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THERE IS NO STOPPING THE LNG JUGGERNAUT

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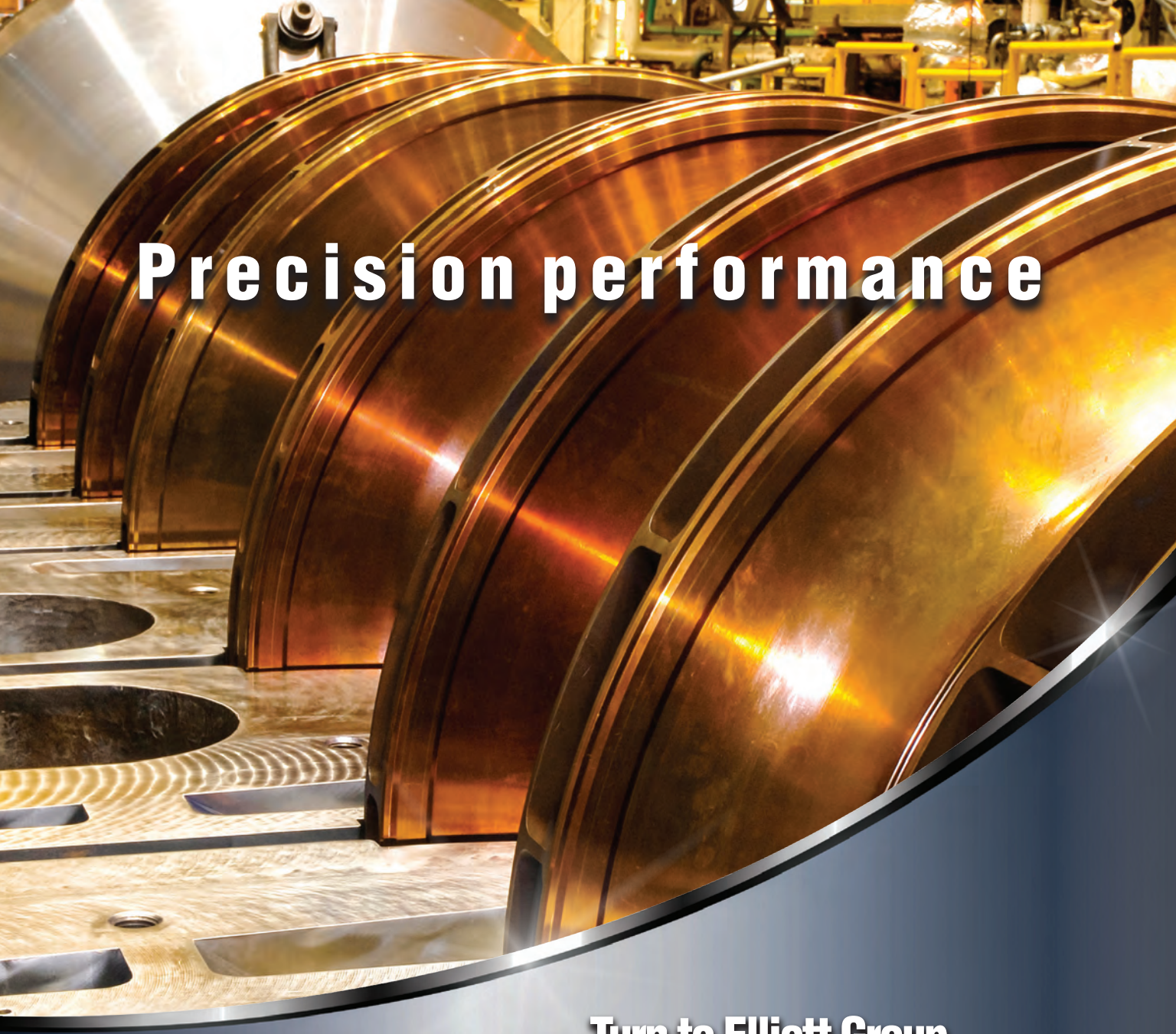
Expanders • Baker Hughes Show Report • Filtration
Turbines • Software and Controls • Compressors
Auxiliaries & Components • Maintenance & Repair



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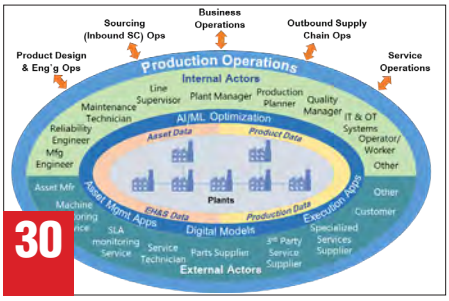

COVER STORY

16 NO STOPPING THE LNG JUGGERNAUT

Liquefied Natural Gas (LNG) is in the midst of a global boom. Terminals are being added across the world. Orders for equipment are flooding in. New, state-of-the-art mega-facilities are coming online, and worldwide production is hitting record levels year after year. There appears to be no stopping the LNG juggernaut. Where gas is abundantly available, export terminals are being erected. Where it is in short supply, import terminals keep popping up. The pipeline for more terminals extends into the future. Global demand for LNG grew by 12.5% to 359 million m.t. in 2019. Some 40 million m.t. of additional supply became available last year, the highest ever single year jump and a record year for investment.

Drew Robb

SHOW REPORT

22 BAKER HUGHES UNFETTERED

Baker Hughes merged with GE Oil & Gas a couple of years ago to form BHGE. That relationship is over. Baker Hughes has emerged as an end-to-end oil & gas giant in its own right. It has absorbed just about all the assets of GE Oil & Gas including a vast turbomachinery portfolio.

The recent separation did not impact attendance at the 21st Annual Meeting, which had a highest ever turnout. The show featured in-depth discussion of artificial intelligence, digitalization, 3D printing and carbon capture technologies.

Drew Robb

SOFTWARE & CONTROLS

28 COMPRESSOR MONITORING AND CONTROL

Compressor monitoring and control are critical for optimizing the performance of compressors. Trends discussed include Software-as-a-Service, digitalization, the Industrial Internet of Things, analytics, machine learning, and enhanced communications to enable remote monitoring.

Tim Shea

SOFTWARE & CONTROLS

29 EDGE BREAK

How to bring handheld 3D measurement and analysis to the shop floor. It focuses on sharp edges and corners in turbomachinery design.

Kramer Lindell

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32 HIGH SUB-SYNCHRONOUS VIBRATION

This article examines vibration in a turboexpander equipped with active magnetic bearings. A turboexpander expansion stage consists of a radial inflow turbine, often with variable-position inlet guide vanes. The compression stage is comprised of a centrifugal compressor stage with a vaneless diffuser.

Tadeh Avetian, Luis E. Rodriguez and Junyoung Park

Cover image: The Tornio LNG import terminal in Finland.

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PROPAGANDA VERSUS REALITY

A campaign is afoot to marginalize natural gas in the nation's energy mix. We mentioned it in the cover story from our Jan/Feb 2020 issue Can Natural Gas Generation Survive? The numbers cited by analysts in that article don't support the move away from natural gas generation any time soon. Yet the propaganda continues. And it is being actively spread to utilities and the general public.

Here is an example:

"Renewables like wind and solar, complemented by flexible zero-carbon resources like storage and demand response, are already providing the same reliability services and energy as new natural gas plants at lower cost," stated Mike O'Boyle, director of electricity policy at advocacy group Energy Innovation. "New gas infrastructure is increasingly likely to become stranded — the natural gas 'bridge' must end now if investors want to avoid massive stranded asset cost risk."

> **"Coal-to-gas switching can make huge progress in emissions reduction."**

The economics of this scaremongering are not backed by real world figures. The idea that grid support and grid inertia alternatives are readily and cheaply available is a fantasy. Perhaps on a small scale, under ideal conditions when the deck is stacked by regulation, someone might be able to make a limited case. But states like California need thousands of MW rapidly every night when solar power fades. It is up to natural gas to provide it.

What is most troubling is the attempt to undermine any investment in natural gas infrastructure. Planning to close a coal plant and replace it with natural gas to cut emissions by more than half? No way! How about upgrading aging natural gas plants to slash their emissions? Forget about it! And what about applying the latest seal and detection technology to reduce methane leakage by colossal amounts, and minimize methane flaring? That's simply, "incompatible with a climate-stable future," they say.

What we have, in effect, is the environmental lobby actively preventing sensible emissions reduction measures in their zeal to save the planet. If the goal is to greatly reduce and eventually eliminate emissions, coal-to-gas switching will make huge progress in that regard.

Seal up all the natural gas pipelines, get rid of flaring and you make another massive leap toward a cleaner planet. Upgrading old natural gas plants makes it possible for more renewables to be on the grid while taking emissions levels down considerably.

Meanwhile, build more wind and solar farms and continue to install storage facilities. Invest in research on hydrogen turbines and better batteries for a possible future when these alternatives are mature enough and cost effective enough for natural gas to fade into the sunset. But that's unlikely before 2050. This bloodlust against natural gas generation is shortsighted in the extreme.

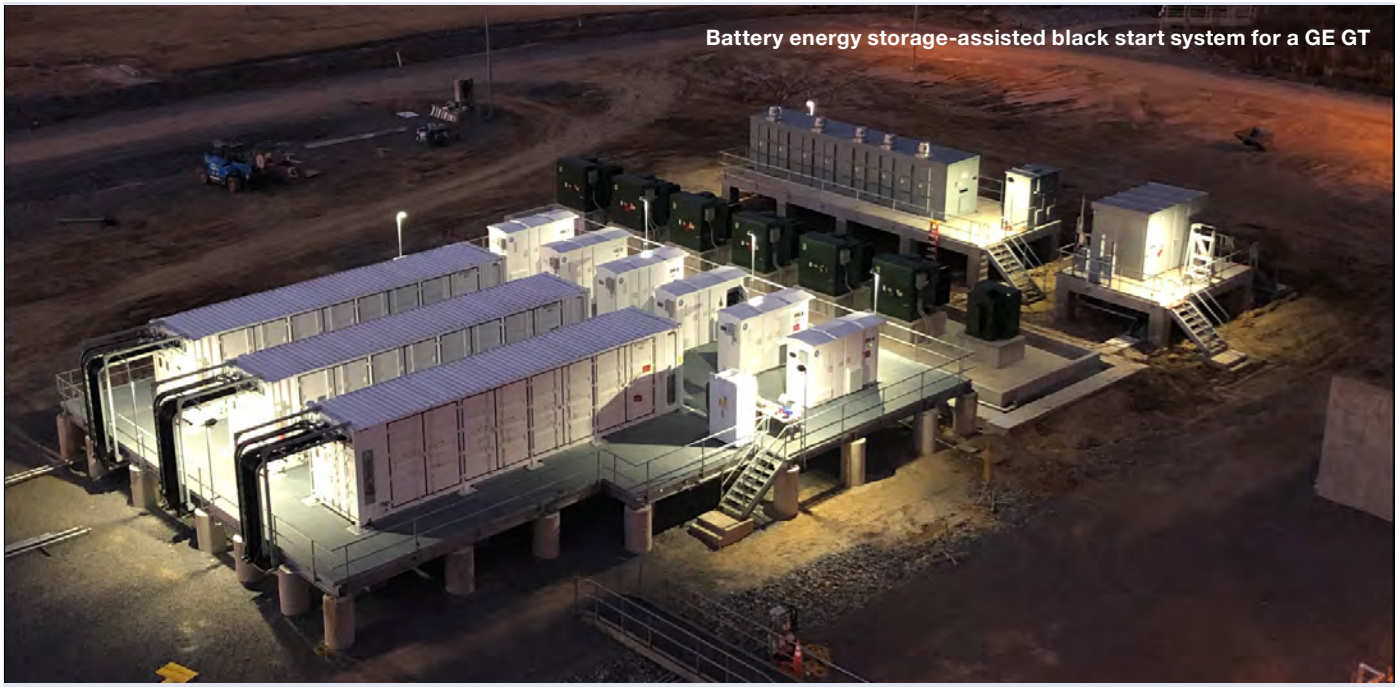
Matt Schatzman, Chairman & CEO of NextDecade, firmly believes that natural gas should stand hand in glove with renewables. "It would be a huge mistake for gas not to be front and center in energy policy," he said at the Baker Hughes Annual Meeting in early February. "Renewables can't replace all the coal generation around the world, but natural gas can." You can read about the conference and the future of oil & gas in our show report on page 24.

NextDecade is engaged in LNG projects such as Cheniere LNG, which already has six large turbomachinery trains operating, as well as Corpus Christi LNG where a third train is being added. You can find out more about the global LNG boom in our cover story on page 17.

The rest of the issue includes informative articles on compressor monitoring and control, machined part measurement, addressing high sub-synchronous vibration in turboexpanders, turbine filtration, data corrections applied in turbomachinery testing, coatings and compressor startup and operation.

We missed you at the Western Turbine Users event in Long Beach due to its postponement. But we hope we get the chance to meet some of you at the Turbo Expo in the summer. Stay safe, happy and productive. ■

DREW ROBB
Editor-in-Chief


Battery energy storage-assisted black start system for a GE GT

GE digest

GE announced the completion of the first battery energy storage-assisted black start of a GE 7F.03 gas turbine (GT) at the 150 MW simple cycle unit at Entergy Louisiana's Perryville Power Station. It is the first time GE achieved a black start of a GE heavy-duty gas turbine using energy storage.

A black start consists of rebooting an idle power plant without support from the grid in the event of a major system disruption or a system-wide blackout. This is one of the most challenging tasks in power generation.

GE will provide its renewable steam technology for the Kamisu Biomass Power Generation plant in Japan. In a deal signed with engineering, procurement & construction (EPC) contractor Hitachi Zosen, GE Steam Power will design, manufacture and supply all core components of the power block for the project including the steam turbine (ST) generator as well as the boiler with its air quality control systems.

The plant will use biomass comprised of palm kernel shells and wood pellets to generate 50 MW. The plant will be equipped with GE's low-NOx circulating fluidized bed (CFB) boiler, a dust-removal fabric filter and a reheat ST with its generator. The plant is scheduled to start commercial operation in July 2023.

Quadra Power Generation's Voronezh CHPP-1 CCPP has begun operation using four GE Sprint LM6000 GTs. The 223 MW Voronezh plant was commissioned in 1933. The Sprint module is also equipped with a Dry-Low Emissions (DLE) combustion system for fuel flexibility and lower emissions.

In addition, GE supplied a multi-stage static air filter unit equipped with anti-freeze protection to support reliable operation in winter conditions.

GE has been selected by Azito Energie to provide the Azito phase IV power plant in the Yopougon district of Abidjan in Côte d'Ivoire with the following: a GE GT13E2 GT in combined cycle configuration, one heat recovery steam generator (HRSG), one ST generator, condenser and associated systems, as well as maintenance services for 20 years. The extension of the plant will generate 253 MW, taking capacity up to 710 MW.

GE received another order from Israel Electric Corporation (IEC) for an 9HA.01GT for the Orot Rabin plant in Hadera, Israel. This facility is converting from coal to natural gas. GE will also provide an ST, generator, HRSG and balance of plant (BOP) equipment as well as a 15-year multi-year services agreement. Once operational, the Orot Rabin combined cycle GTs are expected to deliver up to 1,260 MW.

Ansaldo contract

Iren Energia has signed a contract with Ansaldo Energia for a new combined cycle plant to boost installed capacity at the Turbigo site in Italy, from 850 MW to 1,280 MW.

The plant will have 57% efficiency and operational in 2022. Based on an EPC contract, Ansaldo Energia will manage the executive design phase, the supply of the GT, generators and set-up transformers, heat recovery vapor generator, implementation of civil works, assembly and supply of ancillary electrical, and mechanical installations.


Ansaldo Energia signed a contract to provide Iren Energia with a new combined cycle facility

TRS Services acquisition

TRS Services, provider of component repair and upgrade services for heavy industrial, light industrial and aeroderivative turbines, acquired the assets of Houston-based American Aeromotive Components (AAC).

TRS Services can now manufacture replacement parts in addition to its current light industrial and aeroderivative repair services. The acquisition expands repair capabilities for heavy industrial buckets and blades and provides additional grinding and machining capabilities.

News continues on page 10

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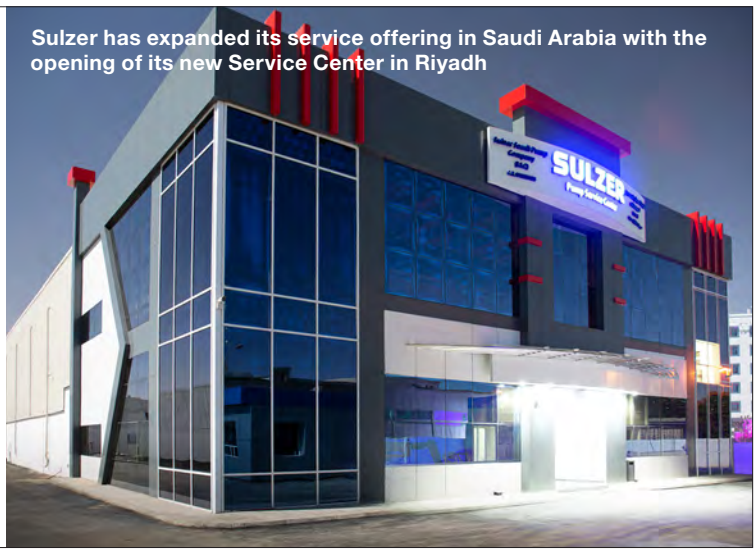
Sulzer pump facility in Saudi

Sulzer has expanded its service offering in Saudi Arabia with the opening of a new Service Center in Riyadh. Building on the company's existing local pump manufacturing capabilities, it will provide maintenance and repair services for all types of pumps.

The Sulzer Saudi Pump Company's (SSPC) manufacturing facility mainly supplies the oil & gas, power generation and water sectors. After-market services include reverse engineering, rerates, spare parts management and maintenance contracts.

The service center is equipped with all new machinery, including lathes, milling machines, balancing equipment, hydraulic presses and 20-m.t. overhead cranes. Located on the same site as the pump manufacturing facility, the service center can take advantage of the larger computerized numerical control (CNC) machine tools, welding equipment and testing facilities next door.



Sulzer has expanded its service offering in Saudi Arabia with the opening of its new Service Center in Riyadh

Titan vacuum furnace by Ipsen USA

Ipsen USA installs vacuum furnace in Washington

Ipsen USA installed a Titan vacuum furnace at Stack Metallurgical Group's location in Spokane Valley, WA. Installation of the Titan H6 2-bar vacuum furnace will be used to process aerospace components.

Thales and GE cybersecurity

Thales and GE Steam Power are collaborating to deliver a suite of cybersecurity solutions to power plant operators. This agreement brings together Thales' cyber knowledge and GE's expertise in power generation to protect against cyberattack.

The growing intertwining of information technology (IT) and operations technology (OT) allows attackers to create bridges between any machine and core infrastructure. While vulnerabilities in IT environments are mostly understood and managed, OT vulnerabilities lack attention. Industrial Control Systems (ICS) and Supervisory Control and Data Acquisition Systems (SCADA) are often targeted in cyberattacks.

Hydropower research

The U.S. Department of Energy (DOE) has awarded Missouri University of Science & Technology a grant to evaluate the benefit of optimized pumped hydropower storage (PHS). About 10% of electricity in the U.S. is created by moving water, or hydropower, according to the DOE's Hydropower Vision report.

DOE is investing about $7.5 million into research projects to improve hydropower and reduce electricity costs for consumers, including Missouri University's grant. A PHS plant uses two water reservoirs at different elevations to generate power as the water descends through a turbine. To generate energy continuously, the plant pumps water from the lower reservoir to the upper reservoir and the cycle starts again.


The Ludington pumped hydro project

CCI subsidiary acquires Spanish power plant

Castleton Commodities International (CCI) has acquired the Amorebieta CCPP in Bilbao, Spain. The 786 MW plant uses two GE 9FA GTs and one Alstom ST.

Korean production and repairs

Korea Western Power (KOWEPO) plans to localize production of high-temperature parts and repair engineering technology for GTs used at the Seoincheon Power Complex. Currently, all GTs used for power generation in Korea are imported.

Core components, high-temperature parts production and repair engineering are also imported during overhauls. The project, which is in collaboration with the U.S.-based Electric Power Research Institute, is in its final stage.

MHPS digest

Mitsubishi Hitachi Power Systems (MHPS) signed a third long-term maintenance agreement for the BLCP Power Station in Thailand for a period of twelve years. The agreement includes regular inspections, efficiency improvements, and equipment replacement, including boilers, STs and flue gas cleaning system built by MHPS.

The extension concludes in 2032, when the 25-year power purchase agreement with the Electricity Authority of Thailand completes. The BLCP Power Station is a 1,400 MW thermal power generating facility comprising of two power plants.

MHPS signed a memorandum of understanding with Power Generation Joint Stock, a power company in Vietnam, to provide operations and maintenance support for its power stations and technical training for engineers.

The customized MHPS hardware and software solutions are expected to increase plant capacity from 324 to 566 MW while lowering fuel and maintenance costs.

MHPS has been chosen by the Intermountain Power Agency (IPA) to supply two MHPS JAC turbines to provide Los Angeles and the western interconnect with 100% renewable, carbon-free hydrogen power by 2045, the first grid-scale hydrogen project in the world.

The current coal-powered Intermountain Power Plant will be decommissioned by 2025, after which the new facility will begin using a 30/70 hydrogen and natural gas mix, ramping up to 100% by 2045.

The hydrogen for this facility will be produced through the Advanced Clean Energy Storage Project, a joint venture between MHPS and Magnum Development to create green hydrogen. The power plant will be owned by IPA and operated by Los Angeles Department of Water and Power. It will provide 840 MW.

MHPS JAC turbines are to be used with a hydrogen/natural gas mix in Los Angeles

Doosan Škoda digest

Doosan Škoda Power will modernize two turbine sets with a capacity of 440 MW at the Mochovce nuclear power plant in Slovakia. The company will supply high- and low-pressure flow assemblies, repair reusable parts, such as the outer casing and the valves of the turbine set, and upgrade the turbine control and regulation system. The work will take place during a planned shutdown in 2021.

Doosan Škoda Power is supplying an ST to Japan. The two-core 75 MW DST-S10 will b used in a new biomass plant in the Sodegaura, Chiba Prefecture. The turbine's launch is expected in 2022.

MAN ES digital platform

MAN Energy Solutions has launched a digital platform under the name "mýa," enabling the integration of OEM data across the marine, power and energy industries. Set up as a nonprofit organization, the platform enables the secure exchange of data among participating OEMs, operators and asset owners.

MAN's goal is to create an independent, non-profit organization to govern mýa and promote collaboration in digital technology. The newly founded mýa Connection is headquartered in Switzerland.

Parker Hannifin research

Parker Hannifin is expanding its research and development capabilities in hollow fiber filter membranes at the Parker Filtration Innovation Center in Columbia, TN. The research is intended to improve the membrane technology for new applications within the food and beverage, life sciences, water purification and gas generation industries. Researchers will use computer models and simulations to predict performance and test fiber filter membrane systems in harsh environments before applied to real-world scenarios.

MANIFEST project

MANIFEST (Multi-Scale Analysis for Facilities for Energy Storage) is a project led by the University of Birmingham, UK. The program investigates how energy storage technologies can be further improved with the aim to accelerate deployment.

GTs for Saudi Arabia

12 GTs in the Saudi Aramco Jazan 3,850 MW power plant, operated by China Huadian, are now connected to the grid. The plant, which uses Siemens SGT6-5000F GTs, is expected to be operational by the end of this year.

The plant will have a capacity of 3,800 MW, from which 1,000 MW will be used internally including 300 MW to be sent to a Saudi Aramco Refinery. The remaining 2,500 MW will be exported to Saudi Electricity Co. for the national grid.

The integrated gasification combined cycle (IGCC) complex also includes a reverse osmosis plant designed to produce approximately 1,700 m3/h of desalinated water for industrial and on-site uses including potable water supply.

Woodward and Hexcel merge

Hexcel, a composites technology company, and Woodward, an aerospace and industrial parts maker, will combine in an all-stock merger of equals to create an integrated systems provider for the aerospace and industrial sectors called Woodward Hexcel. The new company is headquartered in Fort Collins, CO. Hexcel produces composite materials used on the 737 MAX airframe and engines.

Sanad Powertech contract

Sanad Powertech, a thermal energy and maintenance, repair and operations (MRO) service provider, was awarded a contract for the steam engine and power generator of the Shams Power concentrated solar power plant in Abu Dhabi. The project covers 2.5 km2 and has a capacity of 100 MW.

Contract signing for a steam turbine in an Abu Dhabi solar facility

Atlas acquires APR Energy

Atlas Corp. acquired APR Energy. APR is a leasing franchise that owns and operates a fleet of GTs and other power generation equipment.

Second ARES turboexpander

L.A. Turbine (LAT) commissioned its second ARES Active Magnetic Bearing (AMB) Turboexpander-Compressor within a newly established cryogenic natural gas processing plant located along the Panola pipeline in TX. The L3000 ARES AMB turboexpander-compressor is designed to handle a plant flow rate of 200MMSCFD (million standard cubic feet per day) and features the industry's first skid-mounted AMB controller and Programmable Logic Controller (PLC) design.

LA Turbine ARES turboexpander

StandardAero acquires TRS Ireland

StandardAero has acquired TRS Ireland, a provider of component repair and manufacturing processes for industrial, aeroderivative and aircraft GTs. The acquisition will continue to expand StandardAero's Components, Helicopters & Accessories division and its portfolio of MRO and component repair services.

TRS Ireland is a privately held company operating from Cork, Ireland, with nearly 70,000 square feet of MRO operations and more than 100 employees. The company has an installed base of customers that includes Siemens, GE, Rolls-Royce and MTU. With the addition of TRS Ireland, StandardAero now has 40 primary repair facilities located on five continents.

Biomass tax credit

The 30% U.S. Federal Production Tax Credit (PTC) for biomass and landfill gas facilities has been extended through the end of 2020. Customers may elect to claim an Investment Tax Credit (ITC) of 30% in lieu of the PTC.

Funding is also included for several programs including the U.S. Department of Energy's Combined Heat and Power Technical Assistance Partnerships, Advanced Manufacturing Office, R&D funding, EPA's CHP Partnership, Natural GasSTAR programs, and extends other incentives for energy production and efficiency.

Exergy ORC

Exergy, an Italian company producing Organic Rankine Cycle (ORC) systems, and China's TICA Group, which produces high-efficiency HVAC and thermal energy systems, formalized the acquisition of the operational branch of Exergy.

The acquired branch includes all the assets and personnel of Exergy and its Turkish subsidiary, including its project references, know-how, and IP. The merged company will be called Exergy International. The company designs and manufactures radial outflow turbine ORC systems near Milan, Italy.

Uzbek CCPP

The Ministry of Energy of Uzbekistan has signed three agreements with Saudi Arabian utility developer ACWA Power. The agreements include: A 25-year Power Purchase Agreement (PPA) for the development, construction and operation of a 1,500 MW combined cycle power plant (CCPP); the building of a wind power plant with a capacity of 500 to 1,000 MW; and a training center to enhance technical skills of Uzbek students. The plant will be located in Shirin City in the Syrdarya region.

Capstone microturbines ordered for Santos oil & gas facility in Australia

Capstone digest

DTC Ecoenergia signed a new Factory Protection Plan (FPP) long-term service contract for 2 MW of Capstone microturbines installed at an automotive manufacturing facility in Mexico for electronic components and lighting systems. The systems will be used for peak shaving and power-generation only at this time.

Optimal Group Australia commissioned an energy project for oil and gas producer Santos. The project required Optimal to deliver a stand-alone, 1 MW Capstone C1000S system to power a remote oil production facility to replace an aging reciprocating engine at the Tarbat Oil Production Facility in Southwest Queensland.

Santos wanted to achieve significant emissions reductions as part of the energy system upgrade, so it incorporated a 250-kW solar photovoltaic (PV) array, and uses Optimal's Grid Stability Module (GSM) to stabilize electrical load.

Capstone Turbine secured an order for a Capstone C400 Signature Series (C400S) microturbine for a gelatins and collagen peptides manufacturer in Germany. The order was secured by E-Quad Power Systems.

Capstone received a repeat order for five C200 Signature Series microturbines for a federal railway infrastructure project from The Railways of Yakutia in Russia. DV Energy secured the 1.0 MW order, which is expected to be commissioned in November 2020. The C200S microturbines will act as the primary power source for the Aldan Railway Station and provide heating for the main building.

SCE Energy secured an order for a C1000 Signature Series ICHP microturbine for an industrial processing business park in Scotland. The scheduled commission date is April 2020. An additional one to two megawatts are expected to be installed within the next eighteen months rounding out phase three of the development project in 2022.

Capstone's long-term microturbine rental business deployed a C600 Signature Series microturbine in the Permian Basin with an oil and gas company. The rental was secured by Lone Star Power Solutions.

IP Innovative Power of Germany has ordered 20 Capstone C65 microturbines. Delivery is expected to conclude by October of 2020.

Siemens Digest

Siemens AG has transferred its Gas & Power business to the newly formed Siemens Gas & Power. It is now operating as an independent entity. The company also acquired all shares of Siemens Gamesa Renewable Energy (SGRE) held by the Spanish utility Iberdrola.

Siemens Gas & Power was awarded a contract to supply three boil-off compressor (BOG) packages for Venture Global's Calcasieu Pass LNG Project. The new LNG export facility, Calcasieu Pass, is currently under construction in southwestern Louisiana's Cameron Parish, approximately 50 miles south of Lake Charles.

Once commissioned, it is expected to produce 10 MTPA of LNG for export. Site construction is underway, and the compression trains are expected to ship in summer and fall 2020.

Siemens has received an order from RUE Minskenergo, the state-run energy provider for Belarus, to supply six SGT-800 GTs for a peak load power plant in Minsk. Commissioning is scheduled for December 2021.

The plant's electrical capacity, designed for 700 operating hours and 350 cold starts per year, will be 300 MW. The scope of supply also includes generators, the PCS 7 control system, a gas receiving station and high-, medium- and low-voltage equipment.

Ransomware attacks gas facility

A U.S.-based natural gas facility shut down operations for two days after sustaining a ransomware infection. It prevented personnel from receiving operational data from control and communication equipment, according to the Department of Homeland Security Cybersecurity and Infrastructure Security Agency.

The agency did not identify the site, only indicating it was a natural gas compression facility. The advisory said, "at no time did the threat actor obtain the ability to control or manipulate operations." The attack did knock out equipment for monitoring physical processes.

Cranfield University study

An international collaboration led by Cranfield University is set to examine the potential for low-carbon hydrogen as the clean fuel of the future. The HyPER project (Bulk Hydrogen Production by Sorbent Enhanced Steam Reforming) will construct a 1.5 MW pilot plant to test a hydrogen production technology that reduces greenhouse gas emissions. The project involves U.S.-based research and development organization GTI and Doosan Babcock, a specialist in low-carbon technologies.

Freeport LNG

Freeport LNG began commercial operations for the second of its three liquefaction trains as gas deliveries commenced from BP under its 20-year agreement with Freeport. Freeport LNG's Train 1 began commercial operations earlier this year with the commencement of Osaka Gas' and JERA's agreements. Construction on Train 3 is essentially complete. Gas has been introduced to the pre-treatment facilities and it is on track for a commercial start date in May 2020.

Voith training center

Voith signed a memorandum of understanding in the Angolan capital Luanda to build a training center. The Voith Academy is designed to provide basic and advanced training for skilled workers in Angola in technical and commercial occupations in hydropower.

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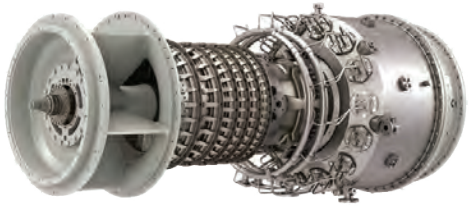

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START-UP & OPERATION OF TURBOCOMPRESSORS

BY AMIN ALMASI

The cleanliness of the gas stream is a key factor in the trouble-free operation and reliability of any compressor. Corrosive, sour or contaminated gases require special provisions and operational considerations. Fouling due to contamination or process reactions can cause rapid degradation and unscheduled shutdowns.

Particular care should be taken when liquids are present in the gas stream. Unlike other compressor types (particularly reciprocating compressors), turbocompressors are more forgiving if the liquid is in the form of a mist.

But a turbocompressor is in danger of severe mechanical damage if suddenly deluged with liquid. For this reason, properly sized suction drums are required to trap any liquids, particularly where there is a possibility of condensation in the suction piping and passages.

Long-term problems have also been reported for mist or small droplets. As a result of erosion, for instance, the effective diameter of the impeller may be reduced over time and could decrease the generated head.

Particles or other forms of contamination are also a concern. Particle size of 30 microns or smaller is probably safe; 80 microns is marginal; 400 microns is too large. The most significant exception to this rule is when gas contains fine, but erosive, particles. In such cases, lower limits should be adopted.

Turbocompressors can be washed on-stream to counteract the effects of fouling. Trial and error help to find the optimum liquid wash and associated parameters, such as rate of flow. The flow should be enough to clean the machine without causing erosion.

In all liquid-injection applications, it is recommended to use tangential sprays when practical. Ideally, the liquid should be injected so it does not impinge on any surface to avoid erosion.

During the first weeks of the operation, all monitoring equipment and sensors should be observed to establish the signature of parameters such as temperature and vibration.

Commissioning and startup

During commissioning, a turbocompressor is started up when all accessories and utilities are connected and ready. Alignment should be monitored as the temperature moves toward the operating level.

Any alignment changes should be properly documented and corrected, if required. This is known as hot alignment, although alignment at operating temperature is a better name for it.

During the first weeks of the operation, all monitoring equipment and sensors should be observed to establish the signature of parameters, such as temperature and vibration. This is used as a baseline for condition monitoring and plays a major role in the overall operation and performance of the unit.

Sometimes, the engineering team and equipment manufacturers do not adequately communicate the bounds of the operating envelope to the operations team. The operations team cannot be expected to operate a machine if the operating envelope is poorly defined.

In many cases, the provided performance curve is inaccurate and not certified during shop tests or site performance tests. Such inaccuracies in turbocompressor performance curves may be the root cause of the problem when the operating point is too close to the surge line or too close to the end of curve.

Sometimes, the provided turbocompressor performance curve can be grossly inaccurate as, for instance, long-term operation at the end of the curve at the choke or stonewall area is not logically possible.

Operating the compressor outside the defined operating envelope is another risk. This can happen due to production and operational pressures, for example. It is important to avoid such a mode of operation.

But if not possible, carefully consider the risks involved. In some cases, it may only reduce efficiency with no significant problem to compressor reliability. But in many other cases, operation outside the allowable envelope is a factor that could seriously impact the reliability and life of the equipment.

Therefore, the operating point should be as close as possible to the best efficiency point (BEP) to receive the highest efficiency possible and minimize impact on reliability. All compressors will tend to experience a rise in operating temperature when operating off-design (off-rated), far from the BEP. In most cases, the operating temperature has an upper limit. Once exceeded, deterioration may take place.■

Amin Almasi is a Chartered Professional Engineer in Australia and U.K. (M.Sc. and B.Sc. in mechanical engineering). He is a senior consultant specializing in rotating equipment, condition monitoring and reliability.


The first train of Freeport LNG in Texas

NO STOPPING THE LNG JUGGERNAUT

NEW TERMINALS, SKYROCKETING ORDERS AND WORLWIDE PRODUCTION ARE AT RECORD LEVELS

BY DREW ROBB

Liquefied Natural Gas (LNG) is in the midst of a global boom. Import and export terminals are being added across the world. Orders for equipment are flooding in. New, state-of-the-art mega-facilities are coming online, and worldwide production is hitting record levels year after year. There appears to be no stopping the LNG juggernaut.

Where gas is abundantly available, export terminals are being erected. Where it is in short supply, import terminals keep popping up. And the pipeline for more terminals extends well into the future.

Global demand for LNG grew by 12.5% to 359 million m.t. in 2019, according to Shell's latest annual LNG Outlook. Some 40 million m.t. of additional supply became available last year, the highest ever single year jump and a record year for investment decisions for new or expanded liquefaction capacity.

"The global market continued to evolve in 2019 with demand increasing for LNG and natural gas in power and non-power sectors," said Maarten Wetselaar, Integrated Gas and New Energies Director, Shell. "Record supply investments will meet people's growing need for the most flexible and cleanest-burning fossil fuel."

Europe was the home for the majority of 2019 consumption growth. Competitively priced LNG encouraged more coal-to-gas switching in the power sector. China, too, has become an LNG consumption haven, with imports rising by 14% for the year.

"LNG demand is growing very strongly across the world," said Fatih Birol, Executive Director, International Energy Agency (IEA). "Countries like the U.S., Canada, Qatar and Australia are making big inroads in terms of expanded LNG export capability."

Turbomachinery surge

Natural gas consumption is expected to rise to 156 trillion cubic feet (Tcf) worldwide in 2025, according to Forecast International. By that time, LNG will serve more than a quarter of worldwide demand for gas.

This, in turn, will drive the procurement of mechanical drive machines as gas needs to be transported by pipeline to LNG export terminals and from LNG import terminals to demand centers.

While smaller gas turbines (GTs) will be used in some cases, Forecast International believes in the coming decade more than half of all models sold for this purpose will be at least 7.5 MW in size. Aeroderivatives, such as the GE LM2500/2500+ and competing models from Siemens, are likely to be in demand.

Similarly, Solar Turbines has plenty of orders to replace older and smaller Solar Centaur and Taurus GTs with larger and more modern units. As a result, Forecast International predicts a 16.7% rise in sales of mechanical drive GTs delivered between 2019 and 2028, compared with the previous ten-year period.

That adds up to $23.95 billion over the decade. Whether from new pipelines or upgrades to existing compressor stations, sales of 3,294 turbines are expected for the forecast period.

Baker Hughes, for example, is dealing with the largest order backlog in its history. From the last quarter of 2018 to the end of

Cover Story continues on page 18

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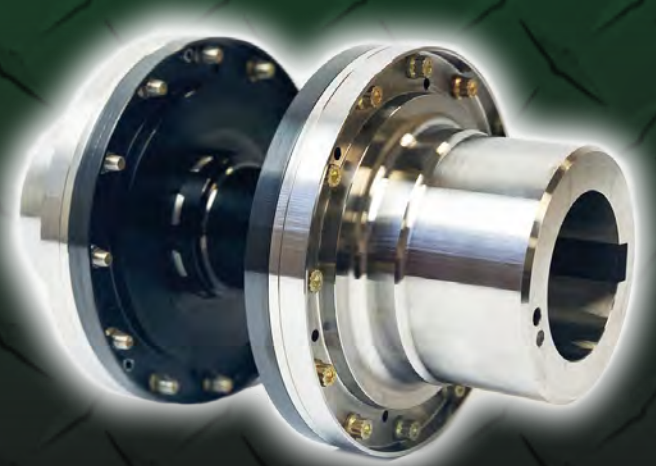

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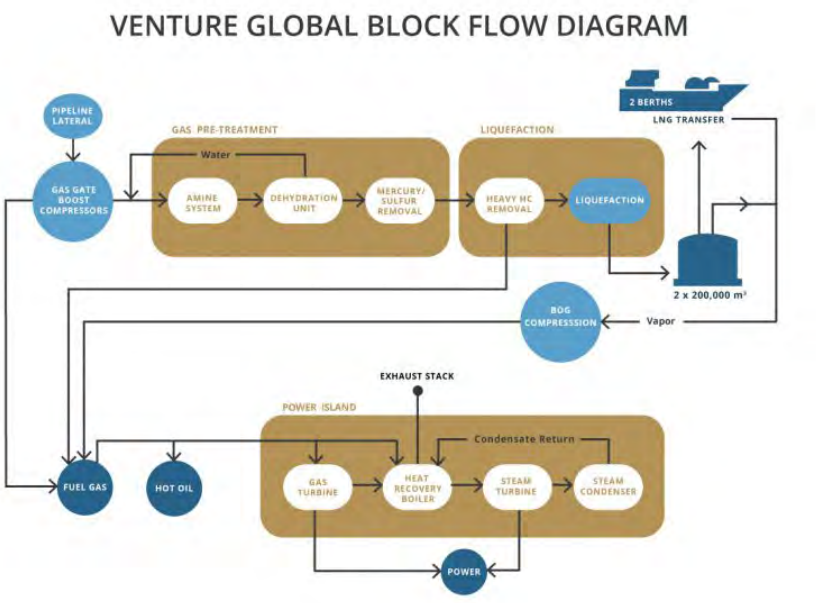

The Calcasieu Pass LNG project in Louisiana

2019, the company was awarded 90 million m.t. per annum (MTPA) of LNG contracts.

Projects include LNG Canada in British Columbia, Golden Pass LNG in Texas, BP's Greater Tortue Ahmeyim floating LNG in Africa, Mozambique LNG and Calcasieu Pass LNG in Louisiana. That adds up to dozens of compressors and GTs.

Hot on the heels of a best ever year, Baker Hughes received an order for six 7EA GTs and twelve centrifugal compressors for three LNG trains with a capacity of 16 MTPA of LNG for the Golden Pass LNG export facility in Sabine Pass, Texas. Golden Pass is being jointly developed by ExxonMobil and Qatar Petroleum.

Baker Hughes is also providing turbomachinery for the Calcasieu Pass LNG and the Greater Tortue Ahmeyim FLNG project. The later will consist of four trains using the PGT25+G4 aeroderivative GT to drive a centrifugal compressor.

Global energy firm Jera is a major participant in the Freeport LNG project in Texas that started commercial operation for its first liquefaction train at the end of 2019. It produces LNG for export from natural gas procured in the U.S. When all three trains at Freeport are operational, its capacity will be 15 MTPA.

Venture Global is developing several LNG projects in the U.S. This includes Plaquemines LNG in Louisiana. It consists of 18 liquefaction blocks, each with a capacity of 1.2 MTPA.

It has 200,000 cubic meter LNG storage tanks with cryogenic pipeline connections to the plant and the three docks that can host ocean-going vessels.

Each ship can pick up to 185,000 m3 per load. Its combined cycle power plant has a capacity of 611 MW. A second project phase will double the power plant's capacity.

Rendering of the Rio Grande LNG project

Venture Global is also involved in the Calcasieu Pass project, which will have nine 1.2 MTPA liquefaction blocks and two 200,000 cubic meter LNG storage tanks. There will be two 0.6 MTPA trains per block, each with an electric driver.

The combined cycle power plant will use feed gas and boil off gas to produce power to drive the electric motors of the liquefiers. A 5 x 2 GT-to-steam-turbine configuration makes maintenance easier while maintaining production.

An LM6000 aeroderivative GT will also be placed on site for startup and peaking needs. The project has 20-year LNG sale and purchase agreements with Shell, BP, Edison, Galp, Repsol and PGNiG. Additionally, Venture Global is developing the 20 MTPA Delta LNG project in Louisiana.

LNG development specialist NextDecade is working on an export terminal for Permian Basin shale gas. The 27 MTPA Rio Grande LNG facility is in Brownsville, Texas. The 4.5 Bcf/d Rio Bravo Pipeline will funnel gas from Agua Dulce, TX to the export terminal.

NextDecade hired Bechtel for engineering, procurement, and construction (EPC). The first phase of Rio Grande LNG consists of three liquefaction trains, two 180,000 cubic meter storage tanks and two marine berths.

Each liquefaction train is expected to have a capacity of up to 5.87 MTPA. Technology providers include Air Products and Baker Hughes. It should commence operations in 2023.

"Once we get the first two trains running, we can add more trains easily as the costs go down," said Matt Schatzman, Chairman & CEO of NextDecade. "Cheniere LNG already has six trains, and we are adding a third train at the Corpus Christi LNG facility."

World LNG tour

The U.S. is far from the only game in town. Projects are popping up all over the globe. Jera reports projects as far apart as Africa and Canada. Jera provides receiving and storage facilities to the LNG market.

Its assets include 7.74 million cubic kiloliters of LNG tank capacity, representing 40% of the Japanese total as well as eight LNG receiving terminals. Hendrik Gordenker, Chief Global Strategist at Jera, noted that there are so many more sources of LNG than before, citing Canada and Mozambique as recent examples.

"LNG competitors include renewables, coal and pipeline gas," Gordenker said. "New markets face a lot of invest-

Cover Story continues on page 20

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Dredging at the marine offloading facility in the Douglas Channel in British Columbia as part of repurposing the wharf so it can receive LNG carriers

ment to establish the terminals, turbomachinery and transport for LNG."

LNG Canada, for example, is an export facility under construction in Kitimat, British Columbia. A joint venture between Royal Dutch Shell, Petronas, PetroChina, Mitsubishi and Korea Gas, it will consist of two LNG processing trains. LNG Canada represents the largest private sector investment in Canadian history. And it should be operational around 2025, according to Peter Zebedee, CEO of LNG Canada.

Extensive preparation work has been done including clearing away vegetation, dredging to allow for the large LNG carriers to berth at its jetties, and construction of a village to house 4,500 workers. It is permitted to export 28 mtpa of LNG annually.

The project is part of Canada's reaction to the shrinkage of U.S. demand for Canadian oil and gas. Canada traditionally sold almost all its natural gas to its southern neighbor. But the low price of U.S. shale gas changed everything. Now Canada's abundant supply of natural gas is looking for new markets in Asia.

"Our advantage is that 93% of our electrical power is hydro-based and this makes for production of some of the cleanest LNG in the world," said Zebedee. "Independent benchmarking studies show that LNG Canada will emit 50% fewer greenhouse gas emissions than the average facility, and 30% fewer than the best performing facility."

Nigeria LNG consists of six trains capable of producing 22 mtpa of LNG. A typical train consists of GE 7EA GT drivers for Baker Hughes 3MCL horizontally split centrifugal compressors, AN200 axial compressors and 2BCL radially split centrifugal compressors. On the power generation side, the train uses four GE Frame 6B GTs.

The company boasts 23 ships that delivered close to 5,000 cargoes to date. It currently has 200 Tcf (trillion cubic feet) of proven reserves with the potential for up to 600 Tcf — lots of room for expansion in Nigeria. Thus, a seventh train is under development to bring annual production capacity to 30 mtpa.

Tony Attah, CEO of Nigeria LNG, said his company has reduced gas flaring from 65% to less than 20% with more work being done to bring it down further.

Oman LNG operates three liquefaction trains with a capacity of 10.4 MTPA. The company is adding a new gas engine-driven power plant by MAN Energy Solutions. Oman LNG recently inked a deal to supply 1.1 MTPA of LNG to BP Singapore for seven years.

Australia has been a star in the LNG world for some time. It is on track to surpass Qatar as the world's top exporter. Australia's capacity is around 11.4 Bcfd (billion cubic feet per day), following eight big LNG projects coming online since 2012: Wheatstone, Ichthys, Pluto, Gorgon, Queensland Curtis, Gladstone, Australia Pacific and Prelude. Gorgon, off the northwest coast, for example, produces 15.6 MTPA of LNG via three trains.

Hitoshi Okawa, Executive Vice President Australia for Japanese oil & gas company Inpex, the developer of the Ichthys LNG project, said his company is backing LNG and natural gas as a long-term and fundamental solution for the low-carbon economy.

As a result, the company is shifting its portfolio from oil to gas. It used to hold 80% oil and 20% gas. It has reduced its oil holdings to 60% and is aiming for 50%.

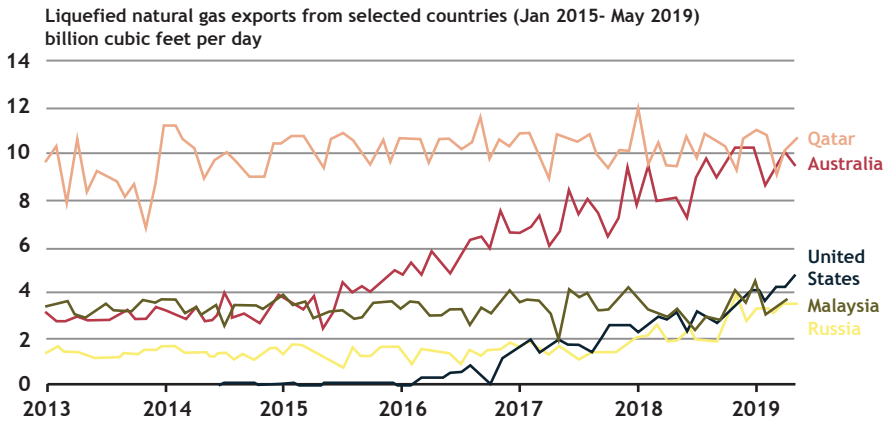
"Without gas and LNG, we won't have growth," said Okawa.

Mark Gvetvay, CFO of Russian natural gas producer Novatek, touted Russia as being highly gasified yet having a low carbon footprint. Natural gas is far more than a short-term transition fuel, he says.

His company is involved in building more infrastructure to support rapid expansion of Asian markets which currently lack the capacity to store LNG. This includes Arctic LNG 2 in Siberia, due to open around 2023.

Once operational, Arctic LNG 2 will have a production capacity of almost 20

Oman LNG operates three turbomachinery trains with a capacity of 10.4 MTPA



MTPA. Novatek is working with Italy's Saipem to build offshore platforms for Arctic LNG 2. Train two and three of Yamal LNG are operational, taking that site to 16.5 MTPA.

LNG is everywhere

The sheer volume of cheaper LNG coming onto the market is opening the door to LNG-fueled transportation. Nigeria LNG is using some of its natural gas reserves to provide alternatives to the wood-burning fuel prevalent in the nation.

Chart Industries, a company that has supplied cryogenic equipment for LNG to 71 countries (including cold boxes and brazed aluminum heat exchangers for Venture Global's 10 MTPA Calcasieu Pass LNG export terminal project in Louisiana) is installing LNG fueling terminals around the world.

According to President & CEO Jill Evanko, Chart completed the installation and commissioning of Europe's largest LNG fueling station for Alternoil on Germany's main A1 highway. Chart's Saturation on the Fly technology eliminates methane emissions and recognizes both spark-ignited and compression engines. This allows the station to fuel all LNG trucks, regardless of original equipment manufacturer or brand.

Further, truck maker Iveco has announced an LNG truck that can travel 1,200 km per load. And recent tightening of shipping regulations is forcing many carriers to consider switching from diesel to LNG.

Fueled by consumer, industrial and power generation consumption, LNG expansion is predicted to continue for some time. Global LNG demand is expected to double to 700 million m.t. by 2040. South and Southeast Asia are expected to generate more than half of the increased demand over the next two decades.

But even in regions avowedly anti-gas, LNG terminals multiply. The reality is that natural gas is in high demand, and LNG is often the easiest way to get it to these markets.

"The LNG market is growing and that will continue for a long time to come," said Mike Sabel, Co- Founder & Co-CEO and Founder, Venture Global. "The current growth potential is greatly underestimated." ■

Lorenzo Simonelli delivered the opening keynote to a highest ever crowd

BAKER HUGHES UNFETTERED

BAKER HUGHES MOVES ON FROM GE, PUSHES AI, DIGITALIZATION, 3D PRINTING AND CARBON CAPTURE

DREW ROBB

Baker Hughes merged with GE Oil & Gas a couple of years ago to form BHGE. That relationship is over. Baker Hughes has emerged as an end-to-end oil & gas giant in its own right. It has absorbed just about all the assets of GE Oil & Gas including a vast turbomachinery portfolio.

The recent separation did not impact attendance at the 21st Annual Meeting (AM). In fact, the opposite turned out to be the case. The AM boasted a highest ever turnout of 1,750, according to Lorenzo Simonelli, Chairman and CEO, Baker Hughes.

"These are challenging times with new attitudes and expectations," he said. "The world needs more energy, and more from energy." He added that the industry has to be competitive with alternatives while remaining reliable, safe and efficient.

The company is in the midst of lowering its carbon footprint. The answer, he said, begins and ends with technology. Baker Hughes, for example, has developed offshore directional drilling accomplished via a remote operations center situated onshore.

Another initiative revolves around digital transformation. The company is harnessing artificial intelligence (AI) to identify maintenance issues. One example cited by Simonelli was a large plant where AI detected 52 valves in critical condition.

"Digital is not easy so we are creating an ecosystem to address it," said Simonelli.

A big part of this is partnerships with Microsoft Azure and an AI company called C3.ai. Baker Hughes' joint venture alliance with C3.ai is called BakerHughesC3.ai. They recently launched the jointly developed BHC3 Production Optimization. It is an AI-based application that allows well operators to view real-time production data, better project future production and optimize operations for improved oil and gas production rates.

"Energy companies globally are being challenged to make operations more efficient, safer and more productive," said Ed Abbo, president and CTO, C3.ai. "To do this, they will need to analyze massive amounts of data for actionable insights."

This AI-based application continuously uses machine-learning algorithms to quickly aggregate historical and real-time data across production operations. It creates a virtual representation of production from individual and multiple wells to the pipeline, distribution and point-of-sale.

It also detects anomalies, forecasts pro-

duction and prescribes actions to improve performance. Engineers can use it to pinpoint which injection wells to tune for higher output.

"BHC3 Production Optimization delivers the data visibility and optimization capabilities critical for upstream businesses to meet production targets during a time of growing energy demand," said Derek Mathieson, Chief Marketing and Technology Officer, Baker Hughes. "It generates flow rate, pressure and temperature predictions of hydrocarbon production and flow across wells, pipelines, and network assets."

Microsoft's role in the partnership with Baker Hughes and C3.ai is to harness its Microsoft Azure cloud computing platform and AI microservices to host AI solutions. Shell, for example, is using the C3.ai platform on Microsoft Azure to accelerate digital transformation across its business, improve efficiencies, increase safety and reduce environmental impact, according to Jay Crotts, CIO of Shell Group.

Shell is also using AI to implement predictive maintainence of rigs and turbomachinery, and for reservoir modeling. One rig records 30,000 measurements a minute, and encompasses the monitoring of half a million valves.

IT guru

The Annual Meeting featured a keynote from legendary IT guru, Tom Siebel, now CEO of C3.ai. His credentials date back 40 years to being one of the original developers of the Oracle database, as well as the founder of Siebel Systems, a company that pioneered customer relationship management (CRM) software.

Siebel called the chance to partner with Baker Hughes and Microsoft Azure to address the world's energy needs, "the professional opportunity of a lifetime."

AI for maintenance is the "killer app" for the energy sector, he said. Predictive maintenance with high accuracy has the potential to save billions in terms of inventory and running costs, avoided downtime and overall productivity, he added.

One example: The U.S. Air Force has been using this technology to increase the availability of its fleet from 50% to 85%.

Siebel claims his company has reduced the complexity of AI from 1013 to 103. He labeled the power grid as the largest and most complex machine in the world, one that involves staggering data volumes. That data can be analyzed to initiate big changes in power and oil & gas management.

Take the case of European energy company Enel. It already operates 42 million smart meters in Spain and Italy. In addition, 75 million sensors feed data into the system. That adds up to 65 billion data updates per day, according to Siebel.

The exhibit featured turbomachinery and software from Baker Hughes and its partners

Adding AI to wind turbines, conventional generation and millions of kilometers of transmission network has enormous potential, he said. Enel is using AI for fraud detection in regions where the theft of electricity is commonplace. The system can help detect it at an early point.

"We are analyzing compressor operation in real time with models," said Siebel. "This can help prevent leaks, reduce greenhouse gases and eliminate unscheduled downtime."

At Baker Hughes, initial efforts are centered around the optimization of Bently Nevada systems.

"Baker Hughes is way ahead of others in oil & gas," said Siebel. "We are witnessing a massive market shift as oil & gas businesses undergo enterprise-level digital transformation to improve efficiencies and increase safety, while simultaneously reducing environmental impact."

Another area of marked technology shift is additive manufacturing (AM) or 3D printing. At its manufacturing plant in Florence, Baker Hughes produced more than 20,000 3D-printed parts last year.

In total, 450 parts are qualified for 3D printing within its catalog. Scott Parent, Vice President of Engineering and Technology, Baker Hughes said this includes printed parts for gas turbines, compressors and drilling equipment.

AM is used to enhance product design and reduce assembly through part consolidation. A CT scanner scans 3D parts during inspection. The gathered information is looped back to the design, engineering and production stages to improve components and equipment.

Most design tools are oriented to subtractive manufacturing, said Parent. With AM, it is now possible to print multiple materials with various geometries at the same time, i.e., plastic, metal and glass can be laid down on the same part rather than having other materials press-fit, bolted or welded.

"This capability enables us to go back to the design stage and make improvements," said Parent. "AI allows us to consider better geometries, understand thermal constraints, develop far more rapidly and then print that part directly."

He offered a drill bit example. These components suffer wear as they pummel through rock strata in search of oil. Typically, subjective evaluation is done to determine if a bit can continue to operate effectively, needs repaired or should be thrown away.

Methods are now evolving whereby the bit can be scanned and the digitalized information can be reviewed against operational wear patterns to determine the best course. That data can also be used to improve its design or to get another bit more fitted to conditions underground, which can vary significantly.

And if the bit needs repair, a printer can be used to return it to service within 24 to 48 hours. Additionally, Baker Hughes used AI to determine optimal bit design based on various constraints. That offered up a wide range of options, and each one used about 50% less material.

"We are refining technology to be able to reprint a bit to make it more optimal for a specific site," said Parent

Luca Maria Rossi, Vice President Technology of Turbomachinery & Process Solutions, continued in a similar vein. He said Baker Hughes has a long-term plan to

place more printers around the world to eliminate supply chain bottlenecks. If the Talamona plant in Italy becomes backed up, parts could be printed elsewhere and sent rapidly to wherever they need to be.

The latest effort is to reduce the number of hot gas path components and speed development time. A hot gas component prototype such as a fuel nozzle is now developed 50% faster. LM9000 and NovaLT turbine components such as fuel nozzles are currently being produced using additive manufacturing. Printing of legacy vanes has been added and limited series production has been introduced.

Rossi said the next chapter will be the development of gas turbine rotating components that require the overcoming of the strength limitations of current materials. But he expected technology to be able to solve those problems soon.

Casting of parts will not go away. The choice of one technology (AM) versus the other (traditional casting) is driven by economic analysis for a particular component or use case.

There are limitations imposed by the size of printers, though. A turbine casing is too big to print, for example. But machines are getting bigger. Even casting companies are turning to 3D printing to create molds, as well as tooling for casting.

Destination Gas

In recent years, some have tried to label natural gas as no more than a transition fuel between coal and renewables. Simonelli addressed the role of natural gas in our energy future.

"Gas is not a transition fuel, it is a destination fuel," he said. "Gas demand is going to increase by 32% in the coming years."

The switch from coal to natural gas has eliminated 500 million tons of CO_2 in recent years, he added. Baker Hughes is also researching the use of hydrogen in gas turbines and has reconfigured its NovaLT gas turbine generator technology to operate 100% on hydrogen.

Fatih Birol, Executive Director, International Energy Agency (IEA), continued the environmental theme. Global emissions have hit historic high, he said, because of the rise of the SUV. A decade ago, SUVs accounted for 18% of worldwide car sales.

Now they account for 42%, and produce 25% more CO2 than the average car. Meanwhile, between 2000 and today, global coal consumption has risen by 65% despite the end of coal being widely publicized.

Birol noted that U.S. shale will continue to dominate oil markets for many years. Although its dramatic growth is set to slow a little, the resources are there to maintain output and reach almost 20 million barrels per day by 2030.

The worldwide combined market share of OPEC and Russian oil production has dropped from almost 55% in 2005 to 48% today and will fall to about 46% by 2030. This limits their ability to dictate market prices, added Birol.

"Oil will lose ground to electricity in terms of consumed energy, and oil demand growth will slow as a result," he said. "Oil use for road transportation will gradually flatten off."

Natural gas demand, on the other hand, is predicted to be strong for some time. This, said Birol, will be mainly driven by China, SE Asia and India. Food processing, textiles, fertilizers and other industries are further drivers.

To reduce emissions, he recommended a switch from coal to gas in power plants, more renewables and the implementation of carbon capture, utilization and storage (CCUS).

"Fossil fuels are stubborn: they are likely to have a stable 63% share of the market for another 20 years despite cheaper renewables," said Birol.

His belief is that all energy technologies are needed to solve the world's energy. As a result, it would be a mistake to cut investment in oil and gas.

"We need oil and gas and we need more investment to keep fields productive, efficient and with their emissions lowered," said Birol. "Reducing methane emissions, for example, can be easily done without the need for new technologies." BP, for example, is implementing Baker Hughes FlareIQ solution to reduce methane emissions from its oil and gas facilities.

U.S view

Steven Winberg, Assistant Secretary for Fossil Energy, U.S. DOE, outlined his nation's, "All of the above" energy strategy.

"We don't think it is necessary to pick one energy source over another," said Winberg. "Technology development has in the past, and will in the future, take us where we need to be."

He dismissed the latest wave of environmental forecasts, saying that technology has always stepped up to the plate and solved the problem. He sees CCUS as being vital to meeting any emissions goals, but it needs more investment in demonstration projects.

He touted the U.S. as a leader in this area, having spent $200 million a year for more than a decade.

"We need to reduce the cost of carbon capture from $60 a ton to $30 a ton to achieve broader adoption," said Winberg.

He thinks we have not yet climbed the learning curve on unconventional oil and gas. AI and other technologies can be used to see what is really under the shale plays. That could be a game changer that doubles production, he predicted.

Naomi Boness from the Natural Gas Initiative at Stanford University challenged the ongoing narrative to eliminate fossil fuels, particularly natural gas. She explained that there is quite a difference in emissions between the various fossil fuels, with natural gas being by far the cleanest.

"Natural gas has a big role to play in our energy future," said Boness.

In the state of California, solar farms, rooftop installations, and wind can provide about half of the electrical energy consumed at noon. However, fast forward to the evening and it drops to less than 20%. Natural gas generation takes over.

To eliminate the large amount of flaring of natural gas in places like Texas and North Dakota, the Natural Gas Initiative calls for more pipelines to be built to

This year's event had a highest ever attendance

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channel that gas to the Northeast and other areas which are subject to seasonal gas shortages.

As a result of current bottlenecks and scarcities, gas prices routinely spike in New England and New York despite the nation having an abundance of gas. A year ago, the spot price of natural gas in New York rose to $140 per million per Btu (it averages around $4).

Yet that state has begun outlawing new natural gas installations in residential new-builds and is largely opposed to new pipeline projects.

The solution to methane leakage and flaring (a major contributor to greenhouse gas emissions) is well within existing technologies — better valves, efficient maintenance and more pipelines. Yet some states are actively preventing their implementation based on local environmental considerations. The Natural Gas Initiative believes a wider view is necessary.

It advocates that the best thing for the environment, public health and the climate is to move away from coal and toward natural gas as quickly as possible. Dismissing fossil fuels from the energy mix at an arbitrarily rapid rate would be destructive to the global energy system.

The show featured several panels from industry leaders

Carbon capture

With coal and natural gas unlikely to disappear from the global scene anytime soon, CCUS is receiving more attention. CCS Stefano Maione, Chief Development, Operations & Technology Officer at Eni, views CCUS as a necessity in achieving emissions goals. His company, for example, has set an upstream net-zero emissions target by 2030.

Currently, the worldwide capture capacity is 35 million tons of CO_2 per year (30 of that is in the U.S.). Maione called for a 15% per year capacity growth in CCUS to achieve 3 gigatons per annum of carbon capture by 2050.

That, in turn, requires 30 to 60 storage facilities to be added per year, as well as pipelines that can feed CO_2 to those centralized storage facilities.

Eni has developed the eCCS-lens platform encompassing capture, transportation, subsurface modeling, monitoring and more. The company is involved in five CCUS projects with one already operating in Norway with Equinor (Sleipner). Others under development include two sites in UK, one in Libya and one in United Arab Emirates.

In tandem with CCUS innovation, some are pushing the development of hydrogen-fueled turbines. Marco Alvera, CEO of European gas utility Snam, is promoting the use of hydrogen produced from renewable sources.

Snam is experimenting with up to 10% hydrogen mixed with natural gas in its pipeline network. According to a study commissioned by Snam, hydrogen could cover almost a quarter (23%) of the Italian energy demand by 2050.

"In the long term, gas is no longer seen only as a fuel for the transition but as a pillar of a decarbonized world, particularly in the various sectors with limited possibilities for electrification," said Alvera. "This role will be strengthened thanks to the rapid development of renewable gases, particularly the biomethane supply chain."

Further, Snam is working to reduce methane emissions by 40% by 2025 (based on 2016). This is being achieved through the application of a methane leak detection and repair campaign, component replacement, and the adoption of the latest technologies.

"Italy is positioned to be a hub for green hydrogen from North African solar fed into Europe," saic Alvera.

Snam is working with Baker Hughes to prepare compressors and other assets for hydrogen use. The idea is to harness renewables to generate renewable gases that can be fed into the pipeline network.

Another environmental initiative touted at the show is green ammonia (CO_2-free ammonia). Sam Muraki, Chairman of the Green Ammonia Consortium explained the difficulty in using renewables as they are often far from major markets.

Current thinking is to use renewables to produce hydrogen and transport it in liquid form. Muraki thinks ammonia is the most economical way to do this, and it can be combusted without CO_2 emissions. Large players in the fertilizer industry, such as Yara and OCP have launched green ammonia pilot plants.

Specific to the power sector, Mitsubishi Hitachi Power Systems, is involved in ammonia co-firing with coal in thermal boilers, i.e., a coal-burning power plant replaces some of its fuel with up to 20% carbon-free ammonia.

Another MHPS initiative entails the extraction of hydrogen from ammonia. If made economically viable, this could solidify the business case for hydrogen-fueled gas turbines. Ammonia is much easier to store transport than hydrogen.

Digitalization

What does Formula 1 racing have to do with oil & gas? A lot, it turns out, when you factor in digitalization and analytics. Mark Gallagher, a Formula 1 Data Scientist, delivered a keynote at the AM on the power of this technology.

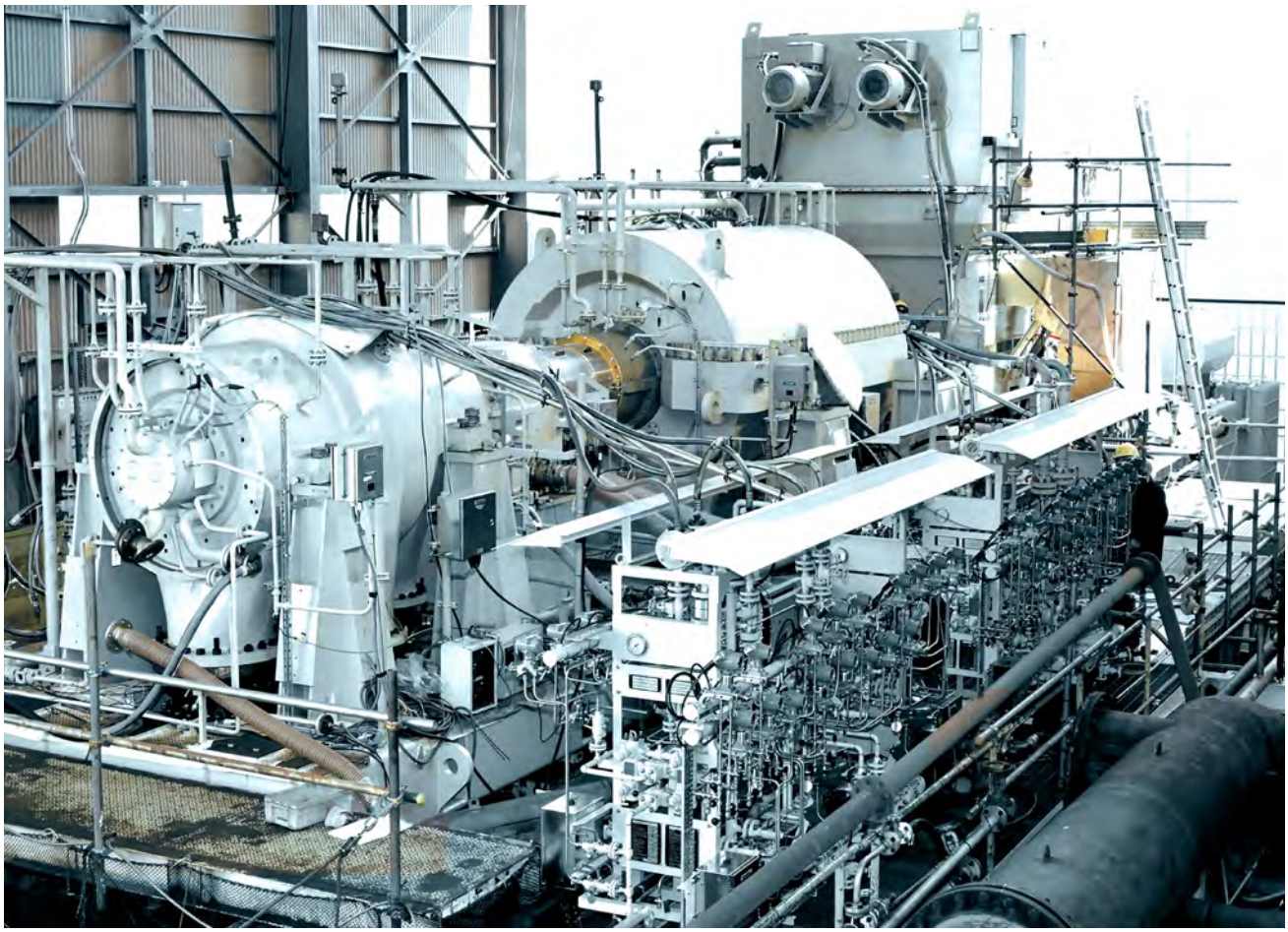
For the first 20 years of the sport, it was all about speed: how to make the cars go faster. The second twenty were mainly devoted to lighter aerospace materials and aerodynamics. Now it is all about digitalization and data science.

"The first 40 years saw 45 driver deaths," he said. "The last 25 years have witnessed only a single fatal outcome."

Data enables better decisions, engineered systems and integrated systems. Digitalization has empowered engineers, maintenance staff and drivers.

World champion Lewis Hamilton is a case in point. He finished every race last season. Drive too fast and you risk wearing out the tires. It is optimized driving that wins races. And so it is in power generation and oil & gas: optimization of gas turbines and compressors. "Data minimizes human error," said Gallagher.■

MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP



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COMPRESSOR MONITORING AND CONTROL

TOP TRENDS INCLUDE SOFTWARE-AS-A-SERVICE, INTERNET OF THINGS AND DIGITAL TRANSFORMATION

BY TIM SHEA

Compressor monitoring and controls are critical for optimizing the performance of compressors widely used across the oil & gas, refining, chemical and petrochemical industries.

Economic drivers include the growing demand for energy, improving compressor efficiency and increasing production of compressor-related products.

Further drivers include emerging Industrial Internet of Things (IoT)-enabled tools, such as advanced analytics, machine learning, and enhanced communications to enable remote monitoring of compressors and other complex rotating equipment. These will help users realize greater performance, higher compressor uptime, and lower maintenance costs.

In addition to greenfield installations, many legacy control systems will require upgrades to extend the life of the compressor. These upgrades will enhance functionality and boost their performance capability.

Software-as-a-Service

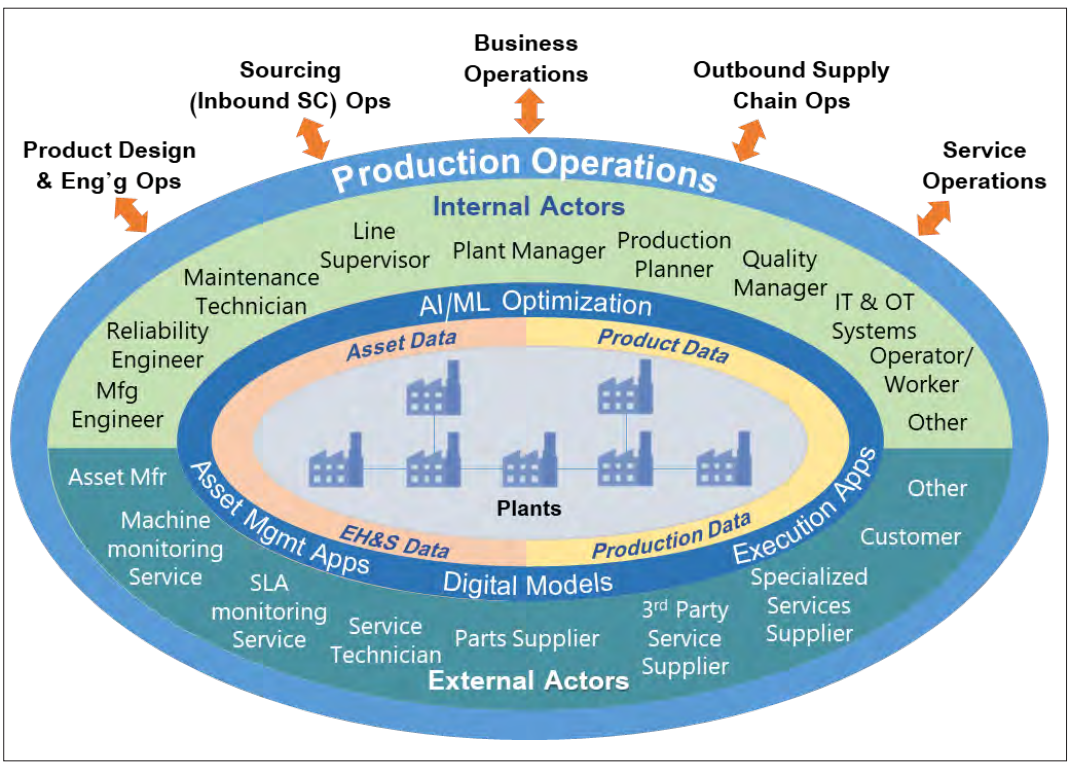
The marketplace for compressors and their related monitoring and controls solutions is now evolving at a face pace. Demand for service-based compressor monitoring and controls is expected to outpace that of hardware- and software-based products over the next five years as a growing number of operators and end users decide to outsource some or all of their compressor monitoring and controls.

This is typically known as Software-as-a-Service (SaaS) or Platform-as-a-Service (PaaS). SaaS is a model where the user buys a subscription-based license. The software itself is hosted in the cloud. Benefits include little or no upfront costs and no need to maintain the software as that is taken care of by the provider.

Most vendors in this space focus on compressor controls. But expect to see more robust growth for systems that have a primary function of monitoring as users seek to leverage Industrial IoT-enabled solutions for asset performance management and compressor optimization.

Most companies today employ on-premise compressor monitoring and controls. A small fraction are hosted by their compressor OEM via a remote service program. The latter segment will experience solid growth.

Similarly, there will be robust growth for the currently tiny share deployed via the cloud. Users are overcoming their fears about operating in the cloud and beginning to embrace the benefits of lower total cost of ownership, more flexible operations, and access to the world-class security and ana-



lytics of companies, such as Microsoft, AWS and Google.

The advent of smart, connected compressors is opening the doors to new business models. Suppliers can now become providers of services, such as compressed air-as-a-service or natural gas compression. Many are already offering remote monitoring and control services as users struggle to do more with fewer personnel.

Digital transformation

Industrial IoT-enabled tools can provide business and operational value across many areas. However, rotating equipment, such as compressors, turbines and pumps, represents the lowest hanging fruit for operators and end users.

Compressor monitoring and controls solutions are increasingly being updated with new features to fulfill market demands and increase their value proposition. Smart Industrial IoT-connected compressors provide opportunities to increase operational efficiency from the plant floor (or the platform) to the supply chain by optimizing data, information and analytics. In the centrifugal compressor space, for example, monitoring and control packages are focusing on several areas:

- Pushing out performance of the surge line
- Reducing instances of stall
- Optimizing load distribution
- Using analytics to help optimize centrifugal compressor performance and increase or extend the life of the compressor.

Data gathering and communication capabilities via standard networking technologies are built-in features of some compressor monitoring and controls solutions. With the Industrial IoT, smart compressors could improve industrial processes. This, in turn, would drive the use of more automation.

In addition, the Industrial IoT offers opportunities to apply new kinds of business models that will promote growth. Suppliers in this space may start selling contract compression services along with compressor hardware or could partner with compressor manufacturers or packagers to offer remote monitoring and control services for a monthly or yearly fee.

As the shift to LNG from oil grows and demand for natural gas grows, the need for compression will increase. Downstream manufacturing operations have become increasingly dependent upon the performance and availability of compressors.

To increase availability, monitoring and controls providers need to incorporate technological innovations, such as Industrial IoT, to increase reliability, optimize load control, and — for centrifugal compressors — operate closer to their maximum designed performance or surge line.

Continuing innovation in sensors, embedded control algorithms and predictive condition monitoring are critical to the future of smarter compressors. Some users are specifying future-proof compressor monitoring and controls that are Industrial IoT-ready.

In addition, the growing adoption of cloud- and edge-based solutions will help optimize compressor performance. Digitally enabled approaches that leverage artificial intelligence, machine learning, enhanced communications and software can go a long way towards realizing operational excellence.■

Tim Shea is Senior Analyst at ARC Advisory Group in Dedham, Massachusetts, a company specializing in technology market research firm for industry, manufacturing, infrastructure and cities. For more information on ARC's recently published Compressor Monitoring & Controls Market Analysis Report, contact tshea@arcweb.com

EDGE BREAK

BRINGING HANDHELD 3D-MEASUREMENT AND ANALYSIS TO THE SHOP FLOOR

BY KRAMER LINDELL

Sharp edges and corners on nearly all machined parts in turbomachinery are typically "broken" in a process called edge break. It is accomplished in one of two ways: by rounding off the corner, creating a radius, or by machining a flat to reduce the sharpness of the edge transition, creating what is known as a chamfer.

Performing this operation serves different purposes depending on the application. For parts subject to high stresses, radiused and chamfered edges are necessary to limit possible fracture points along the edge when under high loads, in seal teeth, for example.

Other components where edges have a large effect on air flow, such as turbine blades and nozzles, have tight edge-break tolerances to ensure proper performance. Chamfer geometries are precisely controlled when using fasteners to ensure the fastener does not protrude from the rest of the part, as in shafts and casings.

In addition to these functional reasons, sharp edges can pose a safety risk to those coming into contact with parts. Due to this, radii and chamfers are key parameters that have thousands of call outs throughout gas turbines, centrifugal pumps, steam turbines and other turbomachinery. MRO and new make shops have a need to quickly and accurately make radius and chamfer measurements.

Producers of machined parts have become reliant on interferometric optical metrology to quantify surfaces and geometries. Optical metrology comes in many different levels of accuracy, prices, forms and uses. Shop-floor, 3D-measurement systems save time and improve an inspector's accuracy.

Parts do not have to be moved to a measurement laboratory for characterization, and 3D measurement eliminates errors associated with misalignment of a 2D trace against a radius or edge.

Shop floor systems are also necessary because some objects, such as turbine blades, shafts or engine cowlings are too large to be tested using a laboratory-based stylus or 3D microscope system. Additionally, 3D optical measurement systems provide non-contact measurements. Some optical systems are immune to vibrations.

Currently on the shop floor, edge-break geometries are measured to with various two-dimensional methods including visual tests and contact or laser-based line profiles. Visual tests are inherently subjective. They can vary depending on inspector, lighting, and alignment of the visual comparator.

More importantly, a visual test provides no quantifiable data. These methods may be quick and efficient. But they do not provide data either accurate or consistent enough to keep pace with the tolerances of the turbomachinery industry.

Perhaps the most common instrument-based method for assessing edge break and chamfer geometries is use of a portable 2D stylus profiler, which may in some cases be placed on the object.

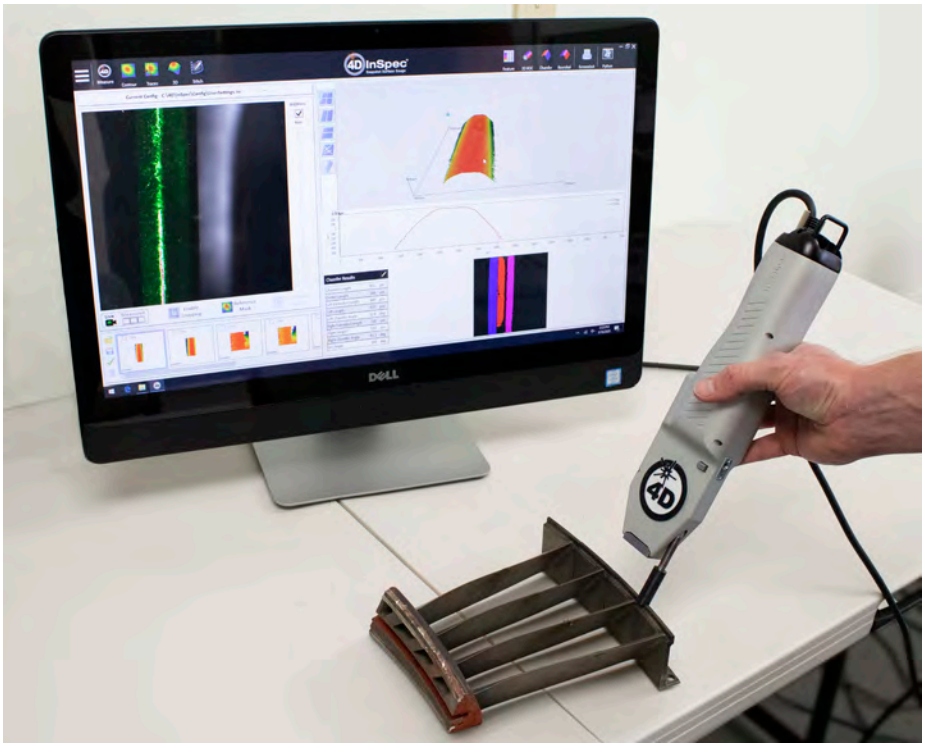
This system suffers from alignment errors, is affected by vibration and can struggle to measure over sharp edges without breaking the stylus tip. In addition, stylus profilers for shop-floor use have a limited vertical range and may not be able to measure large chamfers on machined holes.

That is why some sites use multiple inspectors to take the same measurement and decide on the actual value later. Due to setup time and scan time, it can take more than 30 minutes to achieve a single high-quality trace.

Another approach has been the use of a replication material to make a facsimile of the edge. From there, cross-sections of the replication material can be taken as close to perpendicular to the radius or chamfer as possible.

These cross-sections are analyzed in an optical comparator or shadowgraph. This process is time consuming and only accurate if the cross-sections are perpendicular to the radius or chamfer.

Laser-based gauge guns can provide some shop-floor capability for edge-break and chamfer measurements, but only over a single line. Further, alignment errors persist, and variations in the geometry across the edge are not



The analysis program on this handheld edge-break gauge, known as 4D InSpec, detects and calculates radius of curvature of an edge break on this turbine blade part.
Courtesy of 4D Technology Corp.

assessed. With lateral and vertical resolutions of tens of micrometers, they cannot measure fine geometries. Material finish, reflectivity and slope can also affect measurement when using laser-based gauges

In order to accurately assess radii and chamfers, 3D surface data must be taken and analyzed. 3D data can be acquired on the shop-floor using fringe projection or structured light systems.

Structured light systems acquire 3D surface maps by projecting lines onto a surface. Based on the way the lines are distorted, a 3D reconstruction of the surface can be created. Such systems typically require multiple cameras or camera frames to analyze the distortion of the projected fringes, preventing structured light measurements from being instantaneous, vibration immune and handheld.

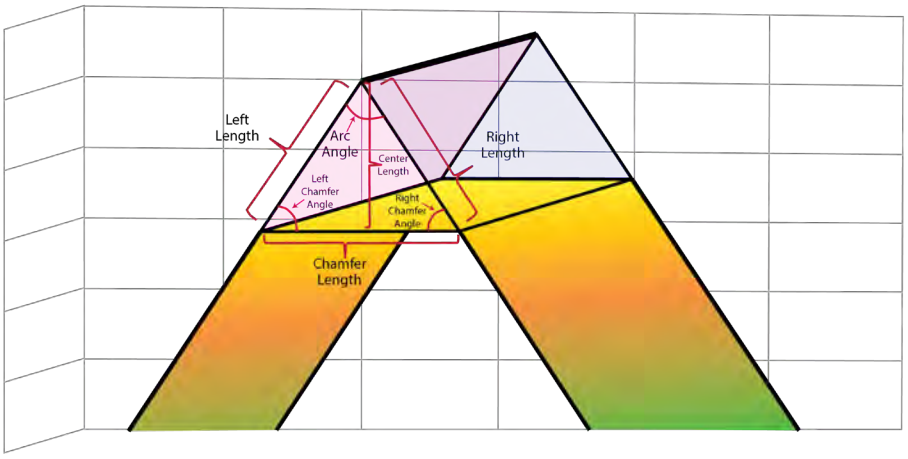


Figure 1: Chamfer geometries. Courtesy of 4D Technology Corp.

Instantaneous measurement

Instantaneous measurements with a fringe projection system must be done with a single camera in one frame. This can be achieved on the shop floor using polarized-structured-light systems to map small geometries in three dimensions.

Calculating edge-break and chamfer geometries accurately requires a capable measurement system as well as extensive data processing to adequately section the data and perform all required calculations.

In a two-dimensional measurement system, a line is fitted to each of the two sides of the corner. The radiused or chamfered portion of the trace is determined by looking at when the best-fit lines deviate by some set amount from the surface trace.

For an edge break radius calculation, a best-fit circle is fitted to the trace that resides between the two end points of the lines. For a chamfer calculation, the linear distance between those end points is calculated.

In addition, other parameters are typically calculated, such as the length of the extensions of each side to where they intersect, the angle between the two sides of the trace, and others (Figures 1 and 2).

Typical tolerances on lengths for precision machined parts are around 150 micrometers and on radius are on the order of 300 micrometers. For gauge-capable results, in which errors due to reproducibility and repeatability of the measurements are considered negligible, you typically will need a measurement system to have resolution at least 10 times better than the tolerances.

Polarized structured light, which can exhibit vertical resolution better than 2 micrometers over a 2.5mm vertical range, provides an adequate solution.

To successfully analyze chamfers, rounded edges, and the radius of curvature of cylindrical objects, polarized-structured-light software can process measurements in several ways. Chamfer and radius dimensions are guaranteed to be perpendicular to the edge. This removes the cosine errors seen with 2D measurements. The software extrapolates the dimensions of the removed edge material from the analyzed data.

For production lines, reduced uncertainty generally leads to an increase in yield. Inspectors no longer need to reject parts to avoid the risk of a potentially bad part going further in the production process.

Putting 3D measurement in the hands of an inspector on a shop floor provides an efficient way to quantify edge break callouts in turbomachinery. Using millions of data points in 3D surface maps and analyzing these geometries mathematically removes any uncertainty and inaccuracy caused by 2D measurement. ■

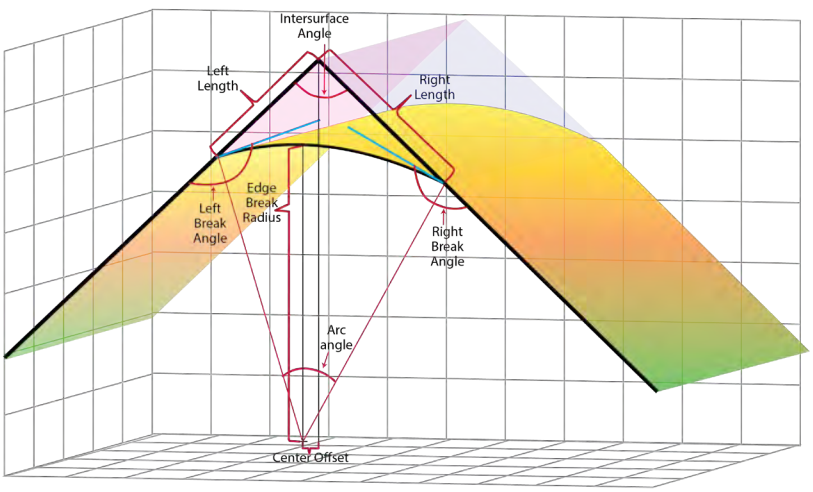


Figure 2: Rounded edge geometries. Courtesy of 4D Technology Corp.

Kramer Lindell is an Application Engineer at 4D Technology Corp., a company specializing in high precision, instantaneous measurement of surface shapes. 4D Technology is an Onto Innovation business. For more about the 4D InSpec product, visit 4dInSpec.com or write to 4Dinfo@nanometrics.com

HIGH SUB-SYNCHRONOUS VIBRATION

HOW TO ADDRESS VIBRATION IN A TURBOEXPANDER EQUIPPED WITH ACTIVE MAGNETIC BEARINGS

TADEH AVETIAN, LUIS E. RODRIGUEZ AND JUNYOUNG PARK

Turboexpanders (TEX) are standard in the natural gas industry for liquefaction and dew point control. They are also used in the petrochemical, air separation, refrigeration and power generation industries.

The TEX expansion stage consists of a radial inflow turbine, often with variable-position inlet guide vanes. The compression stage is comprised of a centrifugal compressor stage with a vaneless diffuser.

Many traditional machines featured hydrodynamic oil bearings for supporting and controlling vibration. Active magnetic bearing (AMB) technology, offering operational and environmental advantages (Figure 1), was recently introduced in newer machines.

Forces can be induced due to cross-coupled stiffness by aerodynamic interactions between rotating and stationary components. If high enough, this may induce unstable vibrations that impact the mechanical performance of the machine and even lead to failure.

The inlet of a typical expander is located downstream of the gas-liquid separator thus, the expander inlet gas is saturated. This impacts the thermodynamic state of the TEX inlet. The gas composition commonly exhibits a retrograde dew point. A retrograde dew point is a point on the vapor-liquid equilibrium line in a phase diagram in which a decrease in temperature or pressure results in condensing of the gas, ultimately leading to liquids entering the TEX (Figures 2 and 3).

The inlet gas is accelerated through the inlet guide vanes (IGVs) leading to high swirl or tangential velocity. This swirling gas enters the expander wheel, which is ideally spinning fast enough such that its blade tip speed matches the gas swirl velocity.

The work performed by the gas is absorbed by the compressor, thereby losing angular momentum as it travels through the expander wheel. This power balance occurs at a speed based on the design and sizing of the expander and compressor wheels.

Most TEXs are designed with a 50% reaction turbine. Accordingly, the expander wheel usually has a high velocity, two-phase fluid surrounding its outer diameter. The aerodynamic forces on the rotor due to this complex flow are not well understood, particularly regarding their effects on lateral rotordynamics.

Troubled machine start-up

Take the case of a TEX that was unable to reach design speed because it suffered several trips on high sub-synchronous vibration (~40-50% of the rotation speed)

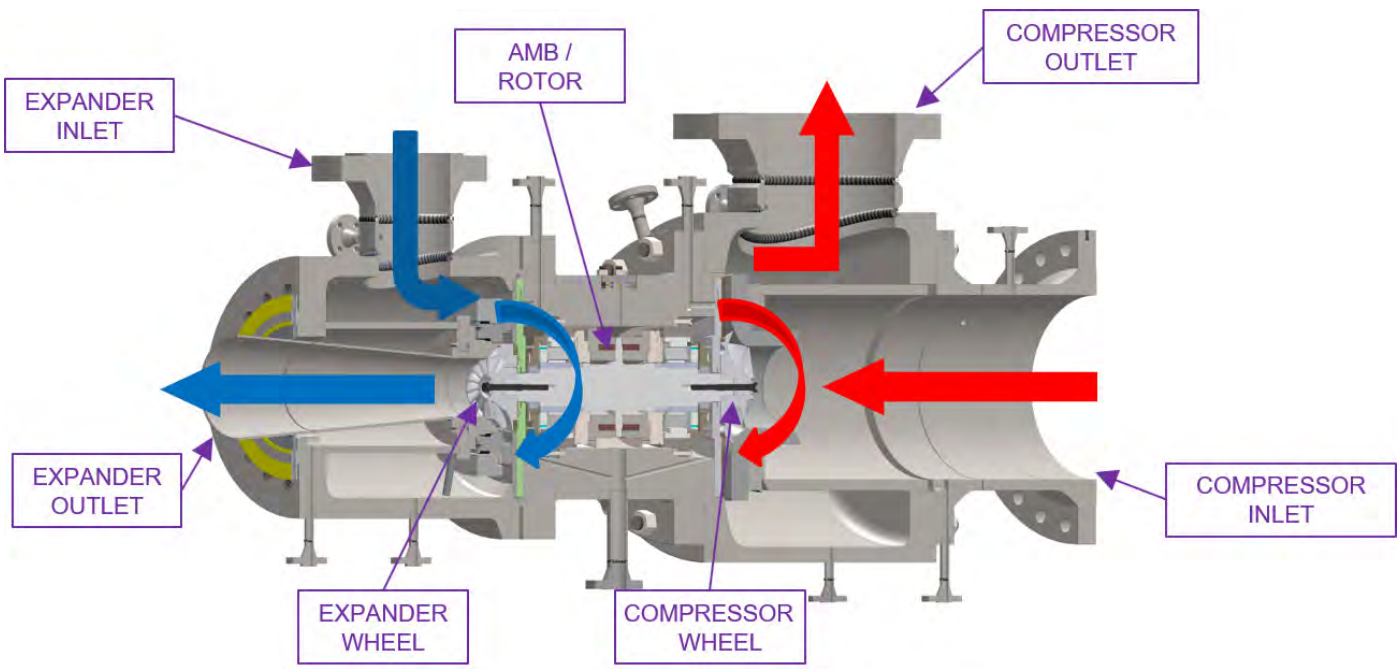


Figure 1: Typical turboexpander design equipped with active magnetic bearings

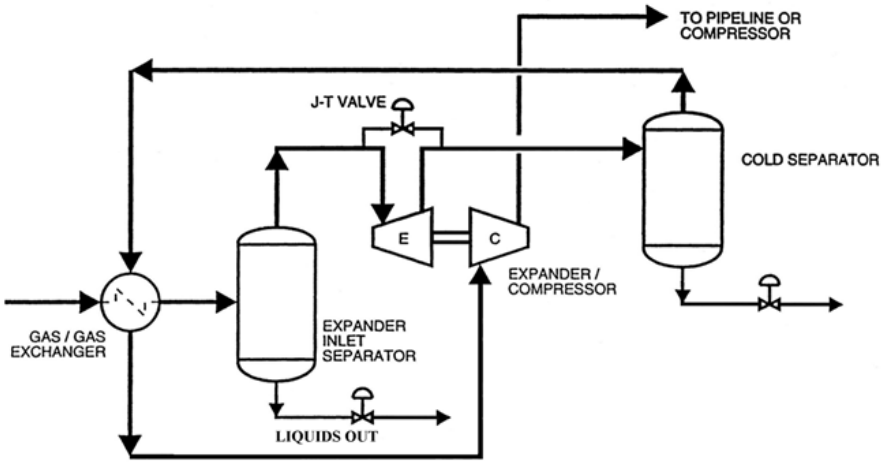


Figure 2: Typical natural gas liquefaction process

at a speed of around 15,000 rpm. The amplitude of vibration on the expander side bearing peaked to as high as 4 mils while the trip level was set at 3 mils.

At first, it was thought that reducing the amount of liquids present around the wheel outer diameter (OD), as well as the swirl velocity, would alleviate the problem. The theory was that liquid was being trapped in the wheel cavity causing the instability.

An attempt was made to operate the machine with the IGV in almost fully open position, using the expander inlet valve to attempt to regulate flow. However, the machine tripped again due to high sub-synchronous vibration.

It was taken offline and removed for teardown and inspection. The seal was cleaned and the clearances opened to help evacuate trapped liquids from the wheel cavity. The machine was then re-assembled and tested using different ramp rates. These attempts were unsuccessful as the machine was only stable for a short period of time before it would trip.

Various other unsuccessful remedies included ensuring dry gas was supplied to the expander inlet, adding heat tracing and insulation, and revising the design and sizing of the inlet separator. Operational improvements brought process conditions closer to design conditions.

However, the machine kept tripping due to high sub-synchronous vibration, now at ~21,500 rpm. Additionally, the AMB supplier maximized the stiffness and damping of the AMBs by modifying the controller. The unit could now reach ~25,000 rpm before tripping again (still falling short of design capacity).

The only recourse left was to reduce the cross-coupling effects by means of an invasive re-design to reduce liquid formation after the inlet guide vanes, reduce swirl velocity and add damping at seal locations.

The first two goals are best achieved via an aerodynamic re-design of the expander wheel. A shroudless wheel was desirable due to its superior aerodynamic performance. Whatever advantages are afforded by a shroudless wheel, they could not outweigh the risks of a structural failure. In such a high visibility situation, a shrouded wheel was selected.

High density and high swirl velocity were thought to be the key contributors to cross-coupling effects, i.e., the amount of liquid leads to an increase in density. Increasing the pressure at the wheel outer diameter, then, would have the largest benefit (a reduction in cross-coupled stiffness), and a shrouded wheel would maximize this benefit.

The OEM predicted the redesigned expander wheel would increase wheel inlet pressure by ~20%, increase wheel inlet density by ~15%, reduce liquid content by ~14%, and reduce swirl velocity by ~13%.

The third goal of the re-design was to add damping at the seals in the expander wheel. Shrouded wheels are usually equipped with two seal areas, one in the back and one in the front. The original labyrinth seals were replaced by pocket damper seals (PDS) (Figure 4).

They introduced a higher direct damping coefficient (which attenuates vibrations), as well as a reduction in cross-coupled stiffness (to eliminate sub-synchronous instabilities). The PDS features narrow-width rectangular cavities in which gas pockets form. The rotating shaft and pressure pulsations inside the pocket tend to oppose rotor vibration. Also, partition walls in the pockets obstruct gas swirl.

This type of seal operates at an increased clearance and thus suffers from increased seal leakage, leading to reduced wheel efficiency. However, the pocket-damper seal design offered more damping than a labyrinth seal. In addition, process engineers were confident that the expected reduction in expander efficiency would not jeopardize production requirements.

A rotordynamics analysis suggested PDS seals had the potential to alleviate sub-synchronous vibration. The redesign included: an expander wheel with reduced discharge flow area (maximized the pressure at the outer diameter of the expander wheel to reduce swirl velocity); pocket damper seals (reduced cross-coupled stiffness and added direct damping); and PDS equipped with integral swirl brakes. Due to these modifications, the TEX could operate at full capacity with negligible vibration.

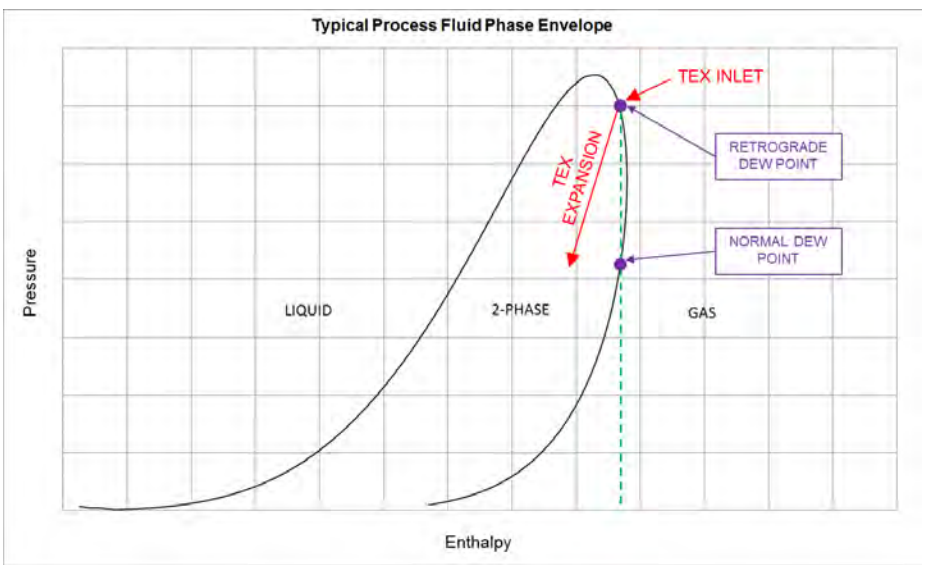


Figure 3: Typical natural gas phase diagram

The root cause for the high sub-synchronous vibration problem stemmed from aerodynamic cross-coupled forces induced by the expander wheel and labyrinth seals. This exceeded the stabilizing capabilities of the AMB system.

These forces are poorly understood, and the lack of analytical tools and experimental data pose a challenge for TEX designers. Currently designers must rely on empirical relationships and rules of thumb to predict these forces.

Recently, a qualitative approach was suggested to provide guidance for TEX design. That approach is covered in a paper presented at the 46th Turbomachinery Symposium, 2019, "Addressing High Sub-Synchronous Vibrations in a Turboexpander Equipped with Active Magnetic Bearings," by Avetian, T.; Rodriguez, L.E.; and Park, J. ■

Figure 4: Redesigned front wheel seals

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Junyoung Park, Ph.D is the Rotating Machinery Leader Engineer at Samsung Engineering. For more information, visit SamsungEngineering.com.

WHAT CONSTITUTES THE IDEAL INLET AIR FILTER?

Stuart Blackburn, Product Management Director at AAF International, discusses his company, evolving market trends and what constitutes a good filter for gas turbines.

Tell our readers about AAF

AAF International was founded in 1921 and specializes in air filtration across residential, industrial and commercial applications. Founded in Louisville, Kentucky, it now has office and manufacturing locations around the world.

Since the 1960s, AAF has focused on the gas turbine (GT) air inlet filtration market, suitable for all GT technologies across a wide range of applications and environments. The focus of the business is to ensure GT owners and operators can extract the maximum plant performance, availability and reliability by using optimized air inlet filtration systems.

As well as upgrading existing installations, AAF supplies OEMs with new equipment, including air inlet filtration systems, inlet heating and cooling, acoustic enclosures and exhaust systems.

What trends have you noticed with regard to filtration?

There is a growing need for inlet filter system optimization. GT air inlet systems present far higher levels of complexity and individuality than previously appreciated. Owners and operators have begun to understand the benefits available from optimizing these systems to improve performance, availability and reliability, while reducing operating costs and CO_2 emissions.

Solutions need to be individual, and based on operational requirements and environmental conditions. A tailored approach increases inlet air quality, reduces offline water washing frequency and reduces GT maintenance spend.

What changes have you observed in the GT marketplace?

Customers are moving away from traditional F-grade filters and upgrading to high performance(H)EPA filters. Their positive impacts outweigh initial filter supply costs.

The higher the operating hours, the more likely you are to see the greatest benefit. But it is dependent on the plant's contractual arrangements. Overall, high-efficiency filters have grown in popularity and low cost, low-performance filters are viewed as a false economy.

What advice would you pass on to GT users?

Air inlet filters represent the largest consumable spend on a GT power plant outside of the hot section. This makes them a high priority for spend reduction initiatives.

The benefits derived from optimizing filter systems can be many multiples of the filter cost. Therefore, don't be fixated on filter cost. Instead, focus on total cost of ownership (TCO), by taking into account performance, longevity, GT maintenance and other factors.

Also, be sure to understand environmental operating conditions: do you have periods of high dust concentration or high humidity, extreme temperature or driving rain, seasonal pollen or insect swarms, high levels of industrial pollution or a high concentration of hydrocarbons? For example, regular early morning fog requires a filtration system that can remove moisture without spikes in differential pressure.

What constitutes a good filter for GTs?

The filter efficiency grade and the filter media are significant features, as well as how the filter deals with varying environmental conditions, and how the construction of the filter affects performance. GTs consume large volumes of air every second. Therefore, a well-designed filter frame and faceguard (or protective screen) add much more than just strength.

Shutdowns, restarts and changing operating conditions lead to large variations in the airflow through the filter system. These turbulent conditions can result in distortion and weakening of the filter over time. A high-strength GT filter supports both the media pack and the filter frame, eliminating the risk of distortion of the filter and deflection of the media pack. This results in extended stable filter life, for optimum performance and protection.

Tell our readers about one of your products

AAF's HydroGT V450+ has a larger media area for higher dust holding capacity. It is designed to maximize protection for GT turbine performance and power output. Its (H)EPA efficiency reduces compressor fouling and the need for offline water washing, resulting in increased machine availability and reduced operational costs.

The frame and protection screen prevent distortion of the media pack over its lifespan. The media repels water, oil, hydrocarbons and salt. Efficient drainage ensures performance is maintained and the GT remains protected, even during moist and humid conditions.

What other products and services do you offer?

AAF Optimize is a new web-based platform to help operators understand TCO. It contains details on over 33,000 GTs around the world. Based on site location, it can understand environmental challenges and weather data. An operator enters operating data to establish existing TCO and to evaluate how this figure could be improved with better filtration.

What changes have you noticed in the oil & gas market?

In the oil and gas industry, there remains a limited amount of capex spend so operators are keen to find filtration solutions without a major overhaul. Ambient air offshore is heavily contaminated with sea salt aerosols, salt in solution, fog and mist.

Industrial processes such as drilling, grit blast, and mud burn, as well as GT and supply-vessel exhaust fumes further contaminate the air. High velocity (smaller) air inlet filtration systems that use low efficiency bag filters are the norm offshore.

However, these bag filters provide inadequate protection against highly contaminated ambient air. The result is air compressor blade fouling, corrosion, erosion and frequent offline water washing. The AAF N-hance filter provides EPA E12 efficiency and can be retrofitted internally within the existing filter housing with no increase in differential pressure.

MAN ES has released a new lubrication monitoring system

MAN lubrication monitoring system

The MAN Fluid Monitor for lube oil is a light system developed by MAN Energy Solutions (ES). It enables owners to monitor the degradation and contamination of lube oil and protect industrial assets. Used alongside laboratory analyses, it alerts operators with alarms and stop recommendations as soon as it detects a degradation in lube-oil quality revealing minor wear of mechanical parts.

Thanks to swift detection of anomalies, especially important during such sensitive engine phases such as restarts where 50% of damage occurs, this solution allows the operator to anticipate maintenance, protect major components, and identify part-wear before breakdown.

The fluid monitor has recorded over 18,000 test hours on pilot industrial sites, complies with industry standards and has been certified for marine applications. It has received its first order for third-party equipment in the Pacific region.

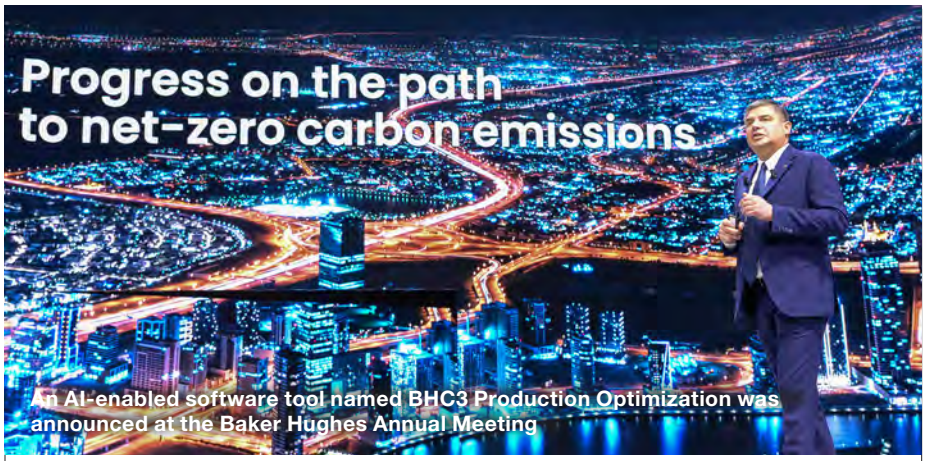
man-es.com

Linear position sensors

H. G. Schaevitz, Alliance Sensors Group released its PG Series LVDT linear position sensors, designed and engineered for valve position sensing applications for steam turbine control systems in electric power generation plants. Previously, these type of sensors were either designed by OEMs decades ago or were catalog LVDTs slightly modified for operation in steam turbines.

Key design features include: cores that cannot break loose; standard body clamps, flange mounts, ball joint couplings, and rod eye ends; two double contact shaft seals prevent contaminants from getting inside the LVDT's bore; and operation in ambient temperature up to 350°F.

alliancesensors.com



An AI-enabled software tool named BHC3 Production Optimization was announced at the Baker Hughes Annual Meeting

AI oil & gas software

BHC3 Production Optimization is an artificial intelligence (AI) software application from Baker Hughes that enables oil & gas production and facility engineers to visualize, analyze, and optimize upstream production operations.

Operators benefit from increased production volumes, quantified dependency scores of injection wells on production wells, more accurate well production reporting, and integrated tools to investigate and take action to prevent production losses.

The software leverages all available data to train AI models of hydrocarbon flow in wells and surface production networks. The models are used to generate a virtual metering network by inferring hydrocarbon state estimations (flow rate, pressure, temperature) from wells, pipelines, and network assets that are inaccurately or only periodically instrumented.

This continuous virtual metering estimation enables operators to allocate production to individual wells, identify injection well optimizations and recommend improvements to address production and sensor issues.

bakerhughes.com

Vibration transmitters

PCB Piezotronics, a subsidiary of MTS Systems, announced the release of Models 682A14 and 682A15, low-cost vibration transmitters designed for use with a 100 mV/g ICP accelerometer. The products were developed for use in process monitoring and PLC/DCS/ SCADA monitoring applications.

pcb.com

New vibration transmitter from PCB Piezotronics

Miratech Catalyzer

Miratech, a supplier of exhaust emissions and acoustic systems for diesel and gaseous-fueled engines, has developed a web-based program to apply and optimize emissions controls, silencers and related hardware.

Miratech Catalyzer software can be used to create exhaust system project calculations for acoustics and system backpressure, along with technical drawings. It assists in the system design of reciprocating diesel and gaseous-fueled engines used in power generation, gas compression, marine, industrial and off-road applications.

It also enables selection and pricing of acoustic products and exhaust accessories. It incorporates a preloaded database containing exhaust and acoustic data from hundreds of the most widely used engines ranging from 30 to 4,000 hp. The program can create a 3D rotatable model of the exhaust system for reference as the user configures a system.

miratechcorp.com

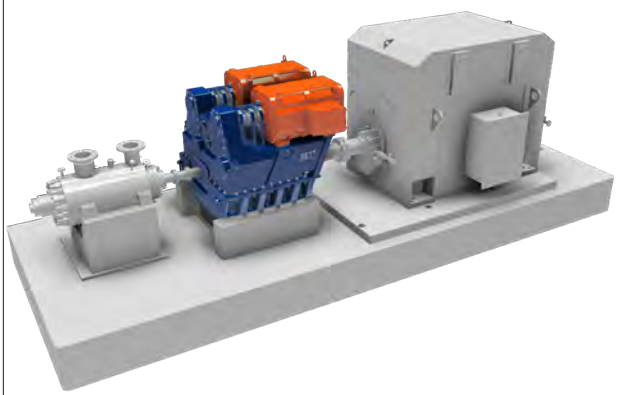
Simpson Eagle digital meter

The Simpson Eagle is a programmable digital meter with a reinforced fiberglass enclosure that protects electronics from harsh environmental conditions. The Eagle meter can measure AC/DC voltage, AC current or frequency.

The user programs the Eagle by computer via an included USB port and cable. The programming can create bar graphs and pre-set alarms that alert operators when an established parameter is out of range. It also can set configurable backlighting that colors the screen white, red or green to instantly indicate the state of the system being monitored. The screen incorporates a message board that displays 4-character custom messages, alarms and annunciators that keep the operator informed.

simpsonelectric.com

Simpson Electric's digital meter



Variable speed gearbox by Set

Variable-speed gearbox

Setcon is a variable-speed gearbox by Set that replaces existing direct drive systems thanks to its speed variability range, efficiency and robustness. Compared to conventional solutions like variable frequency drive (VFD), hydro-dynamic coupling (HDC) or hydro-dynamic variable-speed drive (HDVSD), it produces a higher rate of energy efficiency (up to 97%). The combination of mainly mechanical power transmission and small, low-voltage electronic components results in high performance and reliability.

The smaller package size, lower oil volume and oil cooling, reduced heat generation and air conditioning, and simpler pipework result in lower investment costs. The main drive can be downsized by up to 20% of the total power rating. In most cases Setcon can be retrofitted into existing drive systems without repositioning of the main components. The company has been awarded a contract to install its electro-mechanical differential gear system at a refinery in Germany.

set-solutions.net

Microturbine generator

UAV Turbines announced its Micro-Turbogenerator System (MTS), a compact and lightweight, military-grade generator. It provides first responders, search and rescue, disaster relief and military operations with a power generation source that can easily be transported to remote locations by two people.

These microturbine generators operate with less vibration and a lower noise level than other generators. The MTS can deliver power ranging from 3 kW to 40 kW. UAVT developed it based on its Monarch 1 microturbine.

uavturbines.com

ADINDEX

MYTH: DATA CORRECTION: ALL I NEED ARE THE CURVES

Testing turbomachinery requires corrections between actual test conditions and those originally specified as the acceptance, operating or design conditions. The factory or field test will usually be performed at different ambient conditions, different process gases, and different pressures and temperatures.

As a result, the industry has developed procedures to determine valid conclusions from tests at different operating conditions. Once the machine has left the factory and operates at different conditions from originally specified, how does one correct from one set of conditions to another?

For centrifugal compressors, this procedure is relatively straight forward. The relevant ASME Power Test Code (PTC 10) provides well thought out and proven methods for data correction. Correction and test methods are based on the concept of finding aerodynamically equivalent operating conditions using the fan laws, and keeping Mach number and Reynolds number deviations within prescribed limits.

However, if the machines have multiple sections, intercooling, or incorporate side-streams, data correction analysis can be difficult.

Similarly, for steam turbines, especially the type with condensing flow back-ends, data correction methods are challenging: There is a phase change and liquid fractions must be assumed or measured.

It is important to note that ASME PTC 10 describes the correction procedure for specific operating points, but not for a complete compressor map. This means that if operating conditions range widely, the entire map must be recreated and there is no single correction factor.

The testing of a gas turbine creates a number of different complications. A gas turbine consists of two or more sets of turbomachinery, i.e., there are at least one compressor and one or more turbine sections.

Between the compressor and the turbine, there is a combustor where fuel is converted to heat. This means any method that uses the concepts of aerodynamic similarity is limited by the fact that it is nearly impossible to have all components at aerodynamic similarity at the same time.

Additionally, the parameters that impact performance, such as clearances, do not follow similarity rules and may be dependent on actual temperature levels. As there are multiple aerodynamically and thermodynamically integrated components in a gas turbine, their performance is not independent. This becomes more complicated if the power turbine is tested separately from the gas generator section of the engine.

Correction curves

An easy way out seems to be the creation of correction curves. These are sets of curves that separately correct for engine inlet temperature, ambient pressure, inlet and exhaust losses, relative humidity, power turbine speed, and others. Curves also exist that correct for part-load operation.

At first sight, this may appear to be a perfectly valid approach. Unfortunately, these correction factors are not independent. If they were independent, the only action needed would be to multiply all individual correction factors to yield the overall correction for power and efficiency at any given site condition. But that is an incorrect assumption since these correction factors are physically interdependent.

For example, the impact of relative humidity depends on the engine inlet temperature. Similarly, for two-shaft generator sets, even though the generator runs at a constant speed, the power turbine driving the generator operates at various distances from optimum, which depends on ambient conditions and load.

Correction curves do not predict the impact of control settings. And in a gas turbine, clearances are not determined by ambient air conditions, but by temperature levels within the engine. Therefore, even if aerodynamic similarity is accomplished, the running clearances may be different.

The accuracy of curve-based corrections is typically enough for simple troubleshooting and condition monitoring purposes. Such curves can also be used for day-to-day operation monitoring by correcting for ambient temperature and elevation.

The engine is tested at the prevailing ambient temperature. The relative difference between the tested power or efficiency, and the value on the correction curve are calculated. The same relative difference is applied to the curve at the originally specified ambient temperature. This yields the engine performance at that ambient temperature within a reasonable accuracy appropriate for condition monitoring purposes.

What can the operator do when higher accuracy is required? One way is to use the cycle performance deck of the manufacturer. Many condition monitoring systems and digital twin approaches do that. The use of the software, which is usually proprietary, then becomes a trust issue. ■

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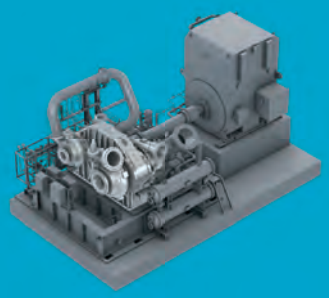

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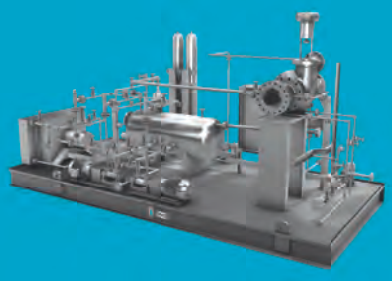
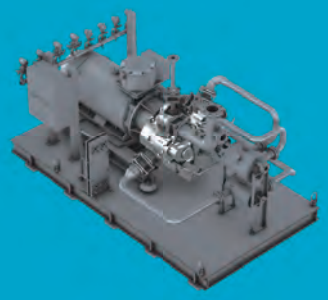


Expander Compressor for NGL recovery

PROCESS SCREW COMPRESSORS



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