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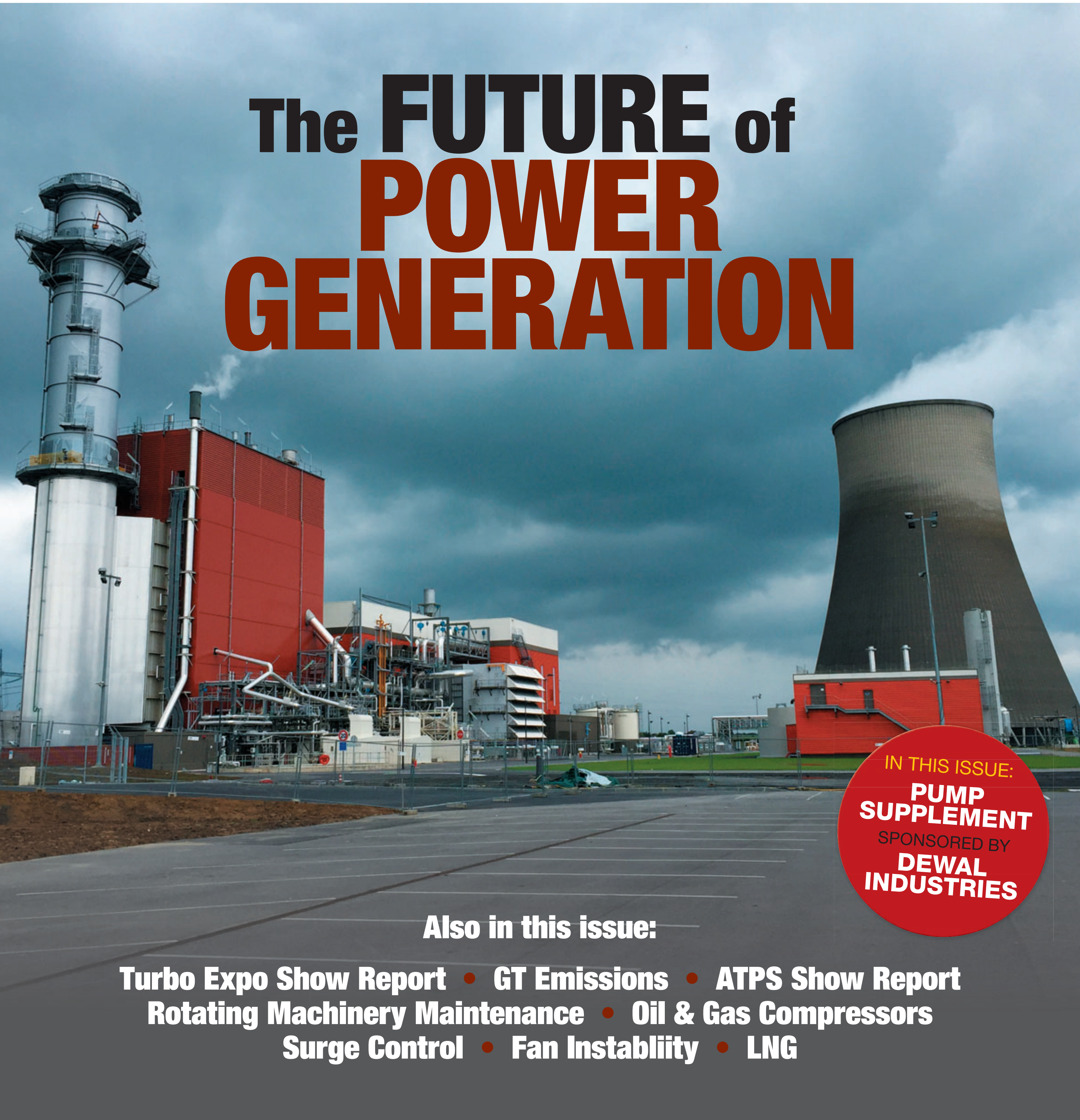

The FUTURE of POWER GENERATION

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Cover image: The Bouchain Power Plant in France harnesses GE HA gas turbines
Courtesy of GE Reports/Tomas Kellner

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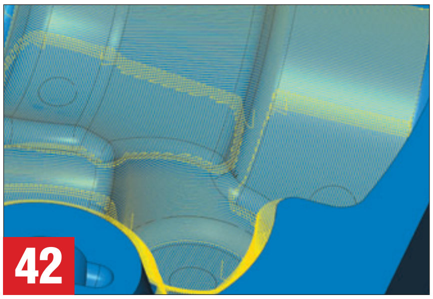

COLUMNS

With coal receiving ten times the R&D funding of natural gas, it is time the industry started to speak up about the benefits of GTs and their role in the future energy mix. This is particularly important in the face of efforts to minimize the value of GTs by policy makers in some regions. The EU, for example, believes GTs can be phased out of power generation by 2030.

Drew Robb

This column addresses how to deal with fan instability and other fan stability issues. It includes a section on how to go about the selection of the right fan for specific applications. Tips include how to match the characteristics of operation for a particular fan with the requirements of the system in which it will operate.

Amin Almasi

Surge is a violent physical phenomenon that occurs in centrifugal compressor systems with the potential to cause significant damage to the compressor. Some advocate that it may be okay to operate in surge, or at least minimize any surge control margin. The Myth Busters disagree. They offer alternatives to increasing the operating range of the compressor that do not involve reduction of the margin.

Rainer Kurz & Klaus Brun

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SPEAK UP

Our cover story is about the future of power generation and how gas turbines will fit into the energy mix. Some startling facts have emerged.

Currently, coal in the U.S. receives 10 times more research funding than gas. Yet coal is statistically in severe decline. In fact, U.S. natural gas generation surpassed coal last year as the top source of delivered power.

Policy makers in Europe consider gas to be no more than a bridging technology for another decade by which time renewables, energy storage and other forms of energy are expected to carry the entire load. The European Union aims to phase out natural gas generation by 2030.

"Renewable advocates are painting gas with the same brush as coal. What is missing is a strong voice from the gas generation camp.

The U.S. has not set similar policy. But states such as California and New York are already taking potshots at gas. This takes the form of defunding upgrades to combined cycle plants and outlawing natural gas use in new homes.

Renewable advocates are painting gas with the same brush as coal. What is missing is a strong voice from the gas generation camp. A few gas advocates are speaking up. You can hear what they have to say in our cover story, in a feature about emissions and in our Q & A column.

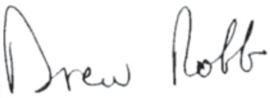
This issue also contains two show reports: The annual Turbo Expo and the ATPS Industry Summit contained an abundance of material on operations, maintenance, new technologies, trends, digitalization, manufacturing techniques, LNG, CHP and much more. Read through our summary of some of the best sessions, keynotes and panel discussions from these events.

Our Myth Busters tackle the idea that it is okay to operate in surge. They take this view to task, lay out the facts and provide sound advice for compressor operators. Meanwhile, our Turbo Tips column discusses centrifugal fans and the various instability issues they may experience.

The Pump Supplement offers useful advice on pump operation, an overview of some of the various kinds of centrifugal pumps and where to run them to achieve maximum efficiency.

In upcoming issues and our annual Turbomachinery Handbook, you can read a report on our visit to the Heat Recovery Steam Generator (HRSG) Forum in Orlando, Florida, another show report from our visit to the Turbomachinery and Pump Symposium in Houston and get up to speed on the latest trends in the U.S. power generation sector as well as on worldwide and regional gas turbine sales.

We look forward to seeing many of you in September at the Turbomachinery & Pump Symposium in Houston. ■



DREW ROBB
Editor-in-Chief

Doosan contract

Doosan Skoda Power has been awarded a contract to supply two steam turbines (STs) with a capacity of 110 MW for a power plant to be built at an oil refinery operated by Petroperú. The Peruvian power plant will be built as part of the Talara Refinery Modernisation (TRM) project. It is to be commissioned at the end of 2019. The project aims to expand capacity to produce gasoline and gas, increase crude oil refining capacity and minimize waste.

Baker Hughes GE

Baker Hughes, a GE company, has been awarded a contract to supply turbomachinery equipment for the first phase of BP's Greater Tortue Ahmeyim floating liquefied natural gas (FLNG) project located offshore Mauritania and Senegal in Africa.

BHGE will provide the technology for four compressor trains for offshore gas liquefaction on board Golar LNG Limited's industry leading FLNG solution, expected to deliver 2.5 million m.t. of LNG per annum. Each of the four trains will consist of a PGT25+G4 aeroderivative GT driving a centrifugal compressor. The GTs and compressors will be manufactured, tested and transported from BHGE's plants in Italy.

Turboden is supplying a new ORC unit to a geothermal plant in El Salvador

Geothermal complex

Turboden signed an agreement with La Geo for the supply of an ORC geothermal power plant in El Salvador at Berlín Geothermal Field. The plant is designed to produce up to 8 MW. The Turboden unit will operate with hot separated brine from a group of wells, without requiring extra drilling, recovering heat at 172°C before reinjection.

Ethos contract

EthosEnergy has recently taken over operations and maintenance of the Louisiana Station power plant for ExxonMobil. This combined cycle cogeneration facility supplies power and steam to an adjacent integrated refining and chemicals complex in Baton Rouge, LA. The five-year contract includes transition services and full care, custody and control of the facility. The Louisiana station consists of gas turbine (GTs), heat recovery steam generators (HRSGs), conventional boilers and STs.

Microturbine order

Capstone Turbine distributer TOO Synergy Astana of Kazakhstan sold a C1000 microturbine to an oil and gas producer operating in Western Kazakhstan. The turbine will be installed this summer. TOO Synergy Astana also secured an order for three C65 microturbines for the expansion of a Kazakhstan pipeline that already uses 60 Capstone microturbines.

Houston shop

Global Compressor, a one-stop-shop for compression parts and service, has expanded its Houston headquarters. The expansion allows for 7,300 square feet of additional space, housing a machine shop and valve repair center, doubling the number of machines onsite. The newly expanded facility will also house additional sales offices, with 35 employees based at the facility. The facility is located at 13415 Emmett Road, Houston, TX 77041.

Kawasaki floating plant

Kawasaki Heavy Industries has developed an LNG floating power plant equipped with its own high-efficiency power generation equipment. This integrated system has LNG fuel tanks, LNG regasification unit, power generation equipment and switchyard all outfitted on the hull.

It is towed on the sea or river and moored at the installation site, where it generates power on the hull that is then supplied to the onshore power grid. When operating as a combined cycle plant, it can provide 80 MW via 2 GTs, 2 HRSGs and an ST.

Demand for this type of power plant is expected to be strong in countries where demand for electricity is rapidly increasing, such as in Southeast Asia, especially on islands or in locations where it is difficult to secure stable power sources, and also in areas with geographical problems such as lack of land for constructing onshore power plants.

Continues on page 10

GE digest

The Kuwaiti Ministry of Electricity & Water (MEW) and GE Power are implementing Total Plant Solution upgrades at MEW's 2,000 MW Sabiya West CCPP. Phase 1 included installing GE's Advanced Gas Path (AGP) GT upgrade, which boosted output of two GTs by 6% and adding 35 MW without any additional fuel.

Once completed, the entire set of upgrades across three power blocks will raise output by 7%. Sabiya West is equipped with six GE 9FA GTs and three GE D11 STs. GE has provided operations and maintenance services at the plant since 2011.

GE Marine's LM2500+G4 gas turbine powers the Italian Navy's new Paolo Thaon di Revel Pattugliatore Polivalente d'Altura (PPA) multipurpose offshore patrol ship. This hybrid-electric powered ship was launched at the Fincantieri Shipyard in La Spezia, Italy.

It will be delivered to the Italian Navy in 2021. Seven PPA ships will be built by Fincantieri by 2026, each using the LM2500+G4 GT. The ship's propulsion plant features small gearbox-mounted motors for low speed operations, two propulsion diesels for mid-speed service and the GT to reach 31 knots.

GE plans to demolish the Inland Empire Energy Center in California that features the steam-cooled H-class GT as the plant is no longer commercially viable in a state where wind and solar dominate. This type of equipment also lacks fast-start capabilities.

The Birdsboro Power Plant started commercial operation using GE's 7HA GT technology. The 485 MW plant is located in Berks County, PA and uses a single GE 7HA.02 heavy duty GT and a D652 ST in a single-shaft configuration.

GE Steam Power will continue providing maintenance services on two turbine islands at the Cernavoda nuclear power plant in Romania under a new agreement with Societatea Nationala Nuclearelectrica (SNN). In addition, GE Steam Power is supplying four nuclear turbine generator sets for Turkey's first nuclear power plant. These include the Arabelle half-speed ST, Gigatop 4-poles generator and condenser vacuum pumps.

MHPS digest

Mitsubishi Hitachi Power Systems (MHPS) signed a memorandum of understanding (MOU) with the Ministry of Energy of the Republic of Uzbekistan and Mitsubishi Corporation. The entities are discussing a Comprehensive Service and Maintenance Program (CSMP) to support the operation and maintenance of thermal power plants in Uzbekistan.

The MOU applies to three power plants: the Navoi plant operated by Thermal Power Plants of Uzbekistan; and two plants currently under construction. MHPS will provide parts supply for the GTs in use at the plants, perform regular inspections and train engineers.

NGK Spark Plug and MHPS have concluded an agreement to establish of a joint venture to manufacture and sell cylindrical cell stacks as the power generating elements found in solid oxide fuel cells (SOFC). The integration of NGK's mass production technologies for ceramics and MHPS' cylindrical cell stack design technologies has resulted in the commercial development of high-performance cylindrical cell stacks.

J-Power USA Development Co. Ltd. (J-Power) has ordered two 1-on-1 M501JAC power trains for the 1,298 MW Jackson Generation Project in Elwood, IL. Carbon dioxide emissions from Illinois' electric power grid have fallen by 32% since 2001, due to retirement of coal-fired power plants and their replacement with a combination of natural gas and renewable power.

This new power project from J-Power continues the decarbonization trend using MHPS GTs. The Jackson Generation Project will also feature MHPS-Tomoni Very Low Load (VLL) technology, which enables each 1-on-1 power train to operate at less than 25% of full load while remaining in emissions compliance.

This allows the Jackson Generation Project to operate at a low output during times of high wind or solar generation and able to ramp up quickly to full load when the renewable resources decline.

MHPS will upgrade its GTs and other components at two Egyptian power plants. It will supply new components for M701F GTS and other generator parts at the 750 MW Siki Krir and El Atf power plants. Siki Krir is located west of Alexandria while El Atf is east of the city.

Pruftechnik acquired

Fluke Corp has acquired Pruftechnik, a condition monitoring and non-destructive testing company that does laser-shaft alignment. Founded in 1948, Fluke offers compact electronic test tools and software for measuring and condition monitoring.

Continues on page 12

Emerson digest

Emerson is partnering with Dragos, developer of the Dragos Platform for industrial cybersecurity asset detection, threat detection and response. The goal is to enable power producers and water utilities to strengthen security of critical assets.

Emerson will integrate the Dragos Platform into its Ovation automation platform as well as its Power and Water Cybersecurity Suite. The Dragos Platform identifies assets and monitors network communications, recognizing threats through intelligence-driven analytics.

Rotating equipment repair boom

A new study by Persistence Market Research shows strong global demand for rotating equipment repair through 2028. This is being driven primarily by the power generation and oil & gas sectors which account for 55% of the market for centrifugal pumps, centrifugal compressors, agitators & mixers, and turbines (gas and steam). The report anticipates global market revenue to surpass $25 billion by 2028.

The repair, refurnish, and retrofit segment of the market is another strong performer. It is predicted to account for a 37% share of the total during the forecast period. Geographically, South Asia, Latin America are predicted to have the most robust growth.

Mobile power

U.S. Well Services (USWS) selected PW Power Systems (PWPS) 30 MW FT8 MobilePac for mobile well stimulation services powered by natural gas. The resulting fracturing operations are said to be quieter, safer and more fuel efficient. USWS uses these aeroderivative GTs to power its Clean Fleet technology. It has to cope with limited space, large and sudden changes in power demand, quiet operation and the ability to move to a new site quickly. USWS has now deployed these units in two additional well pads.

Kobelco Europe

Kobe Steel has established Kobelco Europe (KEU) to serve as the European headquarters for the Kobe Steel Group. KEU grew out of an existing company, Kobelco

Siemens digest

Siemens Water Solutions installed and started up a Zimpro wet air oxidation (WAO) system at a global petrochemical company's olefins plant in the Southern U.S. This is the second Zimpro WAO system supplied to the customer.

It will treat spent caustic generated in the production of ethylene by destroying odorous and high chemical oxygen demand (COD) pollutants. The system also generates an effluent that can be safely neutralized and sent to a biological treatment plant, where it is further treated for discharge.

Siemens will supply the key components and long-term power generation services for the 840 MW Maisan combined cycle power plant (CCPP) in Iraq. CITIC Construction of China and Iraqi developer MPC awarded the contract.

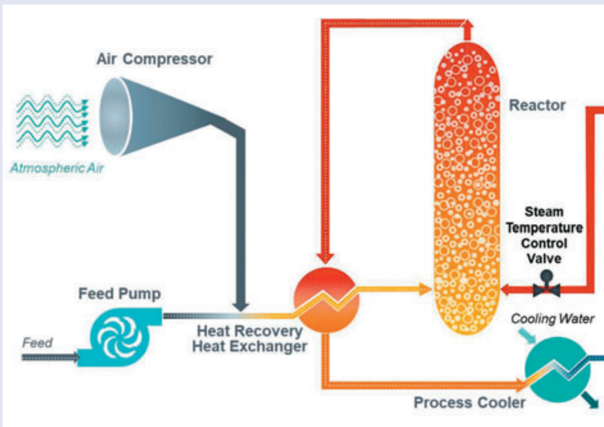
It is expected to deliver power by 2021. The Siemens scope of supply includes two SGT5-4000F GTs, one SST5-4000 ST, and three SGen5-2000H generators, along with the SPPA-T3000 control systems, transformers and related electrical equipment and the fuel gas system.

Siemens will provide MODEC with three 34 MW SGT-A35 GT packages to power a floating production, storage, and offloading (FPSO) vessel "Eni Mexico Area 1 FPSO." It be deployed 6 miles off the coast of Mexico at a depth of 105 feet.

MODEC is responsible for the engineering, procurement, construction (EPC), mobilization, installation, and operation of the FPSO. Once operating in 2021, it is expected to process 90,000 barrels per day (bpd) of crude oil and have a storage capacity of 900,000 barrels.

Siemens will supply a complete power island for the new Yerevan 2 CCPP at the existing plant site in the Armenian capital. The new plant will have a capacity of 250 MW and is expected to go into operation by mid-2021.

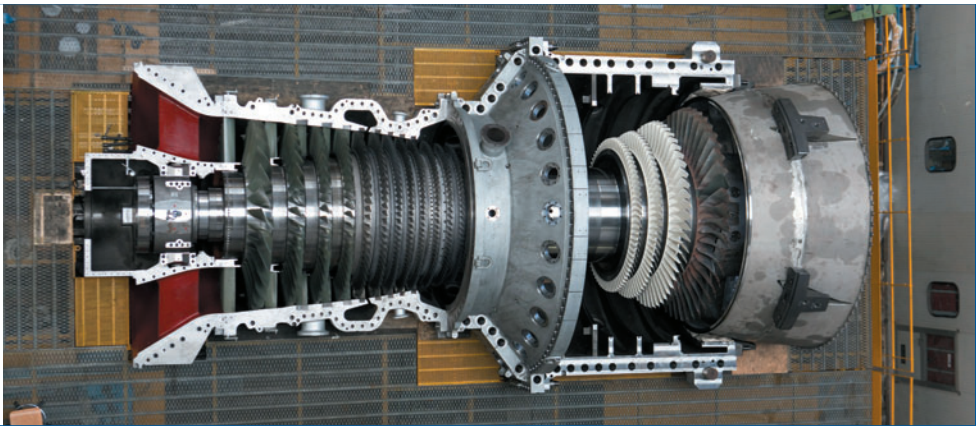
Siemens' scope of supply includes an SGT5-2000E GT, an SST-600 ST, two SGen-100A generators, and the heat recovery steam generator (HRSG). It also covers the SPPA-T3000 control system. The operating and maintenance agreement includes power diagnostic services, support from the Remote Expert Center, and remote operation support.



Flow diagram of Siemens' Zimpro wet air oxidation system

Ansaldo contract

Ansaldo Energia has been awarded an EPC contract for the design, supply and installation of an open-cycle thermoelectric power plant with an installed power of 300 MW in Irsching, in southern Bavaria (Germany). Irsching 6 will be equipped with an AE94.3A GT, its generator and auxiliary systems. The plant will be operational by October 2022.



Ansaldo Energia AE94.3A gas turbine

Machinery Europe (KME) in Munich, Germany.

KME was established in 2012 as a base for Kobe Steel's Machinery Business in Europe, mainly the marketing of non-standard compressors and tire and rubber machinery. KEU plans to continue the business activities of KME, while strengthening the management of Kobe Steel's operations in Europe, starting with corporate governance and compliance. KEU will be responsible for the Group's locations in the Middle East.

Mobile power

APR has signed a contract with Saavi Energía of Mexico to help address power supply issues which may occur in the Mexicali area when connected plants are brought offline for maintenance services. Three mobile GTs have been ordered to supplement the grid by producing power as needed during high-demand times. ■

MAN ES is helping develop large-scale hydrogen storage systems

MAN digest

MAN Energy Solutions (ES), Hydrogenious LOHC Technologies and Frames Group signed an agreement to jointly design and build large-scale hydrogen storage systems based on Liquid Organic Hydrogen Carrier (LOHC) technology.

Heat transfer oil is used as a carrier for hydrogen, allowing it to be stored under ambient conditions. The process triples the amount of hydrogen that can be transported compared to standard pressurized containers. As a first step, systems with hydrogen capacities of 5 and 12 tons per day are being developed.

MAN ES has been awarded a contract to support the front-end engineering and design (FEED) study of a subsea compression solution for the Chevron-operated Jansz-Io field in Western Australia.

Jansz-Io will be the first gas field outside Norway with subsea compression. It is 200 kilometers off the north-west coast at a depth of 1,350 meters. It is part of the Gorgon liquefied natural gas (LNG) project designed to produce 15.6 million metric tons of LNG per year.

The subsea infrastructure will also be used to transport the gas from the Jansz-Io offshore field to Gorgon's onshore facilities with its three LNG processing units. The project also comprises a domestic natural gas plant.

SELECTING & OPERATING FANS

HOW TO DEAL WITH INSTABILITY AND OPERATIONAL PROBLEMS

AMIN ALMASI

Fan selection begins with definition of its characteristics. The fan should be able to provide sufficient energy and pressure to force a volume of gas to reach a specific flow-rate efficiently.

If the fan delivers too much or too little energy, the capacity, pressure or both will be more or less than required. Capacity control devices, such as dampers, variable-speed variable inlet vanes and variable pitch, are often used to adjust operation. The key point in fan selection is to match fan operation with system requirements.

Most fan manufacturers have standard models and families of various sizes. If the blade angles and proportions are the same, the fan family is said to be homologous.

Often, only one fan size in a family of homologous fans will operate at the maximum efficiency point on a given system. If the fan is too big, operation will be left of the best efficiency point (BEP).

If the fan is too small, operation will be right of BEP. In either case the operating point will be off peak and the operation will be inefficient and often unreliable.

Oversized fan

Some experts recommend slightly oversizing a fan to deal with unexpected issues and problems. Due to degradation over time, an extra margin on capacity and power rating are needed.

Also, calculated capacity and pressure might be too idealistic. Actual friction and pressure drop could be more than theoretically calculated. Thus, a 10% to 20% margin is recommended.

However, some applications might be better with a slightly undersized fan for reasons of cost and stability. The primary driver of selection, though, is to find a fan that operates most of the time at or around BEP.

Selecting and rating a fan from a catalog of fan families and models is a matter of fan-system matching. When it is recognized that two of the catalog sizes may be able to provide the capacity and pressure, try each to compare speed, power, cost and so forth. The final choice is a matter of technical and commercial evaluation.

Instability

There may not be any indication of unstable operation. Pressure and power fluctuations that accompany unsteady flow may be so small and rapid that they can only be detected by the most sensitive instruments.

But less rapid fluctuations may be detected on the ordinary instruments used in fan testing. The changes in noise that occur with each change in flow rate are easily detected by ear. The main point is that the overall noise level will be higher under unsteady flow conditions compared with steady flow.

The key point in fan selection is to match fan operation with system requirements.

Many instability conditions occur only when the operating point is to the left of the defined limits of the curve (surge limit). This point (surge point or instability point) is usually the point of maximum pressure on the fan curve. Pulsation and fluctuation can be prevented by rating the fan to the right of the surge point.

Fans are usually selected on this basis, but it is sometimes necessary to control the gas flow delivered to a value below that at the surge point. This may lead to pulsation and fluctuation.

If the required capacity is less than the surge limit, one approach is to bypass or bleed off sufficient gas. In this way, the actual operation is moved to the right side of the surge limit.

Other possible methods are the use of pitch, speed or vane control for flow reduction. In any of these cases, the point of operation on the new fan curve should be to the right of the new surge point.

One condition that is frequently referred to as instability is associated with flow separation in the blade passages of the impeller. It is evidenced by slight discontinuities in the performance curve.

There may be a small range of capacities at which two distinctly different pressures may be developed depending on which of the two flow patterns exist.

Unsteady flow may develop at low capacities. This is known as blowback or puffing as the gas puffs in and out of a portion of the inlet. Operation in the blowback range should be avoided, particularly with high-energy fans.

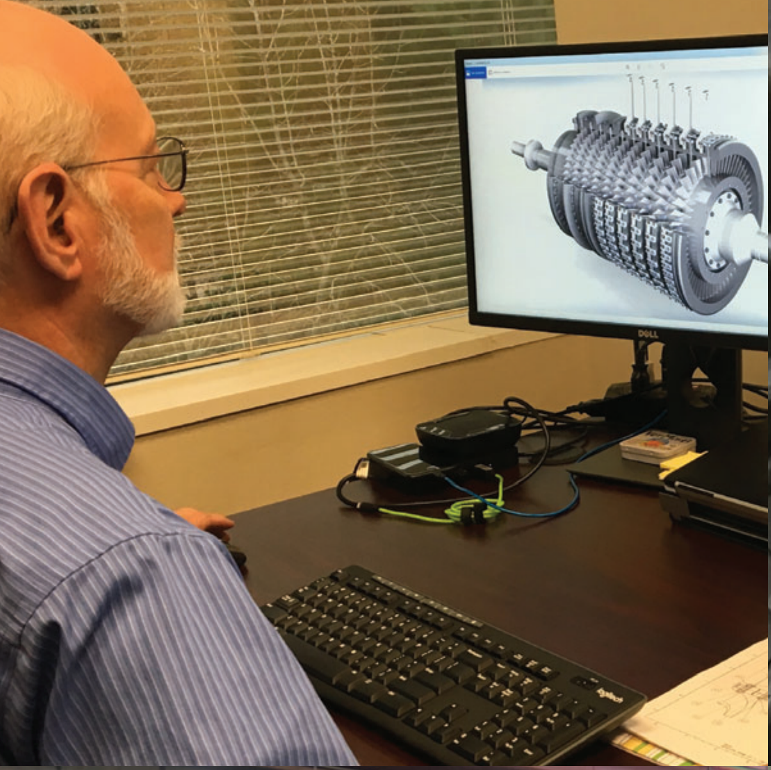
Fans in parallel

A different type of unsteady flow may occur when two or more fans are used in parallel. If the individual fan characteristics exhibit a dip in pressure between surge point and operating point, the combined characteristic will contain points where the point of operation of the individual fans may be widely separated even for identical fans.

If the system characteristic intersects the combined-fan characteristic at such a point, the individual fans may suddenly exchange loads. That is, the fan operating at high capacity may become the one operating at low capacity and vice versa. This can produce undesirable shocks on electric motors and ducts.

Careful matching of the fan to the system is required to avoid such cases. This situation has mainly been reported on forward-curved centrifugal fans and axial fans. ■

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 FUTURE OF POWER GENERATION

KEY CONCERNS: PLANT FLEXIBILITY, LOSS OF TECHNOLOGICAL EXPERTISE, DEFICIENT R&D INVESTMENT AND MORE STRINGENT EMISSION LAWS

BY DREW ROBB

The global power generation industry is undergoing a period of transformation as companies strive to keep up with rising customer expectations, more stringent environmental regulations and a rapidly changing energy landscape. But uncertainty, lack of investment and resistance to change has slowed this process. More funding for gas turbine (GT) research and development (R&D) and a willingness to consider alternative technologies may be the keys to future success.

Recent Electric Power Research Institute (EPRI) surveys of power plant operators reveal that inflexible power plants and the deep loss of technology expertise were top concerns. Those in the executive suite, on the other hand, worry mainly about how CO_2 regulations will impact the future generation mix.

The U.S. National Electrification Assessment cited several scenarios that may play out by 2050:

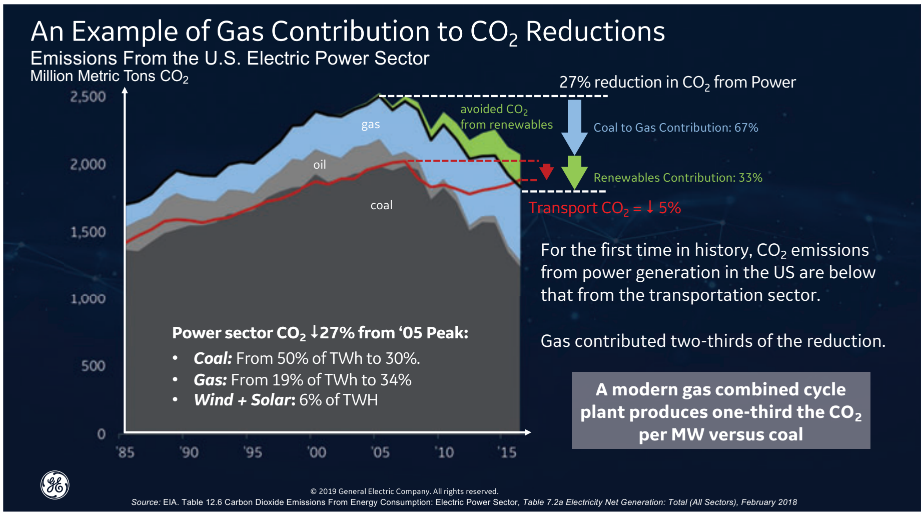
The conservative scenario has coal and nuclear quite slowly declining and gas generation almost doubling over that period. Other scenarios show a steep reduction in coal with only a small amount remaining based on Carbon Capture & Storage (CCS). Along with that, traditional natural gas generation goes into a steep fall after about 2030, with gas CCS helping to maintain the share of gas in the power mix.

"We have seen a 44% drop in CO_2 emissions in the U.S. since 2005, and 80% of that was from the electricity sector," said Thomas Alley, Vice President of Generation at EPRI. "Energy efficiency and cleaner generation have been the reason for these gains. Fuel blending can also help lower CO_2 further."

Alley brought up the famous California duck curve which, he said, is getting more pronounced. 2020 predictions show California needing to add 13,000 MW in 3 hours to cope with the sudden decline of solar generation during the evening peak period.

California may have the most extreme curve, but the same phenomenon is now being noticed in other areas, such as Arizona and even Italy, said Alley.

In such areas, peaking plants pick up



the slack. But the damage from frequent start-ups and shut downs must be addressed in budgeting and in maintenance schedules to eliminate forced outages.

He pointed out that many combine cycle power plants (CCPPs) will reach end-of-life starting in 2030. By then, the industry needs to develop new gas turbine technology that harnesses low carbon fuels.

Government regulations

Nations are passing strict CO_2 emissions laws, and the power generation sector is in the crosshairs. In 2018, the power generation sector produced 36.2 gigatons of CO_2, the bulk from coal.

The German government has announced that it will decommission all of its coal plants by 2030 (106 are currently operating). Several U.S. states are following a similar path. An estimated 60,000 coal plants are operating worldwide.

Emissions regulations gradually forcing coal plant closures are also impacting natural gas-fired facilities. In some quarters, the intention is to eliminate gas, or at least inhibit upgrades and new build.

"Technology investment in gas turbomachinery is key to a lower carbon future," said Guy DeLeonardo, General Manager for Application Engineering, GE Power. "An increase of one percentage point in CCPPs in the U.S. is the equivalent in CO_2 emissions reduction of taking 2 million cars off the road."

"In the U.S., three out of four kWh come from fossil fuels and nuclear," he said. "Natural gas offers the lowest cost per kW of any generation source."

CO_2 levels peaked in 2005. The switch from coal to gas in the power sector has contributed to 67% of the reduction in CO_2 since that peak. Renewables contributed 33%. Additionally, the transportation sector has moved above the power sector as the largest contributor to CO_2 emissions.

Two out of three new kW built in the U.S. and worldwide will be renewable. Most forecasts show gas power-based electricity growing at around 2% per year (worldwide and U.S.) through 2027.

Coal is currently receiving about 10 times the investment of gas in R&D, said DeLeonardo. Much of this has been going to CCS.

A general lack of investment in GT research and development, and a cautious stance among OEMs means that alternate technologies receive little attention, he said.

Turbine efficiency

The efficiency trajectory of simple cycle turbines has gone from around 33% in the early eighties to over 40% today, said John Gulen, Senior Principal Engineer at Bechtel. It can reach as high as 44% in some cases.

"OEM machines are finely tuned Swiss watches and their gradually improving

technology path has accelerated in the past decade," he said. "Materials, coatings, seals and cooling techniques have resulted in big gains."

When it comes to CCPPs, the exhaust gas output monitors steam turbine output via the heat recovery steam generator (HRSG). Current GT turbine inlet temperatures (TIT) are above 1,600°C.

CCPPs, like those in Irsching, Germany and Bouchain, France (shown on cover), are the most efficient, he said. He estimates that the best field-measured net performance is between 61.5 and 62%.

The next hurdle is achieving machines with a 1,700°C TIT. Gulen believes Ceramic Matrix Composites (CMC), additive manufacturing (colloquially known as 3D printing), data analytics and model-based (adaptive) controls will help enable this.

"The best you can engineer a CCPP for efficiency at 1,700°C TIT is 65.3% based on basic thermodynamics and backed by wonderful engineering," said Gulen

The future of GTs

GT capacity currently outstrips demand by four times. 55 GW of GT orders worldwide in 2015 has declined to 25 GW in 2018. Meanwhile, trends toward decarbonization, decentralization and digitalization

A session on the future of gas turbines at the Turbo Expo 2019 was one of the most popular and informative

have made this a challenging time for power generation.

Still, whatever the future holds, new GT designs are a necessity.

"Since the invention of the GT, it has been the standard practice to stick to conventional designs by increasing TIT as a means of efficiency augmentation," said Meinhard Schobeiri, Professor at Texas A&M University. "This is no longer an option."

Schobeiri's ultra-high efficiency gas turbine (UHEGT) concept includes a fuel injection system, an ignition system, a stator system and a rotor system. The stator system includes multiple stators positioned radially around a central axis.

The ignition system is located within the stator system where fuel is injected, and combustion takes place. The rotor system also includes multiple rotors positioned radially around the central axis downstream from the stators.

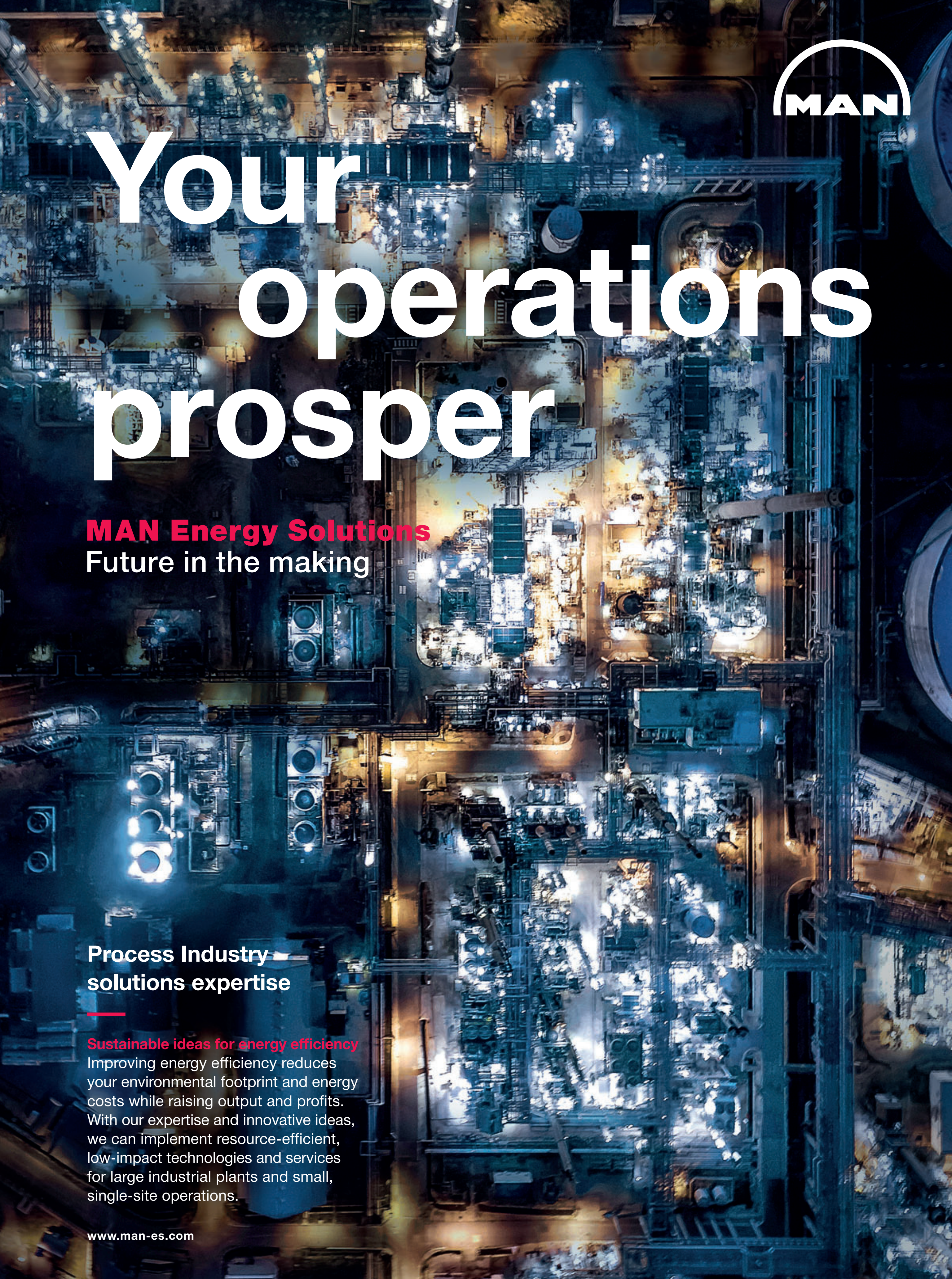
This eliminates the combustion chambers, replacing them with a distributed combustion system using stator-internal combustion technology. This technology allows for an increase in GT thermal efficiency of about 7%.

"Basically, there are two combustion chambers and a low-pressure and high-pressure turbine," said Schobeiri. "The pressure ratio has to be close to 38."

Part of the logic of this concept is that conventional gas turbines have a large mixture and combustion zone that generates corner vortices. As a result, exit temperature non-uniformity is about 22%.

This alternative design reduces these vortices by making the combustion path longer through controlled, induced secondary flows to keep fuel particles in circulation longer. Schobeiri urged investment in this approach to achieve market viability.

Continues on page 22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CHP

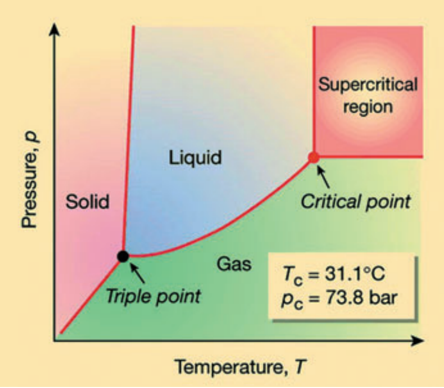
CHP is a potential growth area for GT-based power generation. Some 1,500 GTs currently provide CHP in the U.S., said Neeharika Naik-Dhungel, Combined Heat & Power (CHP) Partnership Program Manager for the U.S. Environmental Protection Agency (EPA). Microturbine installs are up in the last decade along with small simple cycle units. But there has been a drop in larger combined cycle installs for CHP.

Most installs are in California, Texas and New York. She believes there is abundant potential for CHP in the nation, but policy changes have led to speculation that energy storage could replace GT peakers. This may inhibit CHP growth.

"Gas CHP can economically improve efficiency and reduce emissions, but it requires consistent state policy to promote CHP growth," she said.

Ongoing programs for advanced turbines and future power systems include work on integrated gasification combined cycle (IGCC), i.e., using a high-pressure gasifier to turn coal into syngas then removing impurities from the gas prior to the power generation cycle. The U.S. Department of Energy (DOE) is also funding projects that use natural gas instead of coal with this technology.

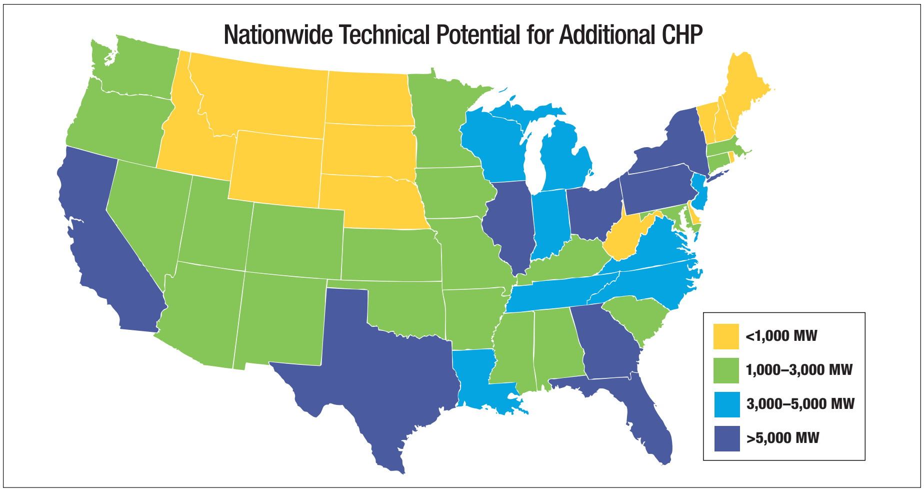
"Switching from H-class to J-class turbines in an 820 MW plant is equivalent of removing 14,300 cars from the road," said Richard Dennis, Technology Manager, Advanced Turbines and SCO_2 Power Cycles Programs at the DOE's National Energy Technology Lab.



Supercritical CO_2 is one area of turbomachinery receiving investment

Supercritical CO_2

Supercritical CO_2 (sCO_2) has a higher efficiency and potentially a 20% lower cost of energy than steam, said Dennis. But ongoing R&D efforts in this technology are not enough. Supercritical CO_2 will require regulation that favors the implementation of CHP and natural gas to encourage sufficient investment.



GE Global Research is examining an sCO_2-based closed Brayton Cycle, along with other working fluid alternatives. A 10 MW sCO_2 demonstration plant is under construction. It uses CO_2 instead of steam. Rather than condensing the fluid, it is cooled and reused.

Douglas Hofer, Senior Engineer at GE Global Research said sCO_2 can be effective in high-temperature and low-temperature applications. With a 150°C increase in temperature beyond steam, there is a 6.8% bump in Carnot efficiency. sCO_2 also has benefits for small applications. It can go below 100 MW without the need for a reduction gear.

Low-temperature applications apply mainly to waste heat recovery.

"CO_2's single-phase heat transfer is a better match than steam for the GT exhaust," said Hoffer. "That means lower HRSG losses."

Needed advocacy

Changes in emissions policy and permitting are needed to promote the expansion of clean gas turbine-based energy that includes low-carbon solutions, said Manfred Klein, Principal Consultant at MA Klein and Associates. The system changes as more renewables enter the grid.

"We need other solutions that can partner with renewables to address the intermittency of renewable generation," said Klein. "Thermal power should also be used for district heating and cooling."

He emphasized the efficiency and emissions-reduction credentials of the power industry. Cogeneration, using HEPA air filters, duct firing, steam or water injection, Dry-Low NOx (DLN) combustion, methane leak prevention, fast and flexible response time, and waste heat recovery have all helped to raise efficiency and lower all types of air emissions.

"DLN is a huge success story: no other industrial technology has prevented emissions to that degree," he said.

Klein attacked the notion that reducing NOx to tiny levels was a sensible course.

States such as California try to hold gas turbine plants to NOx levels below 10 ppm and sometimes as low as 5 ppm. He believes ppm is a misleading metric and prefers pounds per MWhr of power and heat output, as it gives a more accurate picture of actual pollution (see page 38).

If a ppm level had to be set, he felt 25 ppm (or one lb/MWhr) was more than enough for most applications. Anything below that just adds heavy cost, does not deal with CO_2 mitigation, is difficult to accurately measure and does not provide much return in terms of real emissions reduction.

Efficient natural gas should not be painted with the same brush as oil and coal, he said. It gets lumped together with these others under the fossil-fuel umbrella. This is leading to a knee-jerk reaction in some areas to try to eliminate gas generation, although more must be done to address fugitive methane leakage.

"Gas is very different from oil and coal; as a hydrogen-based fuel you don't have to turn it from oil or a solid into a vapor to then burn it," said Klein.

The European angle

In Europe, the big market trends are decarbonization, decentralization and digitalization, said Christer Björkqvist, Managing Director of the European Turbine Network (ETN).

Christer Björkqvist

The EU has legislated a 20% drop in greenhouse gas (GHG) emissions by 2020, a 40% drop by 2030 and an 80% drop by 2050 (measured against 1990 levels), he said. But the majority of EU members states advocate net zero emissions by 2050.

They believe that electrification, energy

efficiency, the use of hydrogen as an energy carrier, and new technology backed by lifecycle changes will help to reach that goal.

Power-to-X, for example, is garnering a lot of attention and has two meanings. Primarily, it refers to the conversion of typically renewable energy into methane gas (Power-to-Gas), liquid methanol (Power-to-Liquid) and others.

It also refers to conversion technologies that enable an integration of the energy consuming sectors — buildings (heating and cooling), transport, and industry — with the power producing sector.

The X refers to the numerous conversion possibilities, for example: power-to-hydrogen, power-to-ammonia, power-to-chemicals, power-to-heat, power-to-liquid, power-to-methane, power-to-mobility, and power-to-syngas. In the latter case, the resulting synthetic gas can be transported through existing pipelines and used in gas-powered engines.

Germany alone produces more than 40,000 MW of wind and solar, yet 5,500 MW is lost as the grids cannot absorb all of it. This excess power could be used for production of hydrogen and oxygen via electrolysis.

Due to the shortage of H_2 infrastructure, you can add CO_2 to hydrogen in a methanation reactor to produce a methane-based syngas, which would be regarded as carbon neutral. It could be used in power generation or transportation using existing infrastructure.

Björkqvist believes gas turbines have a future both in the energy transition and beyond. He cites rising investment and demand for LNG and natural gas in recent years to show that traditional hydrocarbon-based fuels still have a role to play for many years to come.

Looking ahead, he thinks it is feasible to convert peaking plants and combined cycle power plants to gradually run on an increasing percentage of renewable syngas and eventually supply net-zero electricity.

Meanwhile, European countries are initiating CO_2 taxes ranging from $24 to over $100 per ton. This is happening in tandem with legislation to outlaw coal. Norway already has no coal, France plans to get there by 2022, Sweden by 2022, UK by 2025, Italy by 2035 and Germany by 2038.

"Rising CO_2 taxes give more incentives for coal replacement," said Björkqvist. "Fast-growing renewables also offer grid balancing and Power-to-X opportunities for gas turbines."

EU policy makers consider gas turbines as little more than a bridging technology to achieve the 2030 targets until other technologies mature. A major challenge lies ahead to convince politicians that GT technology can be developed to operate safely on low-carbon and carbon-neutral fuels by 2030 when natural gas may be labelled a high carbon fuel.

"The gas turbine is not just a transitional technology to 2030; it can be an enabler in meeting the long-term climate and energy targets," Björkqvist said. "The perception of our technology has to change to ensure public funding and support for the required research & development."

Many politicians believe that increasing energy efficiency, introducing more renewables and smart grids and implementing available storage technologies should be enough to meet their goals.

Björkqvist said this pathway will not succeed. The more intermittent renewables (wind and solar) there are in the energy mix, the higher the backup capacity and load following capability that will be required.

"The future is in our hands," said Björkqvist. "We have to make the general public and governments realize the value of our technology and, in parallel, ensure that the required technical solutions are being developed." ■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The opening keynote at Turbo Expo drew a large crowd

TURBO EXPO 2019

ADDITIVE AND SUBTRACTIVE MANUFACTURING, CLEAN POWER, LIQUEFIED NATURAL GAS, WET GAS COMPRESSION AND SPACE TRAVEL

DREW ROBB

The 2019 American Society of Mechanical Engineers (ASME) Turbo Expo took place in Phoenix, Arizona. As ASME's premier turbomachinery conference and exposition, it featured over 300 sessions of 1,000+ papers and more than 80 panel, tutorial and lecture sessions. The best and brightest minds of the industry assembled to share the latest in turbine technology, research & development and application.

Speakers from NASA Glenn, EPRI, Integrated Inspection Systems, FLC Flowcastings, Intech DMLS, Doosan ATS America, John Crane, Bechtel, Southwest Research Institute, Baker Hughes GE and others covered a lot of ground.

Hot topics included additive and subtractive manufacturing, clean power, LNG, coatings, materials, wet gas compression, waste heat recovery, the future of gas turbines (page 18) and space travel.

Janet Kavandi, Director NASA Glenn Research Center, briefed the opening keynote crowd on a new lunar program named after Artemis, the twin sister of Apollo and goddess of the moon.

NASA Glenn is providing power and propulsion elements for the space ship as well as the Lunar Orbital Platform-Gateway, which will function as a lunar-orbit space station, a solar-powered communications hub, science lab, a short-stay habitation module and holding area for spacecraft.

"We plan to land on the moon by 2024," said Kavandi.

Beyond the space program, NASA Glenn has set its goals on reducing energy use in aircraft by 60%, emissions by 90%

The exhibit hall featured many turbomachinery and software vendors and noise by 65%. Innovations in meeting these targets include:

• Embedding engines inside the wings or fuselage to reduce drag and increase efficiency

• Developing an integrated inlet and distortion-tolerant fan for an aircraft engine

• Raising the power density of the engine core using Ceramic Matrix Composites (CMCs) that can withstand and radiate high temperatures.

In addition, an icing project seeks to characterize the icing environment, as well as its impact on aerodynamics and engine performance. Simulations are being done of ice growth on aircraft using wind tunnels and computational models. The findings will improve icing-protection technology.

Subtractive or additive?

Additive manufacturing (AM) has gotten a lot of attention lately. That is understandable, given the greater accessibility and affordability of 3D printing equipment.

Yet traditional or subtractive manufacturing remains the dominant approach in turbomachinery. Whether through the use of casts, molds or metal fabrication, subtractive manufacturing accounts for the vast majority of components and equipment.

Metem, a specialized supplier of machining and assembly of turbine super-alloy components, uses a variety of subtractive manufacturing techniques, including Electrical Discharge Machining (EDM).

Lucas Guarino, Senior Manufacturing Engineer, explained the process. In EDM, a spark discharges and melts material which then floats away. This works well for slots, holes and cavities in hard-to-reach areas, he said.

EDM is also used for fast-hole drilling and milling which is best for complex profiles and drilling holes. Milling and drilling can be done with the same tool.

Electro Chemical Machining (ECM), said Guarino, is good for holes, slots, cavities and contours on metals. Shaped Tube Electrolytic Machining (STEM) is used to produce cooling holes in gas turbine blades and vanes.

It is a de-plating process where the electrolyte conducts an electric current from the workpiece to the tool, he said. As the electrolyte streams through a small machining gap, the tool produces precise geometries without contacting the workpiece metal being machined.

Traditional machining provides straight holes. The latest techniques can provide curved holes with a tight radius, such as S-curves and holes that are not round.

"STEM drilling can put shapes into the cooling holes, such as little ridges to improve heat transfer by swirling the air in the holes," said Guarino. "You can improve heat transfer by up to three times by introducing swirling."

Metem also has a drill-through coating process, which can drill through a part with a thermal barrier coating (TBC).

Kenneth Morgan, Casting Engineer, Integrated Inspection Systems, talked about final machining of parts with complex geometries.

His company offers MetBase software for coordinate measuring machining, which also includes computer numerical control functionality to deal with the dimensional variability in parts.

Traditionally, a six-point nest is the preferred technique to prepare a part for machining. This works well on smaller parts and those with limited variability. For the complexity of many modern components, Integrated Inspection Systems uses a point cloud (dozens or even hundreds of points surrounding the object) to more precisely measure each part. The company guarantees cutting to 1,000th of an inch.

Morgan gave the example of machining a 3rd stage vane. A single gate would take two hours to fit manually. MetBase reduces this to 20 minutes. Parts can be turned around in less than 48 hours.

Steve Rauch, Casting Manager at FLC Flowcastings, covered the process used in investment casting. A ceramic core is made first and then wax is injected into it to produce a pattern for casting.

Once the cast is made, post-cast cutting, and finishing is done. His company uses a rapid-machined-pattern process that reduces production time from 370 to 220 days for a gas turbine blade casting core.

Traditional manufacturing also continues to play an important role in the production of many components. Blake Fulton, Prototype Leader at GE Advanced Manufacturing Works, deals with 3D printing, ceramic components and process optimization. Ceramics, he said, are used for thermal coatings, ceramic matrix composites and castings. Traditional hot gas path manufacturing is still used to create turbine blades, nozzles, vanes and shroud tiles.

Additive Manufacturing parts are on the rise. Instead of making hundreds of sets at one time as was the norm in the past, dozens can be made with 3D printing to satisfy the market.

"Materials behave differently when 3D printed as compared to cast," said Fulton. "Additive manufacturing gives us enhanced cooling, better combustion mixing and reduces post-cast operations."

It is also making it possible to achieve tighter tolerances, add new features, raise higher firing temperature, and minimize cooling airflow by improving the distribution of cooling channels in blades.

3D printing has many benefits when making hot-gas-path components: larger parts with smaller features, tighter clearances, thicker coatings, less leakage, more cooling holes that are smaller, smaller batch sizes, more exotic materials and concurrent engineering. And more trials can be conducted up to the last minute as opposed to the old pattern of design, then engineering, and then manufacturing.

"The additive age will continue to enable new capabilities and products, and hot gas path manufacturing will continue to be optimized," said Fulton. "Materials are now moving beyond conventional superalloys. However, the cutting and finishing of 3D printed parts still needs to be improved."

A digital twin mirrors and simulates the operation of a component, an asset or a system of assets.

Coatings

Oxidation coatings extend the life of gas turbine blades, said Dheepa Sriniivasan, CTO at Intech DMLS. Her company developed a process to extend the life of coatings from 3 years to as long as 15 years using a rejuvenation heat treatment process.

A lively session on materials, manufacturing and coatings was well attended

These coatings interact with the atmosphere and superalloys, she said. Internal coatings range from 50 to 100 microns. External coatings range from 250 to 300 microns.

She offered an alternative to recoating of blades. A cold-spray coating process is used to spray metal powders at supersonic speeds to add material for part repair. As no heat needs to be applied, this coating can be applied as thick as 1 inch.

Digital twins can also extend the life of aeroderivatives, said Ashok Koul, President of Life Prediction Technologies. A digital twin mirrors and simulates the operation of a component, an asset or a system of assets. It can be used to optimize system design, assess life cycle, detect anomalies and optimize performance.

Koul said there are two types of digital twin. A data-driven digital twin targets operational data from the engine, massages the data and recognizes patterns to build a twin. A model-based digital twin is created independently of physical engine data and made to match it.

His company offers the XactLife GT digital twin software to help in trending, pattern recognition and determining component efficiency. It uses microstructure-based damage models that can quantify material changes. It provides 3D thermodynamic semi-empirical analysis and finite element modeling of turbine components, blades discs and vanes.

"A quantitative damage analysis is necessary to make sound maintenance decisions," said Koul.

Manufacturing considerations impact life extension, said David Day, Principal Engineer at Doosan ATS America. Stainless-steel parts become sensitized when exposed to high temperatures. Sensitization is the precipitation of chromium carbide into the grain boundaries that leads to corrosion and cracking.

Solutions include stainless steel made with less carbon, and the addition of titanium or niobium to preserve the chromium.

Day noted that there are always tradeoffs with alloys. Alloys that provide longer life for a part may also be very difficult to repair or weld, and the cost may be much higher. There may also be a tradeoff between maximum stress and fatigue life, based on the choice of heat treatment.

"A fine grain in blades is better for strength and fatigue, but a coarse grain is better for creep," said Day. "You have to consider both the chemical composition and the manufacturing process."

Dry gas seals

In the oil and gas industry, pipeline compressor emissions have been identified as an important source of methane released

into the atmosphere. Wet seals (oil seals) are unable to meet new targets being set for methane emissions.

"One strategy to reduce methane emissions is to replace oil seals in existing centrifugal compressors with dry gas seals," said Christina Twist, Team Leader Gas Seal Development at John Crane. As wet seals are typically compact in nature, there is flexibility in how they can be installed into a compressor.

Dry gas seals, on the other hand, generally occupy a larger cross-sectional footprint. Therefore, said Twist, it was necessary to develop a gas seal that could be retrofitted into the same cavity without the need for machining of the compressor shaft or housing.

The narrower cross section of this John Crane dry gas seal design can replace wet seals within older centrifugal pipeline compressors. Converting to the new seals minimizes wear, lowers operating costs by removing oil-seal supporting systems, reduces energy consumption due to the shear losses associated with oil seals, cuts down on maintenance costs and reduces emissions.

This dry gas seal can provide sealing at maximum pipeline compressor duties of up to 120 barg and 100 m/s. The smaller cross section of the rotating (mating) and stationary (primary) sealing faces required finite element analysis and computational fluid dynamics simulations to optimize the seal design and groove patterns, said Twist.

They have undergone testing through the performance envelope for pressure, speed and temperature, as well as testing to replicate seal lifetime.

"Tests of this narrow cross-section seal showed less than 15% of the leakage commonly seen in wet seals," said Twist.

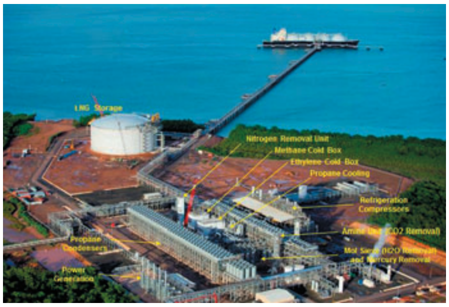
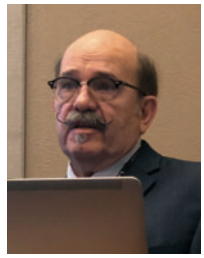


Figure 1: An aerial view of an LNG plant

LNG liquefaction

George Orme, a Consultant for Berkshire Hathaway Specialty Insurance, lectured on how property risk assessments are done for LNG liquefaction plants. Large gas turbines, compressors and heat exchangers operate under extreme conditions and any failure can be catastrophic.

One metric is probable maximum loss (PML), which relates to a single event with adverse conditions. This might be one active protection system impaired while the others are operating.



George Orme

Replacement costs are needed and the business interruption amount (by far the largest value) have to be calculated. For example, PML would be used for a foreign object entering the compressor, or high cycle fatigue failure.

Another metric is Maximum Foreseeable Loss (MFL). This concerns a single event with no protection and no response. As a result, it is costlier. It also requires debris removal, pollution control and other actions. An example of MFL might be overspeed resulting in mechanical failure with significant damage requiring major repairs or replacement.

Orme gave the example of two plants. One consisted of two trains with 14 MTPY capacity. Each train has three refrigeration stages. Each stage has two 50% capacity GT compressors. The PML for this plant turned out to be \$3.5 billion to cover replacement and business interruption whereas MFL would be \$12.7 billion

The other LNG plant used a spiral wound heat exchanger shared by many systems. This heightened its exposure to risk or its 7 MTPY train with one main refrigeration stage. Two 50% capacity compressors have helper electric motors. Its PML was calculated at \$3.5 billion, and its MFL at \$8.0 billion.

"Potential loss increases almost linearly with respect to plant net output," said Orme. "The rate of increase is higher for MFL."

High-pressure single-shaft boil-off gas (BOG) centrifugal compressors with synchronous motor drives are often used in LNG liquefaction plants. As LNG trade increases, owners look for ways to lower costs through economies of scale, said Matt Taher, Principal Engineer at Bechtel's LNG Technology Group.

"The larger overall output of an LNG liquification plant typically results in higher rates of BOG," said Taher.

Depending on the LNG process technology and the rate of BOG generated in the LNG storage tanks, BOG can either be recycled to the liquefaction units and re-liquefied or compressed at higher pressures and used as fuel gas for turbines.

Matt Taher

BOG compressors are used to maintain and control the vapor pressure in the LNG tanks resulting from flashing of the liquefied natural gas in different operating modes.

While the required pressure ratio of BOG compressors varies in a narrow range, BOG flow rate swings significantly as operating modes switch between loading and holding said Taher. This is a major factor in facility design.

Large synchronous motors used as drivers of BOG compressors can be used to generate reactive power to improve the power factor of the plant.

"The use of synchronous motors for power factor correction may also eliminate the need for reactive power compensation by capacitor banks," said Taher.

The low inlet temperature to the BOG compressor results in high machine reference Mach number, which amplifies the effect of aerodynamic stage mismatching as gas flows thought multiple stages of the compressor. "The use of adjustable inlet guide vanes (AIGV) is an effective regulation method for high Mach number multistage compressors," said Taher.

At the Darwin LNG plant in Australia, for example, its 188,000 m^3 LNG storage tank has continuously generated BOG. This can cause flashing as the gas approaches the LNG tank pressure.

The BOG compression system, therefore, is mainly there to manage the pressure inside the tank. BOG can also be used for GT fuel. Ship loading produces the most BOG, but it is also produced when the tank is in holding mode.

"The flow rate of BOG can swing significantly as operating modes switch between loading and holding," said Taher. "This is a major factor in facility design."

2019 ASME R. Tom Sawyer Award

Each year at the Turbo Expo, the annual R. Tom Sawyer Award is presented. Named after the founder of Turbomachinery International, the 2019 award went to Om Sharma, Senior Technical Fellow in aerodynamnics and gas turbines at the United Technology Research Center.

He helped to enhance the design processes used in axial flow turbines. He also pioneered the use of 3D airfoils, clocking airfoil rows, and clocking of combustor-generated hot-streaks to enhance the performance, durability and structural integrity of high- and low-pressure turbines.

At Darwin LNG, the inlet temperature of BOG is 160°C at a pressure of 1 bar and an inlet flow of 300 m^3/min. The compressor had to be designed with a rotational speed of 8,000 to 10,000 rpm with both the high-pressure and low-pressure compressors running at the same speed.

Waste Heat Recovery

Thermodynamic cycle analysis improves the efficiency of production cycles by selecting the right design, said Clement Joly, Lead Engineer at Softinway, speaking about design considerations for waste heat recovery systems. It is vital to understand the thermo-physical properties of potential fluids before approaching the entire waste heat recovery cycle.

Non-traditional fluids, such as supercritical CO_2, R245fa and ethanol each come with their own specific design needs and fluid requirements, he said.

Joly compared the net power production in Organic Rankine Cycle (ORC) systems when fueled by ethanol, steam, R134a and R245fa, as well as other factors that must be considered in design.

He also delved into ORC costs. SoftInWay's AxStream was used to analyze eight different configurations to determine the best option for each type of fuel. It offers the ability to design a machine ranging from a turbocharger in a small car engine, to a 125 MW gas turbine or even a turbopump for a liquid rocket engine based on factors, such as size, cost and complexity.

Wet gas compression

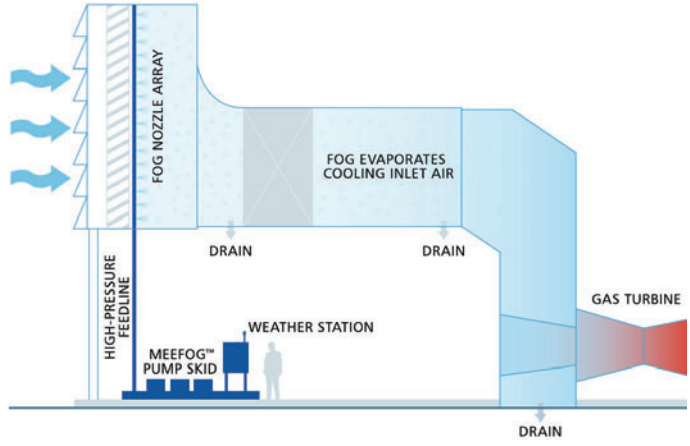
Wet gas compression is of growing importance in oil & gas applications. Gas gathering, processing and pipeline operations always produce liquid. The traditional approach has been separation equipment.

But a desire to decrease the equipment footprint for environments, such as subsea, has led to designs that eliminate the separator. In these cases, the compressor must be able to cope with wet gas.

Southwest Research Institute (SwRI) has been researching wet gas compression. "Compressor performance in wet gas can vary significantly," said Griffin Beck, Senior Research Engineer at SwRI.

For example, wet gas performance tests at SwRI demonstrated that, at a low flow rate, there is a slightly higher-pressure ratio than with dry gas, but as the flow increases, the pressure ratio is lower than dry gas.

He added that extra power is needed to deal with loss of pressure ratio and lower compressor efficiency. To cope with sub-synchronous vibration issues in wet gas compressors, a labyrinth seal was replaced with a pocket damper seal. Erosion and corrosion also have to be factored in due to the presence of liquid, said Griffin.



Inlet air should be evaporatively cooled, or chilled to the dew point, prior to wet compression to avoid large temperature differences at the compressor inlet.

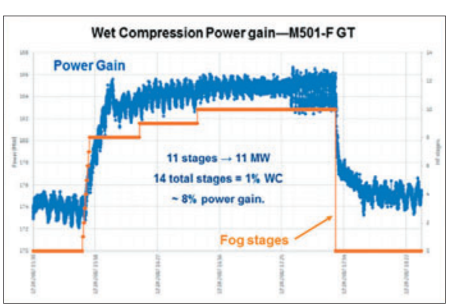
"Scrubbers are often used to eliminate or minimize liquid in the compressor," said Giuseppe Sassanelli, Senior Engineering Manager, Baker Hughes GE. "But it is better to have a compressor that can handle a larger amount of liquid."

Baker Hughes GE has developed a wet gas compressor. The WBCL302/A prototype has been running in a test rig in Norway for more than 1,000 hours of harsh qualification. Its Liquid Mass Faction (LMF) ranges from 0–30% and its Liquid Volume Fraction (LVF) from 0–3%. The suction pressure is from 20–110 bar

"There is lots of complexity in measuring performance when there is so much change in LMF and LVF," said Sassanelli.

Some of the features of the compressor include two stages, an impeller made of IN625m with an IGV multilayer coating of TiN, seal teeth on the rotor, internal extraction for DGS and shunt holes, as well as swirl brakes at the impeller eye.

BHGE compared the performance of dry gas and wet gas. The dry gas maintained a vibration level below 20 microns with no sub-synchronous vibration. The wet gas compressor showed the presence of some sub-synchronous vibration and a small increase in overall vibration. But this was not enough to cause any rotor instability issues.



Wet Compression Power gain—M501-F GT: stages of wet compression were integrated with the Automatic Generation Control signal.

BHGE also wanted to eliminate the possibility of the thrust load variation when LMF increased. Testing showed that despite big changes in LMF, the amount of thrust stayed the same.

However, pressure ratio (PR), power consumption as well as head rise to surge increased along with LMF. "Water washing recovers performance lost due to fouling," said Sassanelli.

"For a fixed compressor operation point, operating at 30%, LMF results in a lower operating speed, a small increase of power and a rise in pressure ratio," he said.

From wet gas compression, attention shifted to wet compression, i.e., intentionally sending fog-saturated air into the compressor to lower inlet air temperature, increase mass flow and boost power output.

Wet compression is used on 30% of our 1,000 fogging systems, said Tae Lee, Regional Sales Director at Mee Industries.

The system can be deployed within four months during an outage of one-to-three days. Installed and operating costs are low for an average power boost of 8 to 10%.

He offered safety tips for wet compression and fogging:

- Fogging nozzles should be wired to prevent foreign object damage
- Droplets should be maintained at a size of 20 microns or smaller to avoid blade erosion
- Nozzles should evenly distribute fog and avoid air-flow-induced vibration
- Drainage systems should be installed to eliminate standing water
- Drainage should be monitored through a viewing window.

He gave the example of the Watson Cogen plant in Southern California, using wet compression on its GE 7EA turbines. "After more than two decades, fogging has caused no blade erosion at the plant," said Lee.

Next year's Turbo Expo will be in London, England. ■

ATPS INDUSTRY SUMMIT

BIG DATA, DIGITALIZATION AND THE INDUSTRIAL INTERNET OF THINGS

BY KALYAN KALYANARAMAN

The ATPS Industry Summit included several panels

The biennial Asia Turbomachinery & Pump Symposium (ATPS) grew out of Texas A&M Turbomachinery Laboratories' (TAMU) annual Turbomachinery & Pump Symposia (TPS). This year's Industry Summit was conducted in Kuala Lumpur, Malaysia.

The welcome address by Dennis Lawrence, Head of Wells at Petronas, touched upon the development of young engineers and machine learning applications for asset management. Further speakers emphasized trends, such as big data, digitalization and the Industrial Internet of Things IIoT). Viewpoints ranged from skepticism through grudging acceptance to wholehearted endorsement of these mega trends.

Eight case studies covered a cross-section of rotating machinery problems. "More and more, the participants want to return to their workplace and apply what they learn," said Eric Petersen, Director of Turbomachinery Laboratories. "That's why content is weighted in favor of case studies."

Petersen sees supercritical CO_2, high pressures in compression, advanced materials to handle corrosive gas use, combustion at different operating conditions, and bearings as the areas where cutting-edge research and technology development is happening. He raised concern about the knowledge gap created because of the retirement of a generation of turbomachinery engineers.

ATPS chair Dag Calafell said current buzzwords, such as big data and predictive analytics are often driven by this knowledge gap. "Asset management that improves safety and operability while reducing cost is a big trend," he said. "Due to attrition in expertise, assets are vulnerable to declining reliability, especially in offshore production."

He called for greater collaboration to break down the barriers imposed by proprietary development. Otherwise machinery domain knowledge may not be available to end users.

Future technology

Junya Ujiie, Senior Vice President of Asia Pacific at Mitsubishi Heavy Industries, said his company is focused on technologies to sharply lower carbon emissions. Products for the future will be high-efficiency, large-capacity gas turbine (GT) combined cycles, GTs burning hydrogen, integrated gasification combined cycle, solid oxide fuel cells and machinery for nuclear power. Its next generation combined cycle will have a projected efficiency of 65%. With integrated SOFCs, this could reach beyond 70%.

In post-combustion CO_2 capture, Mitsubishi delivered the Petra Nova plant in Texas that started operations in 2016. Five thousand tons of CO_2 are captured every day and used for enhanced oil recovery. The Mitsubishi equipment includes an eight-stage integrally geared compressor and a CO_2 inline compressor with a discharge pressure over 200 bars (2,900 psig).

To cater to remote, off-grid areas near coasts, Mitsubishi developed a floating LNG power plant with an integrated supply chain. It leverages MHI's capabilities in LNG shipbuilding and power plants.

The DNV-approved solution is economical if fuel costs do not exceed $10 Mbtu. Mitsubishi offers several power ranges. For large outputs of 150 to 350 MW, the lead time is under three years.

The combined cycle plant onboard would have efficiencies in the range of 50% to 56%. For up to 100 MW, the prime mover can be either gas turbines or gas engines, with delivery in one year. Efficiency would range from 35% to 50%. The supply chain would include small LNG shuttles to transport fuel from bigger vessels.

Digital twin

A lecture by representatives of Tri-Sen and Elliott Group outlined the compressor digital twin. Klaus Brun, Elliott's R&D director, said trends like Artificial Intelligence (AI), digital twin and IIoT have two drivers. One is a generational change among those working in the industry. They are accustomed to computers and prefer simulations. The second reason: veteran turbomachinery experts who can predict machinery condition are retiring. AI is required to help replace their expertise.

Jim Jacoby, VP of engineering at Tri-Sen, explained the nuances of the digital twin. A physics-based simulation of the machine generated by OEM-supplied parameters is compared with the actual equipment.

ATPS featured panel discussions, keynotes, tutorials and case studies

The digital twin allows the operator to compare predicted results with real-world performance to identify emerging malfunctions or opportunities. Jacoby explained that head, flow, speed, as well as gas molecular weight and conditions such as pressure and temperatures are required inputs for the model.

The digital twin lecture prompted lively discussion. A key point emerged: compressor surge lines may have altered in the field because of changed impedances due to piping. Brun explained that so much effort goes into simulation and modeling, yet instrument errors can introduce errors in predictions.

Dr. Masdi bin Muhammad from UTP presented a keynote on predictive analytics. We need to use maintenance and operational insights, he said, and ensure operational efficiency through alarms prioritization and recommendations. But challenges such as unreliable data, selecting the right model, and frequent changes in the field must be overcome.

Industrial Revolution 4.0

On Day Two of the summit, Hj Khairol Anuar Shukri, Head of Group Technical Solutions, Project Delivery and Technology of Petronas, outlined the broad trend of what is known as the Industrial Revolution 4.0.

The first industrial revolution involved steam power and mechanization. The second phase in the 1870s brought about mass production. The next revolution came about through computers and electronics starting in the late 60s.

The features of the present one, IR 4.0, are cyber physical systems, IIoT and networks, he said. The key enablers are AI, cloud, system integration, simulation, robots, big data and digitalization. Market disruptors are operating in tandem to IR 4.0 are U.S. shale production, technological innovation, environment concerns and the public's perception of the industry.

During every industrial revolution to date, some large companies disappear without trace. To stay relevant, it is necessary to adapt, digitalize and collaborate. This means working together with governing bodies, standards organizations, higher learning institutions and engineering fraternities where all participate, said Shukri.

For instance, even a few years ago, the big oil and gas companies had difficulty achieving standardization of commonly used equipment. Today, the Christmas tree, switch gear and other equipment are standardized.

This reduces the need for specification overlays, reduces costs and cuts delays, said Shukri. "Transparency and communication are the key to facilitate networking within organizations and without."

The last session on IIoT was kicked off by Girish Kamal, Principal Rotating Engineer from Petronas Upstream. He talked about the need to become a data-driven organization and how the world's top performing companies harness data for insights to make smarter and faster decisions and unlock new value.

Dr. Ir. Harris A. Rahman Sabri, Staff Rotating Engineer from Petronas Upstream showcased his company's journey in developing Petronas Rotating Equipment Analytics (Protean), an inhouse predictive maintenance solution that covers 79 GTs, 35 pumps, 50 compressors and 29 generators. Some decisions are referred to humans while others are made by computers.

Arun Kumar, General Manager for Reliability and Maintenance at HPC, Mittal Energy of India, gave a presentation about his company's digitalization plans and how AI had reduced downtime. Polypropylene, for example, could sometimes solidify in the reactor during process upsets and lead to weeks of shutdowns. AI prevents solidification via a closed-loop feedback system.

Sandip Jadhav, CEO of CCTech, a software solutions firm based in Pune, India, used big data to design butterfly valves to maximize the flow coefficient and minimize the hydrodynamic coefficient.

A lively interaction followed among the panelists. Rainer Kurz, Manager of Systems Analysis at Solar Turbines, asked how to choose between physics-based models and big data.

Jadhav responded that in the butterfly valve case, the traditional approach would be to use CFD and attempt a solution to the Navier Stokes equation. This would require a trade-off between speed and accuracy.

"The effectiveness of machine learning models depends on the data," said Jadhav. "We used a combination of physics and machine learning to reduce cycle time. Physics-based models are not adaptive."

A four-day ATPS Symposium and Exhibition is scheduled for April 7–11, 2020 at the Kuala Lumpur Conference Center. ■

ROTATING MACHINERY MAINTENANCE

NEW TECHNIQUES IMPROVE RELIABILITY AND PERFORMANCE

Rotating equipment lies at the heart of most oil & gas processes. Wells, pipelines, refineries and liquified natural gas (LNG) plants rely on turbomachinery to perform daily operations and fulfill their energy demands.

However, the presence of aging equipment, variations in process conditions and the financial penalties incurred by downtime make it important to pay close attention to maintenance.

A vital first step is to understand the operating environment, the performance of a machine and expectations with regard to turnaround times and equipment lifespan. From there, sources of degradation and potential mitigation efforts can be assessed.

Repair options

Whether it is a planned or unplanned outage, equipment needs to be inspected to understand the extent of damage and potential repair options. Visual and dimensional inspections are done to assess the components in their as-found condition.

A range of non-destructive testing (NDT) procedures, such as wet magnetic particle inspection (MPI), ultrasound and liquid penetrant inspection can also be used to discover defects in components invisible to the naked eye.

Repair recommendations are made depending on type of damage, as well as size and location of defects. Based on this, it is determined whether a part can be salvaged, and if so, the most effective method of repair.

Basic components, such as shaft seal sleeves, split rings and keys can be easily manufactured. However, specialized tasks, such as improving impeller or turbine blade geometry require engineering analysis.

Worn or damaged components can be refurbished by localized welding. If the damage is minimal, surface restoration coatings can be used instead of welding. Weld repairs and coating restoration can often save expense by reconditioning the existing components instead of outright replacement.

Reverse engineering is another possibility. This can even be applied to major rotating or stationary components such as rotating blades, impellers or diaphragms.

Compressor refurbishment

Oil & gas compressors perform a challenging role that places considerable wear and stress on parts. Regular maintenance inspections and planned repair schedules are essential for continued reliable operation, especially for highly stressed parts, such as rotors and critical sealing components.

Due to wear (erosion, corrosion) or damage (rubs, impact from foreign objects), the impeller may not be repairable. A new impeller must be reverse engineered and manufactured to replace the original component.

Modern impellers can be made from a single forging of a low alloy or stainless steel using 5-axis milling or electrical dis-

Left: Reblading of a steam turbine rotor
Right: Steam turbine blades upgrades to the integral shroud

charge machining (EDM). These processes can save many weeks of manufacturing time while delivering a more dimensionally consistent and stronger component than the original, riveted or partially welded construction.

It may be possible to refine the impeller design along with changes to the vane geometry to provide a more efficient gas path design. Combined with improvements in materials and manufacturing techniques, efficiency and reliability can be upgraded. Gas path efficiency can be similarly improved.

Process seals

Process seals are critical for compressors in oil & gas applications where process gas leakage to the atmosphere cannot be tolerated for safety and environmental reasons. Oil bushing seals and mechanical dry gas seals (DGS) are the most common types used.

Oil bushing seals have been used extensively in centrifugal compressors for many decades. There is still a lot of rotating equipment, especially in refineries, outfitted with this type of seal. They can suffer from buffer oil leakages, problems with oil quality or issues with the auxiliaries, such as oil pumps or degassing tanks. In addition, there are cases when oil bushings have locked up and affected the mechanical stability of rotors due to increased vibration.

As a result, there is a trend toward upgrading oil bushing seals with mechanical dry gas seals (DGS). However, substantial engineering effort should be done before such an upgrade is executed. But

Restacking of a centrifugal compressor rotor

when installed, operated and serviced properly, DGS will improve reliability of the compressor and reduce operating and maintenance costs.

Upgrading turbine blades

Steam turbine blades can fall victim to a variety of damage mechanisms from high temperature creep to erosion, fatigue and stress corrosion cracking. Boosting blade reliability is paramount when repairing a steam turbine.

A complete engineering reevaluation of blade design is recommended if a failure has occurred or the turbine's operating speed has changed.

Such evaluation includes a structural and modal analysis by means of finite-element analysis (FEA) software tools. It provides an insight about stresses in the critical areas (blade root, fillets, shroud) and natural frequencies of the blade that can be excited by the passing frequencies of stationary vanes at a certain running speed. This can cause resonance.

Based on the analysis, recommendations can be made to change the blade or locking hardware material or redesign the root. Resonance issues can be solved by avoiding the speeds of concern, modifying an airfoil or a shroud redesign to shift its frequencies and increase damping.

Upgraded blading provides both efficiency and reliability improvements, which can be further enhanced by the application of protective coatings to extend their life.

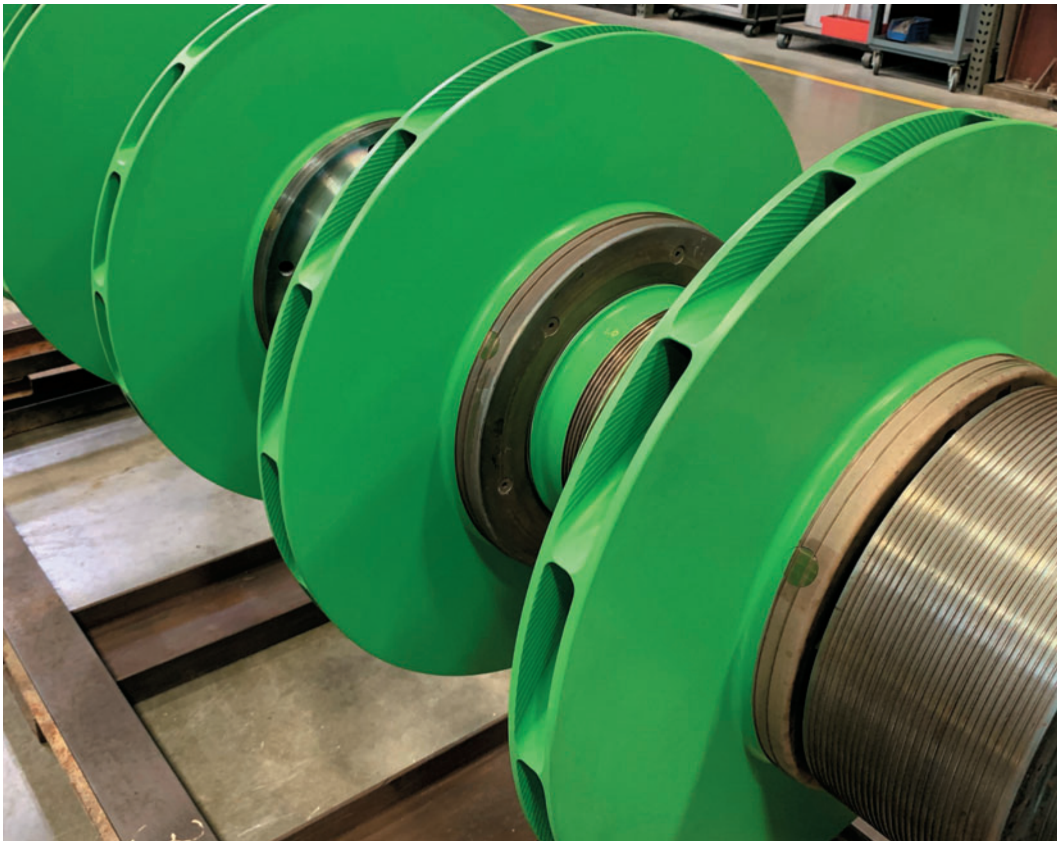
Coatings for durability

Coatings can be applied for dimensional restoration or protection of base material against wear or fouling. Air spray coatings are widely used for protection against fouling and corrosion.

Teflon-based coatings, for example, applied to centrifugal compressor gas path components create a non-stick protective layer on the base metal surface. This improves the efficiency of the parts in the presence of sticky hydrocarbons.

Another type of air spray coating is used for corrosion protection. This is typically an aluminum-filled metallic-ceramic coating. Due to conductivity between coating layers, one substance acts as a sacrificial anode and prevents attack on the base metal.

Hard-face coatings, such as chrome carbide, tungsten carbide and stellite are applied by the high-velocity oxygen fuel



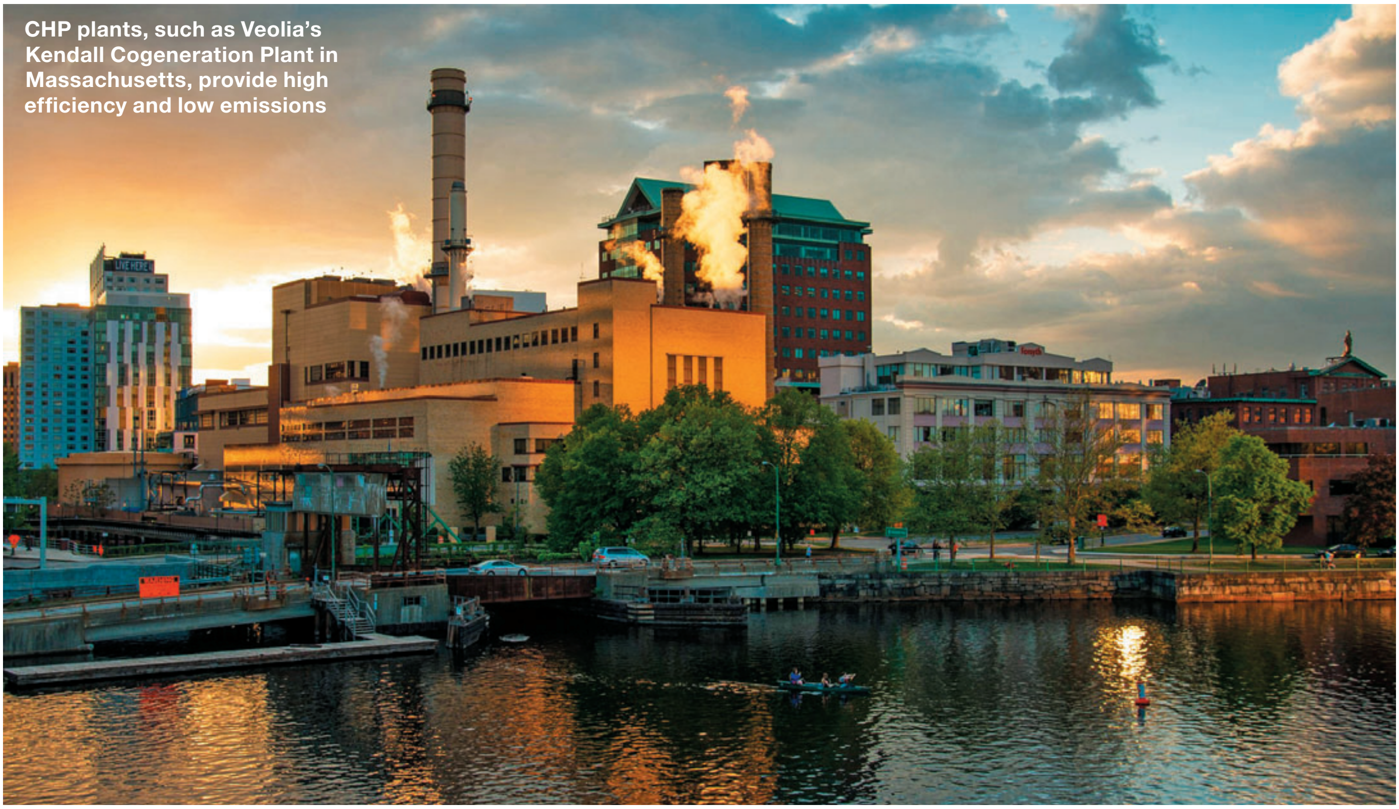
An anti-fouling coating applied to new impellers

(HVOF) process. They are harder than the base material to provide protection from erosion, rubbing or fretting.

Common applications include steam turbine blades, shaft seals and other surfaces where touching and rubbing to the stationary components may occur. In addition, hard-face coatings are sometimes used for dimensional restoration.

They can be applied to rotating component bores to reclaim the required interference to the shaft, shaft journals and seal areas. This saves time during the repair process by allowing the part to be reused instead of replacing it. ■

Sulzer is an independent maintenance provider for rotating machinery with a global network of specialist service centers. For more information visit: Sulzer.com



CHP plants, such as Veolia's Kendall Cogeneration Plant in Massachusetts, provide high efficiency and low emissions

AIR EMISSION PREVENTION

WHY REASONABLE EMISSION RULES SHOULD REPLACE EXISTING NOX REDUCTION MANDATES

BY MANFRED KLEIN

Air priorities in the environment have changed over the past thirty years. It is likely, for example, that CO_2 and fugitive methane emissions will overtake NOx and other pollutants as major new challenges. However, air pollutants, toxics and greenhouse gas (GHG) emissions come from the same sources. They can be prevented together. And efficient gas turbines (GTs) have a major role to play.

GTs, fuelled mostly by natural gas and operating in conjunction with renewable energy, can provide large quantities of electrical and mechanical power, thermal heat and cooling services in an environmentally friendly manner. But there are a few facts that should be better understood.

Gas turbines are called that because their Brayton power cycle is based on air mass flow, not gas fuel. Natural gas is quite different that other types of fossil fuel as it is a hydrogen-based vapor that burns cleanly. Due to its low level of pollutants and CO_2 emissions, local natural gas-based cogeneration and district energy offers an efficient and resilient energy cycle.

Advances in lean premix Dry Low NOx (DLN) combustion technology have lowered NOx emissions from the 150–300 ppm level of the 1980s to the 15–40 ppm level today, depending on the size and type of unit.

This 90% reduction (3 kg/MWhr to 0.3–0.5 kg/MWhr) through cost-effective pollution prevention is unmatched by any other industrial sector and represents a major pollution prevention success story.

However, while most DLN systems on large-frame engines work well, additional experience with new DLN systems in aeroderivatives and small units is required before users can be confident of their off-design operating ranges and reliability.

New hydrogen combustion systems that have high NOx but zero CO_2 emissions could be credited with more flexible NOx requirements. It could also be claimed that with high-efficiency inlet air filtration capturing local ambient dust and volatile organic compounds (VOCs), there are no net particulate emissions from a modern GT system.

Reasonable emission limits

Most regions today have clean energy policies for efficiency, renewables and natural gas. When air pollution and GHG controls conflict with each other, the GT can sometimes get caught in the crossfire. It is recommended that governments and industry bodies switch to improving system efficiency and reliability instead of attempting to reduce NOx levels toward zero.

It is unlikely that GTs emitting a moderate 25–30 ppm level of NOx have ever caused a significant air pollution problem. If forced to further limit emissions to single-digit levels of 2–9 ppm, with high cost and little or no environmental benefit, the ability of GTs to participate with renewables on the grid will be limited.

This would be the case, for example, if backend control with ammonia and Selective Catalytic Reduction (SCR) is used after DLN combustion to hit unrealistic NOx targets.

Ammonia-based liquids are dangerous

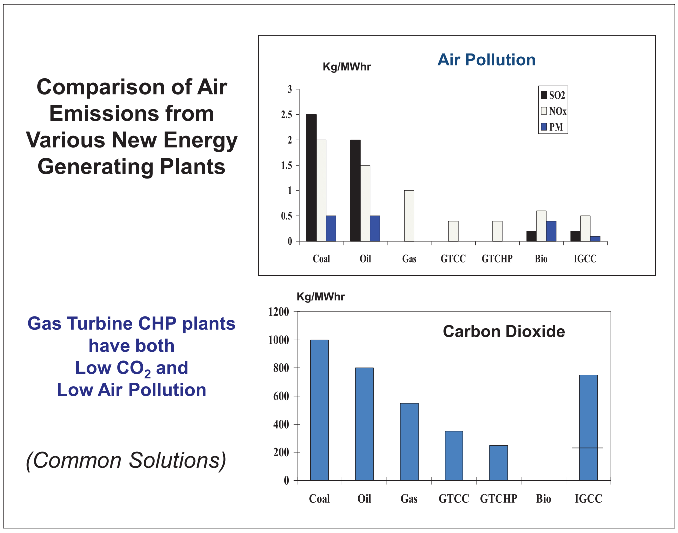


Figure 1. Gas-fired plants offer low emissions and high efficiency

to transport and handle, and SCR produces ammonia slip, particulates, and fouling of the Heat Recovery Steam Generator (HRSG). Additionally, catalytic systems with narrow temperature windows do not perform well in cycling. Their low temperatures may create nitrous oxide (N_2O) as a greenhouse gas.

Low-ppm DLN combustors have been installed in large frame engines for peaking and combined cycles. However, smaller cogeneration units that are better matched to heat-to-power ratios for a thermal host have small combustors operating more reliably in the 25–40 ppm range.

Operating ranges and start-up conditions could also be improved with simpler combustion designs, and the use of auxiliary duct burners.

Low-ppm design requirements encourage larger plants, excessive fuel use, lower system reliability and collateral emissions from SCR. In small GTs used for pipeline compression, reduced reliability may cause compressor engine trips that can lead to pipeline system upsets, methane venting and GHG releases.

A more recent issue is the response to intermittent renewable energy. It requires flexible operating range and start-up/shutdown cycles, which are difficult for both low NOx/CO combustion, and those using SCR systems. These and other issues call for a review of emissions policy to consider a broader view of environmental consequences instead of a rigid adherence to ppm limits.

Output-based emissions

One may wonder why gas turbines are still designed and regulated on the basis of NOx concentration (ppmv) standards when reciprocating engines, cars, aircraft and others use output-based standards, such as g/kWhr, g/mile or kg/1000 kg of thrust. A change is needed in the way emission rules are designed.

In 1992, a Canadian government-industry group produced a national guideline for GTs to promote cogeneration with low NOx emissions, based on grams of NOx per gigajoule of power output and GJ of heat output to promote cogeneration (Figure 2).

These guidelines reflected cost-effective pollution prevention, CHP system efficiency and unit sizing while addressing both NOx and CO_2 emissions. An update was published in 2016 to address larger GTs.

In 2006, the U.S. Environmental Prevention Agency issued a rule (40 CFR 60, subpart KKKK) to incorporate a lb/MWhr output-based emissions standard (OAR-2004-0490, amended in 2012) along with concentration-based rules.

As with the Canadian rules, these did not require SCR and had a cogeneration

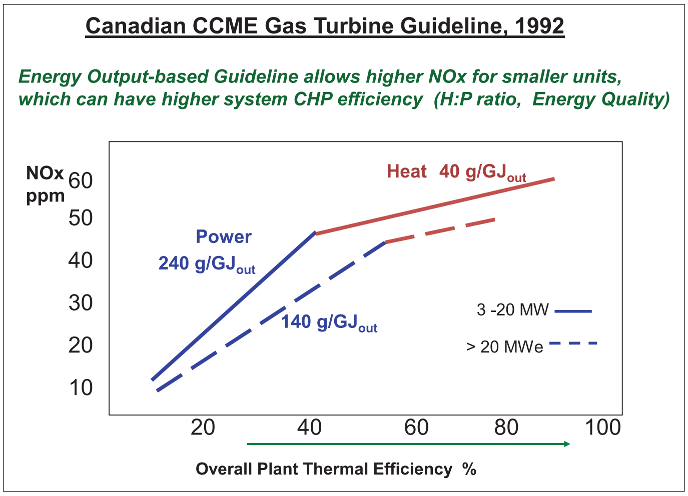


Figure 2. NOx traded off against efficiency and GHG emissions

thermal component with flexible emissions monitoring. More recently, several states have passed energy efficiency policies and laws to advance clean and renewable energy, mostly due to climate risk concerns. Most, however, still use ppmv standards for NOx/CO emissions.

A successful lb/MWhr (not ppmv) standard can allow for:

• More flexibility and reliability in clean energy system design. If these are applied to the plant instead of the unit, designers can think more about overall efficiency of power and heat and lower parasitic losses to minimize all emissions

• Recognition of the associated waste heat recovery system, HRSG and steam turbine or district energy piping, as useful "zero emission" or pollution prevention energy devices. A typical cogeneration plant with a H:P ratio of 1:1 will have a net CO_2 rate of 250 kg (or 550 lb) per MWhr

• Better operation at transient load or changing ambient conditions if combustor mechanical design is not tied to low ppm constraints but rather to optimal power, fuel rate and mass flow. This allows better integration with wind and solar energy.

There is much discussion about life-cycle emissions, and how natural gas has half the GHGs of coal (cogeneration would be a net 70% reduction). A better way to conduct this analysis would be based on a combination of air pollutants, toxics and GHGs.

A mix of gas turbine simple cycle, combined cycle and cogeneration systems would achieve a 70%-to-90% reduction in total air emissions compared with coal, if upstream methane emissions can be minimized.

Modern GT cogeneration plants represent a dramatic decrease in all air pollutants and carbon dioxide, while providing local reliability. With clean fuels, and in combination with all renewables and district energy, fuel cells and hydrogen systems, they represent a reasonably sustainable solution for at least the next 50 years.

These topics will be considered at the upcoming Canadian Gas Turbine Energy Network conference in Banff Alberta, Oct 21–23, 2019 (www.gten.ca). ■

Manfred Klein is principal of MA Klein & Associates, a consulting firm specializing in natural gas energy systems, gas turbines, distributed energy and air emissions solutions. For more information, email maklein@rogers.com

SIEMENS PREPARES TO LAUNCH NEW ENERGY COMPANY

Arja Talakar, Chief Executive Officer at Siemens Oil & Gas, discusses the impending separation and reorganization of its energy sector portfolio, as well as opportunities for growth

Tell us about yourself

I began my career with Siemens in 1996 as a rotating equipment and automation systems engineer. I've held roles in the United States, Germany, South Korea and Saudi Arabia.

Before becoming CEO of Siemens Oil & Gas, I was responsible for Siemens Saudi Arabia. We developed close ties with oil and gas, energy and petrochemicals companies, and executed large infrastructure projects. I hold an MBA from IMD Business School in Switzerland, and an Engineering degree from Germany's Technische Universitaet Braunschweig.

Can you explain the reorganization and separation from Siemens?

Siemens AG will consolidate its Gas and Power (GP) Operating Company, which combines the Siemens oil & gas, power generation, transmission, and related service businesses into an independent, stock-listed energy company.

Siemens Gamesa Renewable Energy will be part of the new company. The launch will create a pure-play company with a portfolio along the entire energy conversion value chain.

What opportunities does the spin-off offer?

It creates a company dedicated to overcoming the challenges facing the energy sector. Our portfolio will encompass conventional and renewable energy solutions from a single source. This will give us the agility we need to adapt to an ever-evolving market.

What equipment comes under the new entity?

For oil and gas customers, we will continue to provide engineering and digital solutions. Our focus markets will include offshore upstream; the entire gas-to-power value chain (gas plants, pipelines, LNG, etc.); refineries and petrochemical plants; and unconventional resources.

Rotating equipment (steam and gas turbines (GTs), centrifugal and reciprocating compressors) will remain integral to our portfolio, bolstered through the acquisitions of Dresser-Rand and a division of Rolls Royce.

What trends do you see developing in LNG and pipelines?

Today's hydrocarbon conundrum is less about supply than environmental impact. Renewables and natural gas are both part of the solution.

The latter is abundant and economical, thanks in large measure to the U.S. shale boom. It's also cleaner relative to other fossil fuels. As we work to make renewables more cost competitive, the world needs natural gas.

Growing demand for clean energy is driving the buildout of transportation infrastructure, namely LNG plants and pipelines, to move natural gas to destination markets.

Siemens has developed solutions to address increasing demand to reduce emissions, and the related need for electric-driven LNG designs. We have been developing turnkey solutions, in some cases as an EPC joint venture partner.

The pipeline market is also under pressure to drive efficiency and competitiveness. Machine data and Internet of Things (IoT) solutions are part of that journey.

LNG and pipeline operators can harness data to optimize critical equipment, thereby reducing risk and costs while driving efficiency. Another emerging challenge is cybersecurity. Siemens has bolstered its IoT solutions for oil and gas with a dedicated cybersecurity team.

What trends are evolving in combined cycle power plants (CCPPs)?

Historically, CCPP designs have been used in traditional power plants to boost efficiency and in onshore oil and gas applications requiring large-scale power plants. More recently, we are seeing positive development in offshore CCPPs. This could become a trend due to the advantages of all-electric solutions that reduce the dimensions of CCPPs.

What can be done to reverse the downward trend in GT sales?

We need to differentiate between gas turbines above 100 MW and those below 100 MW. Above 100 MW, the market appears to be stabilizing.

The oil and gas market has picked up, driven by the need for additional power. Regions like North America are driving growth because of increased needs for power, but they're also using using GTs as mechanical drives for compression applications.

This is particularly true for large pipeline companies and gas processing companies. We're seeing an increase in the use of large power block GTs in compressor trains, particularly in the pipeline market, due to the advantages of using fewer compression trains driven by larger (30 MW) turbines. Studies on compressor trains driven by large power block GTs show tremendous savings potential in terms of footprint and emissions.

How will wind and turbomachinery work together?

Wind energy and turbomachinery are complementary. With oil and gas, power generation, and transmission, the new company will provide the complete spectrum of energy solutions across the conventional and renewable energy landscape.

What digital solutions have the strongest market reach?

Advances in sensor technology and data analytics have paved the way for industrial asset optimization across all verticals. We can use machine data to predict and preempt the failure of critical equipment and enhance safety and efficiency.

Similarly, artificial intelligence (AI) is taking asset optimization to the fleet level. Other areas of opportunity include additive manufacturing and virtual reality. Additive manufacturing makes it possible to 'print' spare parts and components on demand, and digital twins enable design, testing and training in virtual, risk-free environments. ■

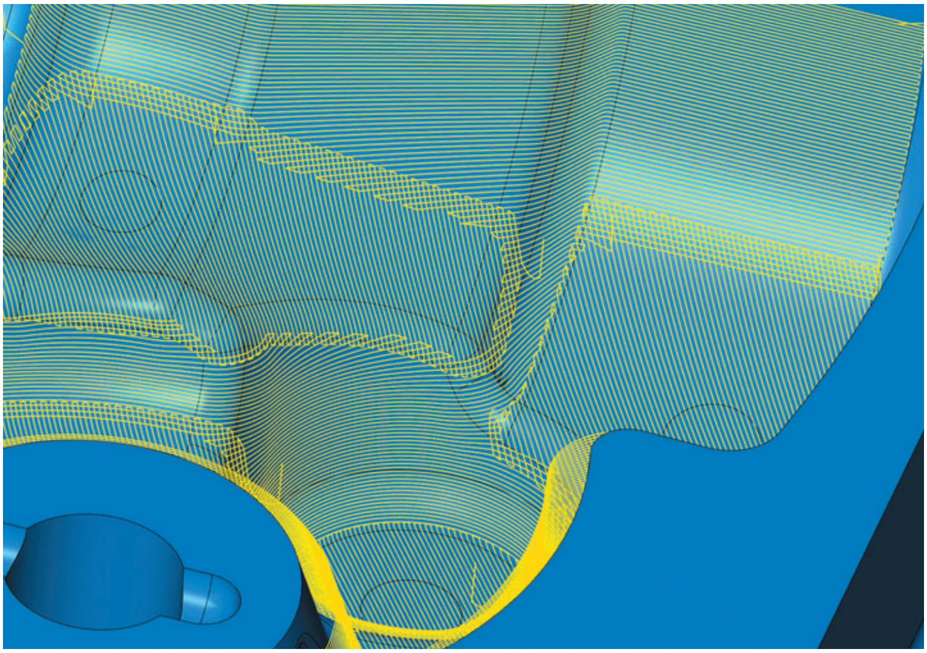
CAD/CAM software

Open Mind Technologies has introduced hyperMill 2019.2, an update to its CAD/CAM software suite. Added features include high-precision 3D finishing, 5-axis tangent machining, high-performance turning, and new CAD-for-CAM technologies.

Programming process times have been improved and CAD utilities have been directly integrated into some CAM strategies. When using the 3D shape Z-level finishing cycle, it offers a high precision surface-mode option that ensures smooth surfaces with tolerances in the micron range.

This saves time on post-machining finishing processes, especially for mold makers. Open Mind has also enabled more secure and simpler programming. Full-text searching is available in the macro database and users can define machine and material groups as defaults to make it easier to select macros.

openmind-tech.com



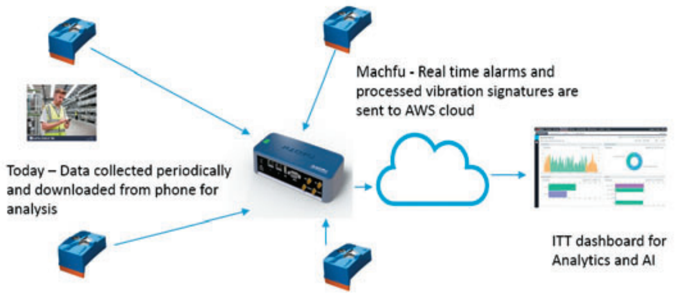
High precision surface mode in hyperMill 2019.2 ensures smooth surfaces in the micron range

Torque monitoring

Nord Gear has released a gearbox torque monitoring system known as TorqueProtect. Designed for wastewater treatment facilities, power generation plants and other industries that require low-speed, high-torque drives, it provides real-time load monitoring and continuous feedback to give operators visibility and control over the torque performance process.

Available in two configurations, the Nord TorqueProtect monitoring system includes: A Nord gearbox, a stainless-steel control panel and load cell, digital display, and an analog output module.

Nord.com



Bluetooth health monitor

Where many plants are checking and recording vibration signatures in rotating equipment with handheld devices, technology is rapidly supporting the acquisition of machine condition data through wireless monitoring.

ITT has developed a machine monitor (sensor) adapted for rotating equipment, called the i-ALERT Bluetooth Equipment Health Monitor. This sensor mounts directly onto the equipment. It tracks factors, such as tri-axial vibration, temperature and runtime hours. It wirelessly syncs this data to a mobile app via Bluetooth devices and uploads data to the cloud.

It can continuously upload machine performance information to the cloud without technician scanning the monitor at the site. This is made possible because of the system's high-application gateway. Developed by Machfu, the MACHGateway constantly polls the machine sensors. It uses the bandwidth and low latency of cellular networks.

machfu.com

Video measurement

The L.S. Starrett Co., The L.S. Starrett Co. has introduced a new generation of its HDV300 and HDV400 benchtop Digital Video Comparators with speed increases and improved illumination, design and convenience enhancements. CNC motion is faster, enabling greater measurement throughput.

At 10mm/sec., speed on the Y-axis has tripled and X-axis speed has almost doubled at 45mm/sec. In addition, improved LED ring lighting provides a more consistent illumination.

Starrett.com

Turbo motor

Yaskawa Environmental Energy (The Switch) has delivered thousands of turbo motors for specialized high-speed pump and compressors applications. The same technology is now available as standardized motors paired with drives of 100 to 600 kW and speeds of 6,000 to 20,000 rpm.

The solid rotor motor eliminates the need for a gearbox, while allowing the application to reach higher speeds and availability. The solid rotor construction provides high mechanical strength and stability, requiring up to 50% less space than a conventional design. Each solid rotor motor is paired with a matching Yaskawa GA700 drive. Operating voltages range from 380 V to 690 V. The air- or liquid-cooled motor comes in three frame sizes.

theswitch.com

Yaskawa offers standardized solid rotor motors paired with matching drives

Hydraulic pumps

Enerpac has announced E-Pulse durable, high-efficiency hydraulic pumps available with five valve options. The motor can maintain constant power and provide higher flow than traditional one-half horsepower pumps.

It has an adjustable speed and an interactive pendant that delivers visual and tactile feedback, programming and diagnostic status to the operator through yellow, green and red LEDs and vibration pulses.

A fault code indicator warns operators of any issues related to voltage, temperature, button controls or service conditions. A .85hp direct-drive motor offers a six-piston block design that provides even flow and smooth operation.

Enerpac.com

Fire retardant film

Cortec believes it can cut equipment preservation costs by up to 60%. Heavy-duty film from its MilCorr line features multi-metal vapor phase corrosion Inhibitors (VpCI), flame retardant additives, and ultraviolet inhibitors. It is used for military and other types of industrial equipment.

Equipment shrink wrapped for corrosion protection from Cortec

MilCorr FR VpCI shrink film offers long-term outdoor storage. It can replace conventional rust preventatives, such as oils and desiccants, while extending equipment life.

Metal parts packaged in MilCorr FR VpCI receive continuous multi-metal, contact, barrier and vapor-phase protection against salt air and humid environments, moisture, aggressive industrial atmospheres and metal corrosion.

cortecpackaging.com

AD INDEX

MYTH: YOU CAN OPERATE IN SURGE

We have previously written about surge in our Myth Buster column. It is a violent physical phenomenon that occurs in centrifugal compressor systems with the potential to cause significant damage to the compressor.

Surge occurs when the compressor is not capable of overcoming the discharge pressure imposed by the system: when the compressor operates on the low-flow side of its operating range. This is where the capability of its impellers drops below the point where it can produce sufficient head to overcome the pressure difference between the high-discharge pressure and low-suction pressure.

At that point, the gas will flow backwards through the compressor from the pressure side to the suction side. As a result, the discharge pressure imposed by the system is reduced. Eventually, the discharge pressure becomes low enough that the compressor can overcome it, and the flow will again go from suction to discharge. If nothing in the system is changed, this process repeats.

Surge is thus a periodic cyclic phenomenon that occurs at compressor and piping system characteristic frequencies unrelated to the running speed. As full flow reversal occurs, there are significant forces created during surge with the potential of severe damage to compressor internal components as well as the piping and related structures.

Surge control

All compressors can experience surge, and surge control systems are designed to keep the compressor safely away from crossing the surge line into this unstable operating region. The compressor surge control system, in its most basic form, is a recycle loop and valve that opens to increase the flow into the compressor whenever it approaches low flow surge.

Conventional practice uses a 10% margin away from the surge line to start opening the compressor recycle valve. This margin generally avoids surge in all steady and transient operating scenarios.

No compressor should be operated in surge. It is dangerous, damaging and inefficient. There may be cases when the surge line is briefly crossed, either accidentally or unavoidably during a fast shutdown. But no compressor should be intentionally operated in surge for an extended period of time since this will likely cause harm to the compressor

Research efforts are ongoing to extend compressor operating range by control rather than aerodynamic means. Range extension can offer operational flexibility and potential efficiency improvements by running closer to the best operating point and by recycle avoidance.

But the surge-control margin is designed primarily to satisfy critical operating functions: start-up sequencing, normal shut-down, emergency fast shut-down and system upsets causing sudden flow reduction.

The last two drive a large safety margin between the surge line and where the recycle control line is set. If the compressor goes into a fast shutdown or experiences another upset that causes rapid flow decrease, the recycle valve opens. Modern control systems and recycle valves perform this function in less than a second.

The question is not whether a compressor can be operated in surge but how significant the surge forces are.

But what are the surge forces on key internal compressor components and are they sufficient to cause damage to the machine if the transient surge event is very short?

Unfortunately, this requires more than a simple analysis. It is basically a two-step process requiring a transient surge analysis to determine where the compressor crosses the surge line during a system upset and a second much more complex fluid-rotor interaction analysis to determine the axial (and to a certain extent radial) forces acting on the shaft during surge.

Note that methodology and prediction results from fluid-rotor surge interaction analysis is uncertain. Three analysis approaches are currently proposed:

- A simple non-dimensional number also know as the "Surge Severity Coefficient"
- A basic lump-sum, fluid-transient surge model based on the Greitzer surge cycle
- A detailed transient rotor-fluid interaction model including a dynamic model of all relevant time-dependent forces acting on the rotor as a mass-spring-damper system.

The first two provide an initial indication of surge severity and are primarily used to determine whether further analysis is warranted.

The third model is a complex fluid-rotor time domain transient analysis that requires detailed knowledge of compressor design and operating characteristics. The problem is made more difficult as surge forces are not strictly axial. Interaction with a flexible rotor has to be considered.

Alternatives to increasing the operating range of a compressor do not involve reduction of the surge-control margin. They rely on more conventional methods, such as restaging the compressor, cycling machines on and off for line-pack/un-pack, wider range impeller designs, hot gas by-path loops, delayed shutdowns, faster surge control systems or even advanced pipeline operating control schemes.

"Can my compressor operate in surge? For how long? Will it be catastrophic?" are valid inquiries to assess a specific compressor's potential to have an increased operating range on the left side of the conventional surge control line. The answers require complex analysis that generally leaves a significant margin of uncertainty.

Compressors do operate in surge and can survive surge events. The question that is unanswered is, how often, how long, and at what severity can a centrifugal compressor be exposed to a surge event without showing damage or performance deterioration. ■

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Learn more by visiting our team at the ADIPEC Exhibition & Conference on November 11–14 at booth 6210, hosted by NAMA Development Enterprises.