WESTERN TURBINE Users

Las Vegas
March 2019

29th Annual Conference and Exhibition

What's Inside:

Conference Highlights

SUNDAY, March 17

5:30 p.m. to 8:30
Exhibitor-sponsored Welcome Reception
Exhibit Hall, Pavilion B/C/D
Special raffles (users only) with great prizes. Listen for announcements.

MONDAY, March 18

8:00 a.m. to 10:15
General Session
Grand Ballroom

President Chuck Casey's welcome, plus WTUI's value proposition, program updates, introduction of officers, board members, and breakout session chairs, treasurer's report, presentations by the authorized service providers (ANZGT, IHI, MTU, TCT), and other announcements

10:45 a.m. to 11:45
Gas-Turbine Business Update
Grand Ballroom
Consultant Mark Axford reflects on 2018 market statistics and gives his predictions for 2019.

2:30 p.m. to 5:30
Breakout Sessions
Details on p 4.

6:00 p.m. to 9:00
Monday Night Reception
Grand Ballroom
A Vegas Spectacular! Great entertainment, great food, everything you'd expect on a night out in this city. Name badge or wristband required for entry; must be 21.

TUESDAY, March 19

8:00 a.m. to 9:30
and 10:00 to noon
Breakout Sessions
Details on p 4.

Noon
Awards Luncheon
Exhibit Hall, Pavilion A

2:30 p.m. to 5:30
Special Technical Presentations
Details on p 5.

WEDNESDAY, March 20

8:00 a.m. to 10:30
Breakout Sessions
Details on p 4.

Mark Your Calendar

Celebrating 30 Years of Service to the Industry

WESTERN TURBINE USERS
2020 Conference & Expo

Long Beach Convention Center, Long Beach, Calif
March 29 – April 1

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WESTERN TURBINE Users

29th Annual Conference and Exhibition

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Welcome! On behalf of the board of directors, officers, and support staff, thank you for being a part of Western Turbine Users' Conference 2019. What began as a small group of LM2500 and LM5000 owners desperate to share information and experiences has grown into the industry's largest gas-turbine users group with over 1100 members worldwide.

The power-generation industry is changing rapidly. As fossil fuel and nuclear plants are forced to shut down, the Clean Power Plan mandates historic levels of renewable energy and energy storage. This is challenging our LM turbines to start faster and more often, operate at lower emissions, and turn-down to very low outputs—all while staying reliable and available under budget. Natural-gas prices are at unsurpassed lows with a stagnant forecast amplifying the feasibility and relevance of gas turbine/generators. To stay relevant, we need our aeroderivative engines to be more flexible, adaptable, and versatile than ever before.

Please join us in the sharing of GE aero experiences. We must challenge equipment suppliers, gas-turbine engineers, and owner/operators to improve their products and operations to maximize the performance and lifetimes of our gas turbines and facility support equipment. The WTUI annual conference is a perfect setting to discover solutions to your operational issues by allowing professionals to network with industry-experienced personnel.

The conference program includes technical breakout sessions for the General Electric LM2500, LM5000, LM6000, and LMS100 product lines and a robust exhibition hall with over 180 vendors ready to serve you. Plus, there are special technical presentations by industry experts on various O&M issues pertaining to gas turbines and balance-of-plant equipment. In addition to the conference program, a golf tournament, bowling tournament, and special Monday Night Reception are offered.

Chuck Casey
President, WTUI

30th Anniversary

WESTERN TURBINE USERS

W.T.U.I. 1990 2020 Long Beach 2020

2020 Conference & Expo • March 29 - April 1

Long Beach Convention Center

The leading forum for aero users provides owner/operators of LM2500, LM5000, LM6000, and LMS100 gas turbines an opportunity to network with peers, and service providers, to identify opportunities for improving engine performance, availability, and reliability while holding emissions to the lowest practicable levels.

Program is under development. Prospective **delegates** and **exhibitors** are urged to contact WTUI conference staff today, by e-mail (info@wtui.com), and ask to be placed on the mailing list for meeting announcements as they are made available.

TECHNICAL

Where to go (see floor plan, p 6)

Registration: Grand Ballroom Foyer
Exhibit Hall: Pavilion B/C/D

LM2500 Breakout Meetings: Sonoma C/D
Chair: Garry Grimwade, Riverside Public Utilities

LM5000 Breakout Meetings: Laguna
Chair: Perry Leslie, Yuba City Cogeneration

LM6000 Breakout Meetings: Napa
Chair: Andrew Gundershaug, Calpine Corp

LMS100 Breakout Meetings: Sonoma A/B
Chair: Steve Worthington, Arizona Public Service Co

Sunday, March 17

AFTERNOON

2:00 to 7:30 Registration

3:30 to 5:30 Welcome/Conference Familiarization, *Sonoma A/B*
All conference attendees

EVENING

5:30 to 8:30 Exhibitor-Sponsored Welcome Reception, *Exhibit Hall*
All conference attendees and spouses/guests

Monday, March 18

MORNING

7:00 to 4:00 Registration

7:00 to 8:00 Breakfast, *Pavilion A*
All conference attendees

7:00 to 8:00 Women in Power, *Palm*

8:00 to 9:00 General Session, *Grand Ballroom*
All conference attendees

9:00 to 5:00 Exhibit Hall open
Must have name badge to enter

9:00 to 10:15 Presentations by ANZGT, IHI, MTU, TCT, *Grand Ballroom*
All conference attendees

10:15 to 10:45 Break, *Exhibit Hall and Ballroom Foyer*

10:45 to 11:45 Gas-Turbine Business Update, *Grand Ballroom*
Mark Axford, Axford Turbine Consultants LLC
All conference attendees

11:45 to noon GE Services Presentation, *Grand Ballroom*
All conference attendees

AFTERNOON

Noon to 2:30 Lunch/Exhibits, *Pavilion A/B/C/D*
All conference attendees, must have name badge to enter

2:30 to 5:30 Breakout Meetings: LM2500, LM5000, LM6000, LMS100
Users, Authorized Service Providers, GE

EVENING

6:00 to 9:00 Monday Night Reception, *Grand Ballroom*
All conference attendees and registered spouses/guests, must have name badge/wristband and must be 21 years old for entry.

PROGRAM

As of Feb 15

Tuesday, March 19

MORNING

7:00 to 4:00 Registration

7:00 to 8:00 Breakfast, *Pavilion A*
All conference attendees

8:00 to 2:30 Exhibit Hall open
Must have name badge to enter

8:00 to 9:30 Breakout Meetings: LM2500, LM5000, LM6000, LMS100
Users only

9:30 to 10:00 Break, *Exhibit Hall and Ballroom Foyer*

10:00 to noon Breakout Meetings: LM2500, LM5000, LM6000, LMS100
Users, Authorized Service Providers, GE

AFTERNOON

Noon to 4:30 Lunch/Exhibits, Pavilion A/B/C/D
All conference attendees, must have name badge to enter

2:30 to 5:30 Special Technical Presentations
All conference attendees

2:30 to 3:30
1. "Installation and Removal of Ameriflex Couplings," Ameridrives, *Napa*
2. "Ageing HRSG Inspection and Maintenance Priorities," HRST Inc, *Sonoma C/D*
3. "CCJ's Best Practices," *Sonoma A/B*

3:30 to 4:30
1. "Boro-blending," Reed Services, *Napa*
2. "Electric Generator Maintenance/Rotor Pull," Mega-Watt Consulting, *Sonoma C/D*
3. "Application of Reliability and Maintainability of GTs on Fleet Management," *Sonoma A/B*

4:30 to 5:30
1. "Tunable Diode Laser for NH_3 Measurement," CEMTEK Environmental, *Napa*
2. "Online Monitoring of Stator Endwinding Vibration," IRIS Power, *Sonoma C/D*
3. "Excel for Daily Reports and Calculating Simple KPIs," T2E3, *Sonoma A/B*

Wednesday, March 20

MORNING

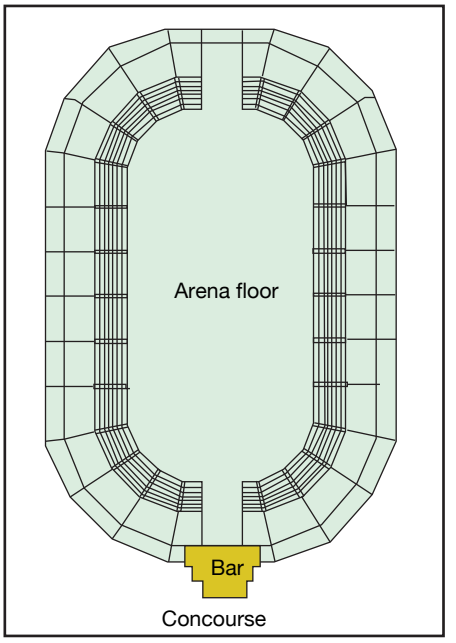
7:00 to 8:00 Breakfast, *Grand Ballroom Foyer*

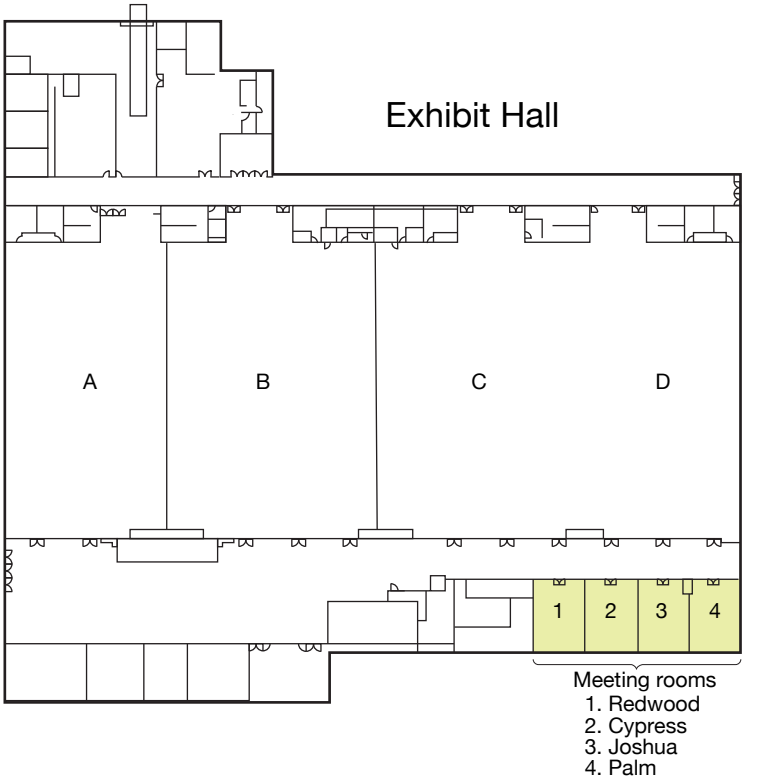
8:00 to 10:30 Breakout Meetings: LM2500, LM5000, LM6000, LMS100
Users, Authorized Service Providers, GE

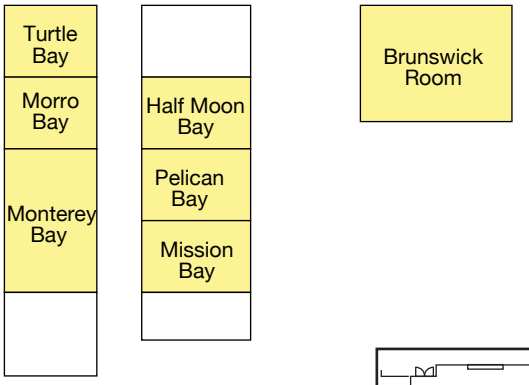
10:30 to 10:45 Break, *Grand Ballroom Foyer*

10:45 to 11:45 GE New Products Update, *Grand Ballroom*
All conference attendees

11:45 to noon Wrap-up/Adjourn, *Grand Ballroom*
All conference attendees







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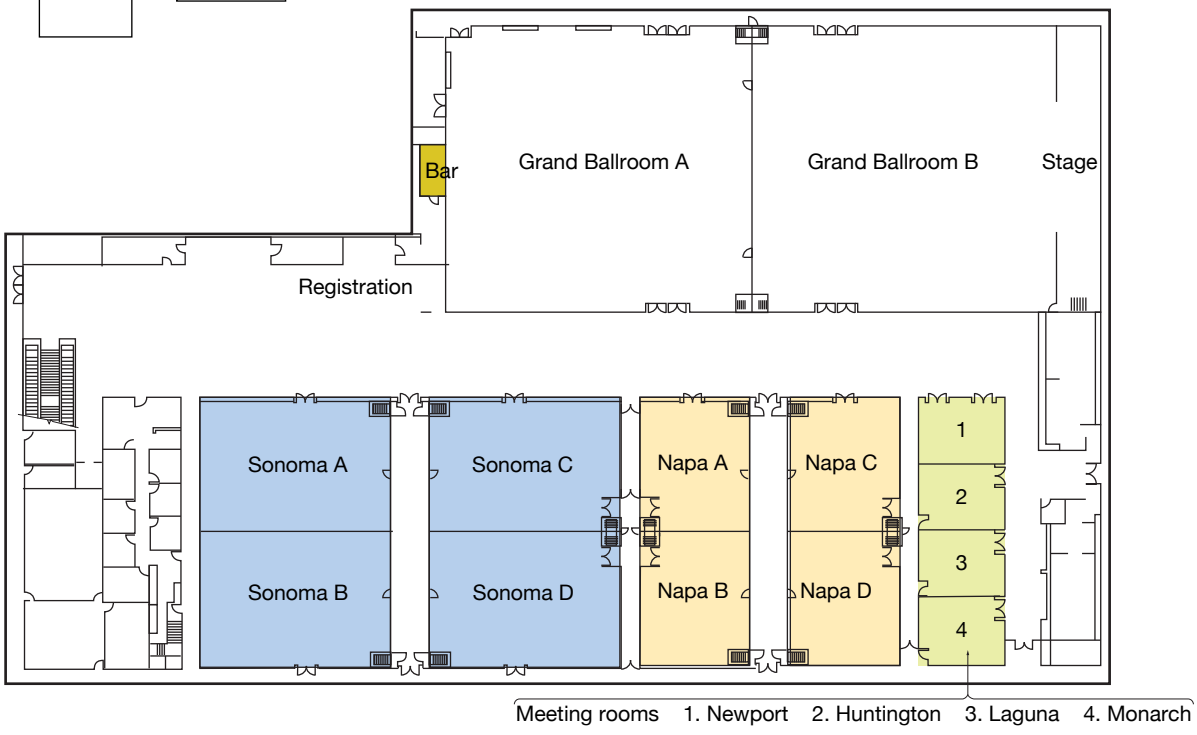

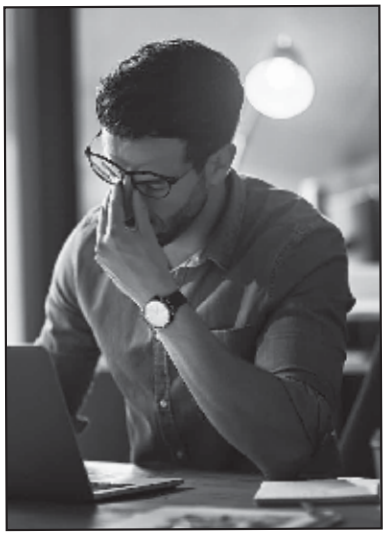

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ACRONYMS TO REMEMBER

AGB—Accessory gearbox (also called the transfer gearbox)
AVR—Automatic voltage regulator
CCM—Condition maintenance manual
CCR—Customized customer repair
CFF—Compressor front frame
COD—Commercial operating date
CPLM—Critical-parts life management
CRF—Compressor rear frame
CWC—Customer web center (GE)
DEL—Deleted part
DLE—Dry, low emissions combustor
DOD—Domestic object damage
EM—Engine manual
FFA—Front frame assembly
FOD—Foreign object damage
FPI—Fluorescent penetrant inspection
FSNL—Full speed, no load
GG—Gas generator (consists of the compressor and hot sections only)
GT—Gas turbine (consists of the gas generator pieces with the power turbine attached)
HCF—High-cycle fatigue
HGP—Hot gas path
HPC—High-pressure compressor
HPCR—High-pressure compressor rotor
HPCS—High-pressure compressor stator
HPT—High-pressure turbine
HPTN—High-pressure turbine nozzle
HPTR—High-pressure turbine rotor
IGB—Inlet gearbox
IGV—Inlet guide vane
IPT—Intermediate-pressure turbine (LMS100)
IRM—Industrial repair manual
LM—Land and marine
LCF—Low-cycle fatigue
LO—Lube oil
LPC—Low-pressure compressor (not on LM2500; just LM5000 and LM6000)
LPCR—Low-pressure compressor rotor
LPT—Low-pressure turbine
LPTR—Low-pressure turbine rotor
LPTS—Low-pressure turbine stator
NGV—Nozzle guide vane
OEM—Original equipment manufacturer
PN—Part number
PT—Power turbine (turns a generator, pump, compressor, propeller, etc)
PtAl—Platinum aluminide
RCA—Root cause analysis
RFQ—Request for quote
RPL—Replaced part
SAC—Single annular combustor
SB—Service bulletin
SL—Service letter
SUP—Superseded part
STIG—Steam-injected gas turbine
TA—Technical advisor
TAT—Turnaround time
TAN—Total acid number (lube oil)
TBC—Thermal barrier coating
TGB—Transfer gearbox (also called the accessory gearbox)
TMF—Turbine mid frame and thermal mechanical fatigue
VBV—Variable bleed valve (not on LM2500; just LM5000 and LM6000)
VIGV—Variable inlet guide vanes
VSV—Variable stator vane

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OFFICERS

Chuck Casey

President

Chuck is Utility Generation Manager for Riverside Public Utilities (Calif), which serves 280 MW over 110,000 electric residents and business customers with an LM2500 combined cycle, four LM6000 peakers, and four GE10B1 peakers. He has 32 years of generation experience—specializing in plant construction and commissioning, and regulatory compliance. Before joining Riverside in 2004, Chuck was a plant operator, I&E technician, plant manager. and consultant for Stewart & Stevenson, GE, and PurEnergy. He began his career as a nuclear electrician on US Navy fast attack submarines. Chuck was elected President of WTUI in 2013; during his 18 years with Western Turbine he has been LM6000 session chair, secretary, exhibit hall manager, and a member of the Board of Directors. He also serves as Chairman of the Southern California Public Power Authority Generation Group and participates in other industry user groups.

Jim Bloomquist

Vice President

Jim served as a WTUI board member before being elected one of the organization's vice presidents. He has more than 40 years of experience with Chevron and is a subject-matter expert specializing in major electrical power systems and process and gas-turbine cogeneration facilities. Jim currently leads the Electrical Engineering Team for Chevron's California San Joaquin Valley Business Unit, an upstream oil producing company.

Bill Lewis

Vice President

Bill is Plant Manager of a 700-MW combined-cycle facility in Lebanon, Pa. Previously, he was Plant Manager of PPL Generation LLC's Lower Mount Bethel Energy LLC. Before that assignment, he was responsible for the company's simple-cycle peaking gas turbines located in Connecticut, Pennsylvania, and Illinois. Lewis served six years in the US Navy as a Gas Turbine Specialist, rising to the rank of Petty Officer First Class before taking a shore-side job.

David Merritt

Vice President

David is a member of the executive team for Kings River Conservation District (KRCD), responsible for the California public agency's power-resources development, flood operations and maintenance, and environmental/fisheries and grant programs. Prior to joining KRCD, Merritt worked for GWF Power Systems/GWF Energy LLC for 19 years as part of the California IPP's management team overseeing nine assets. He was honorably discharged from the US Navy, serving in the aviation field. Merritt holds a BA certification from UC Irvine and currently is completing a certification program in Organizational Leadership at that institution.

Ed Jackson

Vice President

Ed is Plant Manager of Missouri River Energy Services' Exira Generating Station in Brayton, Iowa. His gas-turbine experience includes Allison 501s, Solar Centaurs, LM2500s, and LM6000s. Previously he was a combined-cycle plant supervisor at Maui Electric Co and a field service and commissioning engineer for Stewart & Stevenson. Jackson spent eight years in the US Navy as a GT systems technician (electrical).

Wayne Feragen

Treasurer

Wayne is Senior West Coast Plant Manager for Noresco, currently responsible for powerplants in Colton, Calif, and San Diego. Wayne has over 25 years of powerplant experience, starting as a Gas Turbine Electronics Technician First Class in the US Navy. After leaving the service, he went to Newark Pacific Paperboard and ran an LM2500. After that, he worked at two Sunlaw plants running LM2500s. Wayne has served as WTUI's Webmaster for the last nine years.

Jermaine Woodall

Secretary

Jermaine is a Fleet O&M Manager for Exelon Generation. He has worked in various powerplant settings comprised of peaking units, frames, and renewables. Jermaine brings 16 years of industry experience to WTUI, gained in positions such as Instrumentation Controls & Electrical Technician. He also served in the US Navy for 10 years as an Aviation Electrician's Mate. An alumnus of the University of Phoenix, his academic credentials include Master of Business Administration and Bachelors of Science in Management with a minor in Electronics.

Mike Raaker

Historian/ Ambassador

What do diapers, toilet paper, jet engines, and WTUI have in common? Mike Raaker. He started his career at Procter & Gamble, assigned to install a cogeneration plant at the company's towel and tissue plant in Oxnard, Calif. The LM2500-powered facility would keep Mike busy for the next 30 years and would lead to his, and wife Charlene's, participation in WTUI.

BOARD OF DIRECTORS

John Hutson

Board Member

John is a plant manager for NAES at the Orange Grove Energy Center in California's San Diego County. The facility is owned by J-POWER USA Development Co, one of the largest independent power producers in the world. John has over 20 years of power-generation experience—six years in the US Navy, four years on Siemens frame units, and eight years on GE aeros. He has managed O&M for both LM2500 and LM6000 engines. John has a BS in Nuclear Engineering Technology from Thomas Edison State College and an MBA from the Univ of Connecticut.

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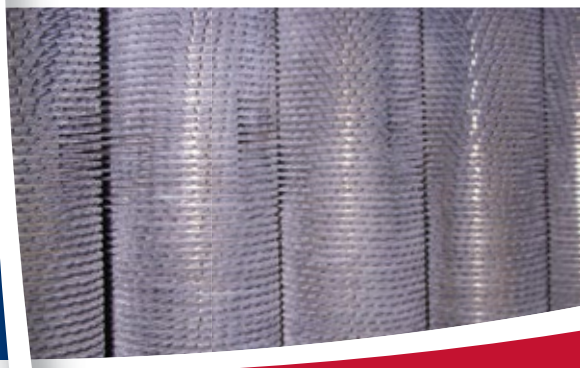

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Charles Lawless

Board Member

Charles joined Southern California Edison Co as an IC&E technician in 2007 after serving as an electrician's mate on a nuclear submarine from 1998 to 2007. At SCE, he was assigned to five LM6000 peakers. Charles earned a Bachelor's in Business Administration in 2012 and an MBA in 2013 from the Univ of Phoenix. He was promoted a year later to O&M supervisor for the utility's peakers. More recently he was appointed maintenance supervisor for two 7FA frame engines. SCE experience also includes responsibility for 25 solar PV installations and two fuel-cell plants.

Andrew Robertson, PE

Board Member

Andrew works for Wellhead Services Inc as a plant manager in the Fresno area. He oversees the O&M for an LM6000-powered combined cycle, simple-cycle LM6000, two plants equipped with P&W FT4s, and two 1.5-MW solar facilities. Andrew has been with Wellhead for 16 years and is a subject-matter expert for SCRs and emissions monitoring systems. Before joining Wellhead he spent seven years at Air Products & Chemicals managing cylinder filling operations and distribution. Andrew served five years in the US Navy as a nuclear-trained officer in the submarine service. He has a BS in Mechanical Engineering from the Univ of California, Davis.

Rob Nave, PE

Board Member

Rob is the plant engineer for Procter & Gamble's largest manufacturing plant, located in Mehoopany, Pa. He has been responsible for major maintenance on P&G's Oxnard LM2500 and LM6000. Nave also has been involved in the maintenance, cost forecasting, and technology transfer and training on Mehoopany's W251B12, as well as the front-end engineering, funding justification, and procurement and installation of the Rolls Royce Trent 64 at that location. He has been the cogeneration leader for P&G since 2002. Following graduation from West Point, Nave spent six years in the US Army. He is a licensed Professional Engineer in Pennsylvania.

Andrew Gundershaug

Board Member

Andrew is the general manager for Calpine Corp's plants in northern California. Previously, he held various other positions at those generating assets—including operations manager, maintenance manager, DCS technician, and IC&E tech. Gundershaug has been with Calpine since entering the industry in 1998 as IC&E tech at the Watsonville Cogeneration Plant, following graduation from UC Santa Cruz. He currently serves on the WTUI board and is in his fifth year as chairman of the LM6000 Breakout Session. Earlier he served for three years as LM5000 Breakout chair.

Alfred VanHart Jr

Board Member

Al joined PSEG Power LLC as a jet engine technician in 2004 after retiring from the USAF with 20 years of service as an aerospace propulsion master craftsman. His propulsion background includes the PWTF-33, GETF-39, GECF6-50c, GEF-110, 7EA, and LM6000PC. Starting at PSEG he was assigned to the turbine shop, rebuilding and maintaining the peaking fleet which consisted at that time of 96 FT4s, five 7EAs, and eight LM6000s. Al was promoted to generation supervisor in 2007, plant engineer in 2010, and work control/CTE manager in 2012. Since 2016 he has served as engineering/technical manager/PSA contract manager for the Peaking Div, now equipped with five 7EAs and 17 LM6000s.

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Wayne Feragen

Board Member

Wayne is Senior West Coast Plant Manager for Noresco, currently responsible for powerplants in Colton, Calif, and San Diego. Wayne has over 25 years of powerplant experience, starting as a Gas Turbine Electronics Technician First Class in the US Navy. After leaving the service, he went to Newark Pacific Paperboard and ran an LM2500. After that, he worked at two Sunlaw plants running LM2500s. Wayne has served as WTUI's Webmaster for the last nine years.

BREAKOUT SESSION CHAIRS

John Baker

WTUI Conference Familiarization

John is a Plant Manager for Riverside Public Utilities (Calif). Previously he was O&M Manager for Calpine Corp's Bethpage Energy Center in Hicksville, NY, responsible for two LM2500s and two LM6000s. He started his gas-turbine career with Calpine at Watsonville, later working at the company's Agnews and Los Esteros facilities before moving to the East Coast. Prior to Calpine, John was in boiler operations at Foster Wheeler Energy Corp. He served nine years as session chair of the LM2500 group.

Garry Grimwade

LM2500

At Riverside (Calif) Public Utilities, Garry is responsible for operating and maintaining four LM6000s, four GE10s, and an LM2500-powered combined cycle. Before his involvement with land-based aero engines, Garry spent a decade working with "big iron," including a 700-MW merchant facility and two GE "H" frames. He immigrated to the US in 1994 from the UK and joined the US Navy as an aviation machinist's mate, serving as a special-missions crewman. After leaving the service, Garry spent five years at the Pacific Gas Turbine Center (FAA Repair Station) as the lead in the rotor-balance department overhauling JT-8 and JT-8D engines.

Perry Leslie

LM5000

Perry was plant manager of Wellhead Electric Co's Binghamton Cogeneration Plant from August 2017 until its closure in February 2018. He also has been a Plant Technician for the Yuba City Cogeneration Plant since 2004. Responsibilities include I&C and mechanical maintenance, and operations. Plus, he is the GT management team leader for Wellhead. Previously, Perry spent six years as a field service technician for GE in the Bakersfield area, working on LM1600, LM2500, LM5000, and LM6000 engines. Earlier he served in the US Navy for six years as a GT systems technician—electrical (GSE).

Andrew Gundershaug

LM6000

Andrew is the general manager for Calpine Corp's plants in northern California. Previously, he held various other positions at those generating assets—including operations manager, maintenance manager, DCS technician, and IC&E tech. Gundershaug has been with Calpine since entering the industry in 1998 as IC&E tech at the Watsonville Cogeneration Plant, following graduation from UC

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Santa Cruz. He currently serves on the WTUI board and is in his fifth year as chairman of the LM6000 Breakout Session. Earlier he served for three years as LM5000 Breakout chair.

Steve Worthington

LMS100

Steve is plant manager of Arizona Public Service Co's Ocotillo Power Plant in Tempe, which is equipped with the following peaking units: five LMS100s, 10 LM6000s, four W501AAs, one GE 7EA, and one GE Frame 5. Prior to joining APS six years ago, he worked at a few eastern utilities and served honorably in the US Navy for 12 years.

SUPPORTING STAFF

Wayne Kawamoto

Executive Director

Wayne was one of the founders of the Western Turbine Users. He served on the first Board of Directors and was the organization's treasurer from incorporation in 1990 until Dec 31, 2017—the day he retired as plant manager of Corona Energy Partners Ltd and shuttered that facility. Wayne's retirement was short-lived; he was appointed WTUI's executive director Jan 1, 2018. He has a BS in Civil Engineering from the Univ of Hawaii and has held numerous positions in project management throughout his more than four decades of professional employment.

Wayne Feragen

Webmaster

Wayne is Senior West Coast Plant Manager for Noresco, currently responsible for powerplants in Colton, Calif, and San Diego. Wayne has over 25 years of powerplant experience, starting as a Gas Turbine Electronics Technician First Class in the US Navy. After leaving the service, he went to Newark Pacific Paperboard and ran an LM2500. After that, he worked at two Sunlaw plants running LM2500s. Wayne has served as WTUI's Webmaster for the last nine years.

Charlene Raaker

Registration Coordinator

As WTUI's Registration Coordinator (and Mike Raaker's better half), Charlene has been supporting the organization for almost as long as it has been in existence. Charlene's is the "voice on the other end of the line" whenever anyone calls the group.

1>2

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Gas-turbine operating metrics in an uncertain energy market

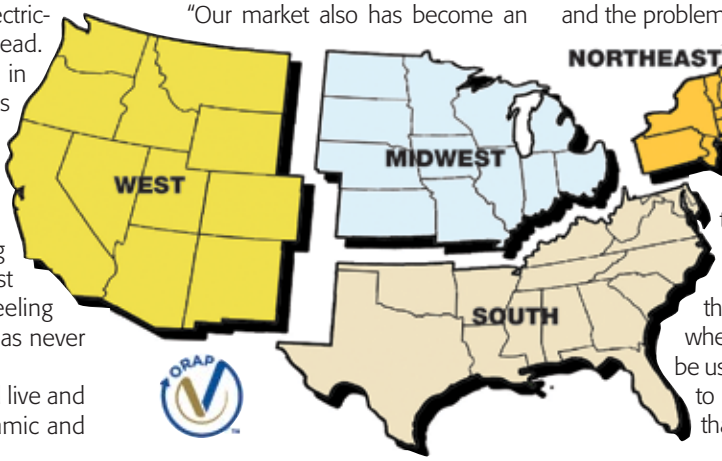
Interview with **Salvatore A DellaVilla Jr,** CEO, Strategic Power Systems® (SPS)

Sal DellaVilla, Strategic Power Systems' CEO (Sidebar 1), typically begins preparing for annual meetings of the Western Turbine Users Inc during holiday quiet time when he can reflect in solitude on the highlights of the year winding down and how they might impact the electric-power business in the year ahead.

DellaVilla called CCJ's offices in early January to tell the editors that the déjá vu he normally experiences when reflecting on the industry he has served for more than two-score years was replaced this year with a feeling of what the organizational theorist Karl Weick calls vu jádé—the feeling or sense this is something that has never been experienced before.

"The global market that we all live and work in today," he said, "is dynamic and very challenging. The global disruption is palpable, whether from the influx and growth of renewables or from the technical and policy changes that influence investment in conventional generating assets. The bottom line: We now work in an 'uncertain market.'

"Our market also has become an industry of headlines," he continued. "In this competitive and uncertain time we are reading and talking about the survival issues of the largest suppliers to the electric-power industry, GE and Siemens. We hear about the massive financial investment Elon Musk has made in batteries, for cars and industry, and the problems he is having.



"We hear about AEP's proposed $4.5-billion Wind Catcher Energy Connection project incorporating 2000 wind turbines and 360-mile transmission line to move renewable energy from the Texas panhandle to Tulsa where the existing grid would be used to distribute the power to customers. Next we learn that what would have been

1. Who is SPS®?

Strategic Power Systems® Inc, Charlotte, NC, is the industry's leading analytics consultancy specializing in the collection, analysis, and dissemination of O&M data for owners and operators of generating plants—in particular those powered by gas turbines. The firm, formed by CEO Sal DellaVilla more than three decades ago, gained recognition quickly because of its work in support of the Western Turbine Users, which began in fall 1990—a few months before the group incorporated.

Recall that Western Turbine serves owner/operators of GE aeroderivative gas turbines, today focusing on the LM2500, LM5000, LM6000, and LMS100. The popularity of the LM2500 and LM5000 grew rapidly as the power block of choice for many of the cogeneration systems installed to take advantage of the Public Utility Regulatory Policies Act, enacted in 1978. Purpa opened up the generation market to non-utility entities as long as their facilities met certain size, fuel, and efficiency criteria. California was fertile territory for cogen systems.

WTUI offered users, some of whom already were meeting at various plants on an ad hoc basis, a formal structure to support the expanding base of operators. The organization's leadership understood new users would require operating knowledge and experience, and would share their desire for continuous product improvement.

They also understood the need to establish and follow a uniform process that WTUI, as an organization, could use to track and report the availability and reliability performance of the LM5000 and LM2500 fleets.

The objective was to have unbiased and accurate data to document the performance of gas turbines and other plant equipment. Users wanted data and metrics they could share among themselves, and with GE. These goals were enabled by SPS's Operational Reliability Analysis Program (ORAP®) and use of this data engine was supported by WTUI and GE.

DellaVilla and company went to work and issued their first ORAP report in June 1991, just three months after the incorporated user group's first meeting. It included data from 24 operating plants representing 19 LM2500s and 14 LM5000s and provided an overview of the reliability metrics that the user desired—including component causes of downtime and engine removal rates.

SPS's service to WTUI members and owner/operators of other engines, including today's largest and most sophisticated frames, has grown dramatically over the years in terms of number of participants, extent of equipment coverage, depth of data analysis, and speed of information delivery.

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Table 1: Key performance indicators for aero engines developed from ORAP® simple-cycle RAM metrics

Parameter	2018 Aero	2017 Aero	2012-2016 Aero
Peaking units:			
Annual service hrs	346	411	446
Annual starts	95	112	113
Service hrs/start	3.6	3.7	3.9
Service factor, %	4.0	4.7	5.1
Capacity factor, %	2.9	3.3	3.9
Output factor, %	67.6	64.8	70.1
Availability, %	90.7	87.2	92.6
Reliability, %	96.3	95.4	97.4
Cycling units:			
Annual service hrs	1798	2026	1930
Annual starts	198	191	193
Service hrs/start	9.1	10.6	10.0
Service factor, %	20.5	23.1	22.0
Capacity factor, %	15.0	17.8	14.6
Output factor, %	74.2	80.6	69.2
Availability, %	89.3	91.6	92.1
Reliability, %	95.8	96.0	96.4
Baseload units:			
Annual service hrs	6718	6801	6603
Annual starts	55	52	63
Service hrs/start	121.8	130.0	104.6
Service factor, %	76.7	77.6	75.4
Capacity factor, %	55.1	69.4	59.5
Output factor, %	72.4	89.1	79.8
Availability, %	91.9	91.7	92.4
Reliability, %	96.3	96.4	96.9

Note: LMS100 included with Aeros

Table 2: Comparing capacity (CF), output (OF), and reserve standby (RSF) factors regionally

Parameter	2018 Aero	2017 Aero	2012-2016 Aero
West:			
CF, %	15.4	14.6	17.3
OF, %	73.0	73.8	80.2
RSF, %	66.4	67.5	69.9
Midwest:			
CF, %	15.0	13.2	13.3
OF, %	71.9	74.1	75.5
RSF, %	70.1	70.4	73.2
Northeast:			
CF, %	22.9	21.2	13.2
OF, %	93.5	93.2	59.7
RSF, %	67.3	70.9	69.4
South:			
CF, %	13.0	10.6	12.1
OF, %	80.3	77.7	78.8
RSF, %	77.6	72.8	77.7

Notes: West includes Alaska and Hawaii; LMS100 included with Aeros

the largest wind project in the US was canceled because utility regulators concluded the project didn't offer sufficient benefits to ratepayers and rejected it.

"All this uncertainty begs the question, 'What is happening in the gas-turbine market?'

"Fundamentally," DellaVilla says, "the question we have to answer is this: 'What role will gas turbines (both heavy-duty frame engines and aeroderivatives) play in this changing market (or set of regional markets) and what will be the fuel of choice or necessity?'

"Perhaps," he added, "we should rephrase the question and ask, 'What are the opportunities for gas turbines as technology and fuel challenges evolve?'"

Looking for answers, DellaVilla reviewed data from a variety of sources, including that published in the "BP Statistical Review of World Energy 2018." Summarizing, he said it shows that conventional powerplants continue to play a significant role in meeting the world's base-capacity needs. Renewables have found a place in the market, and while there is recognition of their potential long-term benefit and value, they are intermittent power at this time—not baseload capacity.

Here are some important points DellaVilla gleaned from the BP report:

- Worldwide generating capacity totals about 6300 GW. Nearly 60% of that capability is installed in six countries: China, the US, India, Russia, Japan, and Germany—in that order.
- Over 86% of the primary energy consumed in these six nations comes from fossil fuels—with coal (for electric production) and oil (for transportation) continuing to play a very significant role.

  Unfamiliar with the term "primary energy"? It is defined as an energy form found in nature that has not been subjected to any human-engineered conversion process. Fossil fuels (coal, oil, and gas), biofuels, wind, solar, and nuclear fuels are all primary sources of energy.
- China (60.4%), India (56.3%), Japan (26.4%), and Germany (21.3%) are major users of coal for power generation.
- Russia (52.3%), the US (28.4%), Germany (23.1%), and Japan (22.1%) are major users of natural gas.
- For the top six energy-consuming nations combined, renewables contribute only 3.8% of the electricity produced, with Germany leading at 13.4%.
- France, No. 7 on the list of largest consumers, relies on fossil fuels for 53.5% of its primary energy—mostly oil (33.5%) and natural gas (16.2%). Interesting to note is that 37.9% of France's electricity is produced by nuclear energy, only 4% by renewables.

Setting aside the BP report, DellaVilla focused on the interrelationship between energy and the environment. "We live in a world that values a clean environment," he said, "and using advanced generation technologies—including gas turbines—is important to help us achieve that goal. There is almost a universal acknowledgement that carbon emissions, in the form of CO_2, must be contained. This puts us in a place where we have never been before—vu jádé.

"Whether you believe in the need to curtail greenhouse emissions or not," the SPS CEO added, "policy and regulations influence the market, and the market acts through technology selection and 'buy decisions.' Just follow the investment money.

"Yet there is little press or recognition that the 27% reduction in greenhouse-gas emissions in North America has satisfied the

Table 3: Gas-turbine models arranged by peer group and OEM

Frame gas turbines					Aeroderivative gas turbines	
Vintage Tech	E-Class		F-Class	Adv Class	Next Gen	<40 MW	>40 MW
GE MS5001 MS5002 MS6001B MS7001ABC GT8/8B GT9 GT11D GT13D **Siemens** W251 W501A/B SGT-700 V64.3	**Ansaldo** AE 94.2 **GE** MS7001E/EA MS9001B MS9001E GT8C GT11N/N1 GT11NM/N1M GT11N2 GT13E/E1 GT13E2	**Hitachi** H-25 H-80 **MHPS** M501D M701D **Siemens** W501D SGT-800 SGT5-2000E SGT6-2000E SGT6-3000E W701D	**Ansaldo** AE 6 4.3A AE 94.3A AE 26 **GE** MS6001F/FA MS7001F/FA MS9001F/FA MS7001FB MS9001FB GT24 GT26	**MHPS** M501F M701F **Siemens** V84.3 SGT-1000F SGT5-4000F SGT6-4000F SGT6-5000F	**GE** MS9001H MS7001H **MHPS** M501G M701G M501GAC M701GAC **Siemens** SGT6-6000G SGT5-8000H SGT6-8000H	**Ansaldo** AE 36 **GE** MS7001HA MS9001HA **MHPS** M501J M701J M501JAC M701JAC **Siemens** SGT5-9000HL SGT6-9000HL	**GE** LM1600 LM2500 **MHPS** FT4 FT8 **Siemens** SGT-A05 SGT-A20 Industrial Olympus SGT-A35	**GE** LM5000 LM6000 **MHPS** FT4000 **Siemens** SGT-A65

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- Lube and Fuel Pumps
- Fuel Nozzles
- Tubing
- Manifolds
- Hoses
- Spiral Wound Gaskets
- Valves (Bleed, Solenoid, CDP)
- Actuators (VSV, VBV, IGV)
- Temperature, Pressure, and Speed Sensors

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Table 4: General characteristics of frame gas turbines by class

Market segment	Base rating, MW	Efficiency, %	Firing temperature	Pressure ratio	State-of-the-art technology	Year introduced
Vintage Tech	<100 (50 Hz) <70 (60 Hz)	SC: <34 CC: <55	<1093C <2000F	<12	None	<1985
E-Class	≥100 (50 Hz) ≥70 (60 Hz)	SC: <34 CC: <55	>1093C >2000F	<15	Air-cooled turbine blades	<1995
F-Class	>200 (50 Hz) >150 (60 Hz)	SC: >34 CC: >55	>1260C >2300F	>15	Aeroderivative compressor design Dry low-emissions combustor DS or single-crystal turbine blades Sequential combustion	>1995
Adv Class	>300 (50 Hz) >200 (60 Hz)	SC: >37 CC: >58	>1370C >2500F	>18	Advanced HGP cooling Active clearance control	>2005
Next Gen	>450 (50 Hz) >300 (60 Hz)	SC: >39 CC: >60	>1600C >2900F	>25	Advanced combustor cooling Advanced thermal barrier coating	>2013

Notes: (1) The criteria described in the table are determining factors in the classification of individual designs and are listed in priority order from left to right. (2) State-of-the-art technology refers only to the technology introduced in a design/model at the date of introduction; it does not refer to retrofits made to enhance existing technology. (3) Efficiency is stated for both simple-cycle (SC) and combined-cycle (CC) applications using the lower heating value of fuel. (4) Base rating represents the simple-cycle equipment only.

Table 5: Key performance indicators for E-Class engines developed from ORAP® simple-cycle RAM metrics

Parameter	2018 E-Class	2017 E-Class	2012-2016 E-Class
Peaking units:			
Annual service hrs	306	280	322
Annual starts	54	44	51
Service hrs/start	5.7	6.4	6.4
Service factor, %	3.5	3.2	3.7
Capacity factor, %	2.5	2.0	2.4
Output factor, %	79.6	72.8	63.0
Availability, %	92.8	93.0	92.9
Reliability, %	97.5	98.4	97.9
Cycling units:			
Annual service hrs	2275	2254	2343
Annual starts	122	124	125
Service hrs/start	18.7	18.2	18.8
Service factor, %	26.0	25.7	26.8
Capacity factor, %	20.9	22.7	19.6
Output factor, %	83.9	88.4	72.6
Availability, %	90.5	91.9	93.8
Reliability, %	96.8	97.5	98.5
Baseload units:			
Annual service hrs	6488	6323	6644
Annual starts	54	51	56
Service hrs/start	120.4	123.1	119.5
Service factor, %	74.1	72.2	75.8
Capacity factor, %	66.2	65.7	70.2
Output factor, %	88.3	88.9	91.1
Availability, %	91.1	89.1	91.3
Reliability, %	98.1	97.9	98.3

Table 6: Key performance indicators for F-Class engines developed from ORAP® simple-cycle RAM metrics

Parameter	2018 F-Class	2017 F-Class	2012-2016 F-Class
Peaking units:			
Annual service hrs	291	309	462
Annual starts	28	33	45
Service hrs/start	10.3	9.5	10.2
Service factor, %	3.5	3.5	5.3
Capacity factor, %	2.5	2.3	3.7
Output factor, %	70.8	72.7	69.8
Availability, %	94.0	89.7	92.6
Reliability, %	97.9	95.5	98.0
Cycling units:			
Annual service hrs	2435	2438	2532
Annual starts	130	120	107
Service hrs/start	18.7	20.4	23.7
Service factor, %	27.8	27.8	28.9
Capacity factor, %	22.1	22.2	19.0
Output factor, %	79.9	78.3	66.7
Availability, %	90.6	89.7	91.6
Reliability, %	97.7	97.2	97.8
Baseload units:			
Annual service hrs	6683	6487	6644
Annual starts	52	54	54
Service hrs/start	127.4	120.5	122.1
Service factor, %	76.3	74.1	75.8
Capacity factor, %	63.8	62.7	53.4
Output factor, %	84.3	84.9	70.2
Availability, %	90.1	89.3	90.6
Reliability, %	97.7	97.2	97.7

2. Definition of terms

Service hours is the number of hours equipment is in service—that is, generating either electricity or motive force. In-service is generally measured from a commercial perspective, from the time when the equipment is fulfilling its intended service until it is shut down and that service has ceased.

Start. A successful start is achieved when the breaker is closed and synchronized to the grid (power generation) or the driven equipment has reached stable operation (mechanical drive).

Service hours per start is a measure of a piece of equipment's average mission time, or the average number of hours the equipment operates each time it is started.

Service factor is the percentage of time a unit is in service.

Capacity factor is the percentage of maximum possible generation achieved over a given period, using the stated unit capacity.

Output factor is the percentage of megawatt production over a specified time period as a function of the total megawatts that could have been produced had the unit been operated at its nameplate rating for the actual operating hours. This statistic can be calculated in either gross or net terms. Net megawatts accounts for in-plant usage of a portion of the electrical output.

Availability is the percentage of time the equipment is capable of operating.

Reliability is the percentage of time in a given period that the equipment was not forced out of service.

desired reduction in CO_2 called for by the Paris Agreement on climate change. This positive reduction was accomplished by a shift to natural gas, a reduction in the use of coal, and the growth in renewables. No other geopolitical region can make the same claim.

"Also, it is valuable to know how gas turbines are performing. ORAP® operating data compiled by SPS offers asset reliability and availability numbers for the recent past, and the present, offering perspective for the selection of future generation resources. Plus, it shows us how the installed base (or a segment of it) is operating regionally, and what changes we have experienced over time."

ORAP data. DellaVilla then walked the editors through the ORAP Simple Cycle Plant RAM metrics (Sidebar 2) for various classes of gas turbines—aeroderivatives, E-Class, F-Class, and Advanced-Class. When reviewing the information presented in Tables 1, 5, 6, and 7, keep in mind that "simple-cycle plant," a term typically used in the reporting of reliability statistics, represents the basic gas-turbine plant arrangement, including the following equipment: GT, controls and accessories, generator, and balance-of-plant equipment to support the gas turbine and generator.

The information compiled in Table 1 comes from 621 aero units for 2018, 657 for 2017, and 834 for the 2012-2016 period. Aeros in the sample include engines from GE, MHPS (formerly P&W), and Siemens AGT (formerly Rolls-Royce), and represent units operating worldwide. A regional analysis of aeroderivative data for the US is presented in Table 2.

Table 3 is important for clarification purposes. Mergers and acquisitions and renaming of gas-turbine models in the last five years or so might allow misinterpretation of the ORAP data if you have not kept up on industry changes. To illustrate: Engines formerly associated with Alstom now appear with traditional GE and Ansaldo assets.

You also may be unfamiliar with Siemens' current naming convention, par-

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Table 7: Key performance indicators for Advanced-Class engines developed from ORAP® simple-cycle RAM metrics

Parameter	2018 Adv-Class	2017 Adv-Class	2012-2016 Adv-Class
Peaking units: Not a duty cycle for this asset class at this time.			
Cycling units:			
Annual service hrs	1708	1445	3486
Annual starts	18	8	22
Service hrs/start	93.3	180.7	161.6
Service factor, %	19.5	16.5	39.8
Capacity factor, %	5.5	12.3	24.7
Output factor, %	26.2	74.6	62.9
Availability, %	89.8	96.1	92.1
Reliability, %	92.6	100	98.0
Baseload units:			
Annual service hrs	7052	7148	7162
Annual starts	36	23	29
Service hrs/start	197.4	312.1	246.0
Service factor, %	80.5	81.6	81.8
Capacity factor, %	68.3	74.0	69.5
Output factor, %	85.5	86.1	86.2
Availability, %	88.0	89.3	91.9
Reliability, %	98.3	97.3	99.0

ticularly after the company's purchase of Rolls-Royce aero engines. Plus, as noted above, what formerly were Pratt & Whitney aero engines are now part of Mitsubishi Hitachi Power Systems' offerings.

Table 4 categorizes gas turbines by firing temperature and pressure ratio to differentiate among Tables 5, 6, and 7 for E-, F-, and Advanced-Class models. Of interest, too, is that SPS engineers are in the process of updating the technology characteristics presented in Table 4 as they evolve over time. Follow these developments in CCJ.

Information compiled in Table 5 comes from 427 E-Class units for 2018, 473 for 2017, and 470 for the 2012-2016 period. The gas turbines in the sample include engines identified in Table 3 from Ansaldo, GE, MHPS, and Siemens operating worldwide.

Table 6 data come from 549 F-Class units for 2018, 557 for 2017, and 646 for the 2012-2016 period. Again, refer back to Table 3 to identify the specific engines included in the global sample.

Information compiled in Table 7 comes from 25 Advanced-Class units for 2018, 27 for 2017, and 31 for the 2012-2016 period.

DellaVilla concluded the interview with the following observation, "From a review of the data presented, and the operational levels gas turbines are achieving, perhaps there is a bit of déjá vu after all. Natural gas and gas turbines have played a major role in our nation's energy mix for more than two decades—and they will continue to do so for the foreseeable future."

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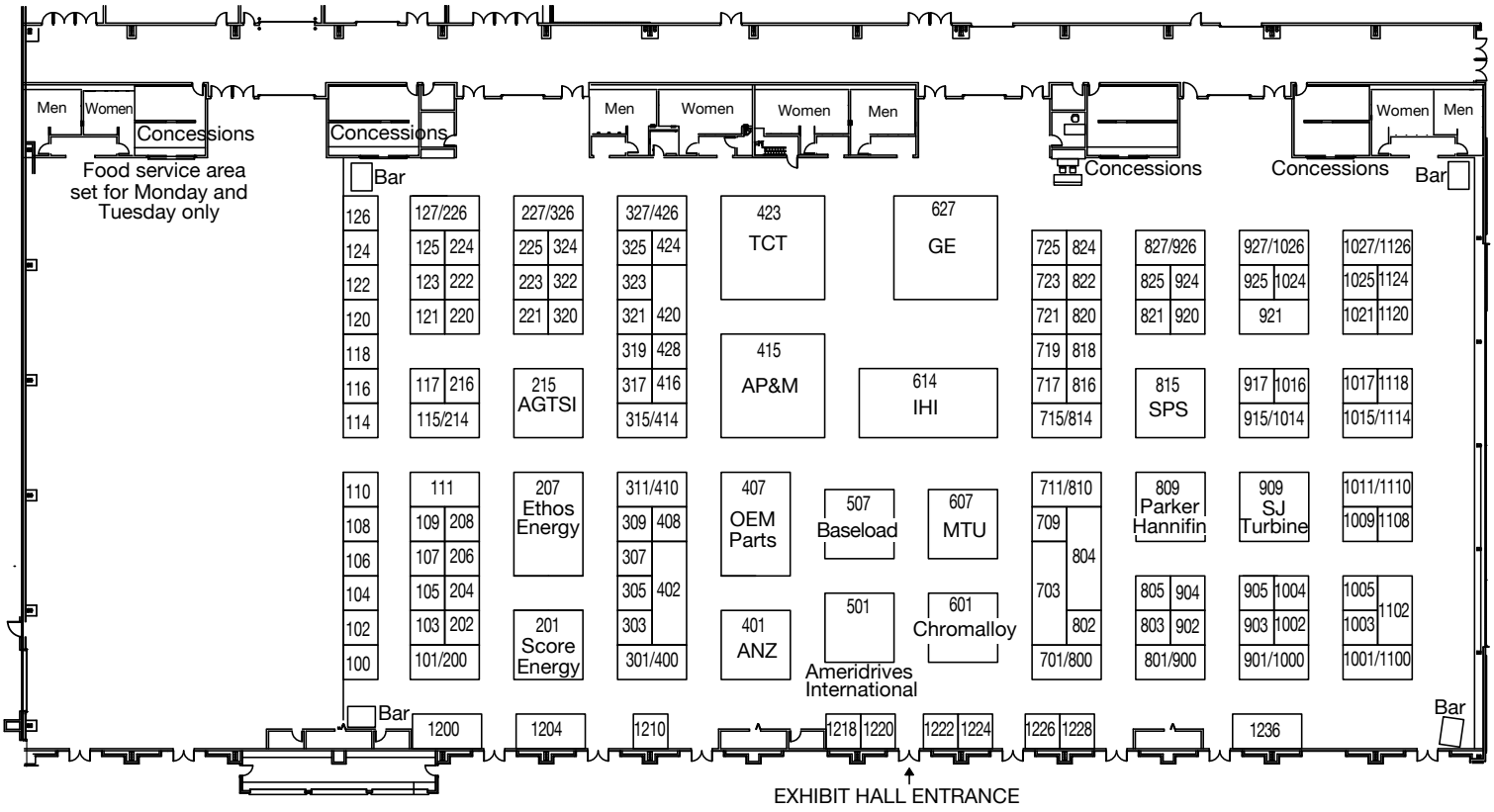


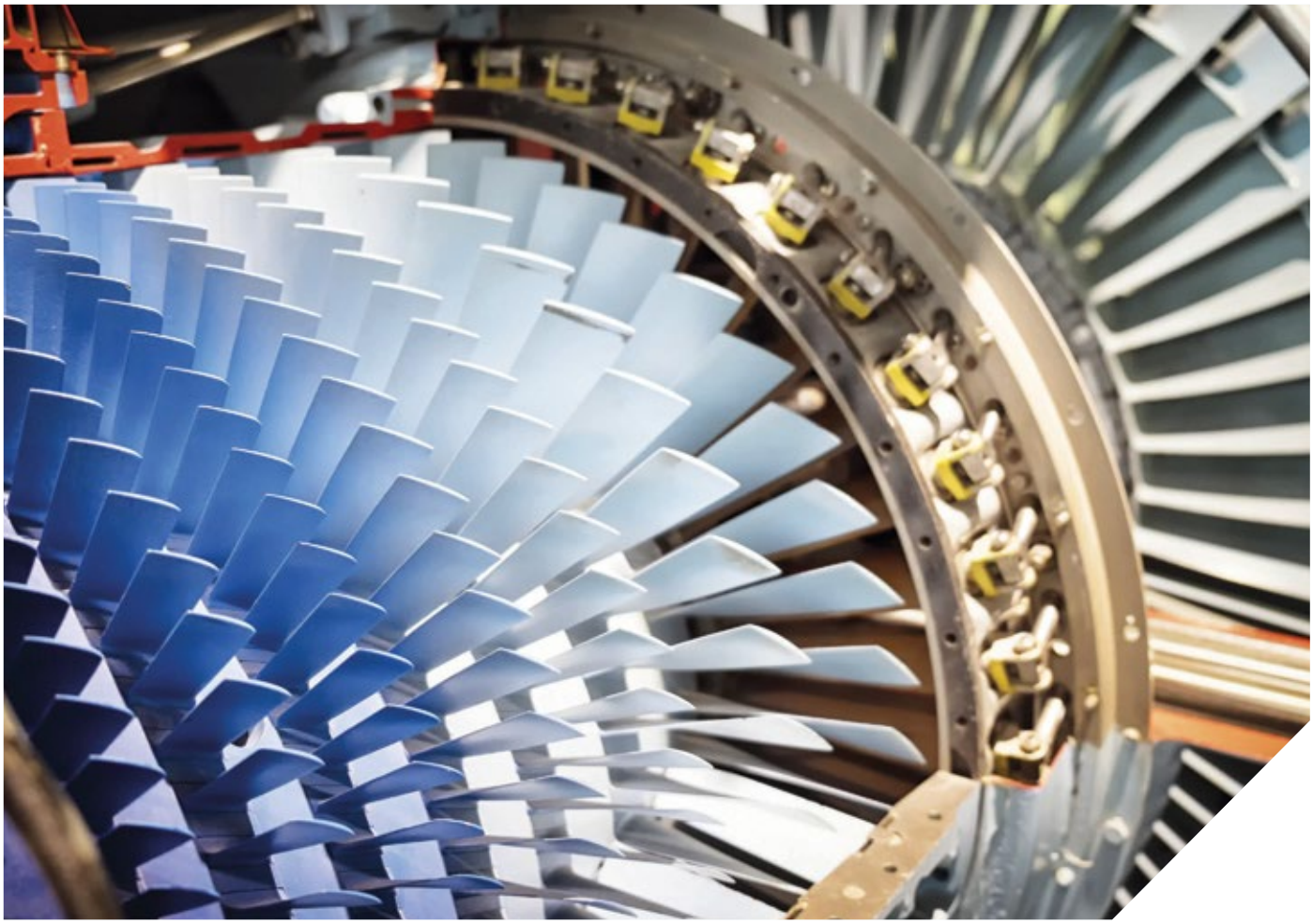
EXHIBITORS

Alphabetical order by company as of February 15

Company	Booth
AAF International	1200
Advanced Chemical Technology Inc	309
Advanced Filtration Concepts	315
Advanced Turbine Support Inc	902
Aero Controls & DLE Consultant	701
AGT Services	126
AGTSI	215
Air Hygiene	323
Airgas Specialty Products	115
Ameridrives	501
AMETEK Power Instruments	109
ANZGT	401
AP+M	415
Baseload Power and Generation Parts & Services LLC	507
BASF Corp	721
Basler Electric Co	124
Beamex	104
Bearing Inspection Inc	202
Bently Nevada LLC	1116
Bradly Griffin LLC	711
Bremco Inc	303
Brush Aftermarket	1224
Caldwell Energy	408
California Analytical Inc	122
Caltrol Inc	116
Camfil Power Systems	1015
Catalytic Combustion Corp	325

Company	Booth
CECO Peerless	802
CEMTEK Environmental	801
Champion GSE	101
Chromalloy	601
Clean and Science Co Ltd	114
CleanAir Engineering	227
CM Solutions (DBA Machine Reliability)	1025
Concord Management Services/Concord Engineering	925
Cormetech Inc	117
Danfoss High Pressure Pumps	204
Detector Electronics Corp	100
Doble Engineering Co	903
Donaldson Company	424
Drake Controls LLC	108
Dynamis Inc	327
EB Airfoils	816
Eco Physics Inc	106
ECT Inc	821
Electrical Maintenance Consultants Inc	221
eLogger	723
Emerson	1011
Environex	320
EthosEnergy Group	207
Evoqua Water Technologies	103
Filtration Group	82
Fossil Energy Research Corp (FERCO)	118
Gas Turbine Controls	1236

Company	Booth
GasTOPS Ltd	311
GE	627
GE Inspection Technologies	824
W L Gore & Associates Inc	805
Groome Industrial Service Group	901
Hach Company	120
Hilco Filtration Systems	1102
Hill Brothers Chemical Co	121
HPI LLC	1017
HRST Inc	105
Hy-Pro Filtration	420
IHI	614
Industrial Air Flow Dynamics	1024
Industrom Power	1226
Innova Global	1222
Integrated Turbomachinery Inc	1003
Iris Power - Qualitrol	107
Johnson Matthey	917
Kobelco Compressors America	1210
Koch Filter	225
Koenig Engineering Inc	206
Liburdi Turbine Services Inc	305
M & C Tech Group NA	827
Machine Reliability	125
Marioff North America	102
Maximum Turbine Support Inc	703
Mee Industries Inc	1004
Meggitt	804
Metrix Instrument Co	208
MPW Industrial Service	1005
MTU	607
Munters Corp	220
NAES Corp	418
National Electric Coil	1120
National Heat Exchange Cleaning	216
National Mechanical Services Inc	825
Nederman MikroPul LLC (Pneumafil)	317
nexGEN	920
OEM Parts Network	407
Olympus Corp	927
Orr Protection Services	222
Pacific Standard Environmental	123
Parker Hannifin Corp	809
PCB Piezotronics	818
Petrotech Inc	224
ProEnergy Services	1001
Puretec Industrial Water	1016
Quality Generator Services	223
Relevant Solutions/Switch Filtration	1002
Rochem Technical Services USA Ltd	416
Royal Purple Synthetic Oil	803
S J Turbine Inc	909
Score Energy Ltd	201
SISU Energy & Environmental	719
Sohre Turbomachinery Inc	322
SSS Clutch Co	127



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StandardAero	1220
Strategic Power Systems Inc	815
STS Aviation Group	915
Suez Water Technologies & Solutions	301
Sulzer Turbo Services Houston Inc	324
Synergy Catalyst	725
T2E3 Inc	307
TAS Energy	1027
Tech Development	319
Technical Training Professionals	921
Teledyne Monitor Labs Inc	924
Thermo Fisher Scientific	321
Toshiba America Energy Systems Corp	822
TransCanada Turbines	423
Turbine Inlet Cooling Assn	1218
Turbine Logic	905
Turbine Technics Inc	402
Umicore USA LLC	709
Universal Analyzers Inc	1124
VAW Systems	110
VBR Turbine Partners	1204
Vector Systems Ltd	1021
ViewTech Borescopes	1009
VIM Technologies	1108
Wellhead Construction Inc	1228
Woodward Inc	111
World of Controls Corp	904
Xona Systems	717
Zokman Products Inc	715

EXHIBITORS

Numerical order by booth number as of February 15

Booth	Company
100	Detector Electronics Corp
101	Champion GSE
102	Marioff North America
103	Evoqua Water Technologies
104	Beamex
105	HRST Inc
106	Eco Physics Inc
107	Iris Power - Qualitrol
108	Drake Controls LLC
109	AMETEK Power Instruments
110	VAW Systems
111	Woodward Inc
114	Clean and Science Co Ltd
115	Airgas Specialty Products
116	Caltrol Inc
117	Cormetech Inc
118	Fossil Energy Research Corp (FERCO)
120	Hach Company
121	Hill Brothers Chemical Co
122	California Analytical Inc
123	Pacific Standard Environmental
124	Basler Electric Co
125	Machine Reliability
126	AGT Services
127	SSS Clutch Co

Booth	Company
201	Score Energy Ltd
202	Bearing Inspection Inc
204	Danfoss High Pressure Pumps
206	Koenig Engineering Inc
207	EthosEnergy Group
208	Metrix Instrument Co
215	AGTSI
216	National Heat Exchange Cleaning
220	Munters Corp
221	Electrical Maintenance Consultants Inc
222	Orr Protection Services
223	Quality Generator Services
224	Petrotech Inc
225	Koch Filter
227	CleanAir Engineering
301	Suez Water Technologies & Solutions
303	Bremco Inc
305	Liburdi Turbine Services Inc
307	T2E3 Inc
309	Advanced Chemical Technology Inc
311	GasTOPS Ltd
315	Advanced Filtration Concepts
317	Nederman MikroPul LLC (Pneumafil)
319	Tech Development
320	Environex
321	Thermo Fisher Scientific
322	Sohre Turbomachinery Inc
323	Air Hygiene
324	Sulzer Turbo Services Houston Inc

Booth	Company
325	Catalytic Combustion Corp
327	Dynamis Inc
401	ANZGT
402	Turbine Technics Inc
407	OEM Parts Network
408	Caldwell Energy
415	AP+M
416	Rochem Technical Services USA Ltd
418	NAES Corp
420	Hy-Pro Filtration
423	TransCanada Turbines
424	Donaldson Company
501	Ameridrives
507	Baseload Power and Generation Parts & Services LLC
601	Chromalloy
607	MTU
614	IHI
627	GE
701	Aero Controls & DLE Consultant
703	Maximum Turbine Support Inc
709	Umicore USA LLC
711	Bradly Griffin LLC
715	Zokman Products Inc
717	Xona Systems
719	SISU Energy & Environmental
721	BASF Corp
723	eLogger
725	Synergy Catalyst
801	CEMTEK Environmental

Booth	Company
802	CECO Peerless
803	Royal Purple Synthetic Oil
804	Meggitt
805	W L Gore & Associates Inc
809	Parker Hannifin Corp
815	Strategic Power Systems Inc
816	EB Airfoils
818	PCB Piezotronics
820	Filtration Group
821	ECT Inc
822	Toshiba America Energy Systems Corp
824	GE Inspection Technologies
825	National Mechanical Services Inc
827	M & C Tech Group NA
901	Groome Industrial Service Group
902	Advanced Turbine Support Inc
903	Doble Engineering Co
904	World of Controls Corp
905	Turbine Logic
909	S J Turbine Inc
915	STS Aviation Group
917	Johnson Matthey
920	nexGEN
921	Technical Training Professionals
924	Teledyne Monitor Labs Inc
925	Concord Management Services/Concord Engineering
927	Olympus Corp
1001	ProEnergy Services
1002	Relevant Solutions/Switch Filtration
1003	Integrated Turbomachinery Inc
1004	Mee Industries Inc
1005	MPW Industrial Service
1009	ViewTech Borescopes
1011	Emerson
1015	Camfil Power Systems
1016	Puretec Industrial Water
1017	HPI LLC
1021	Vector Systems Ltd
1024	Industrial Air Flow Dynamics
1025	CM Solutions (DBA Machine Reliability)
1027	TAS Energy
1102	Hilco Filtration Systems
1108	VIM Technologies
1116	Bently Nevada LLC
1120	National Electric Coil
1124	Universal Analyzers Inc
1200	AAF International
1204	VBR Turbine Partners
1210	Kobelco Compressors America
1218	Turbine Inlet Cooling Assn
1220	StandardAero
1222	Innova Global
1224	Brush Aftermarket
1226	Industrom Power
1228	Wellhead Construction Inc
1236	Gas Turbine Controls

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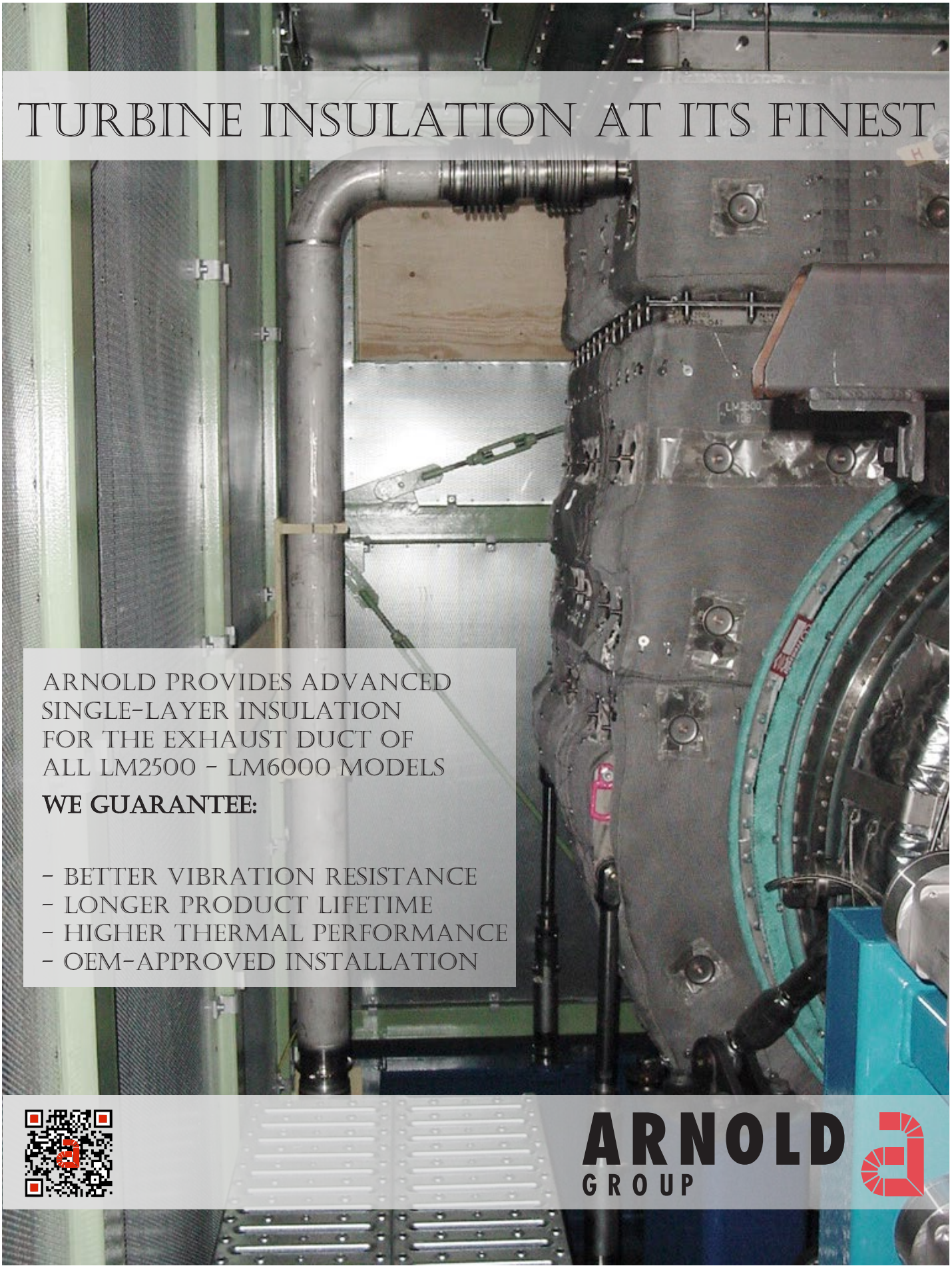

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GasTOPS
GE
IHI
Maximum Turbine Support
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NAES Corp
OEM Parts Network
Rochem Technical Services
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