THE GLOBAL JOURNAL OF ENERGY EQUIPMENT

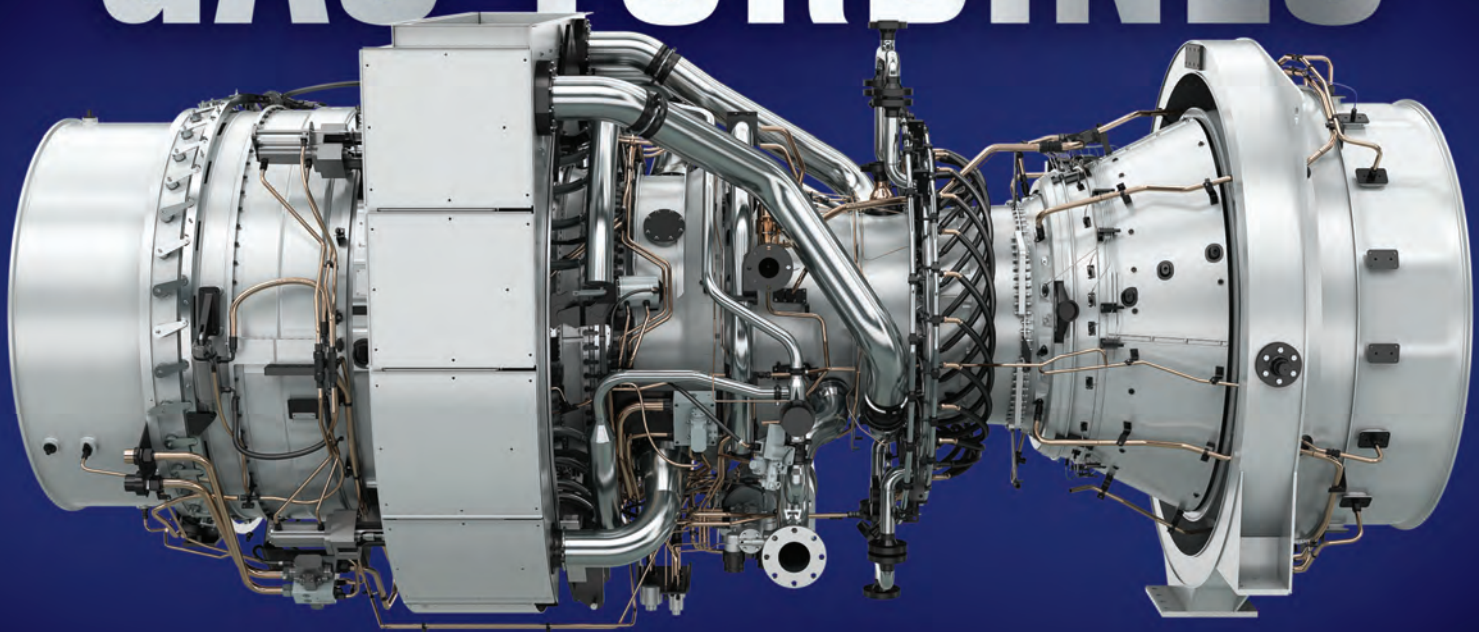
INTERNATIONAL Turbomachinery

NOVEMBER/DECEMBER 2017 • VOL. 58 NO. 7 • $7.50

turbomachinerymag.com

UBM

AERODERIVATIVE GAS TURBINES



Also in this issue: Steam Turbines • Remanufacturing
Advanced Manufacturing • Digital Power Plants
Semi-Closed Recuperated Cycle • Compressors
Combined Cycle Power Plants • Ansaldo Gas Turbines

DOUBLE SHOW ISSUE
Turbo Symposium
PowerGen


SIEMENS
Ingenuity for life
The power of partnership.
Engineering Ingenuity
Making your project a success takes more than just technology. It takes ingenuity — the ingenuity to understand your needs and tailor integrated solutions accordingly. From pipeline compressor and pump stations, to LNG plants and FPSOs, we've got you covered. We draw on an extensive equipment portfolio (including turbomachinery, motors, drives and gearboxes), a comprehensive software suite, as well as engineering expertise. And we'll partner with you every step of the way to ensure your project is a success, from pre-FEED through maintenance. That's the power of engineering ingenuity.
www.siemens.com/turboshow2017
Come see us at TPS, Dec. 12-14, Houston, Booth #1934
IPS

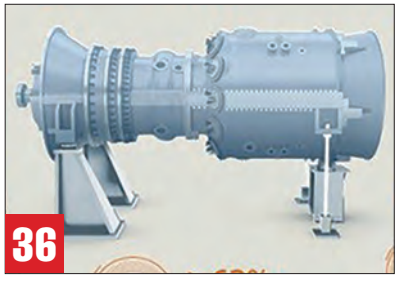
Features

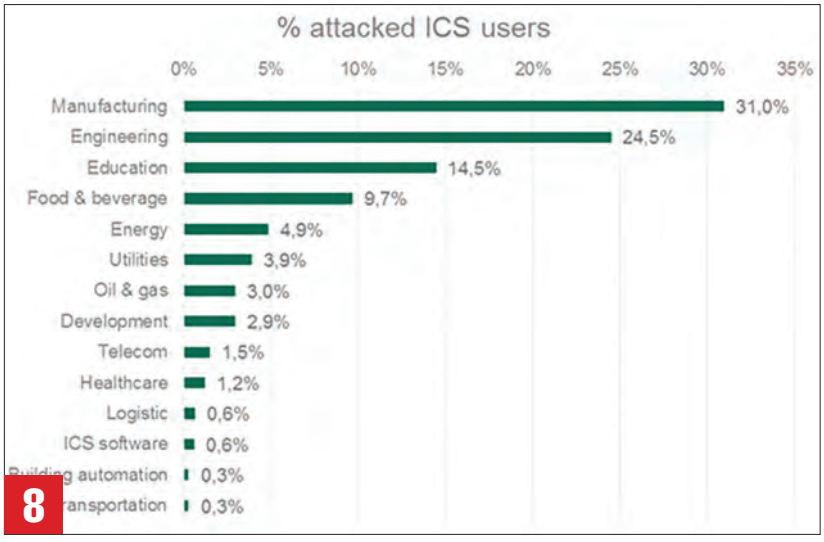
CONNECT WITH US:
www.turbomachinerymag.com
www.turbohandbook.com
Richard.Zanetti@UBM.com
Drew.Robb@UBM.com

Departments

8 INDUSTRY NEWS

36 NEW PRODUCTS





COLUMNS

Cover photo: A Siemens SGT-A65 aeroderivative gas turbine

Turbomachinery & Pump Symposia: Booth 1711

MITSUBISHI HEAVY INDUSTRIES
COMPRESSOR INTERNATIONAL

OUR ADVANCED COMPRESSOR

PROMISE:

WE PROMISE HIGH PERFORMANCE. THEN WE OVER DELIVER.

Reliable Compressor Performance. From Spec to Ship to Support.

With Mitsubishi Heavy Industries, you can expect more than reliable performance. Count on next-generation designed compressors. Expect flexible solutions and greater certainty in project execution, from start to finish. Most of all, count on Mitsubishi's advanced compressor promise – highly engineered, customized equipment built to exact specifications. That's the promise of high performance, delivered.

www.mhicompressor.com/en

INTERNATIONAL
Turbomachinery
turbomachinerymag.com

ESTABLISHED IN 1959

Founders
G. Renfrew Brighton and R. Tom Sawyer

Publisher
Richard Zanetti, 203-523-7053
richard.zanetti@ubm.com

Editor-in-Chief
Drew Robb, 323-317-5255
drew.robb@ubm.com

Executive Editor - News/Blog
Kalyan Kalyanaraman, 203-526-7053
deerpark@gmail.com

Handbook Editor
Bob Maraczi, 203-523-7040
bob.maraczi@ubm.com.com

Executive Correspondents
Klaus Brun, Amin Almasi

Contributing Editors
Mark Axford

Art Directors
Quinn Williams, 218-740-7236
Steph Bentz, 218-740-6811

Production Manager
Godfrey Nicholas, +91-714-845-0252 Ext 6055022

Circulation
Wendy Bong, 218-740-7244

EDITORIAL & BUSINESS OFFICES

UBM, PLC
Turbomachinery International
535 Connecticut Avenue, #300
Norwalk, Connecticut, U.S.A. 06854
Tel: 203-523-7053

Subscription Service
For subscription/circulation inquiries, 888-527-7008.
Outside the U.S. call 218-740-7273,
email to fulfill@hcl.com or send via mail to:
Turbomachinery International, UBM,
131 W 1st St, Duluth, MN 55802

ADVERTISING

WEST, MIDWEST, SOUTHEAST, SOUTHWEST U.S.A.
Gerry Mayer
5930 Royal Lane Ste E #201
Dallas, TX 75230
Tel: 972-816-3534 Fax: 972-767-4442
gm@mayeradvertising.com

NORTHEAST, MID ATLANTIC U.S.A. CANADA
Richard Zanetti
535 Connecticut Avenue, #300
Norwalk, Connecticut, U.S.A. 06854
Tel: 203-523-7053
richard.zanetti@ubm.com

GERMANY, AUSTRIA, SWITZERLAND
Sven Anacker
InterMediaPartners GmbH
Beyeroehde 14
Wuppertal, D-42389, Germany
Tel: 49-202-271-690 Fax: 49-202-271-6920
sanacker@intermediapartners.de

UK, BENELUX, SCANDINAVIA, ITALY, FRANCE
Ferruccio Silvera
Viale Monza 24
20127 Milano, Italy
Tel: 39-022846716 Fax: 39-022893849
ferruccio@silvera.it

JAPAN
Yoshinori Ikeda
Pacific Business, Inc.
Kayabacho 2-chome Bldg., 2-4-5, Nihonbashi Kayaba-cho
Chuo-ku, Tokyo 103-0025, Japan
Tel: 81-3-3661-6138 Fax: 81-3-3661-6139
pbi2010@gol.com

INDIA, MIDDLE EAST
Faredoon Kuka
RMA media
Twin Arcade, C-308
Military Road, Marol
Andheri (E), Mumbai-400059, India
Tel: 91-22-6570-3081/82 Fax: 91-22-2925-3735
kuka@rmamedia.com

KOREA
Peter Kwon
305-402 Hill State Apt.
116 Bokukmoon-ro
Seongbuk-gu
Seoul, Korea 02702
Tel: 82-2-416-2876 Mobile: 8210-8223-2876
Fax: 822-2202-9351
peterhkwon@hanmail.net

SOUTHEAST ASIA
Stephen Moore
Intercedent Asia (Pte) Ltd.
15 Queen Street, #03-01A Tan Chong Tower
Singapore 188537
Tel: 65-6222-7008 Mobile: 65-9687-0420
Fax: 65-6222-9070
stephen@intercedent-asia.com

abm | BPA | UBM

Publisher makes no guarantees or recommendations concerning any process, procedure or device described herein. Turbomachinery International is published bimonthly, plus an extra issue in October, by UBM plc. Executive and Editorial offices, 535 Connecticut Avenue, Norwalk, Connecticut, U.S.A. 06854. Volume 58, Number 5.

Periodical postage paid in Norwalk, Connecticut and at additional mailing offices. (USPS 871-500. ISSN 0149-4147). Publications Mail Sales Agreement No. 1436961. Postmaster: Please send address changes to Turbomachinery International, P.O. Box 6000, Duluth, MN 55806-6000, U.S.A.


A new generation is born
New products.
New technologies.
New service capabilities.
Ansaldo Energia: a global player
in the power generation market.
ANSALDO
ENERGIA
www.ansaldoenergia.com
02/2016 - Peterstyl

GE LM6000 repairs being carried out by MTU Maintenance

AERODERIVATIVES IN THE SPOTLIGHT

Aeroderivative gas turbines (GTs) are one of the growth areas in the turbomachinery sector. They are expected to grow in sales by 5% per year for the rest of the decade at least. Their flexibility, small footprint and reliability have made them popular in LNG, as peakers and as immediately available power on grids with a heavy concentration of renewables.

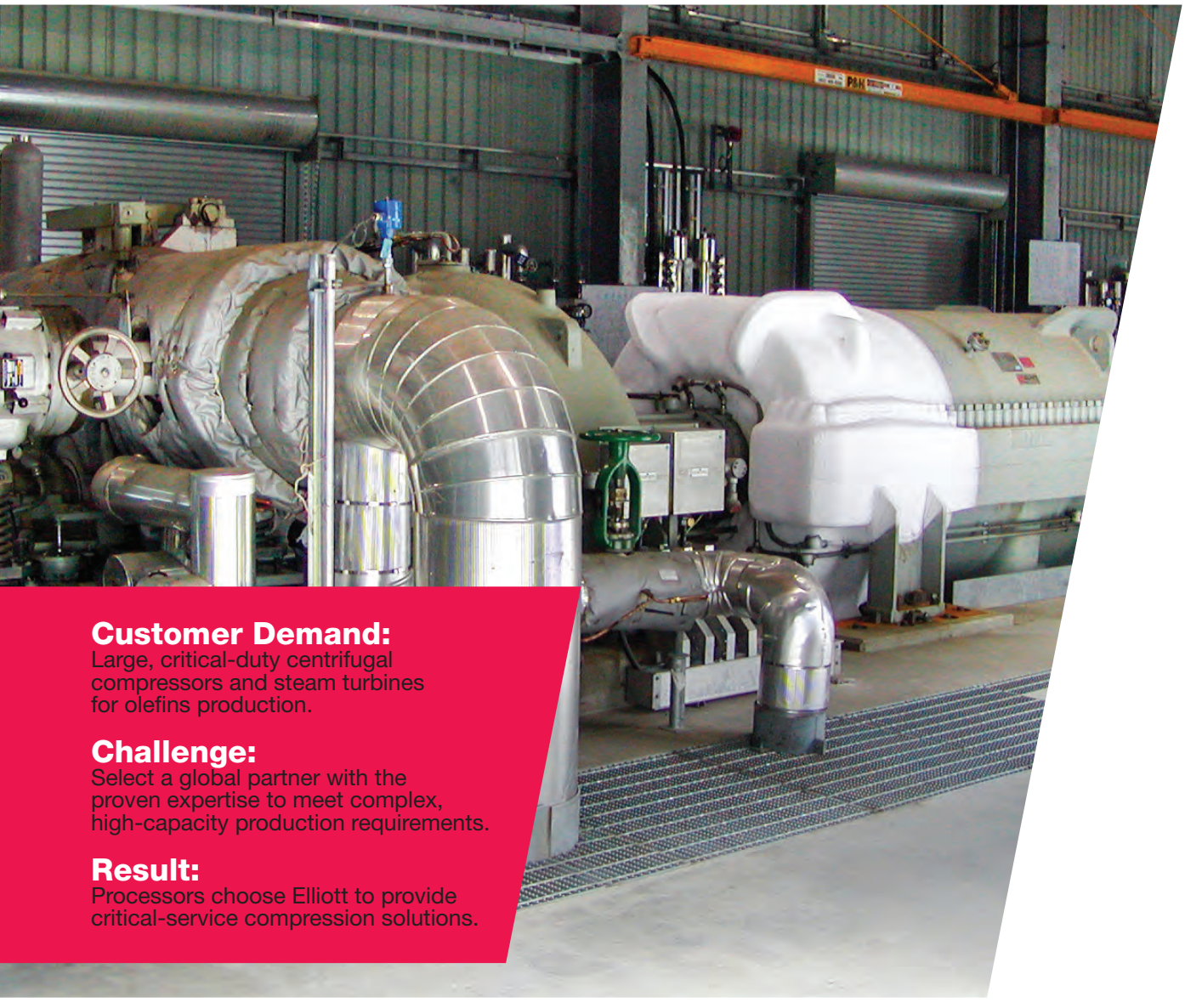
So it is about time we gave them more attention. Our cover story features a review of the many aeroderivatives available from GE, Siemens and Pratt & Whitney Power Systems (PWPS). Each of their models is described in detail. In addition, we cover the aeroderivative aftermarket. Vendors such as MTU Maintenance, EthosEnergy, RWG and Sulzer provide tips on how to maintain these machines and the various services they offer.

Beyond that, the issue includes plenty of worthwhile material. There is a feature on steam turbine maintenance, a look at a novel design for a combined cycle power plant, how 3D printing must evolve to serve the oil & gas sector, and where remanufacturing may be of value in turbomachinery.

Moreover, our Myth Busters tackle the problem of rickety foundations, and Turbo Tips takes a look at hydraulic systems. By the time you read this, two major shows will be upon us. The PowerGen show in Las Vegas and the Turbomachinery and Pump Symposium in Houston. We look foward to seeing you at one or both of these shows.

Drew Robb

DREW ROBB
Editor-in-Chief



Customer Demand:
Large, critical-duty centrifugal compressors and steam turbines for olefins production.

Challenge:
Select a global partner with the proven expertise to meet complex, high-capacity production requirements.

Result:
Processors choose Elliott to provide critical-service compression solutions.

They turned to Elliott

for a long-term partnership and long-term service.

World-scale olefins processors turn to Elliott for compressors and steam turbines that deliver unmatched reliability, efficiency, and value over the life of their investment. Elliott technology and quality ensures customers a competitive advantage in world markets. Who will you turn to?

COMPRESSORS ■ TURBINES ■ GLOBAL SERVICE

ELLIOTT GROUP
EBARA CORPORATION

The world turns to Elliott.
www.elliott-turbo.com

MHPS digest

The Grand River Dam Authority (GRDA) has dedicated Unit 3 at its Grand River Energy Center in Oklahoma, a 505 MW combined cycle power plant (CCPP) equipped with a Mitsubishi Hitachi Power Systems (MHPS) M501J gas turbine (GT). It is the first J-Series turbine produced at the MHPS Savannah Machinery Works, the first to be operational in the Americas and has achieved 62% combined cycle efficiency.

The debut of the M501J in the Americas at GRDA has attained 100% starting reliability since entering loaded operation. It is paired with an MHPS steam turbine (ST) and Mitsubishi generators. GRDA signed a 25-year long term service agreement with MHPS that included MHPS-Tomoni digital solutions.

MHPS Saudi Arabia has opened a turbine rotor repair facility in Dammam, and announced plans to manufacture its most advanced GTs in the Kingdom as part of a phased investment strategy. The facility will be used as a base for servicing MHPS compressors and turbines used in various petroleum and chemical plants. In collaboration with Mitsubishi Heavy Industries Compressor Corporation (MCO), MHPS will handle the maintenance and inspection of a wide range of compressors and turbines delivered to the Saudi Arabian peninsula by MCO.

MHPS has performed rotational vibration testing of a 74 inch (1,880 mm) last stage rotating blade (74IN LSB), bringing the blade's development process to completion. The 74IN LSB expands MHPS's lineup of steam turbines, complementing the latest 54IN LSB (1,375mm). This testing verified the vibratory characteristics of the blades. Steam turbines using the 74IN LSB can be used at 1,200 MW nuclear power plants as well as those exceeding 1,500 MW.

MHPS has updated performance specifications on two combined cycle and one electrical generation model. These updates were not submitted in time to be included in the *2018 Turbomachinery Handbook*.

Combined Cycle Plant Specifications

Model	Power Rating ISO Base Load (MW)		Gross Heat Rate (Btu/kWh)	GTs Number	Model	Frequency (Hz)
	Gas turbines	Steam Turbine				
MPCP1(M501JAC)	394.1	180.9	5,332	1	M501JAC	60
MPCP2(M501JAC)	788.2	364.8	5,315	2	M501JAC	60

Electrical Generation Specifications

Model	Power Rating ISO Base Load (MW)	Heat Rate LHV Shaft (BTU/kWh)	Power Ratio Speed	Pressure	No. of Combustors	Exhaust Flow(kg/sec)	Exhaust Temp.
M501JAC	400.0	7,755	3,600	25	16	694	653(°C)

Note: All ratings on natural gas fuel, with inlet and exhaust losses (LHV base).

Emerson retrofit

Emerson has been selected to retrofit controls at the Elektrik Uretim A.S. (EÜAS) Ambarli A combined cycle power plant in Istanbul, Turkey. Replacing the controls with a unified Ovation platform is expected to improve the overall reliability of the plant.

Ambarli A consists of three, 450 MW power blocks, each in a 2x2x1 configuration, with a total generating capacity of 1,350 MW. The Ovation system will control more than 20,000 points. Ovation technology will directly control and provide overspeed protection for the plant's six Siemens V94.2 GTs. The system will also control three Siemens dual-pressure condensing STs, HRSGs and balance of plant (BOP) equipment and processes.

Elliot VPs

Elliott Group has appointed John Rann, Vice President of its newly integrated cryogenic pumps business, Ebara International Corporation's Cryodynamics Operation (EIC Cryo). EIC Cryo will operate as one of four business units within Elliott Group. Rann has been with Elliott for four decades and has worked for each of its business units. Shugo Hosoda will succeed Rann as Vice President of Engineered Products.

Elliott Group announced today that its Pneumatic Trip System, with or without partial stroke actuation, has received the IEC 61508 SIL 3 capable safety certification. The SIL 3 capable certification was awarded by Exida. Elliott's Pneumatic Trip System provides a safety function for STs. In response to an overspeed event, it shuts the turbine down to prevent damage or catastrophic failure.

Stephan Schaller of Voith

New Voith CEO

Stephan Schaller, member of Voith Shareholders' Committee and head of the global motorcycle division of BMW Group, has been appointed as successor to Dr. Hubert Lienhard, long-standing President and CEO of Voith Management. The change will take place on April 1, 2018.

Schaller studied mechanical engineering at Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen. He has held management and executive positions at BMW, Linde, Volkswagen and Schott. Lienhard will be appointed to the Shareholders' Committee.

GE digest

Competitive Power Ventures (CPV), GE Energy Financial Services and Osaka Gas USA have broken ground on a $700 million, 1,050 MW CCPP to be built in Johnstown, Pa. Known as CPV Fairview Energy Center it will be fueled by natural gas and ethane and feature 7HA.02 GTs, an ST, generators and additional controls and equipment, supplied by GE. Construction is expected to take 30 months.

GE Power has commissioned its 7HA.01 GTs at Chubu Electric Power's Nishi-Nagoya power plant in Japan. The company installed six 7HA.01s at the Nishi-Nagoya Block-1 as part of a contract with engineering procurement and construction (EPC) company Toshiba. Featuring GE's 7HA GT technology and Toshiba's ST technology, the facility holds a capacity to generate around 1,188 MW.

GE Power has signed a multi-year service agreement with Saudi Electricity Co. (SEC) to provide maintenance, parts

HOW MUCH ARE HYDRAULICS REALLY COSTING YOU?

Young & Franklin's Return on Investment calculator can help you find your savings, contact a specialist today for more information.

Think about leaks. Varnish. Servo maintenance. Lube oil system cleaning. Filter replacement. Annual device calibrations. Motor & pump maintenance. Unscheduled shutdowns. And more leaks.

Young & Franklin Inc (YF)'s suite of EMA actuators are designed to be durable, reliable, and virtually maintenance-free for up to 96,000 hours, giving typical users a quick return on their investment. With an installed base of products running on more than 15,000 turbines, YF has built a reputation based on technical expertise and product excellence.

info@yf.com
+1.315.457.3110

YF Young & Franklin Inc.

www.yf.com

and repairs services for eight GE 7F.05 GTs at Riyadh Power Plant 12 (PP12). The contract will span a period of nine years.

GE supplied the 7F.05 gas turbines under a previous contract with SEC, with four units entering commercial operations in 2014, followed by the rest a year later. Operating in combined-cycle mode, the turbines add about 1,800 MW to the grid.

GE will provide support on-site, but equipment at PP12 will also be monitored by the Saudi PowerGen Efficiency Center (SPEC), located in the GE Manufacturing & Technology Center in Dammam. A collaboration between GE and SEC, SPEC monitors over 500 power generation trains round-the-clock.

Apple and GE have formed a partnership to deliver industrial apps to bring predictive data and analytics from Predix, GE's industrial Internet of Things (IoT) platform, to iPhone and iPad. The two companies unveiled a new Predix software development kit (SDK) for iOS, which gives developers the tools to make their own apps.

It will deliver GE's full suite of Predix apps for energy — including APM on the iOS devices workers want to use. This will help utilities that are undergoing digital transformations to better incorporate a mobile app strategy. The partnership will further enable utility workers, ensuring that real-time data is captured and shared with field workers and remote operations using iOS devices.

With half of Jamaica's electricity generation infrastructure more than 30 years old, the country is seeking ways to modernize its plants and decrease its oil dependency by diversifying its energy mix. GE's Power Services business has signed an agreement with Jamaica Public Service (JPS) to modernize its generation equipment at the Bogue Power Station in Montego Bay.

JPS recently introduced LNG into its fuel mix. This began with the dual-fuel conversion of its 120 MW combined cycle Bogue Power Station. With the installation of one of GE's LM2500+ aeroderivative GTs, LNG-fueled generation began.

Boiler acquisition

Nationwide Boiler has acquired Pacific Combustion Engineering (also known as Ponder Burner Company). With headquarters in Washougal, WA (near Portland, OR), the acquired company increases Nationwide Boiler's share in the industrial equipment market and expands coverage in the Pacific Northwest for rentals, sales and service.

It will also enhance overall product offerings, with the ability to provide control systems across multiple industries that use combustion equipment. The panel fabrication shop can perform Factory Acceptance Testing (FAT) prior to shipment to prove that equipment has the same functionality as indicated in the specification and purchase order.

Industrial security threats

As the number of industrial security threats continues to rise, manufacturers are taking a closer look at risks to their environments. Threat detection services from Rockwell Automation help manufacturers and industrial operators monitor, detect and respond to complex security threats.

These services map normal network behavior, and use Rockwell Automation monitoring services to detect and alert operators of irregularities and potential threats in real time. Integrating industrial security software from providers who understand operational functions within industrial protocols can help secure and optimize the industrial control network while offering visibility across all levels of the environment.

The first step in detecting threats is to be able to inventory your environment. The threat detection services take a product-agnostic approach to create an asset inventory across systems. The software maps the end user's network assets and how they communicate with each other.

Once the environment is charted, any deviations from a baseline generate alerts. The alerts are integrated with Rockwell Automation monitoring services to help inform the response and recovery process. This process includes incident impact analysis, as well as containment and eradication protocols.

China LNG records

According to an Energy Information Agency (EIA) report, 2017 will be a record year for China's imports of liquefied natural gas (LNG). The report projects that China will overtake South Korea as the world's second largest LNG importer in 2018.

China averaged 4.3 Bcfd (1.2 X 108 m3/d) for the first seven months of 2017, which is 45% more than first seven months of 2016. Other than a slight decline in 2015, China's LNG imports have increased steadily over the past 10 years.

Natural gas consumption in China is also up 15% from 2016 levels. According to China's National Development and Reform Commission, this growth was driven primarily by coal-to-gas switching for power generation, as well as a decline in hydroelectric power generation due to flooding in central and southern China.

Baker Hughes digest

Baker Hughes, a GE company, has signed an agreement for the provision of Asset Performance Management (APM) software and services for LNG trains and related BoP by Nigeria LNG Limited (NLNG). This deal marks the first APM solution sold and executed both in the LNG market and in Sub-Saharan Africa by BHGE.

BHGE was asked by NLNG to develop a solution to enhance the performance of LNG trains at its gas liquefaction plant in Bonny Island, Nigeria. Using APM software, BHGE developed a digital trip reduction program and has committed to a reduction of 20% of trips on the LNG trains and related balance of plant (BoP) within three years.

BHGE will supply the bundle of its software services, powered by GE's Predix in a multi-year agreement that includes support from GE Power Services and GE Digital. BHGE is the main contractor of the project's LNG trains, power generation and electrical motors units and has had a contractual service agreement in place with NLNG since 2003.

BHGE and KBC a subsidiary of Yokogawa Electric announced a partnership that will provide a combination of process simulation, asset performance management and operational software solutions to the oil and gas industry. Leveraging GE's Predix, it extends KBC's Petro-SIM process simulation modeling further into the full-stream oil and gas value chain. It also provides connectivity between operations, assets, people and business processes.

Controller security

HIMA's HIMax safety controller has been awarded the new cyber security certificate from TÜV Rheinland. The test agency certified the processor and the communications module in accordance with international standards.

The certificate is based on testing and evaluation of all requirements regarding IT security over the lifetime of the safety controller. By combining highest safety (up to SIL 3) with IT security in a single system, it provides optimal protection.

African subsea

RINA Services has been chosen by Eni East Africa to act as certification authority for the design and fabrication of subsea structures and equipment. It will also provide technological validation services for the company's Floating Liquefied Natural Gas (FLNG) unit, which is intended for the Coral South Development Project in Africa. The unit will be installed in offshore Mozambique.

Discovered by Eni in 2012, the Coral natural gas field contains about 450 billion cubic meters (16 tcf) of gas. The first phase of the Coral field exploitation includes the development of five trillion cubic feet (5 tcf) of gas and the commencement of the production is expected by 2021.

The FLNG unit will have a capacity of around 3.4 MTPA (million tons per year) and RINA Services, besides being the certification authority, has been contracted to provide technological validation of those technologies that Eni deems unproven.

Geothermal contract

Toshiba has won a major order to supply a flash ST and generator for Unit 2 of the Kizildere III Geothermal Power Plant in Turkey. Zorlu Energy will construct the plant West Anatolia. Kizildere III Geothermal Power Plant Unit 2 is a 70,000 kW, triple-flash, combined-cycle geothermal power plant.

It will integrate two systems: A 50,700 kW flash steam generation system driven by steam under high pressure, plus a 19,300 kW binary cycle power generation system that uses flash turbine exhaust steam to vaporize a working fluid with a lower boiling point and also uses it to drive a turbine.

Kazakhstan refurbishment

EthosEnergy has been awarded a contract by Zhaikmunai for a refurbishment upgrade of a Frame 5 package and LTSA at its plant in Kazakhstan. Previous work and LTSA contracts had been done with Ethos Energy for its Solar GT fleet. In addition, the company has converted a combustion system to DLN as part of a package refurbishment.

Cybersecurity susceptibility

A new report from Kaspersky Lab found that in the first half of the year, the manufacturing industry was the most susceptible to cyberthreats. Computer industrial control systems (ICS) in manufacturing companies accounted for almost one-third of all attacks.

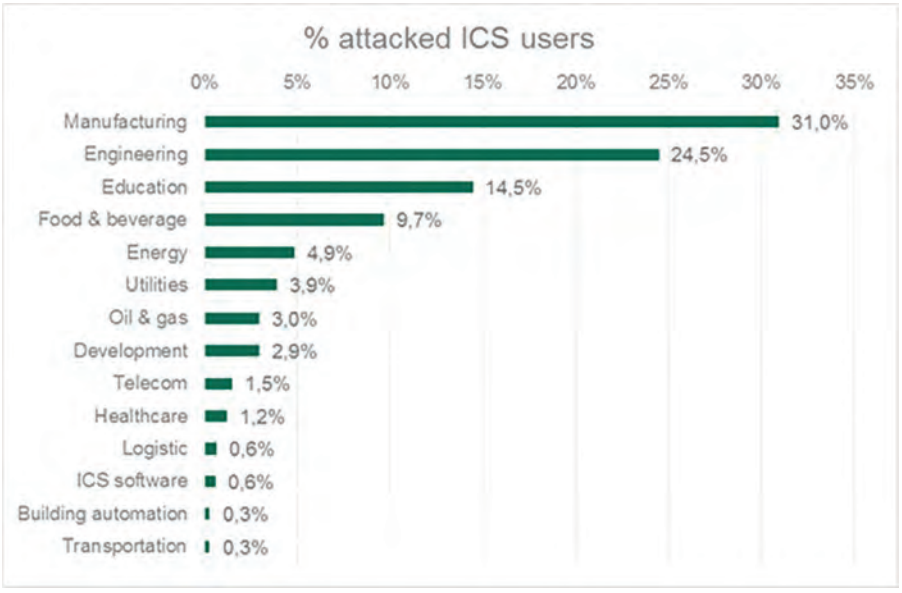
The majority of cyberthreats were in companies that produce various materials, equipment and goods. Other highly affected industries include engineering, education, and food & beverage. ICS computers in energy companies accounted for almost 5% of all attacks.

Experts also discovered that the main source of threats was the internet; attempts to download malware or access known malicious or email phishing web resources were blocked on 20.4% of ICS computers. The reason for the high statistics for this type of infection lies in several areas. The interfaces between corporate and industrial networks can be weak spots. Additionally, there is limited availability of internet access from industrial networks. Further, there is the factor of the connection of computers on industrial networks to the internet via networks for mobile phones.

Ransomware also affects industrial companies. The number of ICS computers attacked by encryption trojan malware tripled by June of 2018. Most were distributed through spam emails disguised as part of the business communication with either malicious attachments or links to malware downloaders.

Kaspersky recommends:

- Take an inventory of running network services with special emphasis on services that provide remote access to file system objects
- Audit ICS component access isolation, the network activity in the enterprise's industrial network and at



Distribution of industrial control systems (ICS) attacked by malware

its boundaries, policies and practices related to using removable media and portable devices
- Verify the security of remote access to the industrial network as a minimum, and reduce or eliminate the use of remote administration tools as a maximum
- Keep endpoint security solutions up-to-date
- Use advanced methods of network and data protection.

Innova acquires Braden

Emissions and noise control vendor Innova Global has acquired the shares of GT auxiliary equipment specialist, Braden from Global Power Equipment Group. The acquisition includes Braden Manufacturing in Tulsa, OK, Consolidated Fabricators in Auburn, MA, and Braden-Europe in Heerlen, the Netherlands.

The acquisition of Braden allows Innova to expand its market presence. Braden has a GT aftermarket retrofit and parts business (from filter houses to exhaust silencers and stacks, diverter dampers, and in-duct products).

Small modular reactors

Canadian Nuclear Laboratories (CNL) has released a report to on small modular reactors (SMR). This initiative yielded responses from 80 organizations, including 19 expressions of interest in siting a prototype or a demonstration reactor at a CNL campus site.

Entitled *Perspectives on Canada's SMR Opportunity*, the report includes proposals for enhanced safety systems and greater levels of efficiency, as well as novel fuel types and engineered systems. Responses to the report also explored the possibilities of SMR technology beyond the generation of electricity. Responses indicated interest in integrating SMRs as part of a more diverse energy strategy, with applications as varied as district heating, co-generation, energy storage, desalination, and hydrogen production. CNL has identified SMRs as one of seven strategic initiatives the company intends to pursue as part of its long-term strategy, with the goal of siting an SMR on its Chalk River site by 2026.

GTT order

Gaztransport & Technigaz (GTT) announced a new order from Samsung Heavy Industries regarding a Floating Storage and Regasification Unit (FSRU). Its delivery is scheduled in late 2020. This contract is the sixth FSRU order obtained by GTT this year. GTT is an engineering company expert in containment systems with cryogenic membranes used to transport and store liquefied gas, in particular, LNG.

New Rexa boss

Geoff Hynes has been appointed President & CEO of Rexa, effective January 1, 2018. Hynes has spent his entire career with Rexa. Rexa President and CEO, Sam Lalos plans to retire at the end of 2017. During his 40-plus years in this field, Lalos has held a variety of technical, business management and executive positions.

Mobile power

APR Energy has commissioned two mobile GTs and connected them to the Puerto

Brüel & Kjær Vibro

SERIOUS ABOUT YOUR VIBRATION MONITORING?

MAYBE IT'S TIME YOU SERIOUSLY UPGRADE

If you're in the market for API 670-compliant condition monitoring and machinery protection, you owe it to yourself to explore the revolutionary SETPOINT® system from Brüel & Kjær Vibro.

Designed and built by the very same engineers that designed the Bently Nevada™ systems you're probably using right now, SETPOINT embodies extraordinary, game-changing capabilities that your incumbent system can only dream about.

Learn more on our informative website where you'll discover 15 compelling reasons to make SETPOINT your next monitoring system - and leave yesterday's technology behind.

- Embedded flight recorder with up to two full years of complete CM data.
- Redundant data storage right in the rack on independent SSDs (up to 480 GB).
- Captures data whenever it changes - same lossless compression concepts as video streaming.
- Full integration with OSIsoft PI System® elimintates the need for separate software like GE's System 1™.
- Truly universal hardware - a single module supports more than 45 different channel types, including aeroderivatives, recips and hydro.

www.bkvibro.com/setpoint

Visit us at Booth 3049
Turbomachinery • Dec 12-14 • Houston

Rico local power grid. The fast-track solution features two new GE TM2500 Gen 8 mobile GTs, which will help to restore power in the San Juan area. APR has used the technology to generate electricity on other Caribbean islands including Martinique and St. Thomas in the U.S. Virgin Islands.

Service on a platform in the Atlantic ocean: MAN PrimeServ and Petrobras have renewed their contract.

MAN digest

MAN Diesel & Turbo will continue to service 20 GTs and compressors on four platforms belonging to Brazilian oil major Petrobras. They are located in the Atlantic Campos Basin. MAN PrimeServ will continue to ensure maximum efficiency and availability of the turbomachinery for another three years, with an option of a further extension. Based on an embedded engineer concept, Petrobras has relied on MAN service for these turbomachines since 2002.

HRST chairman

Bryan Craig is now Chairman of the Board with HRST. Craig started with the company in 2001 as a Systems Engineer. He was elected to the Board of Directors in 2010 and has been instrumental in the growth of HRST. He replaces Robert Krowech who founded HRST in 1998. Krowech remains on the Board of Directors and continues to manage HRST Research and Development.

Siemens digest

Siemens delivered the first GT compressor units to be installed in the compressor station of the Trans Adriatic Pipeline (TAP) near Kipoi, Greece. The order is for six 15 MW SGT-400-driven turbocompressor trains. TAP, which will be 878 kilometers long, is a part of what is known as the Southern Gas Corridor.

The project will transport gas from Azerbaijan's Shah Deniz gas and condensate field to the EU. The pipeline is expected to begin operating in the latter part of 2019. Each train comprises an SGT-400 GT as well as a Siemens barrel-type STC-SV compressor.

Siemens has received an order to supply a complete power island to a 1.3 GW CCPP in Punjab, Pakistan. The contract was awarded by the China Machinery Engineering Corporation (CMEC), which is building a liquefied natural gas (LNG)-operated plant in Jhang, located 250 km southwest of Lahore.

CMEC is the Engineering, Procurement and Construction (EPC) contractor of the power plant dubbed as Punjab Power Plant Jhang. The power island features two Siemens SGT5-8000H GTs, an SST-5000 ST, two heat recovery steam generators (HRSGs) along with control and auxiliary systems. In simple cycle mode, the SGT5-8000H has a power output of 450 MW, which can go up to 650 MW in combined cycle mode.

Siemens has signed an agreement with China Resources Power (CR Power) to implement the setup of a Remote Operation Center (ROC) for CR Power's fleet. Digitally connecting its power generation assets will give real-time insights into operational conditions.

Based on those insights, Siemens' data analytics will make recommendations for improved performance to help extend the operational lifetime of the plants. The ROC project will begin with CR Power's Jiangsu Branch. The connection of the 19 units (9.6 GW) is expected to be completed by the end of 2018.

Dresser-Rand CEO

The Dresser-Rand business, part of Siemens Power and Gas Division, has appointed Paulo Ruiz Sternadt (42) as CEO. He succeeds Judith Marks (54) who is leaving the company at her own request. Sternadt has more than 16 years with Siemens in multiple roles in the U.S., Germany, Mexico and Brazil. Most recently, he was Executive Vice President of Global Solutions for Dresser-Rand and a member of its executive staff.

Siemens and PAS Global, a provider of industrial control system (ICS) cybersecurity, announced an agreement to provide fleet-wide, real time monitoring for control systems. This partnership will provide customers with deep analytics required to identify and inventory assets, and visibility to detect and respond to attacks.

As the utility and oil and gas sectors become increasingly digital, there is a need to identify cyber threats at their earliest stages. According to recent research conducted by Ponemon Institute, deployment of cybersecurity measures in these industries is not keeping pace with the growth of digitization in operations.

Just 35% of survey respondents rate their organization's cyber readiness as high. 68% say their organization experienced at least one cyber compromise, while 61% say their organization's industrial control systems protection and security is not adequate.

The Siemens-PAS partnership intends to bridge the gap to provide a comprehensive view into fleet security. Focused on gathering detailed configuration data down to the sensor level, this will enable users to secure systems in multi-vendor environments.

China's largest acrylic producer, Zhejiang Satellite Energy, selected Siemens to provide a reactor effluent compressor train for Phase II of its propane dehydrogenation (PDH) plant in Pinghu City in China's Zhejian province. The dual-casing compressor train, scheduled for installation in late 2018, consists of two Siemens STC-SH single-shaft compressors driven by a Siemens SGT-750 industrial gas turbine. Plant commissioning is scheduled for early 2019.

Siemens is offering its SGT-800 industrial GT with a power output of 57 MW and an electrical efficiency of more than 40% in simple cycle application. In combined cycle, the power output is 163 MW at a net efficiency of more than 58.5%. The SGT-800 is now available with power output from 47.5 MW to 57 MW.

OPEC report

The 14-nation Organization of the Petroleum Exporting Countries (OPEC) says growth in global oil demand will steadily lessen from an annual average of 1.3 million barrels a day between 2016 and 2020, to 300,000 barrels a day in the 2035 to 2040 period. But it says fossil fuels will remain the main energy source decades from now. The organization's annual World Oil Outlook says renewables are projected to record the fastest growth. However, their share of total energy supply is still anticipated to remain below 5.5 percent by 2040. The OPEC report says that the use of fossil fuels will drop from 81 percent of the global energy mix in 2015 to 74 percent of all energy used by 2040.

LNG container ships

GTT has been chosen by the shipyard Hudong-Zhonghua Shipbuilding, a member of the China State Shipbuilding Corporation conglomerate, and by shipowner CMA CGM for the design of cryogenic tanks for nine LNG-fueled container ships. Of these nine units, the membrane tanks will be built by Hudong-Zhonghua. The delivery of vessels will take place between the end of 2019 and the end of 2020. These Sea Giants will be able to carry 22,000 containers each, instead of 21,000 containers for the biggest container ships

(Continued on p. 27)

ASME 2018 Turbo Expo

June 11 - 15, 2018 | Lillestrøm, Norway

ASME Turbo Expo held in Düsseldorf in 2014:

1345 papers presented
76 student poster presentations
3,051 attendees representing over 150 countries
118 exhibiting companies

Norges Varemesse, Norway Convention & Exhibition Centre in Lillestrøm, Norway

asme.org/events/turbo-expo

American Society of Mechanical Engineers (ASME)

ASME INTERNATIONAL GAS TURBINE INSTITUTE

AERODERIVATIVE GAS TURBINES

FLEXIBILITY, FOOTPRINT AND RELIABILITY ADVANCE AERODERIVATIVE TURBINES IN A CHALLENGING MARKET

BY DREW ROBB

A Sulzer technician inspects a GE LM5000 aeroderivative gas turbine

Aeroderivative gas turbines GTs) are a popular choice for energy generation thanks to their reliability, efficiency and flexibility. Based on advanced aircraft engine technologies and materials, they are significantly lighter, respond faster and have a smaller footprint compared with their heavy industrial GT counterparts.

With up to 45% efficiency compared to up to 35% for heavier GTs, these turbines are often seen as a good choice in smaller-scale (up to 100 MW) energy generation. The turbines are also popular due to their fuel flexibility — they allow a combination of natural gas and liquid fuel operation.

As such, the global aeroderivative GT market is expected to grow at an annual growth rate of nearly 5% between 2016 and 2020, according to a 2016 study by Technavio. Asia, in particular, deploys many of these machines in power trains for Liquefied Natural Gas (LNG) plants. In the U.S., aeroderivatives are mainly being used in peaker operations, or to compensate for fluctuations in the grid caused by renewables or extreme weather conditions.

Just about all the aeroderivatives on the market come from GE, Siemens and Pratt & Whitney Power Systems (PWPS). There is also a healthy aftermarket served by the OEMs, as well as companies such as Sulzer, EthosEnergy, RWG, and MTU Maintenance.

GE LMS100

GE owns the lion's share of the aeroderivative market. Its LMS100 is a fusion between aero flexibility and heavy-duty power output. The LMS100 uses an intercooler to cool the air between the low- and high-pressure compressor. As a result, the LMS100 can deliver up to 115 MW of power at 44% efficiency.

Key features include its CF6 jet engine core derived from the Boeing 747 and the GE LM6000. Its free power turbine can be operated in 50 Hz or 60 Hz without a gearbox. Its 6FA LPC low-pressure compressor comes from the 6FA HD turbine.

Clutchless synchronous condensing can restore full power in less than 10 minutes. It is often deployed for renewable peaking power and electrical grid stability. The LMS100 can meet strict emission requirements at 25% power, and use waste heat from the intercooler for desalination.

GE's fleet comprises 62 units operating in 10 countries (all simple cycle except five). Another 14 units are either in the installation or commissioning phase. Overall, the engines have chalked up more than 650,000 hours and 84,000 starts.

Run times vary per start from 2 to 4 hours in California to 54 hours in Australia. Fleet reliability is 99.7% with availability at 97.3%. Pampa Energia in Argentina, owner of the longest running LMS100 in the fleet, just had its second purchase reach commercial operation in

The GE LMS100 is primarily used in simple cycle plants

August 2017

The LMS100 has been used in several plants as a replacement for the Frame 9E in combined cycle operation due to its low-temperature exhaust. Its exhaust characteristics match up with older 9Es and allow for use in existing plant infrastructures.

LM9000

The LM9000 is a 66 MW to 75 MW unit that operates at 43% simple cycle efficiency. Derived from the GE90 jet engine used on the Boeing 777, it can be throttled to adjust power output, and started or stopped without impacting maintenance intervals. Power is available in under 10 minutes.

Key features include: Dual-fuel capability without water consumption, and maintenance intervals of up to 36,000 hours for the hot section and 72,000 hours for overhaul. It is said to meet 15ppm NOx emission requirements in gas operation, and can switch between different fuels at full load without interruption.

Use cases include support to grids with growing renewable sources, power industrial needs, peaking power for hot days or as reliable baseload to an isolated power island. It is also attracting interest for LNG compression and barge applications.

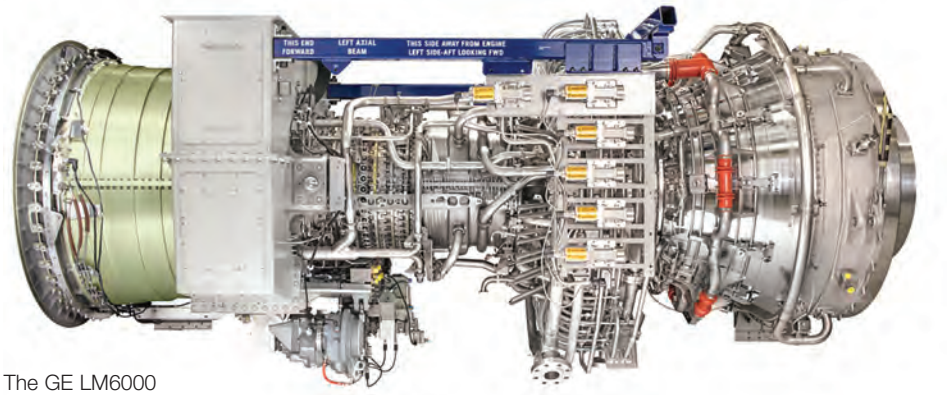
The LM9000 configuration can be laid out to minimize its area footprint for maximum power density. Coupled with its aero core, it can survive the changing environments of a barge while providing maximum power in a space-constrained area. GE will begin shipping the first LM9000 gas turbines in 2019.

LM6000

With 37 million operating hours and an expansive fleet of over 1,200 units shipped, the LM6000 offers +99% operational reliability, +99% start reliability and +98% availability, according to SPS ORAP data. The aviation heritage of the LM6000 originates from GE's CF6 jet engine found in the B747, B767 and Airbus A330. With more than 5,000+ CF6 engines delivered and 400+ million operating hours, the LM6000 now has more than 1,270 units delivered and 37 million operating hours.

Its output ranges from 44 MW to 57 MW in simple cycle and 117 MW to 149 MW in 2x1 combined cycle operation. Four available models are based on SAC and DLE in lower and higher power versions.

The SAC (single annual combustor) uses water for emissions control and has accumulated 26 million operating hours. The DLE (dry low emissions) does not use water and has reached 11 million operating hours. It has been used for peaking power generation, industrial cogeneration, district heating, load following, mechanical drive and combined cycle.



The GE LM6000

The LM6000 features a two-spool optimized design resulting in lower operational maintenance cost in comparison to three-spool designs. Further features: 15 ppm NOx capability; cold start to full power in 5 minutes; gas and liquid dual fuel capabilities; and a compact footprint, high-power density and low-noise capability.

The LM6000 DLE 57 is the latest model in the LM6000 family. Production shipments began in May 2017. It features increased core speed, exhaust temperature, simple cycle output, and combined cycle efficiency.

Relative to the LM6000 DLE 50, the exhaust temperature of the DLE 57 has increased by 39°C. The simple cycle output has increased by 7 MW, and the 1x1 combined cycle output offers an increase of 0.7% efficiency.

Currently, installation and commissioning of two units is in progress at the customer site in Thailand, with commercial operation beginning in March 2018. Mechanical drive applications will be available in 2018.

GE offers a variety of upgrade solutions depending on the operating needs from the unit. These are geared to increasing flexibility, lowering start times, adding up to 5% more power, boosting combustor and hot section life, and battery storage to integrate with renewable power. GE backs up its fleet with a worldwide network of service centers. This includes two Level 4 Service Centers in Houston, TX and Brindisi, Italy and six Level 2 service centers.

The LM6000 was GE's first GT model to feature a battery energy storage system. This Hybrid EGT enables contingency spinning reserve without fuel-burn between demand events, high-speed regulation, primary frequency response, and voltage support (-8 to +5 MVAR).

The Hybrid EGT consists of a lithium ion 10 MW battery, GE Brilliance 1.25 MVA Inverters, and OpFlex Controls upgrades. It incorporates a Mark VIe control system for the hybrid package. Two units are in operation with Southern California Edison Utility in California.

LM2500 and TM2500

The LM2500 is an aeroderivative based on the CF6 aircraft engine. Introduced in 1971, it has three models with multiple configurations and output ranging from 22 MW to 37 MW. Water injected and dry combustor options are available. With more than 90 million operating hours across 2,300 units, the LM2500 is the most widely used aeroderivative GT. It is popular in mechanical drive and offshore power generation applications, as well as CHP and district heating.

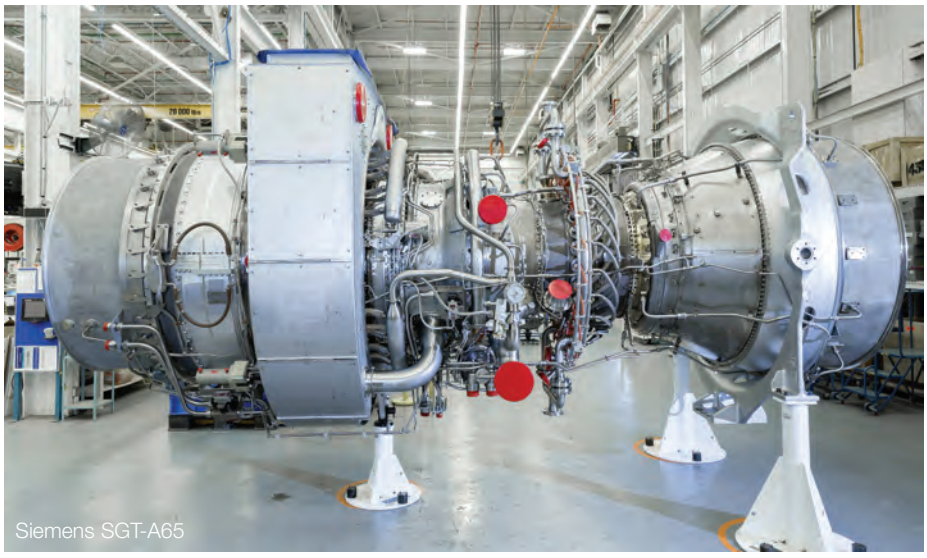
GE also offers a mobile version known as the TM2500. It can run on natural gas, LPG and liquid fuels, and is said to ramp from start to full power in under 10 minutes. A three-trailer design enables commissioning in less than 11 days from parking the first trailer. More than 200 units have been sold in 25 countries over the last 10 years.

Siemens

Siemens acquired several aeroderivatives from Rolls-Royce. These include the 4 to 7 MW SGT-A05 (Industrial 501-K), the 10 to 15 MW SGT-A20 (Industrial Avon 200), the 27 to 38 MW SGT-A30 and SGT-A35 (Industrial RB211), the 41 to 44 MW SGT-A45, and the 53 to 66 MW SGT-A65 (Industrial Trent 60). The overall fleet size is close to 2,500 units installed worldwide.

Aeroderivatives serve market segments that value specific-product attributes. Historically these include lightweight, high-power density, high operational flexibility, such as fast starts and stops, and high simple cycle efficiency. Primary markets include oil & gas for onshore and offshore applications, and power generation in applications ranging from peaking to combined heat and power (CHP).

Siemens has renamed the entire Rolls-Royce aeroderivative turbine line to align with the latest Siemens naming


Siemens SGT-A65

	Since Dec 1, 2014	New name
	Industrial 501-K	SGT-A05
	Industrial Avon 200	SGT-A20
	Industrial RB211	SGT-A30 SGT-A35
	Industrial Trent 60	SGT-A65

Adapted naming convention for aeroderivative gas turbines

conventions. The Industrial 501-K, for example, is now the Siemens SGT-A05 (p. 81, *Turbomachinery 2018 Handbook*). More than 1,600 of these GTs have been supplied for industrial use to 40 countries. They have accumulated 110 million operating hours since their introduction in 1963.

The SGT A05 was originally based on the T-56 turboprop, used in the Lockheed Martin C-130 Hercules transport, E2C Hawkeye, P-3 Orion and other aircraft. Features include lightweight modular construction, ease of field repair, and use of multiple fuels.

With an output between 3.9 and 6.4 MW, the A05 is used in applications, such as co-generation, offshore platforms and emergency power. Single-shaft and two-shaft versions are available. Steam injection can be adjusted to meet varying process steam or electrical requirements, depending on the application.

The Industrial Avon 200 is now the SGT-A20 gas generator. Introduced into service in 1964, it is popular in oil & gas, especially in North America where many units operate on trunk gas lines. Other applications include offshore pumping and compression, stand-by duties at nuclear power stations and combined cycle power generation. Over 1,200 of these units have been sold.

The SGT-A35 (Industrial RB211) is also heavily used in offshore oil & gas applications due to its low weight and high power density. It is available in two 34 MW and 38 MW variants. Siemens has augmented this Rolls-Royce engine with a Dresser-Rand package design optimized for floating applications.

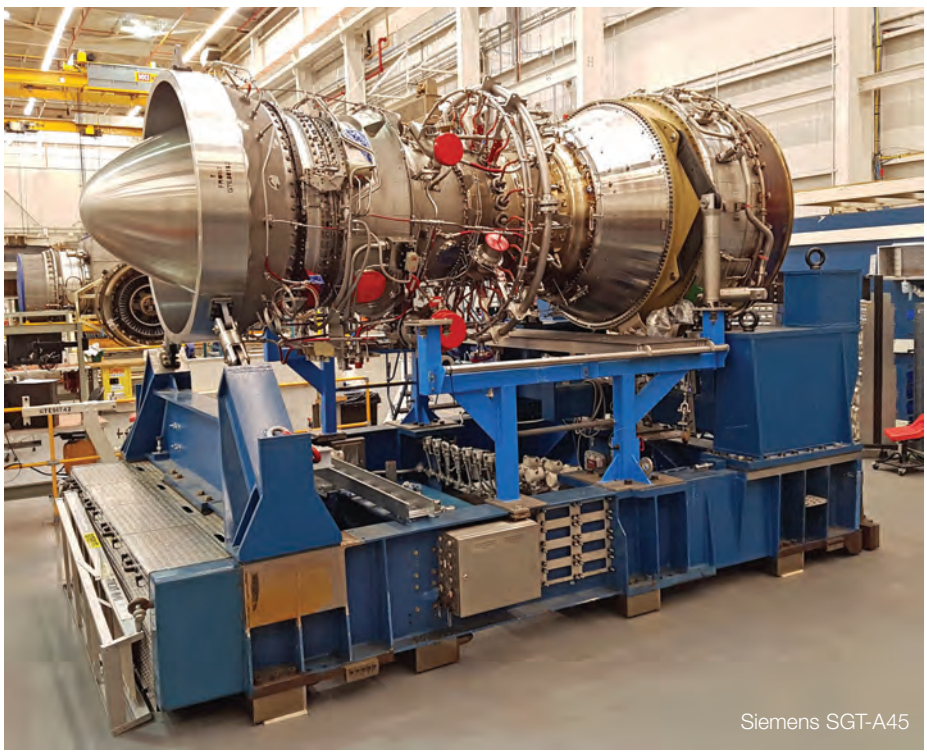
It is 30% lighter than its Industrial RB211 predecessors. The variants of this machine have accumulated over 37 million hours in service. The 38 MW variant introduces a gas generator upgrade through a compressor zero-stage, to deliver about 10% more power without any change in the turbine section, and with the same firing temperature. The power increase is achieved through higher core flow and compressor efficiency, rather than over-firing.

The Siemens SGT-A65 is a triple-shaft GT with three independent spools running inside each other. Based on the Industrial Trent 60, it can shift between 3,000 and 3,600 HP without a gear box. All that is required is to change the number of blades in the LP compressor. It has a two-stage LP, seven-stage IP and four-stage HP compressor.

Siemens has also derived a mobile unit from the SGT-A65. Known as the SGT-A45, it provides 44 MW and has a two-week installation period. It is delivered in three main trailers with some additional shipped elements.

The SGT-A45 can run on gas or liquid fuels, and transition between both fuel types when one becomes unavailable. Low NOx emissions can be achieved by adding water injection capabilities as an optional feature. This option boosts the unit's power output particularly in warm climates.

The GT can generate full power in less than 8 minutes from start without need for


Siemens SGT-A45

ASIA TURBOMACHINERY & PUMP SYMPOSIUM

12-15 MARCH 2018 | SUNTEC SINGAPORE

IMPROVE YOUR BUSINESS.

909 attendees

42 exhibiting companies

38 countries represented

90 technical sessions

LEARN MORE AT ATPS.TAMU.EDU

LEARN.

Learn how to do what you do better with more than 20 technical sessions featuring the latest research presented in lectures, tutorials and case studies led by industry experts.

INNOVATE.

Take a one-day short course on industrial gas turbines or pump cavitation, or sit in on a discussion group with colleagues to learn from their experiences and share your own.

CONNECT.

Network with more than 900 delegates and 40 companies on the exhibit floor and at corporate social events.

statistics from ATPS 2016

auxiliary systems to maintain the unit in an operationally ready standby mode. In the event of a shutdown, the unit can be restarted at any time to restore power quickly, as it has no hot-lockout restrictions.

"The compact design of the SGT-A45 is especially well-suited for mobile power, for example in Africa or Southeast Asia, allowing us to capture a quickly growing market segment," said Karim Amin, Head of Sales and Customer Operations at Siemens Power and Gas Division.

PWPS

PW Power Systems (PWPS) is a group company of Mitsubishi Hitachi Power Systems. The compamy leverages technology derived from Pratt & Whitney aircraft engines. It has more than 2,000 aeroderivatives installed in over 50 countries worldwide. These can deliver anywhere from 30 MW to 140 MW of power. It also boasts a major gas turbine repair and overhaul business.

FT4000 SwiftPac

The FT4000 SwiftPac GT package is the latest power generation solution offered by PWPS. The engine features a two-spool, axial-flow gas generator based on the Pratt & Whitney PW4000 series of engines that currently powers commercial aircraft applications with thrust ratings that range from 52,000 to over 90,000 pounds.

PWPS FT4000 SwiftPac

Industrialized and packaged with a new free turbine, the aeroderivative FT4000 gas turbine can be configured as either a single- engine unit (one gas turbine driving one 60 to 70 MW electric generator) or a twin-engine unit (two gas turbines driving a common 120 to 140 MW electric generator).

The FT4000 SwiftPac has a modular design to maximize the amount of factory assembly and reduce the amount of field assembly leading to lower costs. It features high part-load efficiency, less than 10-minute start-up time, quick engine changeout and greater than 41% simple cycle efficiency. Key markets include onshore and offshore power generation (peaking, base load, cogeneration, combined-cycle), repowering to replace old gas turbines and mechanical drive.

In 2015, after endurance and reliability testing, the FT4000 gas turbine was put into commercial operation. Its two launch customers included a SwiftPac 120 in the United States and a SwiftPac 60 in Argentina. These units have accumulated over 19,200 hours and over 1,575 cycles.

FT8 MobilePac

The PWPS FT8 MobilePac GT offers 30 MW of movable power. The package design includes two trailers. The first contains the GT, electric generator, exhaust collector, diffuser, and engine lube oil system. The second trailer carries the 15 kV switchgear, control system, operation panel, protective relays, batteries and charger, motor control center, and the hydraulic start package. A pre-commissioned FT8 MobilePac can be driven to a site and begin generating power in nine days or less.

Over 130 of these mobile FT8 units have been sold worldwide. More than 40 have been relocated successfully from one site to another.

It can run on liquid, natural gas, or LPG, has optional black start capability and can be operated remotely. With a footprint of 72 feet by 53 feet, little site preparation is required. No foundation or concrete pad is necessary for installation. Its controls are based upon Woodward GAP and HMI software built on the Woodward MicroNet Plus hardware platform. This provides FT8 fleet customers with control in the 5 to 10 millisecond range.

FT8 SwiftPac

The FT8 SwiftPac can be installed in less than 30 days. This package offers 30 MW or 60 MW. It comes with an assembled enclosure incorporating the gas generator, power turbine, inlet plenum, lube system, and exhaust stack. It is also available in a combined cycle configuration.

Features include an integrated lube oil system, quick-disconnect cable, a combined GT and exhaust enclosure, minimal foundation requirements, and a compact layout. It is typically used for distributed generation, peaking applications, and grid support to counterbalance fluctuating wind energy.

The FT8 gas turbine is a derivative of Pratt & Whitney's JT8D aircraft engine. This is augmented with technologies to generate power with less noise, lower emissions, and higher baseload and part-load efficiency using natural gas fuel. It has been in production since 1991 and over 500 units are in operation worldwide. The fleet has accumulated over 6.5 million hours of operation.

PWPS offers a full range of maintenance, overhaul and repair, as well as field service for aeroderivative GTs. Its Long-term Service Agreement (LTSA) provides scheduled maintenance, unscheduled maintenance, spare parts, annual audits, and site support.

PWPS FT8 MobilePac can be transported as air cargo

PWPS FT8 SwiftPac

Turbomachinery INTERNATIONAL HANDBOOK 2019

ACCEPTING LISTINGS *NOW!*

The most comprehensive search database used by over 100,000 specifiers of turbomachinery technology, products and services worldwide.

Get your **FREE company listing** for the online and printed Handbook @ **www.TurboHandbook.com**

Immediate **online Handbook exposure** and the ability for other companies to search and find you for NEW business.

Distribution at **every major turbomachinery industry trade show**, conference & exhibition and user group meeting that we attend.

BACKGROUND: MASTER3D/SHUTTERSTOCK.COM

Turbomachinery INTERNATIONAL
THE GLOBAL JOURNAL OF ENERGY EQUIPMENT

Contact Bob Maraczi for more information.

P: 203.523.7040
E: Bob.Maraczi@UBM.com

Sulzer services the LM5000 and other machines

MTU Maintenance technicians servicing an LM2500

Sulzer

Sulzer maintains and repairs the LM5000 under license from GE. It is a flange-to-flange solution provider for that machine, which GE introduced in 1978 and no longer manufactures or supports. Based on the CF6-50 aircraft engine, over 100 of these 38 MW turbines were produced. The LM5000 has a twin-spool generator driving a free-power turbine.

Sulzer also partners with Air New Zealand Gas Turbines (ANZGT) on maintaining and repairing this legacy turbine. ANZGT manages parts supply for some 25 LM5000s that are still in service.

"It appears that the LM5000 fleet will continue running for another five or ten more years based on customer conversations and surveys," said Michael Andrepont, Manager of Gas Turbine Shop Repairs at Sulzer.

As a result, Sulzer has broadened the supplier lists for consumable items for this power turbine to help reduce overhaul cost for end users. The company has also compiled best practices based on the LM5000's repair history. This enables its technicians to inspect and overhaul these gas turbines in a timely manner.

Over the past two years, Sulzer has witnessed the primary driver for emergent inspections and overhauls being bearing failure. The LM5000 uses roller and ball bearings, which have strict inspection criteria. Andrepont noted that dirty lube oil systems often hinder the condition and function of these intricate bearing systems.

MTU Maintenance

MTU Maintenance is also licensed to support the LM5000. Further, its Berlin-Brandenburg facility is a level IV licensed service depot, offering a full range of MRO services for LM 2500, LM 5000 and LM6000 gas turbines. It also boasts a global network of level II service centers, including locations in Australia, Brazil, Norway, Thailand and the U.S.

With over 20 years' experience in working with LM series GTs, MTU Maintenance offers parts supply, test cell facilities, engine exchange and leasing, training and familiarization as well as package services. Its test cell for GTs is one of the largest in the world, using real-load operating conditions to understand vibration patterns.

MTU Maintenance recommends regular maintenance, including water washing in the field. It advises users to protect inlets during downtime to avoid corrosion that can lead to removal problems and, ultimately, higher scrap rates of parts, such as compressor vanes. Early recognition and regular checks are recommended for continued operational performance and reduced costs.

"Aeroderivative gas turbines used as peakers will have multiple starts and shutdowns, fewer operational hours and, as a result, maintenance needs are different," said Gregor Stöcker, Director Sales Industrial Gas Turbines, MTU Maintenance. "We tend to see more thermal distress and material fatigue in such operations."

RWG

RWG Repair & Overhauls Limited is a Siemens and Wood Group Company specializing in the maintenance, repair and overhaul of Siemens aeroderivative gas generators and power turbines. RWG is authorized by Rolls-Royce Naval & Marine to maintain GTs used for marine propulsion. It has its headquarters in Aberdeen, Scotland and regional service centers in Houston and Kuala Lumpur. Between them, they employ 500 people.

The company offers a wide range of commercial models, including time and materials, fixed-price and fixed-scope options, and repair rather than replacement service for high technology gas generator components and ancillaries. Its focus is to provide tailored work scopes to operators that optimize performance, mitigate risk of unscheduled maintenance, and lower lifecycle cost.

Due to low commodity prices in both oil & gas and power generation, customer behavior has shifted, said Mick Conway, Business Development Manager at RWG. Operators are less reliant on long-term service agreements, placing a greater focus on cost management of individual maintenance events.

Constraints on operator maintenance budgets is extending equipment time between overhauls TBO), he added. Further, lower equipment use in the power generation sector is driving

Equipment Supported	Generic Services (all equipment)
Siemens Industrial Olympus	Gas Generator Repair & Overhaul
Siemens SGT-A05 AE Industrial 501K)	Field Service
Siemens SGT-A20 AV Industrial Avon)	Technical Support
Siemens SGT-A30 RB Industrial RB211)	Operational Spares
Rolls-Royce Marine WR21	High Technology Component Repair
Rolls-Royce Marine Spey SM1A/C	Maintenance Service Agreements
Rolls-Royce Marine Tyne	Failure Investigation
Rolls-Royce Marine Olympus	Equipment Familiarization Training

RWG's range of equipment supported and services offered

RWG specializes in the maintenance, repair and overhaul of Siemens aeroderivative gas generators and power turbines

condition-based work scope innovation.

"Ultimately the work scope and final maintenance cost is determined by the condition of the gas generator," said Conway. "By the time the unit reaches our workshop it's too late to deal with issues that have led to component degradation and failure."

The workshop, though, can advise on probable cause of wear, corrosion and oxidation. However, adherence to good operations and maintenance practices, added Conway, will avoid many common reasons for rejection and replacement of high-cost gas generator components, including:

- Air inlet filtration condition and integrity of housing structure to minimize airborne contamination and risk from foreign object damage
- Routine maintenance of the fuel skid, conditioning units and oil system to ensure each system will meet OEM specification and does not introduce contamination or degrade critical components
- Regular washing and borescope inspection to monitor and report component degradation and to facilitate consultation with a specialist maintenance provider as necessary
- Timely intervention or rejection of equipment in accordance with the OEM service manual or condition based reports.

In Conway's experience, most operators maintain their equipment diligently throughout its service life. However, once a decision has been taken to remove the unit for overhaul, there is less focus on good maintenance practice.

Any complex machine no longer in use will deteriorate quickly, especially in high humidity environments, he said. 'Stand still' corrosion can be a very costly in terms of component rejection. It is critical that an operator applies the same diligence to temporary storage conditions, as they do under a turbine's normal operating environment.

"Prior to storage, routine procedures such as compressor washing, drying, inhibiting of fuel, oil and hydraulic systems will avoid considerable damage from stand still corrosion," said Conway. "In ideal circumstances, the engine should be installed within a purpose-built container, capable of nitrogen purge."

RWG recently earned a long-term maintenance support contract with Gulfstream Natural Gas System. It deals with three Siemens SGT-A30 RB (formerly the Industrial RB211 24G) DLE gas turbine generators.

The three machines are in operation at Gulfstream's Compressor Station 410 located at Coden, Alabama. RWG is responsible for the scheduled maintenance, including mid-life and major overhaul. The scope of work encompasses both in-field repairs undertaken at Gulfstream's facilities, supported by Siemens, and gas generator overhauls performed at RWG's workshops in Aberdeen.

EthosEnergy

EthosEnergy has a full-service fuel nozzle and accessory service center. It has repair licencing agreements with GE, AA TECH, Parker, Titeflex Smiths, Woodward and Hydra Service.

Plants are taking a longer time between removals and maintenance due to lower running hours, said Tom Watson, EthosEnergy's President of Accessories and Components. This, he added, is being driven by more use of solar and wind.

As a result, more units are becoming peakers. Under such circumstances, his advice is to not neglect regular planned maintenance despite lower operating hours.

"Just as importantly, schedule regular checks and plan maintenance on rotatable safety stock," said Watson. "In particular, accessories will suffer from deterioration of seals and other components as they are spending more time on the shelf."

Packaging is also an issue. Badly packaged items sent for maintenance can lead to transit damage, he said. A few hundred dollars of packaging materials could save thousands in unnecessary repairs. ■


EthosEnergy provides testing, repair and overhaul services for aeroderivative fuel nozzles

STEAM TURBINES

GENERAL PURPOSE STEAM TURBINE UPGRADES

BY HEINZ BLOCH & RICHARD SMITH

It is not unusual for large oil refineries to have 160 general purpose (GP) steam turbines installed at a major site. Return-on-investment (ROI) studies and related cost assessments indicate that major refineries may have opportunities to capture steam turbine-related corporate-wide maintenance savings in excess of $3,000,000 annually.

The two areas worth exploring are bearing protector seals and cartridge-style steam glands wherein high temperature mechanical seals replace the century-old segmented carbon ring technology. These issues are of great importance to reliability-focused refineries, fertilizer producers and petrochemical plants to prevent steam from entering the bearing house (Figure 1).

Figure 1: Steam leakage is commonplace from a steam turbine.

Bearing protector seals can virtually eliminate premature bearing failure. These seals achieve contaminant and vapor exclusion by incorporating an axially-moving O-ring. In addition to preventing bearing distress, upgrading to such seals may prevent fires caused by leaking into the bearing housing. Similarly, cartridge-style high temperature mechanical seals can greatly reduce maintenance frequency, and ultimately, the cost of leakage-related turbine failures.

Focus on bearing housing protector seals

Steam intrusion often occurs, for example, when steam gland and bearing housing are adjacent to each other (Figure 2). Lubricating oil can become contaminated by steam blowing past the carbon rings in the shaft glands. The contaminated oil requires periodic discarding and must be replaced by fresh oil. As a precautionary activity, water must be drained off in an effort to extend bearing life and machine reliability. However, by the time free water collects and is visible in a sampling line or sight glass, dissolved water will exist and often cause additives depletion through a process called partitioning.

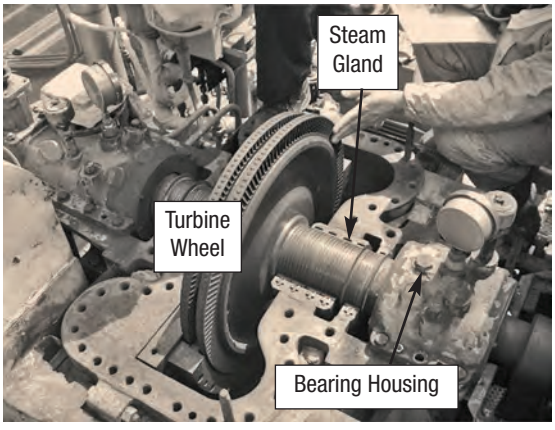


Figure 2: The unavoidably close proximity of a steam gland to the bearing housing encourages moisture intrusion into the lubricating oil.

The additives partition themselves between the oil and water phase in proportions that largely depend on their relative solubilities. When free water is removed from the oil by gravity, polymer absorption or centrifuging, these additives are lost. The loss deprives the oil of the protection normally given by anti-rust and anti-oxidant inhibitors. Moreover, water will combine with airborne dust to form sludge.

Periodic manual removal of water, then is a technically inferior approach. Better strategies are vacuum dehydration, coalescing and air sparging. However, all involve cost. It may be simpler and more cost effective to prevent water intrusion through use of bearing housing protector seals.

The American Petroleum Institute's Standard for General Purpose Steam Turbines in the Petroleum, Chemical and Gas Industries (API-611) has several clauses that apply to bearing housing seals:

> *6.10.4.2.1 Bearing housings shall be equipped with replaceable labyrinth-style end seals and deflectors where the shaft passes through the housing; lip-type seals shall not be used. The seals and deflectors shall be made of non-sparking materials. The design of the seals and deflectors shall effectively retain oil in the housing and prevent entry of steam, condensation and foreign material into the housing.*
> *6.10.4.2.1 (Option): <> If specified, bearing isolation seals providing a positive tight seal to prevent the ingress of atmospheric contaminants shall be supplied.*

Replaceable rotating labyrinth devices can be installed in existing machines without bearing housing modifications. Unlike traditional fixed labyrinths, they use centrifugal force to expel potential contaminants before they reach the oil. During periods of operational idleness dynamic (axially moving) vapor-blocking O-rings provide a secondary level of protection and compliance with the requirements in

API-611, paragraph 6.10.4.2.1.

Lubrication protection must be effective when the equipment is running and when not in operation. With traditional labyrinth seals, moisture aspiration occurs. As the equipment cools, the surrounding ambient air is drawn into the bearing housing. To prevent moisture ingress, a vapor shut-off device is needed. This shut-off feature is often overlooked in seal designs. A well-engineered bearing housing seal prevents moisture ingress. Temperature resistance is achieved by using graphite foil secondary shaft seals (Figure 3).

It is best to incorporate a bearing housing protector upgrade into the normal steam turbine maintenance cycle rather than a pre-planned removal cycle. Hundreds of these seals operate in general purpose steam turbines manufactured by Elliott, for example. Many were retrofitted to steam turbines from legacy equipment manufacturers that included Dresser-Rand, Terry, Skinner, and Worthington.

Throughout the world, these seals are now installed in a wide range of steam turbine sizes. The lube application details in these machines often differ. Take the case of a non-pressurized splash lubrication system (also described as a turbine bearing housing with an oil sump) at a large facility in the Southern United States. The oil sump capacities ranged from two to six liters with no provision for filtration. Oil changes had to be done every two months. After the bearing housing protector seals were added, oil changes would take place about three times every decade. The payback period, therefore, was short.

Cartridge-style steam glands

For about one hundred years, small steam turbines have incorporated bushing-type single-piece and/or segmented carbon gland components to reduce or, hopefully, prevent steam leakage along the shaft. The location of steam glands is shown in Figure 2, although the carbon rings are not shown in that illustration.

However, comprehensive leakage prevention has never been achieved with old style glands. This was due to turbine shafts being made from steel; its coefficient of thermal expansion differs from that of carbon. As a small amount of steam rushes through tiny gaps at sonic velocity, an erosive effect known as "steam cutting" causes the gap to widen. Physics, thermodynamics and hydraulics combine to explain the interacting processes.

In the late 1970s, it was discovered that clean steam can be introduced to create the thin fluid layer between stationary and rotating seal faces in dry gas seals. This fact led, in the early 1980s, to in-plant research and cost justifications initially favoring alloy steel bellows seals in lieu of snug-fitting carbon in the gland area. The carbon rings in the glands of several small steam turbines were discarded and replaced by bellows-type high-temperature gas seals. As a result, steam turbine maintenance costs and steam losses were reduced along with a decline in reported bearing distress events.

The success of high-temperature mechanical seals as upgraded glands in small steam turbines required fitting "loose" parts from so-called component seals. This made mechanical seal-based glands more difficult to assemble than traditional segmented carbon glands.

More recently, an upgrade option became available that replaces the old steam turbine gland seal.

Cartridge versions can point to years of solid operating experience. Assembly by the user-purchaser is no longer needed

Figure 3: Location of bearing housing protector seals. Note the large cross-section O-ring which seals against a static seat if the shaft is stopped and provides an axial micro-gap with shaft operating.

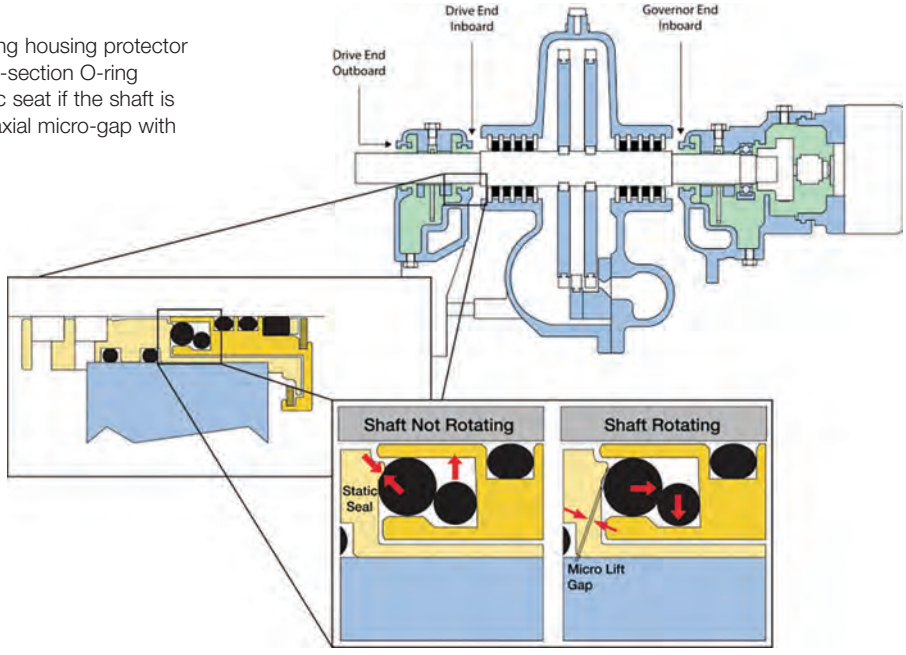


Figure 4: Cartridge-style steam turbine gland incorporating a dry gas seal-based high-temperature mechanical seal

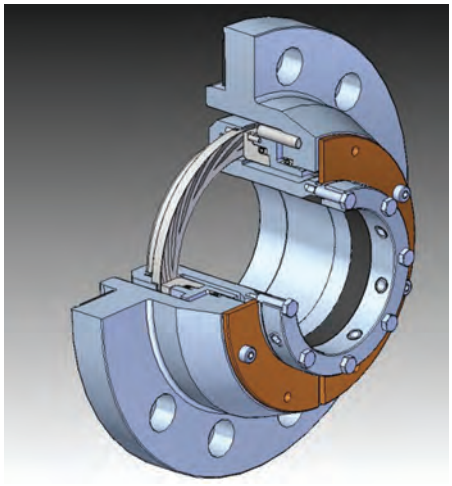


Figure 5: Cutaway view of steam turbine gland shows its dry gas seal heritage

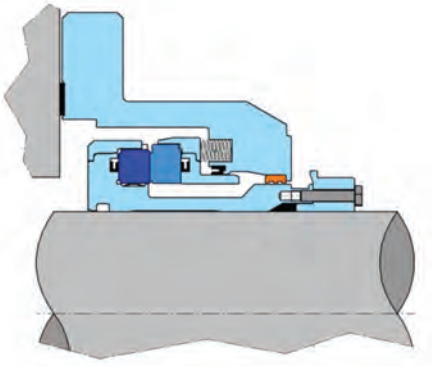


Figure 6: Cross-section view of steam turbine gland shows its non-rotating, flexing components sealed and centered by U-cup style high-temperature elastomers

as the parts are cartridge-mounted by the manufacturer and shipped ready for installation. (Figure 4).

The latest high-temperature steam seals utilize dry-running compressor gas seal technology (Figures 5 and 6). As dry gas seals (DGS) have demonstrated effectiveness in lowering maintenance costs for gas compressors, their successful migration to other fluid machines and application in small and medium-sized steam turbines was foreseeable.

Aging steam turbines

With an aging population of steam turbines existing inside most refineries, maintenance requirements are destined to rise dramatically. Unfortunately, the presence of stationary labyrinth seals and segmented carbon gland components will add to the maintenance burden. These components are ineffective in preventing moisture ingress and contamination of the lube oil. Replacement with the latest bearing housing protector and DGS-based steam gland seals is a way to minimize maintenance costs and extend steam turbine life. ■

***Heinz P. Bloch** is a consulting engineer in Colorado who first entered the work force in 1950 and graduated with BSME and MSME degrees in 1962 (heinzpbloch@gmail.com).* *For more information:* **Bloch, Heinz P. and Hurl Elliott, Mechanical Seals for Medium-Pressure Steam Turbines,** *presented at the ASLE 40th Annual Meeting in Las Vegas, NV, May 1985 (reprinted in Lubrication Engineering, November 1985; and* **Bloch, Heinz P., Petrochemical Machinery Insights,** *(2016) Elsevier Publishing.*

***Richard Smith** (richard.smith@aesseal.co.uk) is a seal application and design expert with over 30 years of professional experience in the field of sealing. He has held executive positions with AESSEAL for decades, a company specializing in mechanical seals and support systems. For more information, visit www.aesseal.com*

(Continued from p. 14)

currently in operation. GTT will design the LNG fuel tanks, which represent a capacity of 18,600 m3 per ship. The membrane insulation system Mark III developed by GTT has been chosen for its space optimization allowing a maximum usage of cargo capacity.

Centrax order

Centrax Gas Turbines has installed and commissioned two CX501-KB5 DLE generator sets for Hera, one of Italy's utilities. The GT-powered units each provide up to 3.9 MW of electrical power at Hera's cogeneration plant in Bologna. They are replacing an existing thermal power plant coming to the end of its operational life. Attached to two Ruths boilers, the generator sets will help to heat around 8,000 apartments and reduce the environmental impact from the decommissioned thermal plant.

The two packages, powered by Siemens 501-k engines, were manufactured at Centrax's headquarters in the UK and shipped to site ready for installation and commissioning at the start of Autumn 2017. Service and maintenance will be carried out by Centrax's Italian support centre in Montale.

New biomass plant

Construction has begun on a biomass-fired unit intended for combined heat and power (CHP) generation and process steam supply. The nearby seaport will be modified to be able to receive up to 9.5-m draught ocean vessels with capacities for 40,000 cu m of wood chips.

A wood chip storage site is being established with a capacity of 80,000 cu m; the biomass-fired boiler needs 3,500 cu m of wood chips every day. Doosan Škoda Power will deliver a complete machine room to the new power station, with a maximum capacity of 30 MW, equipped with a two-casing turbine.

Atlas Copco LNG

Atlas Copco Gas and Process Division has secured a compressor order for the carrier LNG market in Asia. Placed by Samsung Heavy Industries in Korea, it is for a total of four centrifugal gas compressors and four gas screws compressors. In addition, the order also includes supply of the necessary heaters and vaporizers that will be used on two Korean vessels.

Featuring a compact design tailored for the needs of the smaller vessels, the compressors will be deployed aboard two small scale Liquefied Natural Gas Carrier (LNGC) vessels, for the ships' cargo handling system. The vapor return compressors will provide tank pressure control during loading and the fuel-gas compressors will feed excess boil-off gas to the gas engine during operation. With a capacity of 173,000 – 263,000 m^3, the vessels will join the fleet of Kogas, Korea's public natural gas company.

Combined cycle plant

Tyr Energy has chosen Siemens as the technology partner for the Hickory Run Energy Center. It is a new 1,000 MW natural gas-fired CCPP to be built by Kiewit Power Constructors Co. in Lawrence County, Pennsylvania. The facility will feature Siemens H-class technology in a facility designed for fast, flexible operation to support renewable integration. Slated for operation in spring 2020, Siemens has signed an LTSA for the units including remote monitoring and diagnostics.

Siemens will deliver two H-class GTs, one ST and three generators. They will be manufactured at Siemens' Charlotte Energy Hub, which is the main production facility for Siemens' 60 Hz power generation. ■

SEMI-CLOSED RECUPERATED CYCLE (SCRC) WITH WET COMPRESSION

THE PREDICTED EFFICIENCY OF THE SCRC IS EQUIVALENT TO A GAS TURBINE COMBINED CYCLE PLANT, WHILE OPERATING FLEXIBILITY EXCEEDS IT WITH SMALLER EQUIPMENT AT THE SAME POWER OUTPUT

BY HANS E. WETTSTEIN

The semi-closed recuperated cycle (SCRC) is a supercharged recuperated gas turbine. It typically involves two compressors with intercooling. However, the intercooled main compressor can be replaced by a compressor with high fogging (wet compression). This permits a thermal efficiency gain by up to 3% while avoiding a bottoming cycle.

Part-load operation can be made by reducing supercharging pressure instead of temperature. Thermal transients leading to hot part life consumption can therefore be avoided to a large extent.

Additionally, the combustor can operate at nearly constant temperature at low part load with corresponding low emissions. This approach has the potential to add more flexibility in comparison to gas turbine combined cycle plants (GTCC).

In this respect, SCRC is better suited for arid and hot environments than GTCC technology. The predicted efficiency of a SCRC will be equivalent to a GTCC, while operating flexibility exceeds it with smaller equipment related to the same power output.

Figure 1 shows the working principle. The red loop is the supercharged part of the cycle. Ambient air (6) is compressed in the "charger compressor," which is driven by an electric motor allowing variable speed.

This fresh air is mixed with recirculated exhaust gas (5) coming from the recuperator cold end. The mixture (7) is cooled in the after-cooler, where water (8) is condensed and separated. The cooled fluid (1) is mixed with the fine and evenly distributed high fogging water (12), for which no external make-up water is needed because the condensed water (8) covers it sufficiently.

This fluid containing the droplet cloud enters the main compressor and leaves it

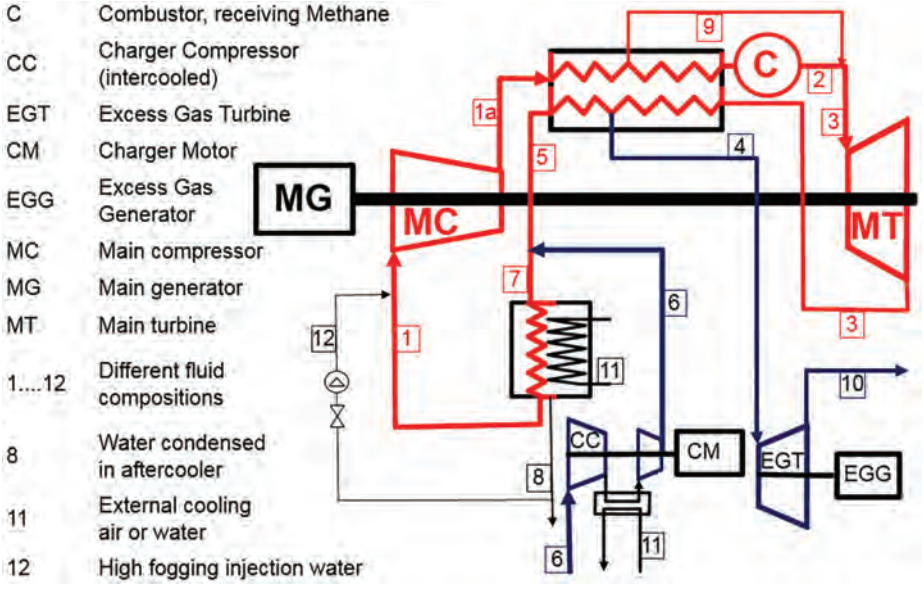


Figure 1: Semi-closed recuperated cycle with intercooled charger and wet main compressor

with the composition (1a). Then it is heated by the exhaust gas in the counter-flow recuperator and passes through the combustor, where methane as a fuel is burnt.

The resulting combustion gas (2) is mixed downstream the combustor with the cooling fluid (9) forming the mixed gas (3) entering the main turbine (this is a well-working simplification for the cycle calculation as used in gas turbine technology, according to ISO standards. The cooling fluid is distributed to different consumers in both the combustor and turbine and finally discharged into the main flow path).

The main turbine drives the main compressor and the main generator via a single shaft. The turbine exhaust gas (3) passes through the recuperator while heating up the pressurized fluid (1a). Within the recuperator it is split into the excess gas (4) and the before-mentioned recirculated fluid (5). The excess gas (4) is expanded to ambient (10) in the excess gas turbine driving an extra generator with preferably variable speed.

The corresponding difference of the excess gas turbine power and charging compressor power is positive in steady state operation or during a downward net power load ramp, but it can become negative in the case of a fast upward net power ramp. This difference forms the minor part of the SCRC power output.

The application of wet compression allows a higher heat sink temperature with the option of external dry cooling with a marginal loss of thermal efficiency.

Due to the supercharging in closed cycles, SCRC can achieve a higher power density with smaller components than any other system. It is directly air breathing and only based on commercially existing GT technology.

Instead of temperature control as in

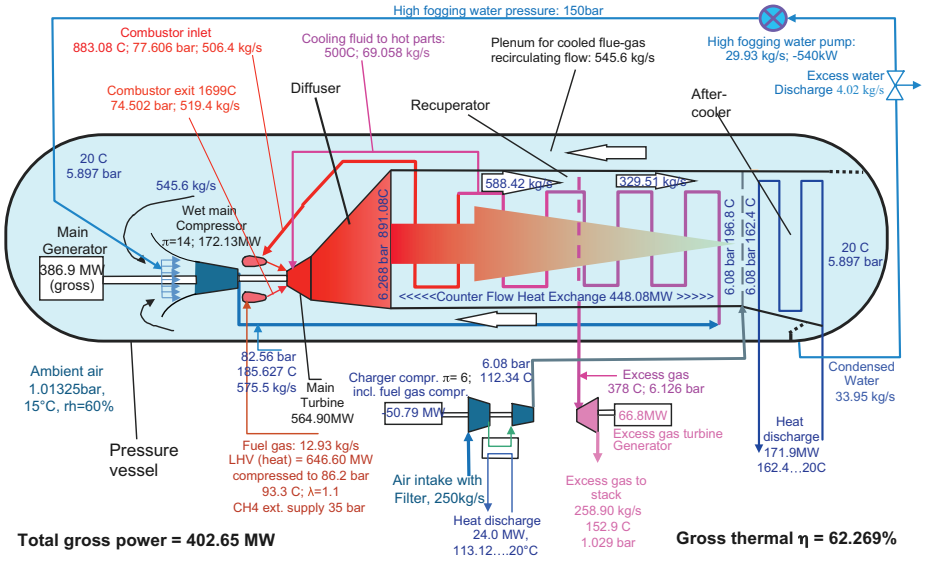


Figure 2: Proposed SCRC layout with data for around 400 MW net output

open cycle GT's, inventory control of the power output allows flexible operation with lower life consumption of the hot parts associated with lower maintenance cost ($/kWh).

High fogging in the main compressor enables a lower compressor exit temperature at a higher pressure ratio with less complexity than intercooling. The steam content in the flue gas implies a higher power density. Water can easily be recycled because it is condensed at the supercharged pressure level. This water and steam circulation acts like an integrated high-temperature steam cycle (Figure 2).

Managing upward load ramps means filling the pressurized volumes of the intercooler, the recuperator and the aftercooler. This requires operation of the charger compressor with the highest possible mass flow rate.

The charger compressor should be equipped with Variable Inlet Guide Vanes (VIGVs) and a speed controllable motor without coupling to the excess gas turbine. At the same time, the flow through the excess gas turbine should be reduced to the minimum possible amount, or even stopped during the ramp time by an extra valve. A design of the charger compressor with a maximal inlet mass flow rate above the base load value could help to accelerate the filling process.

Managing downward load ramps means discharging the pressurized volumes of the intercooler, recuperator and aftercooler, allowing for the fastest and most efficient operation of the excess gas turbine with the highest possible swallowing capacity.

It should therefore best be equipped with VIGVs and an extra speed controllable generator without mechanic coupling to the charger compressor. At the same time operation of the charger compressor should be reduced to the minimum possible or even interrupted during the ramp time by using an appropriate valve, which may be a non-return valve or flap.

Replacing the intercooled main compressor with a single compressor with high fogging water injection improves overall thermal efficiency to above 60%. It also boosts power density to over 1,600 kJ/kg combustion air compared to below 800 kJ/kg for the most advanced GTCC's. The wet compressed SCRC allows a higher heat sink temperature than a GTCC with the option of dry cooling. It does not depend on an external source of make-up water.

The operating flexibility of the SCRC concept combined with low cost make it attractive for cases where callable power is needed from a hydrocarbon fuel while high efficiency is needed at low part load. This is an opportunity for grid frequency support.

The absence of an extra bottoming cycle, relatively small turbomachinery and high-power density represent simplicity and a smaller footprint. Smaller SCRC implementations have a high potential for combined heat and power applications and for naval drives. The technologies needed for developing SCRC are all available within existing capabilities. ■

Dr. Hans E. Wettstein is an Independent Consultant living in Switzerland. For more technical detail concerning SCRC, see his paper* Semi-Closed Recuperated Cycle With Wet Compression *(GT2017-63375), presented at the 2017 Turbomachinery Expo, or email hans.e.wettstein@bluewin.ch

HYDRAULIC SYSTEMS IN TURBOMACHINERY

Hydraulic systems can deliver the high force and torque necessary to operate large and powerful mechanisms within turbomachinery. Hydraulic fluid is practically considered to be an incompressible liquid even in high working pressures. Hydraulic systems offer stiffness in stroke and in operation. They are compact and lightweight.

Hydraulic systems are widely used in steam and gas turbines as well as systems, such as hydraulic actuated valves. They are comprised of hydraulic pumps and actuators, piping, valves and auxiliary components (to generate, transmit, control, and use hydraulic power).

The hydraulic fluid is usually a petroleum or synthetic oil with additives to enhance performance. In some applications, an alternative liquid or a mixture of liquids may be used. For example, properly formulated fire resistance requires a certain kind of synthetic oil to be employed for hydraulics.

Most hydraulic applications employ positive-displacement pumps of the gear, screw, or piston type. Piston pumps can be axial, radial, or reciprocating. These pumps are widely used in high pressure hydraulic systems in many turbomachinery applications.

A pump set, usually operating and standby, acts as the pressure and flow-rate generator. In other words, hydraulic liquid is pressurized in a pump set and pressurized oil is delivered for the required tasks.

The main job of the pump set is high working pressure generation with as high efficiency as possible. The higher the working pressure, the greater the stream density of the transported energy, therefore the higher the efficiency of the hydraulic system. On this basis, many systems use high working pressure and high-pressure piston pumps.

Many medium-pressure hydraulic systems use gear pumps. For small, low power hydraulic systems, a constant flow pump set might be used with bypass or other means of flow control. However, more advanced hydraulic systems have variable stroke hydraulic pumps that can control flow rates without a bypass system.

Power is transmitted from the hydraulic pump set to hydraulic piping, and actuators in the form of pressurized hydraulic fluid. This passes through a combination of tubing, fittings, valves and control items. Flow characteristics of hydraulic circuits should take into account fluid properties, pressure drop, flow rate, and pressure-surging tendencies.

The fluid transmission system should be designed to minimize changes in flow velocity, velocity distribution, and random fluid eddies, all of which dissipate energy and result in pressure drops in the hydraulic circuit. Pipe, tubing, and flexible hose are used for the hydraulic power circuits; suitable fittings are available for all types and to transition from one type to another.

Stainless steel tubing is commonly used for many hydraulic systems. Other tubing materials such as aluminium tubing and others have been used in some applications, but stainless steel is preferred for turbomachinery. Flexible hoses are needed in some movable mechanisms or machinery as rigid piping or tubing cannot serve such applications.

Flexible hose selection

Such hoses require great care for material selection and long life. These should only be used when really needed. Otherwise, rigid piping or tubing should be used. Tubing is more easily bent into neat forms to fit equipment and facilities and to transport pressurized hydraulic fluid to different actuators located in various locations of a large machine or facility.

Hydraulic controls help to monitor pressure, flow rate and flow direction. Valves in many different forms can be used such as safety/relief valves, pressure reducing valves, directional control valves and flow control valves. Directional control valves serve primarily to direct fluid to the actuators. These valves may have rotary and sliding spools.

Important design parameters are flow rate, operating pressure, working temperature, fluid viscosity characteristics, and compatibility of the fluid with wetted materials. Flow velocity in suction lines is generally in the range of 0.5 to 1.5 m/s; in discharge lines, it ranges from 2.5 to 6 m/s. A lower velocity range (2.5 to 3.5 m/s) is preferable to limit pressure drops.

Selection of material, wall thickness, supporting span and others require a safety margin. Safety factors range from 5 to 10% or even higher, depending on the severity of the application.

Hydraulic fluid may be considered incompressible, which results in stability and stiffness during operation. However, for large and high-pressure systems, some compressibility might be observed.

Remote locations will require long runs of piping or tubing. Pressure drops in some cases will cause some operational issues. Tubing and piping can be expensive. Therefore, it is smart to optimize actuator location, sizing and selection. ■

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.

ADDITIVE MANUFACTURING IN OIL & GAS

CAN TURBOMACHINERY PARTS BUILT USING ADDITIVE MANUFACTURING — THE INDUSTRIAL VERSION OF 3D PRINTING — MEET THE CHALLENGE OF SOUR ENVIRONMENTS?

BY BYRON MOHR AND WILLIAM KOVACS

Additive manufacturing (AM) is one of many emerging technologies positively impacting the turbomachinery industry. AM offers several advantages compared to traditional production methods, including quick prototyping, shorter lead times and reduced waste.

However, it also presents challenges, such as variable quality and anisotropy (exhibiting different properties in different directions). This could pose problems for equipment that is operating in sour environments.

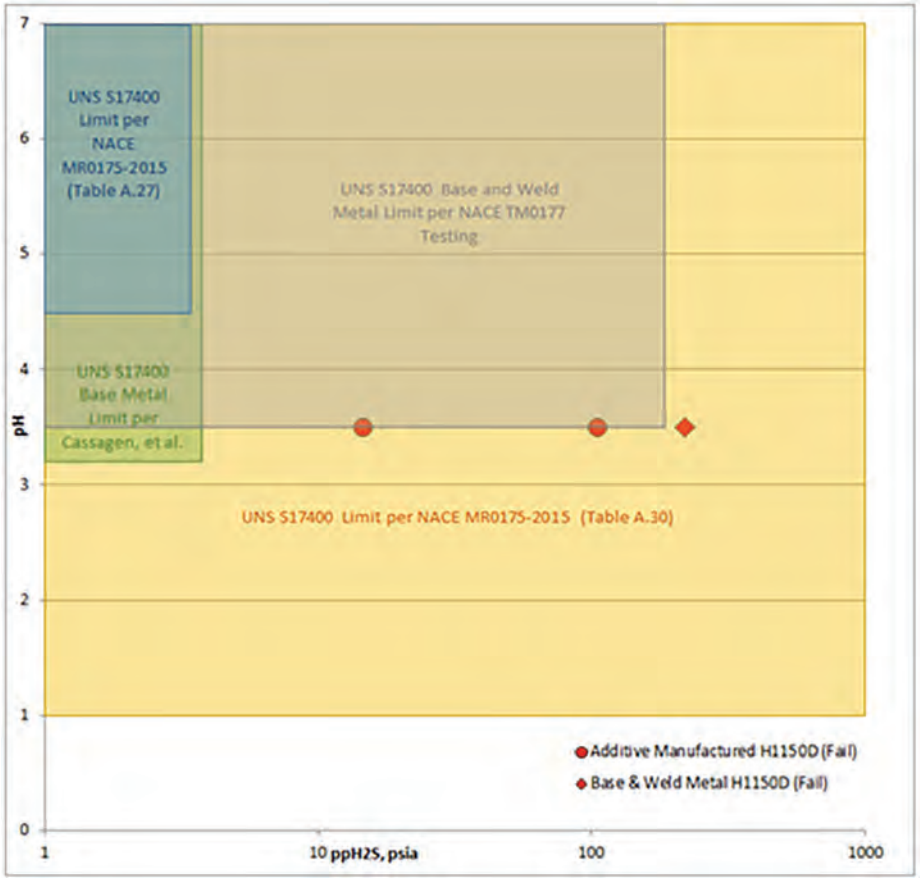
There are several industry standards for sour service capability of wrought and cast materials. This includes NACE MR0175/ISO15156 Petroleum and Natural Gas Industries—Materials for Use in H_2S-containing Environments in Oil and Gas Production and MR0103/ISO17945 Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments.

However, they do not directly apply to AM production methods. As a result, additional qualification and material testing are needed to determine the suitability of AM components for sour service.

Testing for sulfide stress cracking (SSC) can be done, for example, on 17-4 stainless steel (UNS S17400) produced by applying the AM powder bed fusion process. Results can be compared with traditional welded and wrought testing of the same alloy. This testing helps determine if a set of AM specimens can comply with the testing requirements for wrought and welded materials.

Various techniques were used to evaluate the material properties of the wrought, welded and AM specimens. Rockwell hardness testing reading in the "C" scale were taken from AM, age-hardened rod, and welded specimens.

The Rockwell scale hardness test is based on indentation hardness of a material by determining the depth of penetration of an indenter under a large load compared to the penetration made by a preload. There are different scales, denoted by a single letter (e.g., HRB, HRC, and so on), that use different loads or indenters.



Strength versus partial pressure of H_2S test for various production environments that cause sulfide stress cracking within UNS S17400, a widely used stainless steel alloy

All material had been heat-treated. Readings of the AM specimens were distributed onto different XY- and Z- planes. All specimens met the maximum hardness specification, but AM components exhibited slightly lower readings.

AM specimens had inconsistent readings. One specimen displayed a range (min to max) of 7.9 HRC. Ranges for the rod and welded specimens, on the other hand, were 1.2 and 2.4 HRC, respectively.

Yield Strength

Research has shown that yield strength strongly correlates with relative cracking susceptibility of UNS S17400. To that end, duplicate specimens were turned and tested from AM blanks (Z-direction). The tensile properties of the rod and welded specimens were also recorded.

Testing revealed an average yield strength just above 130 kilopounds per square inch (ksi) for the AM specimen. This was higher than other materials with the same heat treatment condition.

As there are some correlations between hardness and yield strength or tensile strength, the use of yield strength alone as a discriminator for AM parts is not encouraged. AM parts manufacturers could, however, incorporate tension specimens for quality control in each of the XY, and Z di-

rections with every build that is carried out.

Previous research has demonstrated that the most likely direction to experience reduced properties is in the Z-build direction. This is a result of the solidification direction and segregation of impurities.

Uniaxial tension is also useful in evaluating the performance of various fabrication routes (AM, wrought, and cast). Testing should be done in two environments: Low H_2S and high H_2S.

Results indicate capability in condensed water conditions beyond the NACE MR0175 listed conditions for plate and welded materials. Relevant NACE MR0175 limits, regarding stress level and partial pressure of H_2S are shown in the figure.

It also shows the results of tested materials and additional values obtained from literature for SSC testing of UNS S17400 stainless steel.

As can be seen in the figure, results of SSC testing of AM parts with the longitudinal direction of the specimen in the Z-axis indicate a significant performance deficit of the AM material tested relative to reference tests on wrought and welded types. When exposed to either the "high H_2S" or "low H_2S" conditions, each set of three AM specimens failed in less than 24 hours.

Independent crack initiation sites were observed on the fracture face. Energy Dispersive x-ray Spectroscopy (EDS) element maps of these sites showed an elevation in the sulfur content. The compositional analysis also showed elevated levels of niobium, manganese, silicon and also in oxygen levels.

Multiple factors may have resulted in the AM specimens' poor performance in the sour environment. This includes inclusions, precipitates, intra-layer defects, porosity, material condition and heat treatment, and microstructure.

There were discontinuities seen in the polished AM surfaces (XZ-plane), along with inferior general and localized corrosion resistance in this direction. This is likely a result of inhomogeneities that occurred during fabrication.

All AM specimens met the compositional, heat treatment and maximum hardness limits specified in NACE MR0175. However, the uniaxial tension test did not achieve the performance in a sour environment compared to wrought and welded counterparts.

AM parts could be distinguished from wrought and welded counterparts by their variability in (macro) hardness, higher yield strength to tensile strength (YS/TS) ratio, reduction of area, and lower ductility in the Z-direction. These test methods and criteria may be useful tools for AM batch process quality control.

Overall, additional testing is needed to more accurately determine the suitability of AM components for turbomachinery in sour environments. Improvements in the AM microstructural control, porosity and mechanical properties would be beneficial to minimize the sources of variability in sour qualification testing. ■

Byron Mohr is Manager of Materials, Welding, Solid Mechanics, and Development Engineer Departments for the Dresser-Rand business, part of Siemens Power and Gas. For more information visit www.dresser-rand.com

William Kovacs III is Senior Engineer, Materials Compatibility Group at DNV GL. This article is based on the paper, "Additive manufacturing for sour service, an experimental investigation" presented at the 2017 NACE Corrosion Conference and Expo. As well as Byron Mohr and W. Kovacs III, additional authors from the DNV GL Pipeline Services Department were L. Cao, K. Evans, C. Taylor, S.A. Waters, Z. Berg and J. Silva.

REMANUFACTURING IN TURBOMACHINERY

SOME COMPONENTS ARE WORTH REMANUFACTURING WHILE OTHERS SHOULD BE REPLACED. HOW DO YOU MAKE THE DECISION?

BY DEREK VANEK

Remanufacturing is the rebuilding of a product to specifications of the original manufactured product using a combination of reused, repaired and new parts. And it requires the repair or replacement of worn out or obsolete components and modules.

The definition, developed by King, Burgess and others, defines a remanufacturing process as, "the only process where used products are brought at least to Original Equipment Manufacturer (OEM) performance specification from the customer's perspective and, at the same time, are given warranties that are equal to those of equivalent new products."

The U.S. is the largest remanufacturer in the world. Between 2009 and 2011, the value of U.S. remanufactured production grew by 15% to at least $43.0 billion, supporting 180,000 full-time jobs, according to the U.S. International Trade Commission.

Remanufacturing, though, might not be right for every application. Sitting at the heart of the decision is the used part that is at the end of its service life. A part that was removed due to failure is considered the same as a part that was disassembled from that same application due to obsolescence.

There are four main strategies for remanufacturing, each of which comes down to value and type of component, according to a study on "Remanufacturing Inspection Models," by Exeter University, UK.

It states: "If cores [end of service life components] are relatively cheap, disposal is an effective way of increasing the reliability of the population as a whole. If cores are expensive they must be processed almost regardless of cost. In the case of low value cores, there is often a new alternative that can be purchased in its place."

Ultimately, the decision to remanufacture a component is made by the OEM or by the company that owns and uses the equipment. This decision depends on the

lead time to make a new part.

In order to create a new component for an existing turbine, the base material needs to be the same, which is not always accessible if the component is made out of an alloy. To assess whether it is worth remanufacturing, the value of the part helps determine if it is worth repairing.

Compare the cost of repair to the cost to remake the component. If the repair costs more than 25% of the value to remake the part, remanufacturing is not an option. It is more effective to replace the part.

Remanufacturing of a component, then, should be assessed on a case-by-case basis. Different processes might be used in the remanufacturing process than were used in manufacturing the original equipment or part.

Further, a repair may result in transportation costs. Due to the high cost of turbomachinery equipment combined with the lead time required to purchase new equipment, remanufacturing generally remains an option.

Nevertheless, there can still be instances when remanufacturing is not viable, because it costs more in time and energy to restore a part than to replace. In some cases, remanufacturing cannot be considered due to the wear, corrosion, or other damage to the part. In other cases, there may be dimensional limits in the design scheme that hinders the ability to perform a selective plating application.

As remanufacturing can add as many as ten or more years to part life, it can be of assistance in minimizing repair times. Remanufactured components may be available with a shorter lead time than those that are manufactured-to-order in overseas locations.

Surface treatment in remanufacturing

NACE estimated the cost of corrosion to U.S. industry to reach as much as $540 billion in 2015.

Surface treatment is a cost effective and common method of restoring a component back to its original specification. Many processes are available, including tank plating, thermal spray and selective plating.

Tank plating immerses the components in a solution. To accomplish this, parts are typically removed and shipped to the plating company.

Thermal spray, on the other hand, provides a mechanical bond. Once the spraying is done, machining is done to bring the component to the required dimension.

Selective plating, also known as brush plating, is commonly applied via a handheld tool. The operator soaks the tool in the plating solution and applies it via an absorbent cover wrapped over the anode of the plating tool. It can be carried out in situ and creates an atomic bond.

Steam compressor housings and stages, for example, experience corrosion due to the build-up of condensation.

Similarly, when leaks form in the seal areas of a turbine, pressure builds and steam releases at such high power, that it gouges or cuts any exposed component. Surface deterioration of metal components can lead to premature failure with the risk of unscheduled downtime.

When a turbocompressor operates at full load, ensuring the correct dimensions of turbine shafts and housing covers is essential to optimal output. It is impossible to resist wear on these components, but there is a way to restore them to size with a nickel alloy without the need for post machining.

The pinion gear is an essential part in a gear train assembly. If not maintained regularly, lubricant in the pinion gear can leak out of the seal, ultimately causing the bearing to seize and gall to the shaft.

When the seized bearing is removed it can also remove excess material from the journal resulting in a gouge to the surface. Plating can prevent galling and raise surface hardness.

With many surface finishing options available, including thermal spray processes, IVD, PVD, tank plating and selective brush plating, choosing the right one for a particular application can be difficult. Selective plating, for example, is best suited for localized areas on inside and outside component diameters or flat surfaces.

Take the case of rotor resizing. One major power generator uses selective plating for the maintenance of turbines. This saves it 50 per cent of the time required to return equipment to service. It builds up rotors with nickel to prevent erosion or wear on the shaft and permit optimal performance.

Selective plating technicians use the OEM specification to determine the deposit to be plated and thickness required. If the shape is out of round or pitting has occurred, post machining is required. If only a small amount of deposit is needed, selective plating can be used to plate to size. ■

Derek Vanek is the Technical Manager for SIFCO Applied Surface Concepts, a company that provides selective brush plating solutions to improve part performance and reduce manufacturing costs through corrosion protection, increased wear resistance, increased hardness, improved conductivity, anti-galling or slip. The SIFCO Process is an application of selective plating used by many in the turbomachinery industry. For more information, visit www.sifcoasc.com

ANSALDO ENERGIA'S EXPANDED PORTFOLIO

Dr. Thorsten Osterhage, GT36 Product Manager at Ansaldo Energia, discusses his company's various offerings, the latest GT36 gas turbine and future directions.

Tell our readers about Ansaldo Energia's turbomachinery portfolio.

Our expanded portfolio ranges from 78 MW at the bottom end to 500 MW (50 Hz) for the brand new GT36, as well as steam turbines and generators.

What turbomachinery trends have you observed?

There is a greater need in the industry for turbomachinery with higher operational flexibility and improved performance. In addition, power producers are under pressure to reduce emissions.

How is Ansaldo responding to these trends?

We are engineering flexible gas turbines (GTs) for simple cycle and combined cycle applications. This includes a high performance F-class engine as part of our enlarged portfolio, as well as the introduction of the new GT36 H-class gas turbine.

Both the GT26 and the GT36 harness sequential combustion to lower emissions. This ensures superior operational flexibility for dynamic power markets. Features include high part-load efficiency, lower emissions for a broader emission-compliant window, and a lower turndown point (parking load) to 10% to 15% of plant load. This is important, as the alternative is shutting down the entire power plant.

What is the latest on the GT26?

Ansaldo Energia owns all the intellectual property for the GT26. Development continues, as well as service upgrades for older GT26 machines rated in 2006. The company has service contracts for more than 40 GT26 engines.

What should our readers know about the GT36?

The GT36 is a new H-class engine for both 50 Hz and 60 Hz markets. It combines high performance and superior operational flexibility in terms of operating range, turndown and fast reserve power.

This enables the user to maximize dispatch and revenues. This new GT has also been optimized for maintenance and serviceability. It underwent full validation in the field at the Ansaldo power plant in Birr, Switzerland.

We are currently ramping up manufacturing of this turbine at our facility in Genoa, Italy. Enlarged production capacities are now available for hot gas parts, welding and final assembly.

How about other Ansaldo turbomachinery assets?

Our AE gas turbines have strong positioning in the market, with two AE94.2 and three AE94.3A units sold this year (2Q-2017). These GTs have been undergoing step-by-step improvements, based on minor modifications to the present configuration. Some of these changes have been driven by customer requests. This is enabling these proven machines to grow in terms of performance, operability and maintainability.

What does Ansaldo have in the development pipeline?

The energy market is rapidly changing due to the increasingly important role played by renewables, the focus on environmental impact, and the possibility of burning alternative fuels. That's why we must be prepared to seize every opportunity to improve our products in line with shifting expectations.

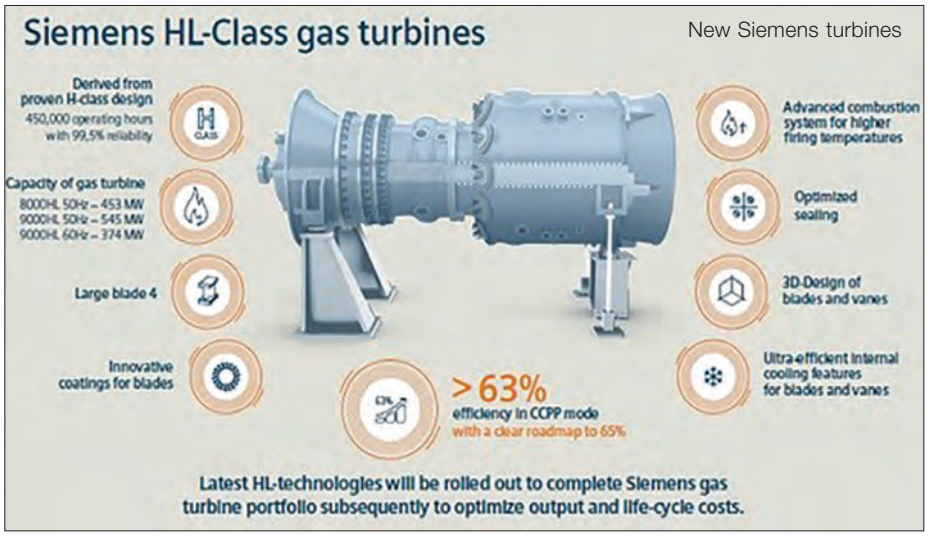
Recent and ongoing service upgrades, such as those for our GT26 and AE fleet, will allow our customers to take better advantage of their installed machines. This will provide them with increased performance, lower maintenance costs, enhanced operational flexibility, life extension and overall profitability.

What specialized services do you offer?

The takeover of Alstom heavy duty gas turbine assets and technology as well as U.S.-based Power Systems Manufacturing, allows Ansaldo Energia to offer customers a large portfolio of technical services. This goes beyond our own machines, but also encompasses turbomachinery from other OEMs. We offer integrated services for GTs, steam turbines and generators. ■

Model	Technology Class	Unit Power MW (*)	Efficiency % (*)	Grid Frequency Hz
» AE64.3A	F	78	36.3	50 / 60
» AE94.2	E	185	36.2	50
» AE94.3A	F	325	40.1	50
» GT26	F	345	41	50
» GT36-S5	**H**	**500**	**41.5**	**50**
» GT36-S6	**H**	**340**	**41**	**60**

(*) GT26 and GT36 including OTC



New Siemens turbines

Siemens is developing the HL class as an evolutionary development step derived from its SGT-8000H technology. The advanced Siemens HL-class gas turbines (GTs) combine new technologies and design features to achieve efficiency levels beyond 63%. The HL-class consists of the SGT5-9000HL, SGT6-9000HL and SGT5-8000HL. In simple-cycle operation the air-cooled SGT-9000HL will provide 545 MW for the 50-Hertz market (374 MW, 60-Hertz). The SGT5-8000HL will provide 453 MW in simple-cycle operation.

The GTs can plug in to Siemens' digital offerings that incorporate connectivity to MindSphere, the cloud-based Siemens operating system for the Internet of Things (IoT). MindSphere offers access to analytics from Siemens and its partners.

"It took us from 2000 to 2010 to increase the efficiency of our combined cycle power plants from 58 to 60%, a further six years to reach 61.5% in 2016 and now we are taking the next step to 63% and beyond," said Willi Meixner, CEO of the Siemens Power and Gas Division.

siemens.com

MHPS hybrid system

Mitsubishi Hitachi Power Systems (MHPS) has launched a pressurized hybrid power generation system that integrates solid oxide fuel cell stacks (SOFC) with micro gas turbines (MGT). The system was developed using a 250 kW version, supported by Japan's New Energy and Industrial Technology Development Organization (NEDO) research agency. The Japanese Ministry of Economy, Trade and Industry is promoting greater adoption of fuel cell systems due to their outstanding power generation efficiency and minimal carbon dioxide (CO_2) emissions.

mhps.com

Kelvion heat exchanger

Kelvion NW150L stainless steel heat exchanger plates have been introduced for viscous and particle-containing media in the lower range. The NW models have a wider plate gap than those in the NT series, which allows efficient heat treatment, only a slight pressure drop of viscous media and liquids with particle diameters up to 5 mm.

The wide herringbone plate corrugation, with a gap width of 10 mm, assures turbulent flow at all points of the plate to counter fouling. The new plates are well suited for applications in sugar production, bioethanol, industrial wastewater and petrochemical processes. Re-assembling the heat exchangers after cleaning or inspection work is simple. The NW150L is compatible with the frames of the Kelvion NT150L series.

kelvion.com

A NW150L heat exchanger plate

New bearings

The Boca Bearing Company has expanded its line of mounted unit bearings and inserts. Mounted unit bearings are used when a shaft axis is perpendicular to the bearing mounting surface. Available in 2- or 4-hole configurations, flange-mounted unit bearings and pillow blocks provide a method of accurate mounting fits and load support. These stainless steel mounted unit bearings are suitable for applications that require frequent wash downs, operate near food or liquid contaminants and have a high exposure to harsh chemicals or humidity.

Boca Bearings also offers thermoplastic-mounted unit bearings consisting of a high-grade, thermoplastic housing with a stainless steel insert. Full ceramic or ceramic hybrid insert bearings can be substituted upon request from a 0.5000 inch bore to a 1.5000 inch bore in metric and inch sizes. Also offered are mini-mounted unit bearings, which have a rustproof housing made with a special alloy or stainless steel 304 with bearings made from high carbon chromium bearing steel or stainless steel 440^{0}C. Low profile mini mounted units are suited for tight spaces.

bocabearings.com

Asset performance

GE's Asset Performance Management (APM) software includes analytics capabilities based on the analysis of more than 125 million hours of data from generators and turbines. These analytics can help to reduce unplanned downtime by up to 5%, reduce false alarms by up to 75%, and reduce operations and maintenance costs by up to 25%, according to GE.

APM is powered by Predix, GE Digital's platform for the Industrial Internet. It can identify patterns and trends in data that could indicate a problem with a machine's performance. This allows industrial businesses to increase machine reliability and availability, while also reducing maintenance costs and managing operations risks.

Typically, plant operators who run traditional monitoring capabilities have limited advanced notice when critical machine issues arise. Warning of potential issues of anywhere from a few days up to several weeks can enable better productivity and lower maintenance costs.

GE Power's Monitoring & Diagnostics Center in Atlanta is utilizing APM to increase the reliability of the thousands of power producing turbines and generators it monitors. More than 500 power producers and utilities responsible for 900 power plants around the world use the M&D Center's data scientists, engineering resources, and monitoring services to identify machine and equipment issues. Every day, the center receives more than 200 billion data tags coming from 1 million sensors attached to 5,000 assets in power plants across more than 60 countries.
ge.com/digital.

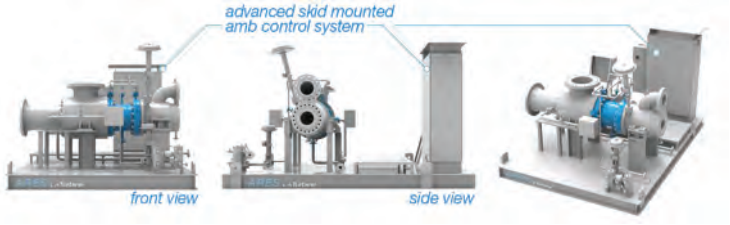
Generator oil

Kohler has introduced a line of aftermarket oil for generator applications. Available in three formulations for different fuel types, they are optimized for use in industrial, mobile, marine, and home generators. The synthetic line was engineered to help generators run at peak performance, reducing downtime and helping to lower total cost of ownership compared with conventional oils used in the same applications.

The 5W-30 formulation is for generators powered by gasoline or gaseous-fueled engines. The 5W-40 formulation is for generators powered by diesel-fueled engines. The 15W-40 option is for generators with gaseous-fueled engines. Each is formulated with a synthetic base oil that maintains viscosity while also resisting "burn off," which can occur with other, lesser quality oils. Special additives oil protect against engine wear and corrosion, extending overall generator life.
KohlerPower.com.

SGT-800 upgrade

Siemens is offering its SGT-800 GT with a power output of 57 MW and an electrical efficiency of more than 40% in simple cycle application. In a combined cycle configuration, the power output is 163 MW at a net efficiency of more than 58.5%. The SGT-800 is available with a power output from 47.5 MW to 57 MW thanks to this upgrade. Only improvements of gas turbine parts using Siemens existing and mature core engine technologies have been made. The improved performance has also been achieved through better gear box, and outlet casing and diffuser efficiencies. To date, more than 325 SGT-800 turbines have been sold across the world. The turbine, which was originally known under the product name GTX100, began development in 1994 and was launched in 1997.
siemens.com



L.A. Turbine Standard Turboexpander Compressor Project ARES

Ares turboexpander

L.A. Turbine's (LAT) first standard turboexpander-compressor with active magnetic bearings (AMB) is in production. The AMB turboexpander configuration, designed for use in a 200MMSCFD gas plant, provides a condensed footprint and reliability; meets the performance requirements and operating conditions of the facility; and features a skid-mounted AMB controller and PLC.

The AMB control system has digital signal processors, and control algorithms to continuously optimize dynamic performance and efficiency. The control panel features secure remote connectivity for monitoring, tuning and diagnostic services. It can also perform automated commissioning.
laturbine.com

Accelerometers

Hansford Sensors launched the latest versions of its HS-100 and HS-150 Series vibration sensors. They are over 10% smaller and lighter than existing versions, and offer greater frequency response, with an improvement in resonant frequency. The new family is designed for use typically on drives and rotating shafts such as those found in pumps, fans, motors, gearboxes and compressors.

The height of each accelerometer was cut by 10mm. Frequency response has been improved to between 0.8kHz and 15kHz. The resonant frequency has been increased to between 26kHz and 34kHz depending on specification. The accelerometers are available with options such as special purpose cable assemblies and a choice of mounting threads.
hansfordsensors.com

Industrial accelerometers from Hansford Sensors

Shaft alignment

Ludeca's Easy-Laser XT660 is a laser shaft alignment system. An iOS or Android phone or tablet can be


Easier shaft alignment from Ludeca.

used for display, or you can purchase Ludeca's watertight, shockproof rugged XT11 display unit. The Easy-Laser XT Alignment App is free to download. The XT660 offers dot laser measurement technology. You can perform measurements on larger machines and over longer distances. Continuous sweep and multi-point measurement capabilities are available.

Ludeca has also released the Easy-Laser XT190 BTA digital laser tool for belt drive alignment. It can be used stand-alone with its built-in display, as an add-on to the XT660 Shaft system or you can download the Easy-Laser XT Alignment App for your phone or tablet. Digital readings allow greater precision and make it easier to meet the alignment tolerances.
ludeca.com

Spectro Scientific FieldLab 58 oil analysis system

Oil analysis

Spectro Scientific has introduced an upgrade to its FieldLab 58 oil analysis system consisting of a more powerful X-ray fluorescence (XRF) module and filter that improves the limits of detection for wear metal elements in oil. The system's coupling of X-ray fluorescence and filter particle quantifier testing meets the new ASTM International Standard D8127. FieldLab 58 is a battery-powered, integrated oil analysis system that provides oil analysis in the field. Packaged within a small case, the analyzer integrates four analytical technologies: XRF for elemental analysis; a filter particle qualifier (FPQ) pore blockage particle counter; an infrared (IR) spectrometer; and a kinematic viscometer (40˚C). In addition, it measures fluid chemistry and contamination per ASTM Standard D7889 and viscosity per ASTM D8092. Using only 3 ml of oil, the four tests generate more than 20 fluid analysis parameters in five to seven minutes.
spectrosci.com

Steam turbine protection

The Pneu-Trip steam turbine protection system, developed by Drake Controls, is easily integrated with existing linear trip valves of API 611 steam turbines. It uses high reliability SIL-certified components to replace mechanical trip valve actuation, thus increasing turbine uptime and safety. Pneu-Trip features a Partial Stroke Test Device that allows exercising the trip valve, trip solenoids and the actuator spring safely and without shutting the turbine down. It is also available for retrofitting general purpose steam turbines that make use of rotary trip valves.
drakecontrols.com

Pneu-Trip system installed on a turbine steam chest

Diffusion pump

Diffusion pumps do not have any moving parts. Their principle of operation is based on steamed propellants, thus enabling extremely reliable and low-maintenance operation. Leybold has upgraded the established DIP and newly developed DIJ diffusion pump series, with the aid of intelligent technologies and innovations. Leybold provides models and accessories for relevant diffusion pump applications. The five-stage nozzle system of the DIJ series does well in the pressure range from 10-2 to 10-3 mbar. Energy consumption has been cut by 30% without sacrificing performance. An improved heating system has been adjusted it to produce propellant steam.
Leybold.com

Leybold diffusion injector pump DIJ

Bearing tests

Napoleon Engineering Services (NES) has announced advancements in bearing test technology, offering expanded test opportunities for low-cost, proof-of-concept research. The NES Three-Ball-on-Rod Tester represents one of the most economical rolling contact fatigue tests available. Testing is performed to evaluate the influence of heat treatment, material, lubricant, and coatings on fatigue life. Run times are short and a single rod specimen can provide many failure data points. High stress cycle accumulation per revolution and stress levels up to 900 ksi (6.2 GPa) provide options to the test engineer. NES has designed these RCF testers with oil heaters, lubricant flow control, test fixture temperature monitoring and vibration sensors.

The NES Five-Ball tester captures the mechanics of bearing fatigue for simulation of bearing testing. The upper drive ball simulates the inner ring, the cup supporting the lower four balls models the outer ring and four planetary balls replicate the balls in a bearing. The NES Cylindrical Roller Tester (CRT) tests ceramic roller quality. The influence of crown geometry on roller life can be done without the risk of ring failure. The NES fretting wear tester (ASTM D4170) is for lubricating greases and oscillation angles.
nesbearings.com

Digital proximity system

The Metrix Digital Proximity System (DPS) eliminates the need for dozens of different proximity probe drivers and transmitters. It is a field-configurable device that can work with multiple target materials, cable lengths, and older probe systems from a variety of manufacturers. It is also compatible with 5mm, 8mm, and 11mm proximity probes. It is: API 670 compliant; adjustable for target materials, probe types, and system lengths; custom configurable for unknown target materials; available as 3-wire voltage mode probe driver or as 4-20mA output transmitter; hazardous-area compliant and well suited for Metrix VibeLock connectors and triaxial cables.
metrixvibration.com ■

ADINDEX

STATEMENT OF OWNERSHIP, MANAGEMENT, AND CIRCULATION

(Requester Publications Only)

(Required by 39 USC 3685)

Publication Title: Turbomachinery International

Publication Number: 0871-500

Filing Date: 9/30/17

Issue Frequency: Bi-Monthly plus Annual Handbook in October

Number of Issues Published Annually: 7

Annual Subscription Price (if any): $49.00

Complete Mailing Address of Known Office of Publication:
535 Connecticut Ave, Norwalk, CT 06854

Contact Person: Wendy Bong

Telephone: 218-740-7244

Complete Mailing Address of Headquarters or General Business Office of Publisher:
2 Penn Plaza, 15th Floor, New York, NY 10121

Full Names and Complete Mailing Addresses of

Publisher: Richard Zanetti, 535 Connecticut Ave, Norwalk, CT 06854

Editor: Drew Robb, 535 Connecticut Ave, Norwalk, CT 06854

Managing Editor: None

This publication is owned by: Advanstar Communications Inc., 2 Penn Plaza, 15th Floor, New York, NY 10121. The sole shareholder of Advanstar Communications Inc. is: Rocket Holdings, Inc., 1983 Marcus Ave., Suite 205, Lake Success, NY 11042.

Known Bondholders, Mortgages, and Other Security Holders Owning or Holding 1 Percent or More of Total Amounts of Bonds, Mortgages, or Other Securities. If none, check box. → ☑

Does Not Apply

Publication Title: Turbomachinery International

Issue Date for Circulation Data Below: Sept/Oct 2017

Extent and Nature of Circulation

		Average No. Copies Each Issue During Preceding 12 Months	No. Copies of Single Issue Published Nearest to Filing Date
A.	Total Number of Copies	11,608	10,320
B.	Legitimate Paid and/or Requested Distribution		
	1. Outside County Paid/Requested Mail Subscriptions Stated on PS Form 3541	4,822	5,221
	2. In-County Paid/Requested Mail Subscriptions Stated on PS Form 3541	0	0
	3. Sales Through Dealers and Carriers, Street Vendors, Counter Sales, and Other Paid or Requested Distribution Outside USPS	1,494	600
	4. Requested Copies Distributed by Other Mail Classes Through the USPS	0	0
C.	Total Paid and /or Requested Circulation (Sum of 15b (1), (2), (3), and (4))	6,315	5,821
D.	Non-requested Distribution		
	1. Outside County Non-requested Copies Stated on PS Form 3541	2,401	2,939
	2. In-County Non-requested Copies Stated on PS Form 3541	0	0
	3. Non-requested Copies Distributed Through the USPS by Other Classes of Mail	0	0
	4. Non-requested Copies Distributed Outside the Mail	800	1,170
E.	Total Non-requested Distribution (Sum of 15d (1), (2), (3) and (4))	3,201	4,109
F.	Total Distribution (Sum of 15c and e)	9,516	9,930
G.	Copies not Distributed	711	390
H.	Total (Sum of 15f and g)	10,134	10,320
I.	Percent Paid and/or Requested Circulation	66.36%	58.62%

Electronic Copy Circulation

*If you are not claiming electronic copies, skip to line 17

Publication of Statement of Ownership for a Requester Publication is required and will be printed in the November/December 2017 issue of this publication.

Name and Title of Editor, Publisher, Business Manager, or Owner:
Christine Shappell, Audience Development Director

Signature: Christine Shappell
Date: 9/30/17
I certify that the statements made by me above are correct and complete.

MYTH: A GOOD FOUNDATION IS HARD TO BUILD

Most of us, when we went to college many years ago, took a freshman or sophomore level engineering undergraduate class in statics and dynamics. During these basic course curricula, we learned all about real-life application of Newton's laws, free body diagrams, and the sum of forces to achieve static and dynamic equilibrium.

When designing, for example, a compressor skid, it is important that engineers continue to apply the principals taught in these classes. Otherwise, the consequences of poor static and dynamic design analysis may include cracks in the foundation, thermal expansion on pipes, high static stress due to misaligned flanges, shacking pipes and skids, complete train movement and bending, and misaligned driver and driven equipment.

Basically, a skid and foundation isolates the rotating and reciprocating machinery from any ground movements. It provides a level and rigid surface for machinery mounting.

Skids and foundations have been around at least since 1780 when the steam engine was invented. Although modern machines run much faster than old steam engines, and therefore produce higher frequency excitations, the design requirements for a machinery support structure have not changed.

Solid structure; level alignment

Specifically, they must provide a solid structure for level alignment of the machine that isolates static, and dynamic machinery forces and moments from the ground, and disallows relative movement between all mounted components. This is achieved through simple mechanical inertia, stiffness and dampening of the skid, sub-skid, and base.

After hundreds of years of experience with machinery skids, there are some basic engineering rules of thumb for their design. There are also comprehensive industry guidelines and specifications on foundation and skid design published by the Gas Machinery Research Council (GMRC), the American Petroleum Institute (API), and the American Society of Mechanical Engineers (ASME).

Additionally, all machinery manufacturers provide complete documentation of the minimum foundation requirements for equipment. These should be strictly adhered to. There are many companies that know this and have expertise in designing a proper machinery base. However, others do not seem to be able to engineer a foundation or skid, as shown in the hundreds of base support-related machinery failures reported every year.

When the foundation fails, equipment starts to shake and high cycle fatigue issues are common on the machine, piping, and structural supports. Even worse, a poor skid design allows misalignment between machinery train components, which results in excessive forces on shafts. This often causes catastrophic failures.

Usually a good skid can be designed from basic statics and dynamics principles. Finite element analysis (FEA) can be helpful to optimize a skid and avoid over-design, especially for high-speed machinery support structures. Also, when multiple machines operating at difference speeds are mounted on a complex support structure, FEA can be used to avoid unexpected harmonics and excitation coincident frequencies.

Obviously, the type, complexity, size, weight, and stiffness-damping characteristics of the skid or foundation are primarily a function of the level of vibration produced, and its anchoring to the ground or sub-surface. Centrifugal compressors and gas turbines (GTs) usually have much lower vibrations, so lighter foundations can be used.

Reciprocating compressors and engines require more rigid and sturdy foundations. But it is not simply a question of the driver and driven equipment excitation dynamics and their proper absorption. The level of allowable foundation strain, rotor-interface misalignment, and case bending are critical design parameters.

For many low-horsepower reciprocating compressors, a welded rectangular I-beam style skid with sufficient cross-stiffening beams is adequate, even when mounted on a gravel pad. However, a growing number of low horsepower compressor packages have been found to experience high vibration due to degradation of gravel pads.

This has led to uneven settlement over time. High skid vibration, in turn, leads to excitation of mechanical responses. These responses would normally not be excited. But they can lead to dangerous levels of vibration and equipment failure. A low horsepower unit may perform adequately on a smaller foundation. However, the assumption that a gravel pad is sufficient for all low-horsepower packages may lead to future problems.

Similarly, one would not want to take this simple approach on a 100 MW gas turbine-driven multi-body compressor skid. Here, a careful skid and foundation design would be more appropriate based on the machinery train's actual static and dynamic loads as well a detailed soil analysis. Using an industry standard such as API 686 will ensure the foundation design will resist all dynamic and static operation loads.

Although it may not be necessary to always dig out the old undergrad textbooks, engineers must understand these fundamentals and should apply sound engineering principles to their design. Fundamental concepts cannot be ignored, such as how static loads are applied to an appropriate machinery support structure or vibrations, their natural frequencies, and the system's dynamic responses.

There are plenty of experts and companies that can help with this. Also, it is not good practice (nor is it necessarily safe) to use heavy machinery to pull flanges and pipes into alignment just to get the bolt holes to line up. ■

Klaus Brun is the Machinery Program Director at Southwest Research Institute in San Antonio, Texas. He is also the past Chair of the Board of Directors of the ASME International Gas Turbine Institute and the IGTI Oil & Gas applications committee.

Rainer Kurz is the Manager for Systems Analysis at Solar Turbines Incorporated in San Diego, CA. He is an ASME Fellow since 2003 and the chair of the IGTI Oil and Gas Applications Committee.

Frank Fierro of SwRI contributed to this article.

Any views or opinions presented in this article are solely those of the authors and do not necessarily represent those of Solar Turbines Incorporated, Southwest Research Institute or any of their affiliates.

HARNESS THE POWER

OF ADVANCED HRSG TECHNOLOGY

The industry leader in Heat Recovery Steam Generators for gas turbines up to 30 MW, RENTECH offers a full range of HRSG systems to meet your toughest project requirements. We custom engineer our crossflow two-drum and waterwall designs to perform superbly in the most demanding applications and operating conditions. We master every detail to deliver elemental power for clients worldwide.

HARNESS THE POWER WITH RENTECH.

HEAT RECOVERY STEAM GENERATORS
WASTE HEAT BOILERS
FIRED PACKAGED WATERTUBE BOILERS
SPECIALTY BOILERS

RENTECH®

BOILERS FOR PEOPLE WHO KNOW AND CARE ®

WWW.RENTECHBOILERS.COM

FROM RELIABLE EFFICIENCY TO KEEPING THE LIGHTS ON

SHELL TURBO MAKES IT POSSIBLE

Power companies are under immense pressure to keep the lights on. As a result, modern turbine oils must be able to cope with increased stress and considerable design and operational challenges. Although selecting an underperforming lubricant rarely results in immediate failures, it can lead to long-term increases in maintenance costs and heavy power-outage penalties. In contrast, adopting a total-cost-of-ownership[1] approach with a high-performing lubricant from the Shell Turbo range can help to reduce costs by unlocking reliable efficiency. Ask us how we can work with you to make it possible.

shell.com/lubricants

SHELL LUBRICANTS
TOGETHER ANYTHING IS POSSIBLE

[1]Total cost of ownership is defined by Shell Lubricants as the total amount spent on industrial equipment, including the cost of acquisition and operation over its entire working life and the cost of lost production during equipment downtime.