the energy transition and what is its implementation path?
- What will be the role of hydrogen gas turbines from a user perspective?
- What kind of hydrogen partnership opportunities exist for gas turbine retrofits?
- What is needed to provide complete upgrade packages to support the value chain of hydrogen implementation within existing gas turbine power plants?

**Key Learning Objectives**

- Understanding the opportunities that may exist along the turbomachinery supply chain from hydrogen
- How will existing power plants, oil & gas, and industrial facilities need to be remodeled/adjusted to include hydrogen-related equipment
- How will turbomachinery evolve, how can current equipment be upgraded, and what technical challenges need to be overcome.

**Who Should Attend**

- Power plant owners, operators, and maintenance personnel
- Industrial facility owners, operators, and maintenance personnel
- Turbomachinery manufacturers and designers
- Turbomachinery supply chain and aftermarket partners
- Control and software vendors and operators

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MAKING MAINTENANCE SMARTER VIA REMOTE MONITORING AND DIGITAL TOOLS

WHAT TRENDS HAVE YOU OBSERVED OVER THE PAST YEAR?
Especially with personnel working remotely, we’ve seen an increase in companies connecting and tracking equipment with sensors and other Internet of Things (IoT) hardware and software to enhance their preventative maintenance capabilities. The coupling industry is catching up with the rest of the world in terms of the data revolution. But even there, demand has exploded in terms of end user interest about how couplings are designed and selected, how they are manufactured, how they operate, how they are maintained, and how they are serviced.

CAN YOU GIVE AN EXAMPLE?
Just like you and I track our orders from Amazon and get regular updates during the process, customers are looking for the same easily accessible live data for couplings. The procurement team needs quick access to product information to make purchases. Project managers are looking at Gantt charts to understand more about the process and status while couplings are being designed and manufactured. Installation and maintenance teams need access to manuals and service experts. The Regal Kop-Flex team is building a complete digital customer experience (DCX) to support these goals.

WHAT ADJUSTMENTS IS REGAL MAKING IN RESPONSE?
We have embraced smart manufacturing via Perceptiv monitoring and diagnostics. Our team utilizes remote monitoring for some customer critical equipment, providing real-time alerts and monthly performance reports. Integrating all a facility’s mechanical components is possible, and we are evaluating the cost benefits and overall ROI of doing so. For some, having their critical equipment monitored is enough, while others want to integrate our components into their existing smart ecosystem.

For example, we have been gathering data from couplings that allows plant operators to make better maintenance decisions by monitoring performance trends with the Kop-Flex Powerlign torque monitoring system. It allows users to minimize emissions and fuel costs by tracking performance trends in connected equipment. This system can be purchased new with couplings or retrofitted to existing Kop-Flex or other brand couplings.

Our Perceptiv intelligence group uses an array of torque monitoring solutions for online monitoring, predictive maintenance and failure analysis. This includes the use of augmented reality tools. Additionally, there is definitely a trend to have spares for all critical equipment. It minimizes downtime if you have a spare coupling to hand instead of having one shipped. Some customers send the main coupling back to our Kop-Flex team for recertification.

WHAT NEW PRODUCTS OR SERVICES ARE YOU OFFERING?
Regal continues to expand Perceptiv on-site and remote monitoring and diagnostics to help our
customers install and monitor equipment 24/7 or as needed. These tools save money by diagnosing potential problems before they happen. Examples include torque monitoring, vibration observation, and motor current signal analysis.

The Regal Tag-It Program powered by Perceptiv intelligence is an asset management platform to view details on mechanical and electrical assets in operation and reduce redundant or obsolete inventory. The program creates a path for continuous facility improvement by enabling faster maintenance and simplifying the MRO procurement process. In addition, users can easily add Perceptiv wireless monitoring to keep an eye on critical equipment. This 24/7 monitoring technology will help customers to increase equipment reliability and maximize production. The combination of hardware, software and “humanware” provides a new way for users to interact with Regal products and their equipment. All of this helps customers to harness the power of IoT in their facilities.

WHAT IS YOUR RECERTIFICATION PROGRAM?
We expanded our coupling recertification program to repair, rebuild, and recertify couplings removed from service to API 671 standards. This allows our customers to have a lower-cost recertification coupling available for future planned outages or emergencies. Customers can recertify their disc, diaphragm, and gear couplings for up to 50% savings from the cost a new item.

Ship the used/worn coupling to one of Regal’s worldwide repair facilities, where they will be disassembled and undergo a non-invasive cleaning. Evaluation determines the material integrity and flexible elements, then we remove and replace any hardware, if necessary. They are then reassembled and rebalanced in accordance with API 671 or original OEM specifications. After a final inspection, they are returned to the customer within 4 weeks.

We also offer a Max-C resilient coupling that provides damping for applications with shock loading or cyclic torques. The Max-C can be mated to disc or diaphragm couplings to tune the drive train. They are frequently used on synchronous and variable frequency drive motors.
Due to the global COVID-19 pandemic, we’ve been bombarded with information about personal air filters (facemasks), how to apply (wear) them, multistage filtration (doubling masks) and filter ratings (N95). As professional turbomachinery engineers, we’re rather amazed at some of the myths perpetuated about air filtration. But as much as we’d like to poke fun at urban legends, we’ll stay focused on air filtration for gas turbines.

The difference between a facemask and a gas turbine filter looks staggering: While a person inhales about two cubic meters of air in an hour, a typical mid-sized gas turbine will ingest over 200,000 cubic meters in the same period. But there are some critical similarities. What are they?

Well…air-particles are air-particles, leaks are leaks, plugging is plugging, and there are liquids the filter must deal with.

Fouling and degradation in gas turbines are to a large degree driven by the quality of ingested air and the fuel supply. The effect of contaminants from the ambient air on a gas turbine (or a human being), which can be controlled by a properly designed/applied air filtration system, is determined by the contaminant’s particulate constituent, size, and wetness. Solid particles in the air can consist of or contain a number of substances — salts, biological matter (pollen, insects, bacteria, etc.), or various types of dirt and sand — that can create significant problems for engine health if ingested without a filter. Salt in combination with sulfur, for example, can cause accelerated hot corrosion.

Most industrial filters effectively remove air particles above a couple of microns in size. However, even the best filters can’t protect the gas turbine if air can bypass these filters. Open man doors or leaking seams in the filter housing, incorrectly installed filters, or leaking gaskets let unfiltered air enter the engine, which obliterates the benefits of an otherwise efficient air filtration system.

One of the characteristics of a filter is the “most penetrating particle size,” the particle size for which the filter has the least efficiency. An N95 filter, for example, can remove at least 95% of particles in the size range of its most penetrating particle size, which is about 0.1 to 0.3 microns. For larger particles, the filtration efficiency is much higher — 99.5% for particles above 0.75 microns. Of course, an N95 respirator only achieves these values with a good face seal.

It’s also important to know that filtration efficiency of a given system is reduced for higher flow velocities through the filter. Efficiency often increases if the filter already has some collected particles and is nearing saturation.

Then there are liquids and liquid droplets. Unfortunately, the ability of a filter to keep liquids out is not directly related to its particle removal efficiency. Liquids, such as water, often can seep through most filter materials. In the process, they
can dissolve solid minerals previously captured by the filter and pass them through. Liquid droplet penetration can be prevented either by separating the liquid droplets from the airstream using demister vanes or by stopping them from entering the filter material by making its surface hydrophobic. The latter method can be used for filters that have a high efficiency for small particles. The former method requires high flow velocities, which compromises its ability to work effectively with filters that have a high efficiency for solid particles.

Why are we talking about this? Air filters can be very effective in protecting a gas turbine from particle penetration. But small particle effectiveness is limited. They always let a small percentage through. The difference between a highly efficient and a not-so-efficient filter can lead to reduced fouling and degradation rates (as expressed by the time between required engine compressor cleaning) by orders of magnitude. But the positive impact is wiped out if there are leaks in the inlet system — just like your N95 facemask is mostly useless if you’re not wearing it over your nose and mouth.

Klaus Brun is the Director of R&D at Elliott Group. He is also the past Chair of the Board of Directors of the ASME International Gas Turbine Institute and the IGTI Oil & Gas applications committee.

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Any views or opinions presented in this article are solely those of the authors and do not necessarily represent those of Solar Turbines Incorporated, Elliott Group, or any of their affiliates.
NEW PRODUCTS

HANDHELD 3D SCANNER
Exact Metrology has increased the capability of its Artec 3D handheld scanners to include a new HD mode. It provides scans for Artec Leo and Artec Eva. Powered by Artec 3D’s artificial intelligence neural engine, users can obtain 3D scans with a resolution of up to 0.2 mm. Trained on hundreds of thousands of carefully selected samples, the engine’s neural network detects familiar patterns, surface details and shapes. This allows the 3D scanner to reconstruct a higher number of polygons per frame, resulting in 3D data that’s denser and higher quality. The desired density can be selected from 1X up to 64X. HD mode makes it possible to capture smaller, thinner elements with the 3D scanner while also reducing noise. Fine edges can be captured in high definition.

NEW CENTRIFUGAL AIR COMPRESSOR
Ingersoll Rand’s MSG Turbo-Air NX5000 centrifugal compressor provides efficiency, uptime, hassle-free operation, and reduced maintenance needs. The compressor series is available in several configurations. Design features include aerodynamic components (inlets, impellers, scrolls and diffusers) combined with low mechanical losses and power-conserving inlet throttle control (IGV) provide up to 5% better specific power than competitive models. An integrated structural base provides a foundation for the main driver and serves as a support platform for the side-mounted lube system/reservoir. A side-mounted lube reservoir with top-mounted components and standard duplex filters ease maintenance requirements and provide continuous, uninterrupted operation. Further features include gearbox inspection covers for simple accessibility, a split pinion bearing and seal design, intercoolers for specific flow and pressure requirements, and dual condensate connections.

The horizontally split gearbox design ensures easy access to major rotating elements, bearing and seals. It is located on the gearbox cover, gearbox inspection ports make quick visual checks of gear and bearing conditions possible.

VISUALIZATION OF EMISSIONS DATA
Mirico announced the public release of the Mirico Cloud for oil & gas. This online platform enables real-time visualization of emissions data collected from gas sensing instruments. It visualizes the detection, localization and quantification of gas emissions across sites.

PARKER HANNIFIN GAS TURBINE FILTERS
Parker Hannifin, a motion and control technology company, launched a new line of filters for gas turbines called clearcurrent Assure filters. They feature durable hydrophobic and oleophobic properties to remove problematic contaminants carried through to the turbine in liquid forms. Their design provides filtration across a range of models including high-performance self-cleaning units.

The performance of the clearcurrent Assure filters through all filtration stages equates to predictable differential pressure (DP). This avoids sudden pressure spikes that lead to unplanned turbine outage or damage to the system. They are designed to an exact fit in the inlet house to prevent them being bypassed.

INDUSTRIAL CYBERSECURITY
Industrial cybersecurity company, Claroty announced Claroty Edge, an addition to the Claroty Platform that delivers visibility into industrial networks in minutes without requiring network changes, sensors, or having any physical footprint. Combined with enhancements to its Continuous Threat Detection (CTD) solution, and software-as-a-service offerings, Claroty offers a portfolio of solutions for industrial cybersecurity. Claroty Edge is termed a zero-infrastructure industrial cybersecurity solution for the edge of the network.

“The recent cyber incidents with Colonial Pipeline and the Oldsmar, Florida water supply have underscored the need for asset owners and operators to mature their cybersecurity programs and make ‘eyes wide open’ decisions about the risks to their critical and vulnerable assets,” said Grant Geyer, chief product officer of Claroty. “Cyber risks to industrial control systems have consequences not only for the organization, but also for public safety and the global supply chain, so every industrial enterprise has an obligation to start their cybersecurity journey.”
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