

# TURBOMACHINERY INTERNATIONAL

May/June 2025 • Vol.66 • No.3

## COVER STORY

Gas Turbine Market:  
2024 Posts Highest  
Units, MW in 22 Years

## PRODUCT SPOTLIGHT

Exergy International:  
Turbo Expanders for  
Modular ORC Power Plants

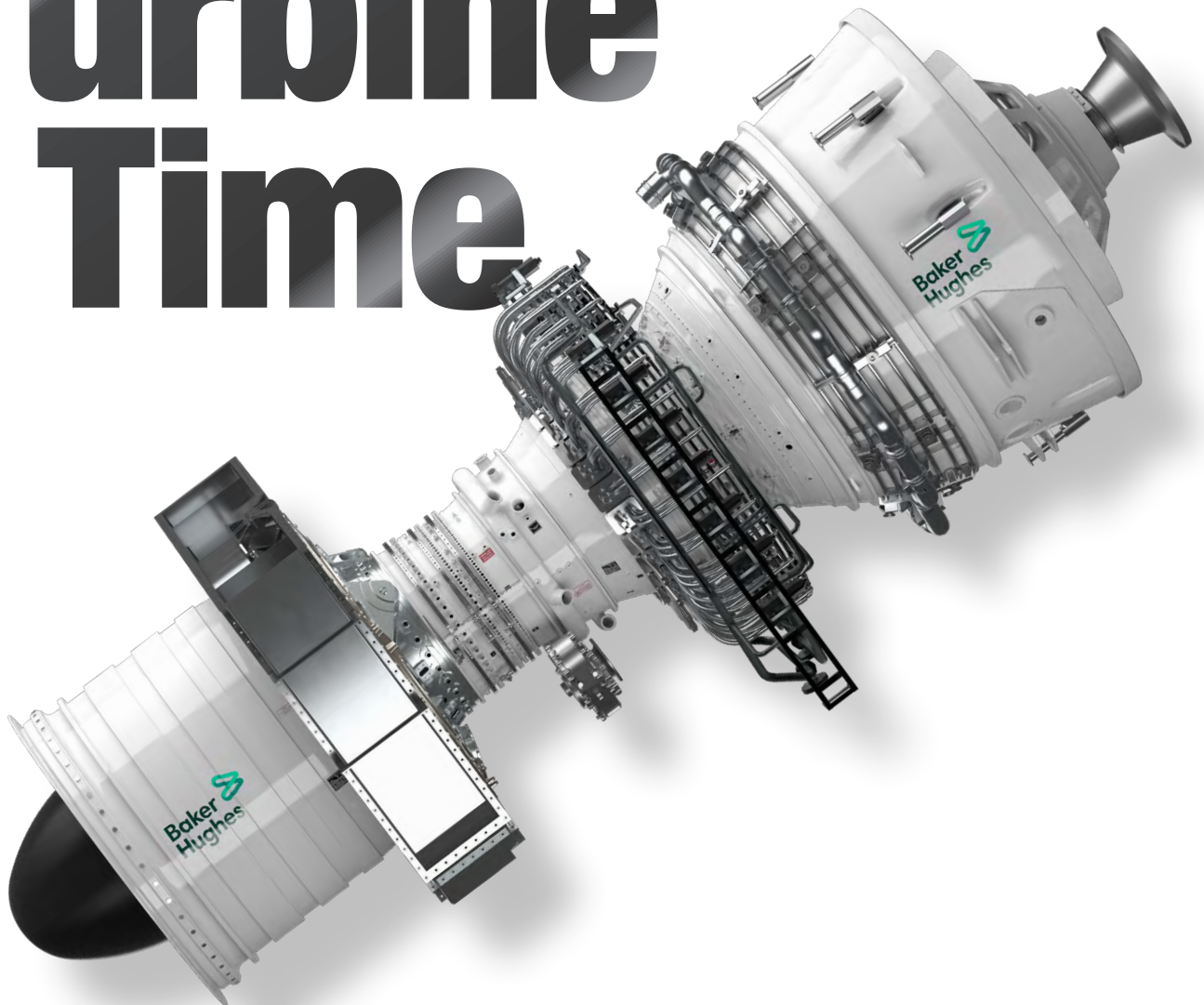
## SHOW REPORT

WTUI 2025 Spotlights Uptick  
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CERAWeek 2025 by S&P  
Global: 'Build Baby Build'  
Reshapes Energy Sector

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# Gas Turbines Post Highest Numbers in 22 Years

It's an exciting time for gas turbines: Unit orders and MWs are up, demand is surging, and government support is increasing. With AI and data centers spiking electricity demands, gas turbines are experiencing sold-out status.

In 2024, reported MW orders were up 32.4%, and unit orders were up 4.1%. "Order activity is up significantly in 2024, primarily driven by large jumbo unit orders for the electric power utility segment, but aeroderivative orders remain strong as well," said Tony Brough, President of Dora Partners & Company.

This year's gas turbine market report spotlights the order activity of advanced-frame, aeroderivative, and packaged gas turbines; it also identifies five market drivers and forecasts for 2025 and beyond. (A shout-out and thank you to Mark Axford of Axford Turbine Consultants and Brough for your data, insights, and edits.)

At CERAWEEK by S&P Global 2025, the U.S. Secretary of Energy, Chris Wright, showed strong support for pipelines, drilling, fracking, LNG, and gas turbines. Utilities and developers in many U.S. regions are racing to install baseload gas turbine combined-cycle power, but they can't get it fast enough—the large gas turbine supply is essentially sold out for the next three to four years, Axford reported.

WTUI 2025 underscored the uptick in power demand and the pressure it's putting on existing power generation. "Energy providers are scrambling to add generation to meet the need," said Ed Jackson, President of WTUI. "Not only is the lead time for major equipment increasing, but even the time it takes to build plants could take years to permit and build. This puts a lot of pressure on the existing generation."

This issue deep-dives into all these topics.

Also in this issue:

- Exergy International, this edition's product spotlight, shares technical details on the company's newly developed turbo expanders for modular organic Rankine cycle power plants.
- The Myth Busters debunk the myth: "We need that last percent." Klaus Brun and Rainer Kurz call it the perfection trap, in which organizations become obsessed with reaching that last percent, but at what cost? This push for perfection is far from perfect, as it is often costly and inefficient, and can lead to delays and even diminished operational flexibility.
- Amin Almasi's Turbo Tips column, "How Vibrations Affect a Turbomachine's Reliability and Operation," dives into how to deal with vibration and prevent operational problems and failures.



Lastly, our team has put together a short state-of-the-industry survey, and we'd truly appreciate your participation and feedback. Scan the QR code to share your insights with us, so we can better tailor our content and ensure we are at the forefront of the turbomachinery industry.

Thank you!

**Alissa Espinoza**  
Assistant Managing Editor

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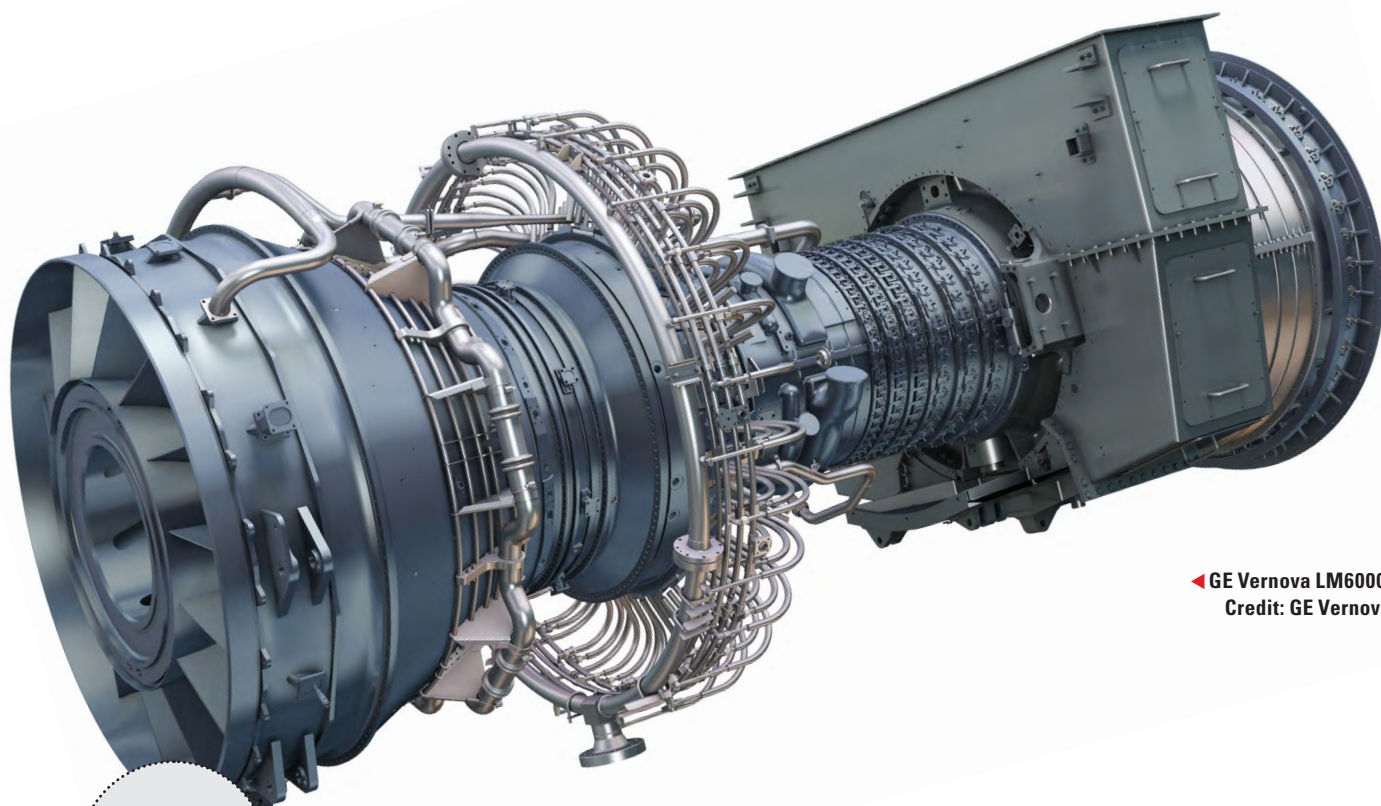
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◀ GE Vernova LM6000.  
Credit: GE Vernova

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“

The power surge from AI and ‘Build Baby Build’ has brought about the remake of the energy transition to the energy addition. ... Security and affordability [not sustainability] now rule the roost as practical solutions rise to the top.”

—Mark Axford, Founder,  
Axford Turbine Consultants

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▲ Palisades Nuclear Plant. Credit: Nuclear Regulatory Commission

## DOE Funds Palisades Nuclear Restart

The Department of Energy granted Holtec a \$56,787,300 loan disbursement to restart the Palisades Nuclear Plant project. Once online and pending licensing approvals, the reactor will generate 800 MW of baseload power for Michigan residents. It represents America's first restart of a commercial nuclear reactor that previously ceased operations.

## Rolls-Royce Enhances Automation in Singapore

Rolls-Royce partnered with the Singapore Institute of Technology to develop and improve equipment health and fleet management technologies for autonomous ships, harbor crafts, and vessels with hybrid propulsion systems. They are developing an automation solution to enhance the availability, fuel consumption, and emissions of hybrid and/or electric-powered ships.



▲ MPA Guardian patrol craft. Credit: Rolls-Royce



▼ McCartney Generating Station. Credit: City Utilities

## GE Vernova Powers Missouri Facility

Springfield City Utilities (CU) ordered three GE Vernova LM6000VELOX aeroderivative gas turbine units for the 100-MW McCartney Generating Station, adding 150 MW of electric generation capacity. The aeroderivative units burn natural gas with fuel oil/diesel as an emergency backup source. CU's plant is expected to operate in 2027.

## bp Digest

bp Trinidad and Tobago began gas production at the Cypré subsea development project, which, at its peak, is expected to deliver approximately 45,000 barrels of oil equivalent per day. The Cypré field is 78 km off Trinidad's southeastern coast in the East Mayaro Block, with water depths of nearly 80 meters.

bp also used the Valaris DS-12 rig to conclude drilling operations at the El Fayoum-5 gas discovery well in the North Alexandria Offshore Concession. Upon completion, the company discovered four potential Messinian gas reservoirs at a depth of approximately 2,900 meters, with a total sand thickness of 50 meters.

► El Fayoum-5 gas well. Credit: Arabian Drilling Co.



## Baker Hughes Digest

Sinochem contracted Baker Hughes to install Cordant Asset Health at 10 chemical production facilities in China. Cordant Asset Health will provide the diagnostics teams with centralized rotating equipment data to minimize unplanned downtime, identify failures proactively, and reduce production losses. It will also improve overall visibility and collaboration in the cloud.

Under a contract with the Dubai Petroleum Establishment and Dubai Supply Authority, Baker Hughes executed integrated coiled-tubing drilling work at the Margham Gas Storage Project. Its CoilTrak coiled-tubing bottomhole assembly system and under-balanced drilling will improve underground gas storage.

The company is also set to install integrated completions systems across Petrobras' Brazilian deepwater fields to optimize production and to deliver traditional upper and lower completions systems, remote operations capabilities, and multizone control to reduce water and gas breakthroughs and expensive interventions.



▲ Integrated coiled-tubing drilling.  
Credit: Baker Hughes



▲ Location for Dry Piney project. Credit: Bureau of Land Management

## Chart Industries Delivers Tech in Wyoming

The company will supply a nitrogen rejection unit, helium process technology, and additional equipment for Blue Spruce Operating's Dry Piney Helium and Carbon Sequestration project in Sublette County, WY. Two separate gas processing trains will permanently capture and store up to 4.5 million metric tons of CO<sub>2</sub> per year.



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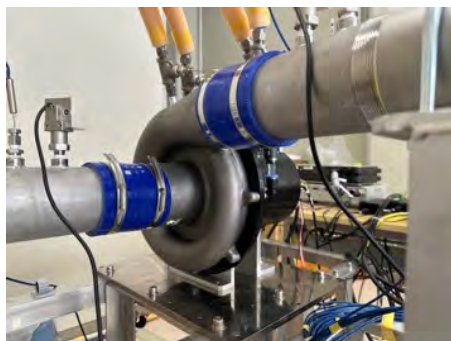


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# NEW PRODUCTS

The latest turbomachinery industry innovations



▲ Vacuum pump with gas-bearing motor.  
Credit: Business Wire

## IHI Corp.: Vacuum Pump

The pump is equipped with a gas-bearing motor to reduce friction and degradation and delivers reliability in the harsh environments of high-altitude flight. Ultra-high-speed rotation technology offers a compact and lightweight design, reducing drag, maintaining stable performance, and improving fuel efficiency in low-density air.



▲ DNR duplex filter. Credit: Eaton

## Eaton: DUA, LWF, DNR Filters

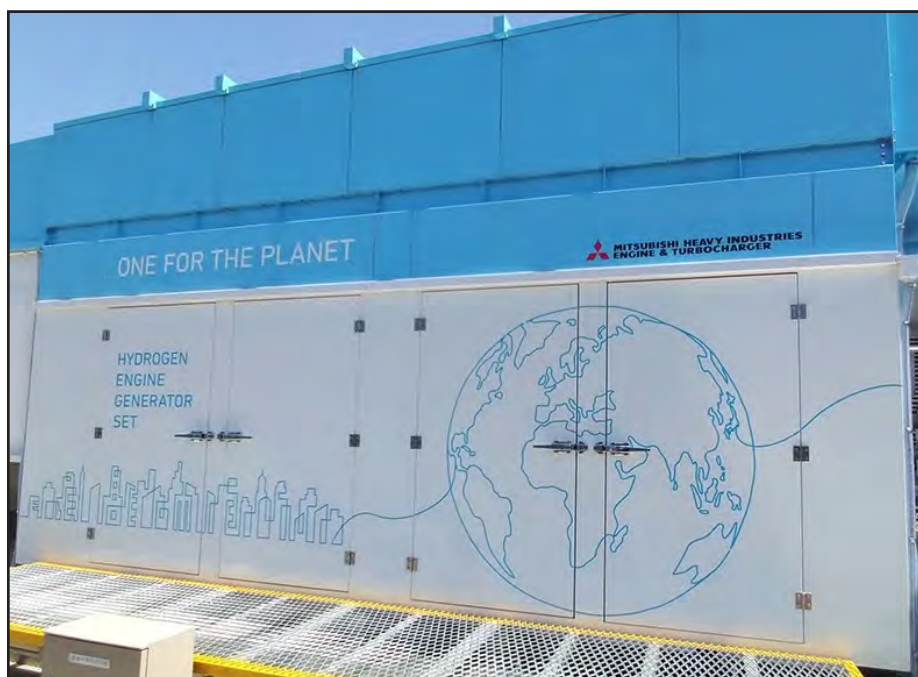
The DNR is a duplex pressure filter suitable for pressures up to 232 psi with a three-way changeover valve and carbon-steel housing. The DUA is a duplex filter for high-demand applications with pressures up to 320 psi. The LWF is an in-line pressure filter for suction, pressure, or return lines with pressures up to 232 psi.



▲ TM2500 mobile solution. Credit: GE Vernova

## GE Vernova: TM2500 Mobile Turbine

The 34-MW water-free mobile power-plant solution uses a TM2500 dry-low emissions aeroderivative turbine with up to 39% efficiency, low NOx emissions and waste, and fuel-flexible capabilities. Its two-trailer frame setup enables a 30-day lead time from contract to commissioning, as well as onsite flexibility and easy shipping.

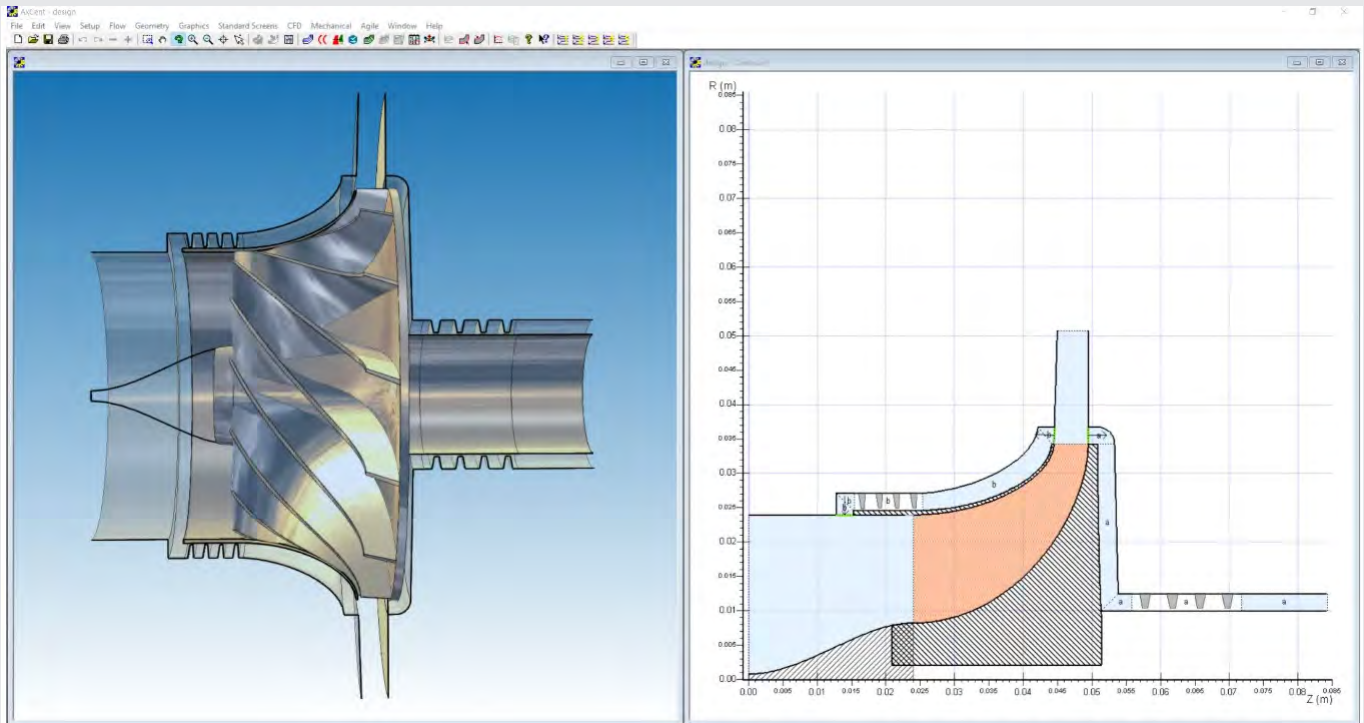


▲ Hydrogen generator set. Credit: MHIET

## MHIET: H<sub>2</sub> Generator Set

The set is a 100% hydrogen-fired, 500-kW, 6-cylinder generator set with a rated operation of 435 kW/1,500 min<sup>-1</sup>. The open chamber-type lean combustion genset emits zero CO<sub>2</sub> emissions with a spark ignition system and is designed to decarbonize distributed power systems by combusting pure hydrogen fuel.

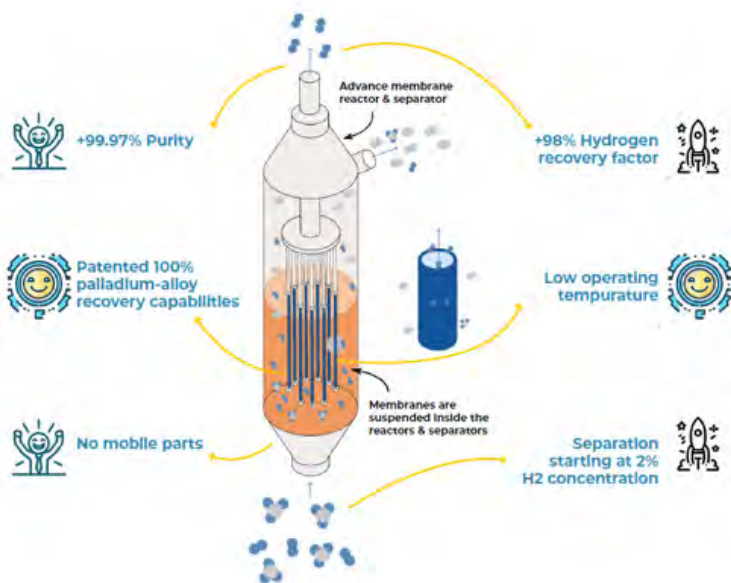




## Concepts NREC: AEDS V2025.1

▲ New feature in the Agile Engineering Design System. Credit: Concepts NREC

The updated Agile Engineering Design System features multiple software modules for turbomachinery-based computer-aided engineering and computer-aided manufacturing. It includes advanced rotating machinery dynamics within AxCent, the CYCAL thermodynamic cycle analysis software, and Code LEO, a 15 to 120 times faster computational fluid dynamics code.



## Kawasaki Heavy Industries: KM Comp-H<sub>2</sub>

The centrifugal hydrogen compressor is designed for liquefaction facilities, handling high flow rates with an 86% lower installation footprint than typical models. It will increase the pressure of refrigerant hydrogen gas and improve efficiencies in the liquefaction process with a new impeller.

▼ KM Comp-H<sub>2</sub> centrifugal hydrogen compressor. Credit: KHI



## H2SITE: Hydrogen Membrane Separator

The palladium-alloy membrane separator extracts hydrogen from 2 - 10% concentrations at pressures above 50 bar, with a 97% recovery rate at 99% purity. It allows the recovered hydrogen to be integrated into fuel cells, hydrogen-to-power solutions, and high-temperature ovens and minimizes the hydrogen content in the remaining natural gas.

◀ Palladium-alloy membrane separator. Credit: Ammonia Energy Association

# How Vibrations Affect a Turbomachines Reliability and Operation

Vibration: How to deal with it and how to prevent operational problems and failures.

BY AMIN ALMASI

.....

**V**ibration is a significant problem for turbomachinery, piping, and facilities. Left unchecked, it can lead to fatigue, cracks, and failures.

Modes and natural frequencies play a significant role in vibrations. Low-order modes/frequencies (first, second, and third modes) indicate when turbomachinery/equipment is most likely to vibrate and usually dominate all the higher-frequency modes.

The mode shape is how equipment (body or assembly) deforms and vibrates at a natural frequency. Mode shapes might involve bending, twisting, elongation and contraction, or a combination of these effects.

The first mode (mode of lowest frequency) is the fundamental mode. It is usually the most critical mode and the focus of the modal analysis and vibration study. This mode is often excited with a risky resonance. Higher-order modes, known as harmonics, are typically more complex than fundamental mode(s) and have more inflection points.

A key feature is the random distribution of modes in an arbitrary equipment or physical object. Modes of different shapes are located one after another. Some successive

natural frequencies are closely located, while others are far apart. The modes' pattern and distribution can significantly affect turbomachinery's behavior under dynamic and vibrational loads.

Sometimes, modes are simple up-and-down, side-to-side, or front-to-back motions; however, there might be one or more harmonic vibrating modes between these simple modes. The shape may not necessarily become more complex for each successive mode, but the overall trend is for the mode shapes to become more complicated as the vibrating frequency increases.

Mass and stiffness are significant operational and mechanical considerations for turbomachinery and equipment exposed to dynamic loads. As an indication, the greater the mass of the equipment/assembly, the lower its vibrating natural frequency. Conversely, greater stiffness means higher vibrating natural frequency. Different factors, such as how the equipment is configured, mass distribution, stiffness distribution, constrained equipment, internal loads/stresses, internal tensions in parts/elements, etc., influence the natural frequencies and mode shapes.

Ideally, resonance should not occur during regular operation. The modal analysis aims to identify and eliminate risky and problematic resonances. Preferably, the first mode should have a frequency higher than any potential excitation frequency. The first natural frequency should be far higher than the excitation frequencies, which are often one time and two times the turbomachinery operating speeds, may be located above the first natural frequency. In this case, the turbomachinery (or equipment) should withstand the momentary resonance that occurs while the rotating shaft/rotor accelerates to the operating speed.

## ANALYTICAL MODELS AND INACCURACIES

Analytical dynamic models require careful attention to accurately reflect the actual turbomachinery (or equipment) during operation. Oversimplifications lead to inaccurate analysis, missed resonances, high vibration, and operational problems.

There have been many closely coupled modes in different turbomachinery and



equipment. Closely coupled modes usually occur in nonlinear and axisymmetric equipment. Refinements on analytical models would result in closely coupled modes instead of a single mode produced using an inaccurate model; in other words, a single mode might be split into two closely coupled modes due to refinements and improvements. Therefore, a refined analytical model may produce more modes and natural frequencies, some close together.

## STIFF MODELS VS REAL TURBOMACHINERY

In many analytical models, theoretical natural frequencies are higher (stiffer) than the measured/actual natural frequencies, while masses are reasonably accurate. In many cases, each refinement in the analytical model/simulation would bring the calculated natural frequencies closer to the exact/measured natural frequencies. However, there might be

situations where a refinement adds one or a few modes or even slightly higher frequencies.

Generally, there are more differences between theoretical and actual modes for the higher modes, and, too often, inaccuracies in analytical models' stiffness and mass distribution show themselves as discrepancies at higher modes. This mismatch and discrepancy at high-order modes is widely reported. This should not be a significant issue because there is less risk of resonance in higher-order modes compared to low-order modes.

## PRACTICAL CHALLENGES OF REAL-WORLD TURBOMACHINERY

Endless variations of modal analysis are required to meet differences due to operational variables and other possible changes, such as actual tolerances/differences in fabrication and minor modifications in packaging. Regarding vibration issues, part quality has a substantial effect, which

engineers and experts have difficulty quantifying. One of the reasons to use simple configuration for turbomachinery/equipment and simple component design is for better and more predictable vibration/modal behavior. Typically, finish-machined parts are more predictable (and manageable) than cast parts. Generally, gear units, gearboxes, and gears have been a major challenge for vibrational/modal analysis.

Ideally, turbomachinery's natural frequencies should be located well beyond standard excitation frequencies, or the complicated matters of tolerances, variations, part quality, operation effects, etc., come into play, adding complexities to the dynamic/vibrational evaluations. ■



Amin Almasi is a Chartered Professional Engineer in Australia and the U.K. He is a senior consultant specializing in rotating equipment, condition monitoring, and reliability.

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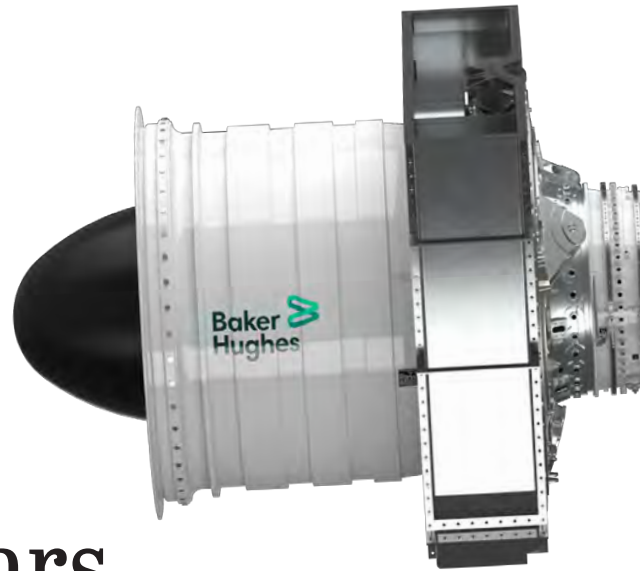
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# Gas Turbine Market Report:

## 2024 Posts Highest Units, MWs in 22 Years



Order activity spiked in 2024, as the market was driven by data center development and natural gas and LNG.

BY ALISSA ESPINOZA .....

**A**fter experiencing a 12.6% increase in MW capacity and a 3% increase in total units sold in 2023, 2024 numbers shine even brighter: Reported MW orders were up 32.4%, and unit orders were up 4.1%.

“Order activity is up significantly in 2024, primarily driven by large jumbo unit orders for the electric power utility (EPU) segment, but aeroderivative orders remain strong as well,” said Tony Brough, President of Dora Partners & Company.

The industrial gas turbine market is being impacted by several factors, according to Brough, including the price of natural gas, LNG, and, of course, the rapid development of data centers and artificial intelligence (AI), which is driving up power demand.

2024 marked the highest unit number and MWs (nearly 500 units and almost 60 MW) reported globally since 2002, up from 40,000+ MW in 2023.

Mark Axford, President of Axford Consulting, estimated an additional 30,000 MW of unreported orders, known as reservation agreements, bringing total orders booked for 2024 to more than 80,000 MW. He predicts gas turbine orders will increase by 7 – 10% in 2025.

Who’s leading the pack? The combined sales of GE Vernova and Baker Hughes, featuring gas turbines manufactured by GE Aerospace. GE Vernova has approximately 85% market share for aeroderivative gas turbines.

“GE Vernova’s numbers were solid in 2024 as it regained the no. 1 spot for advanced-frame

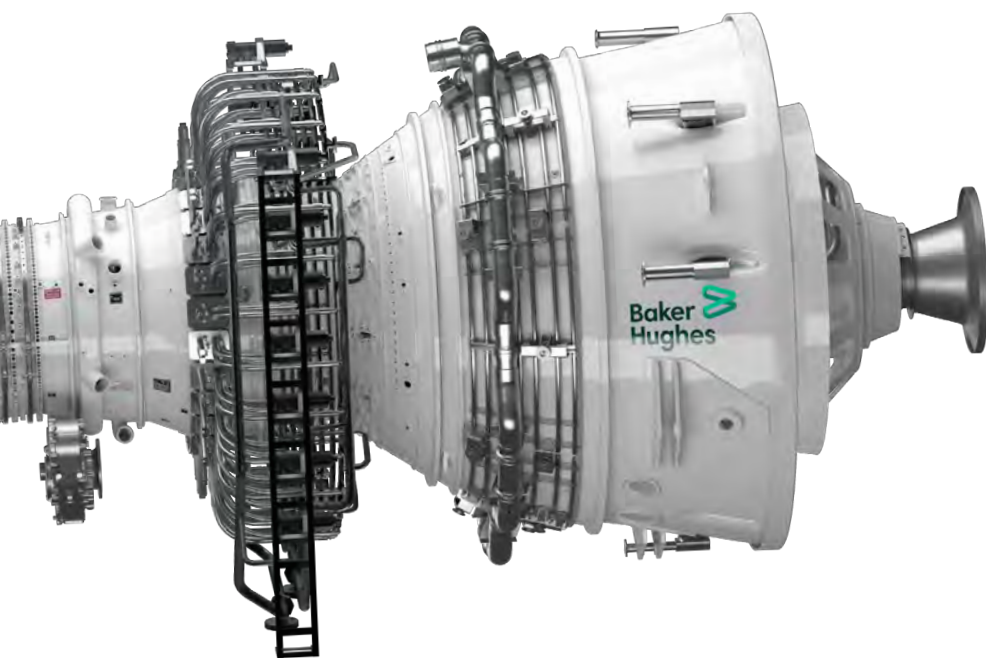
gas turbines—Mitsubishi was no. 1 in 2022 – 2023,” Axford said. In 2024, GE Vernova booked 22 GW of gas turbine orders and is upping its gas turbine factory capacity in Greenville, South Carolina, from 55 heavy-frame gas turbines to 70 - 80 per year in 2026.

Overall, advanced-frame (> 225 MW) gas turbine orders were approximately 80% of all orders (MWe). The top OEMs were GE Vernova (7F.05, 7H, 9F, and 9H), Mitsubishi (F, G, and J series), Siemens Energy (F and H series), Ansaldo Energia (94.3A), and Doosan (DJT 6; ~ 2.5%).

Packaged gas turbines have increased 12 - 18% over the past five years, while gas turbine components experienced up to 25% increases, according to Dora Partners & Company. Field service labor also increased by 10 - 20% in the past five years.

Brough reported the total value of packaged units—EPU and oil and gas (O&G) model units—will reach \$163 billion over the next 10 years. Aeroderivative engine sets will reach \$26.5 billion, and GE Vernova/Baker Hughes aeroderivatives will hit \$21 billion. Over the next decade, Siemens Energy, Mitsubishi Heavy Industries (MHI), and GE/





Baker Hughes will dominate the 300+ MW market, accounting for more than 30% of the total value of engine-set units. The total aftermarket value will reach \$302 billion in the next 10 years.

## MARKET DRIVERS

Brough named five drivers for the industrial gas turbine market, including grid-scale battery storage, coal plant retirements, rapid data center and artificial intelligence (AI) development, grid-scale renewable energy expansion, and natural gas pricing and LNG.

### **Grid-scale battery storage**

Over 150 GWs of grid-scale battery storage have been installed globally, most in the last eight to nine years. In the next three years, 490 new U.S. plants are planned, adding 62+ GWs of capacity. He said the market will be impacted by a decline in large power plants and jumbo frame turbines, with reliance shifting to smaller gas turbines and renewables to recharge, with an uptick in 40 – 100-MW gas turbines and recharge/hybrid systems.

Axford noted that solar + batteries are nearing economic feasibility without subsidies, given their short delivery times compared to gas turbine combined-cycle power, and that solar panel and battery prices are falling.

### **Coal plant retirements**

Coal still accounts for 33% of all electricity produced worldwide. In fact, global capacity struck an all-time high of 2,175 GWs but is expected to plateau in 2027, according to the International Energy Agency.

Dora Partners & Company expects large power plants and jumbo-frame turbines—specifically F, G, H, and J technologies—to increase. Gas turbines in the 40 – 100 MW range will also increase. “Mobile power and peaking will see an increase in demand, and, to a lesser degree, < 20 MW demand will be slightly up,” Brough said.

### **Rapid data center and AI development**

AI and data center buildouts are rocking the power industry and giving gas turbines “sold-out” status. U.S. utilities and developers “are racing to install baseload gas

turbine combined-cycle power, but they can’t get it fast enough,” Axford said. Large gas turbine supply is essentially sold out for the next three to four years.

As Axford put it, gas turbines have gone wild. New orders are now shipping in 2027, 2028, and 2029, and gas turbine and engineering, procurement, and construction (EPC) prices are up sharply. According to Brough, pricing is expected to continue increasing by approximately 5 - 10% over the next 12 - 18 months, with lead times for new units up to 36 - 48 months.

Data centers will also continue to boom. The World Economic Outlook (WEO) reports that well over 11,000 data centers are serving digital commerce and AI computing, with each center averaging an electrical load of approximately 4 MWs—and that’s only expected to increase to meet demand. Nearly 1,400 more are planned in the United States alone. Virginia, Texas, and Georgia have the highest potential for data center buildouts, according to S&P Global Market Intelligence.

Brough said data center buildouts and AI will impact the market the same way coal plant retirements will, but with an increase in onsite power, too.

### **Grid-scale renewable energy expansion**

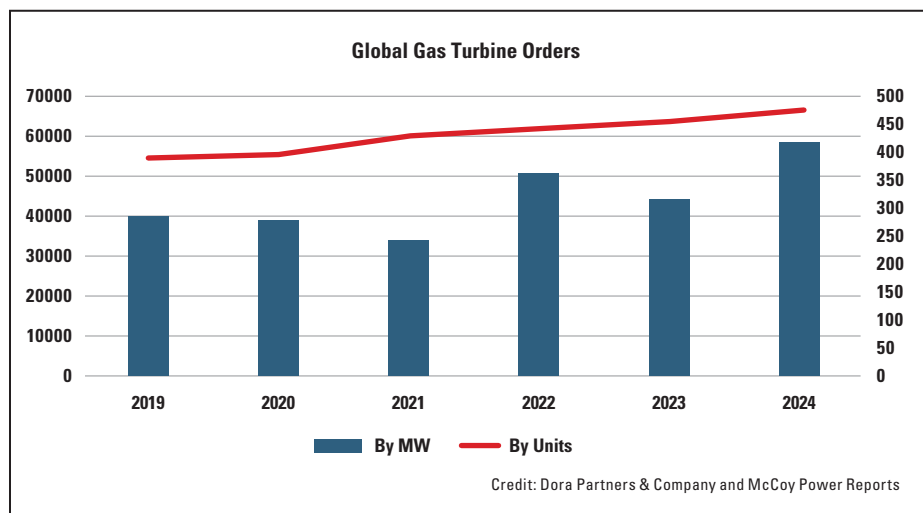
According to Dora Partners & Company, solar PV’s global capacity is now over 1,800 GW, and the WEO forecasts that global capacity will [easily] more than double over the next five years.

Brough said this market driver will also increase mobile, onsite, and peaking power, but “large power plant and jumbo-frame turbines will decline with a slight dilution of F, G, H, and J technologies.”

### **Natural gas pricing and LNG**

“In 2024, the United States was the no. 1 LNG exporter,” Axford said. By December 2028, the U.S. Energy Information Administration projects U.S. LNG exports will increase by 80%.

In terms of natural gas, the cost per MMBTU is expected to remain largely “affordable” in the United States, according to



Brough, which supports the use of gas turbines. Plus, “government policy is expected to keep it that way over the next four years.”

He said large power plants/jumbo-frame turbines and gas turbines in the 40 – 100 MW range will increase.

## AERODERIVATIVES MARKET OVERVIEW

2024 was a strong year for GE/Baker Hughes’ LM6000 and LM2500+G4.

“GE/Baker Hughes LM2500+ remains one of the most popular models in the world for the last 25 years,” Brough said. It has 1,458 units in fleet and accounted for 44% of the aeroderivative market (EPU and O&G models) over the past five years, growing at a compound annual growth rate (CAGR) of 4.1%. However, he said the Solar Titan 250 has displaced the LM2500 base engine business, and the introduction of the Solar Titan 350 poses a strong challenge to the 35+ MW LM2500+.

In 2024, GE/Baker Hughes LM6000 boasted 45 unit orders, but the LMS100 and LM9000 came up short with zero orders, though it is believed Baker Hughes is entertaining a lot of interest in the LM9000. The LM6000 has 1,235 units in fleet and improved its market share over the past five years to 16.4% with a CAGR of 1.8%.

Brough also noted a resurgence of the MHI FT8 in 2024, with 16 units ordered.

In 2023, GE/Baker Hughes’s five-year market share was 61%; in 2024, it increased to 63.7%. Siemens Energy and Rolls-Royce both held 8.1% and 4.5% in 2023 and 2024, respectively; MHI/PWPS held 3.6% in 2023 and 5.4% in 2024, and UEC (Russian Aero) held 9.5% and 9.3% in 2023 and 2024, respectively, according to Dora Partners & Company. The company predicts \$3.6 billion per year will be spent on gas turbine maintenance, repair, and overhaul.

In North America, aeroderivative unit orders saw a 48% increase and a 236% increase in MW orders in 2023 versus 2024, and GE/Baker Hughes’s MW share was 79.6% in 2023. Globally, aeroderivative unit orders were down 14% in 2024, and MW orders were up 10%. GE/Baker Hughes’s global share was 73% in MWs in 2024.

## COMPETITION FOR GE VERNOVA

Who is the competition for GE Vernova’s aeroderivative gas turbines? Axford said in 2000, the answer was Rolls-Royce and Pratt & Whitney. In 2024, the answer was solar panels and wind turbines. Now? The Wärtsilä RICE, Siemens SGT800, and Solar Titan 250 and 350 are taking market share from the LM2500 and LM6000. In 2024, Finland-made Wärtsilä won 800 MW of gensets in the United States (+ 280%) across approximately 85 sites (~ 6,000 MW installed) and already has 700 MW of orders booked for the first quarter in 2025.

“PROENERGY is winning a larger share of the aeroderivative genset business in North

America,” Axford said. A total of 37 PROENERGY LM6000s have been sold globally to utilities and independent power producers since 2009, and 50 LM6000 peakers in Texas alone. One of PROENERGY’s advantages is that its LM6000 and PE6000 gensets are built in Missouri. It also offers field service, level 4 repair, operations and maintenance (O&M), and an EPC turnkey approach that includes selective catalytic reduction for 6000 gensets.

Axford reported that in 2024, PROENERGY received 22 unit turnkey orders from Arizona for its LM6000 gas turbine generator sets. In addition, Colorado Springs Utilities ordered eight PE6000 generator sets. PROENERGY Model PE6000 utilizes refurbished aircraft engines (CF6-80C2) originally in service for wide-body jets such as the Boeing 747 and 767. The PE6000 is rated at a 48-MWe output with water-spray injection. Numerous PE6000 engines have accumulated 8,000+ hours of runtime in Houston, Mexico, and Germany.

## MOBILE POWER

The demand for mobile power is expected to grow in the coming years to increase scalability, meet rising energy demands, and accommodate rapid start-up and deployment.

Dynamis’ DT35 mobile turbine boasts a fast setup and disassembly—“no crane, no forklift.” The model is for sale and lease. Dynamis also leases its 5.5-MW trailer-mounted Solar Taurus 60 and 16.5-MW trailer-mounted Solar Titan 130.

Relevant Power Solutions is building new mobile gas turbine gensets, including a 35-MWe M35 genset (GE LM2500+G4) and a 17-MWe dry low emissions M170 genset (Baker Hughes’ NovaLT). Relevant has 12 M170s in production for 2025 – 2026 delivery. Axford reported that Relevant will commission five refurbished LM6000 gensets in June and November 2025, three in Texas and two in Arkansas. Relevant offers a full-load factory string test before shipment, economical turnkey installation, and contract O&M services. ■



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# WTUI 2025 Spotlights

## Uptick in Gas Turbine Orders

Supply and faster maintenance intervals are impacting the aeroderivative gas turbine market as OEMs try to keep up with demand.

BY ALISSA ESPINOZA

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**T**he 34<sup>th</sup> annual Western Turbine Users Inc. (WTUI), held March 30 – April 2, 2025, in sunny Long Beach, California, welcomed a record number of attendees: more than 1,100. Just over 600 were exhibitors, including 146 companies exhibiting in the exhibit hall.

Attendees had access to authorized service providers for LM turbines, including IHI Power Services Corp., TransCanada Turbines, and MTU Aero Engines, as well as other independent service providers, to help solve turbine and plant issues. Breakout sessions for GE LM2500, LM5000, LM6000, and LMS100 allowed users to present their operational challenges and have fellow LM users offer solutions and troubleshooting techniques.

“WTUI’s forums are very active and getting more so,” said Ed Jackson, President of WTUI and Exira Station Manager at Missouri River Energy Services in Brayton, Iowa. “With the challenging environment of acquiring timely parts and service lately, compounded by reaching maintenance intervals faster due to increased operation, it is more important than ever for users to lean on and support each other. I believe that is becoming apparent in the active user forums and increased communication between users.”

Monamee Adhikari, Global Marketing Leader for Aeroderivatives at GE Vernova, said the top challenges for users at WTUI were “around supply-chain constraints related to parts and turnaround times from our depots. There is a global supply-chain constraint; however, we are doing our best to overcome this and be transparent with our customers. Our main focus is SQDC: safety, quality, delivery, and cost.”

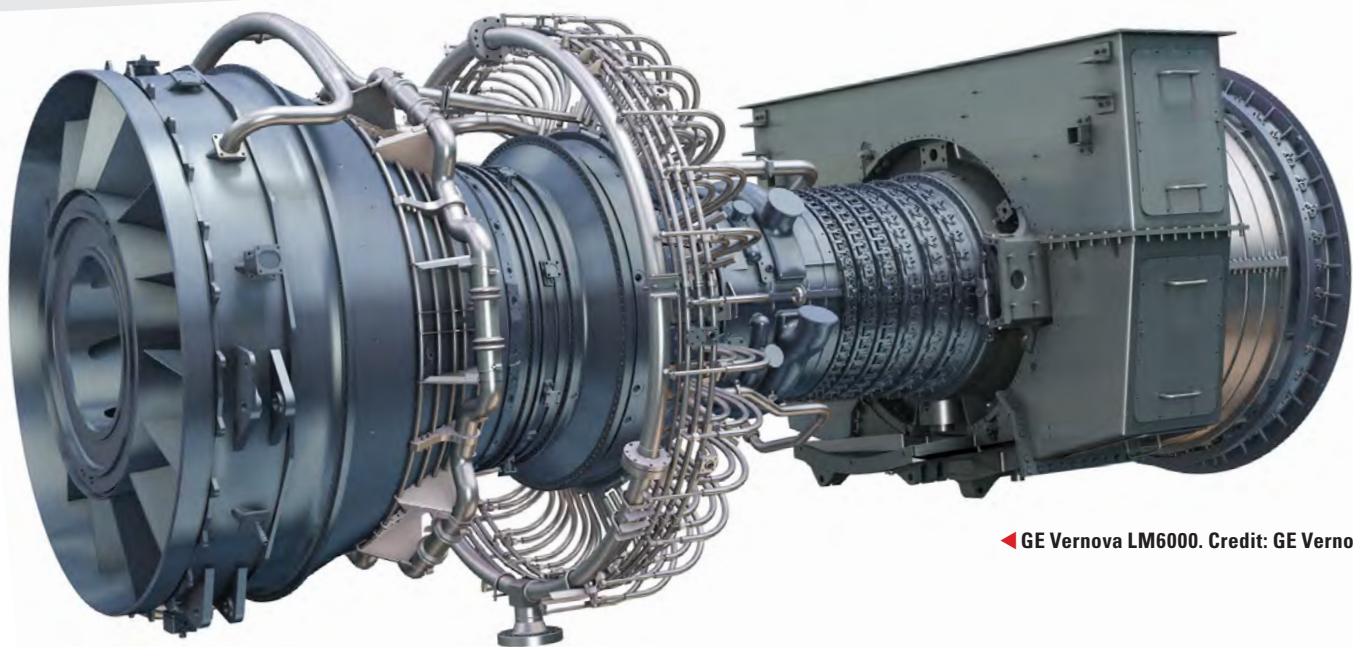
GE Vernova’s focus is on SQDC and its L5, L4, and L2 service shops to ensure they get units back to customers in a timely manner and communicate accordingly to set expectations.

### GAS TURBINE SUPPLY CHAIN

Monday morning, Mark Axford, Founder of Axford Turbine Consultants, and Tony Brough, President of Dora Partners & Co., presented the 19<sup>th</sup> annual State of the Gas Turbine World.

The demand from AI data centers has caused unit sales to surge. “Reported gas turbine orders were up 32% in 2024, with GE Vernova as the market share leader,” Axford said. 2024 marked the highest unit number and MWs (near 500 units and almost 60 MW) reported since 2002.





◀ GE Vernova LM6000. Credit: GE Vernova

In addition, Axford estimated an additional 30,000 MW of unreported orders, known as reservation agreements, bringing the total order book for 2024 to a level exceeding 80,000 MW.

U.S. utilities and developers “are racing to install baseload gas turbine combined-cycle power, but they can’t get it fast enough,” Axford said. GE Vernova, Siemens Energy, and Mitsubishi are now scheduled to deliver their large gas turbines in 2028 - 2029. In fact, he said that large gas turbine supply is essentially sold out for the next three to four years.

“Increasing power demand due to data centers and AI is definitely on everyone’s minds,” Adhikari said. “Almost all OEMs are supply-challenged from a gas-turbine perspective. For GE Vernova aeroderivatives, the lead time on engines is 37 months, and we are trying to bring that down to 24 months or less in conjunction with GE Aerospace. With decarbonization being less of a focus for the new Administration, GE Vernova will still do what’s right environmentally. We are focusing on both pre-and post-combustion carbon reduction and are ready with solutions for our customers whenever they are ready.”

Jackson said energy providers are scrambling to add generation to meet the need. “Not only is the lead time for major equipment increasing, but even the time it takes to build plants could take years to

permit and build,” he said. “This puts a lot of pressure on the existing generation, as many peaking plants that were originally designed to run at capacity factors of 10% or less are now running 30%, 40%, 50%, or more. We are pushing those plants harder and hitting the major maintenance intervals faster, which is putting even more pressure on an already burdened supply chain. Operators have to revise how they used to plan and budget and work with suppliers to ensure the availability of parts and labor. Running these plants is getting more challenging, making it even more important for users to attend conferences and forums like WTUI to ‘compare notes.’”

President Donald Trump’s election has ushered in profound changes to the U.S. energy policy. Axford said the President’s goal is “energy dominance” with less government intervention—“Drill baby Drill” is the new Administration’s anthem driving energy forward. The United States exited the Paris Agreement, and it’s uncertain whether EPA regulations on CO<sub>2</sub> will be altered. Green subsidies and EV mandates are out. Instead, the new U.S. Secretary of Energy, Chris Wright, showed strong support at CERAWeek 2025 for pipelines, drilling, fracking, LNG, and gas turbines.

It’s uncertain how the Administration’s tariffs will impact the supply chain. “Generally speaking, with the tariffs today, it’s early to

kind of understand what the financial implications are for [GE Vernova],” Adhikari said. “But we talked about it in our January earnings. When you think about Canada, Mexico, and China imported into the United States, it’s less than 5% of our material buy. So, it’s not nothing, but it’s something that we’ll manage our way through, and I think it’s something we’re going to have to get smarter on every day, on how we manage through the volatility that we’re going to have with the topic of tariffs. Our team’s working on it every day, and I’m confident we’ll navigate our way through it.”

## POWER-HUNGRY DATA CENTERS

As gas turbine orders surge, the energy transition is being reworked into energy addition. The energy trilemma—reliable, affordable, sustainable—in which each side of the triangle was equal, is shifting its priorities to affordability holding the lion’s share, reliability as the second runner-up, and a small focus on sustainability, according to Axford.

There is no path to net zero by 2050. “It would cost 5% of the world’s GDP for the next 25 years, and we are further away now than we were in 2022,” Daniel Yergin, Vice Charman of S&P Global, said at CERAWeek by S&P Global 2025.

The practical approach is affordable LNG for heating and cooking. In 2024, the United States was the no. 1 LNG exporter. The U.S. Energy Information Administration projects U.S. LNG exports will increase by 80% by December 2028.

Cheniere is the largest U.S. exporter of LNG, and it is “ramping up its exports,” according to Axford. In 2026, exports are slated to reach 55 million metric tons, up 22% compared to 2024. What’s powering Cheniere’s exports? GE’s LM2500 gas turbines.

## GAS TURBINES GONE WILD

Gas turbines [have] gone wild, as Axford put it. New orders are now shipping in 2027, 2028, and 2029, with gas turbine and engineering, procurement, and construction prices up sharply. According to Dora Partners & Co., global gas turbine MW orders were upwards of 40,000 in 2023 and around 60,000 MW in 2024, with reservations for more than 80,000 MW.

“We completed a modern combined cycle in 2022 for \$785 per KW,” said John W. Ketchum, CEO of NextEra. “A new build for 2030 commercial operation will cost \$2,400 per KW.”

GE Vernova saw solid numbers in 2024. It regained the no. 1 market share spot of advanced-frame gas turbines—Mitsubishi was no. 1 in 2022 – 2023—and has approximately 85% market share for aeroderivative gas turbines. The company booked 22 GW of gas turbine “orders” in 2024. It is expanding its Greenville, South Carolina, gas turbine factory capacity from 55 heavy-frame gas turbines per year (now) to 70 – 80 per year in 2026.

Overall, advanced-frame (> 225 MW) gas turbine orders were approximately 80% of all gas turbine orders (MWe). The top OEMs and their gas turbine models include:

1. GE Vernova: 7F, 05, 7H, 9F, and 9H
2. Mitsubishi: F, G, and J series
3. Siemens Energy: F and H series
4. Ansaldo Energia: 94.3A
5. Doosan: DJT 6 (~ 2.5%)

Axford said 2024 was a strong year for LM6000 and LM2500+G4 and predicts 2025 gas turbine “orders” will increase by 7 – 10%.

**“WTUI’s forums are very active and getting more so. With the challenging environment of acquiring timely parts and service lately, compounded by reaching maintenance intervals faster due to increased operation, it is more important than ever for users to lean on and support each other.”**

—ED JACKSON, PRESIDENT OF WTUI

## TECHNICAL SESSIONS HRSG

During the technical sessions, Jack Odum, the Northwest Regional Manager at HRST Inc., outlined how operating and design modifications improve a heat recovery steam generator’s (HRSG) efficiency. His session focused on efficiency from two perspectives: operational efficiency or to ensure the HRSG is running reliably in an ever-changing market and thermal efficiency from the classic heat-rate point of view.

Odum said it’s surprising how even small changes impact HRSG efficiency: “Things like baffle gaps or tube fouling might seem like no big deal, but as they add up, it can mean lost MWs of production in larger HRSGs. Not every efficiency-boosting modification needs to be something like adding an economizer surface or installing an upgraded duct burner. Sometimes, it’s as simple as keeping the HRSG in close to as-built conditions as possible. When it comes to operational efficiency, it’s more directed at running the plant well in an evolving power market, ensuring you can get online fast enough with as little damage to the boiler as possible.”

Odum said he’s seeing two trends: cycling in HRSG operation and design and challenges with the size of newer turbines, like the H-class machines.

## Flow Modeling

Engineering Manager Matt Gentry of Airflow Sciences Corp. presented on flow modeling for aero power plant performance optimization and addressed how it can identify, solve, and optimize parameters such as flow, temperature, ammonia, NOx, and pressure drop.

“Flow modeling is an important component of the engineering toolbox,” Gentry said. “Both computational fluid dynamics and physical-scale modeling can provide detailed predictions of flow, pressure, ammonia, and temperature distributions throughout a gas turbine power plant. These predictions allow for performance optimization without the need for a time-consuming and expensive trial-and-error approach to solving problems in the field.”

Gentry said many flow-related parameters are inter-related:

- Ammonia non-uniformity can cause pressure loss and heat-rate issues
- Poor velocity distribution can result in skewed heat transfer at tube banks
- Tube bank, catalyst, and ammonia injection grid seals/baffles may seem simple, but if they are not maintained, they can have a significant negative impact

WTUI 2026 will be back in Long Beach, California, from Tuesday, April 7 to Friday, April 10, 2026. ■



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# Exergy International:

## Turbo Expanders for Modular ORC Power Plants

Exergy International developed a high-speed axial turbine for waste heat recovery in organic Rankine cycle power plants.

BY FEDERICO BASSI

**A**n organic Rankine cycle (ORC) is a closed thermodynamic cycle characterized by the presence of an organic working fluid, mostly refrigerant or hydrocarbon, with a low evaporation point. It can use low- to medium-temperature heat sources for power production. Heat sources may vary from geothermal wells to industrial processes like cement or glass production and sustainable resources such as biomass or solar power.

An ORC power plant that uses heat sources from different industrial processes is often called waste heat recovery (WHR). The increasing number of WHR ORC power plants in recent years is strictly related to the latest environmental regulations and financial incentives for sustainable energy solutions and transition.

A new challenge for turbomachinery manufacturers operating in this context is the design and delivery of efficient and reliable expanders. With this goal in mind, Exergy, supported by the “Ricerca e Innovazione” grant from the Lombardy Regional Program FESR 2021-2027, developed a new series of turbo expanders designed for modular WHR ORC plants ranging from 0.7 – 2.0 MWe.

### HIGH-SPEED AXIAL TURBINE LAYOUT

ORC WHR plants are usually characterized by a medium working fluid temperature at the

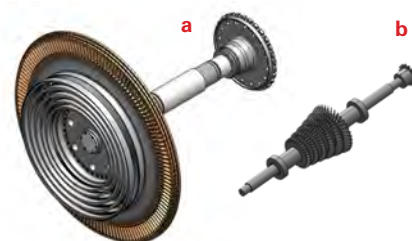
expander inlet (up to 250° C) and a medium volumetric flow rate at the expander outlet (10-20 m<sup>3</sup>/s). Within this range, the radial outflow turbine (ROT) applied to ORC systems has been shown to be efficient and reliable. In the presence of ORC systems with limited volumetric flow rates at the turbine discharge (< 10 m<sup>3</sup>/s), new turbomachinery configurations are being explored by Exergy to find more efficient and reliable solutions, even for small-scale plants.

Exergy developed a high-speed axial turbine (HSAT) architecture for these cases. The rotor's high rotational speed allowed for a more compact design with limited thermal displacements and, consequently, lower radial displacements at operation. This enabled minimum labyrinth seal clearance at the rotor-stator interfaces, which positively affected the expander efficiency.

Moreover, operating with such limited volumetric flow rates and a radially compact design can potentially increase the required blade height of the turbine stages, making them easier to machine using standard manufacturing technologies (e.g., milling) rather than more expensive methods like electrical discharge machining (EDM), which is typically used for low-aspect-ratio blades.

**FIGURE 1** compares the HSAT rotor for a 1-MWe WHR ORC power plant (b) with Exergy's standard ROT solution (a) on the same scale.

**FIGURE 1**



**TABLE 1** summarizes the positive effects of the HSAT design compared with the standard ROT solution.

**TABLE 1:** HSAT and ROT Performance Comparison for a 1-MW WHR ORC plant

	HSAT	ROT
Rotational speed (rpm)	12,000	3,000
Net isentropic efficiency (%)	89.7	77.5
Leakage-windage losses (kW)	35	171
Last stage radius (mm)	170	550

The 12.2% increase in the HSAT configuration's net isentropic efficiency is directly correlated to the stages' reduced radial span, leading to an 80% reduction of leakage-windage losses compared to the standard ROT configuration.



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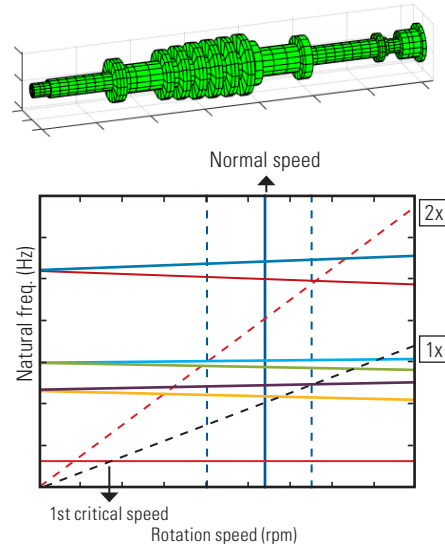


**TURBOMACHINERY LABORATORY**  
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A high-speed axial rotor, however, has challenges when operating at higher rotational speeds than a standard configuration. This includes accounting in the turbo-generator layout for a 4:1 gearbox reducer, which not only impacts the cost of the supplied unit but also introduces a criticality within the rotor dynamics of the complete drivetrain.

While the associated costs have been mitigated with a compact design that ensures a 20% cost reduction compared to the standard ROT design, the issues related to the rotor dynamics are addressed too, as the rotor operates well above its first lateral critical speed (**FIGURE 2**). In this context, commercial EDM machined journal bearings that act like tilting pad bearings have been adopted, ensuring sufficient damping and limiting the vibration amplitude during critical speed crossing at startups and shutdowns.

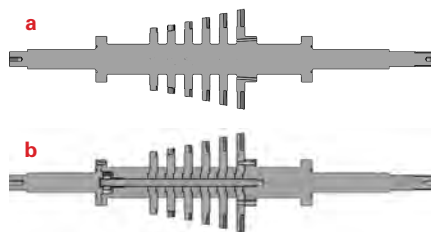
**FIGURE 2:** Normalized Campbell diagram of the HSAT



To minimize machining costs and limit critical part failures, the initial design of a single-component bladed rotor has been replaced by integrally bladed rotors (**FIGURE 3**) held together by a central tie rod.

Specifically designed friction discs have been interposed between each rotor stage to ensure torque transmission without the need for dowel pins that reduce the mechanical strength of the rotor shaft.

**FIGURE 3:** Bladed shaft design (a) versus IBR design for HSAT (b)



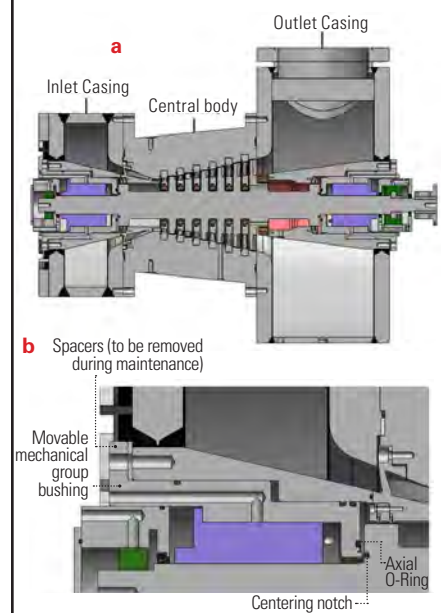
## MECHANICAL GROUP BUSHINGS DESIGN

The turbine casing is divided into three main parts (**FIGURE 4a**):

- Inlet casing
- Central body
- Outlet casing

The inlet and outlet casings are radially split, and the central body is axially split. This means the patented mechanical group bushings can be shifted during maintenance, engaging an axial O-ring on each side that safely confines the working fluid (**FIGURE 4b**). During this procedure, the mechanical group bushings keep the rotor in place thanks to the centering notches that enable the bearings and mechanical seals replacement.

**FIGURE 4:** Triple casing layout (a) and mechanical group bushing for fast maintenance (b)



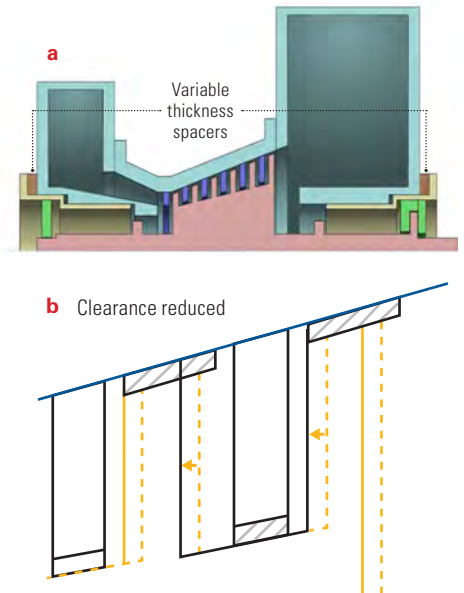
With this operation, ordinary maintenance tasks can be easily performed in half a day, guaranteeing a yearly expander availability of more than 99%.

## CLEARANCE CONTROL FOR PERFORMANCE OPTIMIZATION

The mechanical group layout was easily adapted to permit small axial position adjustments to the rotor shaft. This, in combination with the sloped labyrinth seal configuration (**FIGURE 5a**), enabled the possibility of altering the labyrinths' clearance, affecting the machinery's performance.

This is achieved using variable thickness spacers between the mechanical group bushing-to-casing interface. If the labyrinth gap needs to be adjusted, reposition a variable-thickness spacer from the outlet to the inlet casing side. This causes a negative axial displacement of the rotor relative to the fixed stator casing (**FIGURE 5b**), reducing the labyrinth gaps and increasing expander efficiency by limiting labyrinth seal losses. ■

**FIGURE 5:** Labyrinths clearance control system (a) and clearance reduction scheme (b)



Federico Bassi is a Product Development Engineer at Exergy International.



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# CERAWeek 2025 by S&P Global: ‘Build Baby Build’

“Build Baby Build” has brought about the remake of the energy transition to the energy addition.

BY MARK AXFORD

**S**ince 1983, energy executives have made the trek to Houston for CERAWeek, often referred to as the Superbowl for the energy industry. What started out as an oil and gas conference for a few dozen now draws more than 10,000 attendees with 1,400 speakers from 89 countries. And “energy” includes oil and gas, coal and nuclear, renewable energy sources (solar, wind, geothermal, hydro), and energy storage.

## HIGH-LEVEL POLITICS

First to the stage: U.S. Secretary of Energy Chris Wright

The message was clear: There’s a new sheriff in town with new priorities for U.S. energy policy. At CERAWeek 2024, then U.S. Energy Secretary Jennifer Granholm told the audience: “LNG exports will soon be in the rear-view mirror.” Today’s U.S. Energy Secretary, Christopher Wright, works in an alternate universe seeking energy supply dominance. Wright removed the “pause” invoked on permitting LNG projects by Granholm and is providing permitting support to speed up the construction of pipelines and LNG export facilities.

“Climate change is a global physical phenomenon that is a side effect of building the modern world. I am a climate realist. Everything in life involves trade-offs. Everything,” Wright said.

## RACE FOR AI LEADERSHIP

At CERAWeek 2024, the conference was abuzz with the realization that AI has created demand for more electricity than had been forecasted. However, since March 2024, the magnitude of the pending electricity shortage has become more fully understood. AI has evolved from a gradual step-up in productivity to an arms race.

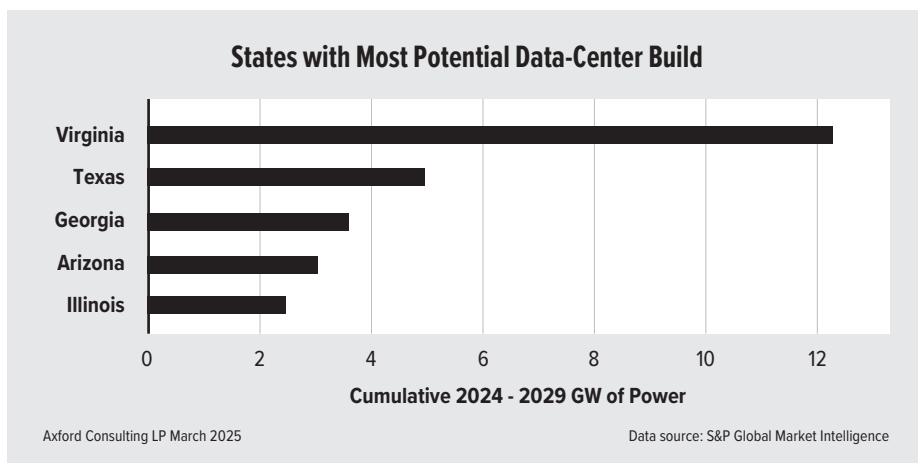
“The implications on national defense make it simply critical that America leads the AI race,” Wright said.

Stated more directly at CERAWeek by Doug Bergum, U.S. Secretary of the Interior, having global atmospheric temperatures increase by 2 degrees by 2050 is not an existential threat.

“The two existential threats at hand are Iran getting nuclear weapons and losing the AI war,” he said.

More generation capacity of all types is needed immediately to supply the electricity-hungry AI data centers. Utilities and developers in many regions of the United States are racing to install baseload gas turbine combined-cycle power, but they can’t get it fast enough (**FIGURE 1**). Deliveries for large gas turbines from GE Vernova, Siemens Energy, and Mitsubishi are now being scheduled for 2028 - 2029. Once the turbines are delivered to the site, it typically takes approximately 12 months to build out a combined-cycle plant. Heat recovery steam generators (HRSG), step-up (or step-down) transformers, and other electrical equipment have their own supply-chain challenges.

John Ketchum, CEO of NextEra Corp., the largest utility company in the United States,



lamented, “We completed a modern combined cycle in 2022 for \$785 per KW, but a new build for 2030 commercial operation will cost \$2,400 per KW.”

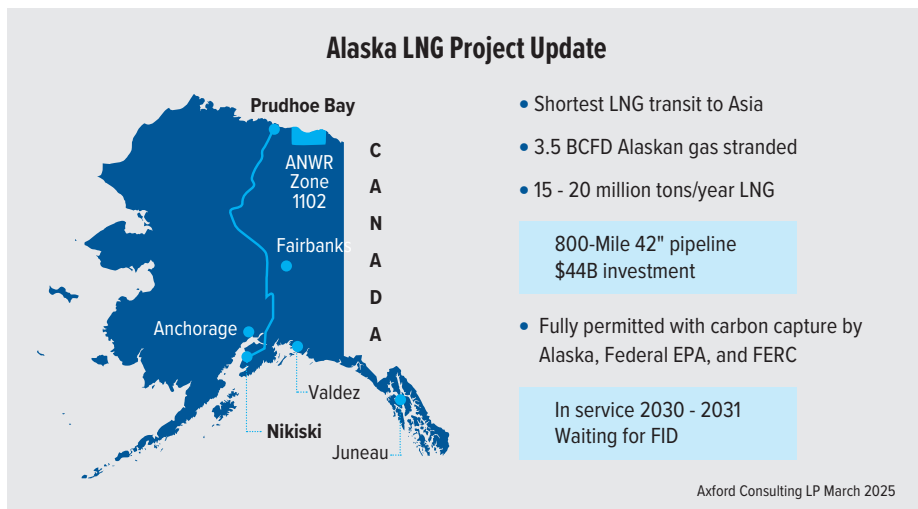
There will be winners and losers in the race for AI dominance and quantum computing market share. Amazon, Microsoft, Alphabet (Google), META (Facebook), and Oracle are all investing billions and racing aggressively to get a competitive edge.

With the large gas turbine supply essentially sold out for the next three to four years, other solutions are coming into play:

- Buying or leasing smaller gas turbines or reciprocating engine gensets as a short-term bridge
  - Unretiring mothballed nuclear plants and coal plants
  - Upgrading transmission lines to de-bottle-neck the grid
  - Using demand-side management to create “virtual power plants” to reduce peak load.
- The power surge from AI will need all these solutions and more.

## ENERGY TRANSITION REINVENTED—NOW ENERGY ADDITION

The power surge from AI has done more than create a bonanza for turbine OEMs and engineering, procurement, and construction contractors. “Build Baby Build” has also brought about the remake of the energy transition to the energy addition. The energy trilemma of security, affordability, and sustainability has been reshaped. Security and affordability now rule the roost as practical solutions rise to the top. Funding for the green energy fantasy of green hydrogen (or any hydrogen) is fading rapidly. Offshore wind generation is not financeable in most regions of the world without substantial government subsidy. Carbon capture as a universal attachment to all gas and coal plants is not affordable. Specialized carbon-capture projects at huge sequestration hubs with substantial economies of scale may survive. Ironically, OXY’s direct air capture technology shows some promise by removing CO<sub>2</sub> from the atmosphere and injecting it directly into oil and gas formations to enhance production of more oil and gas, thus linking to the energy addition.



## SMALL NUCLEAR REACTORS

Modular nuclear reactors are getting serious attention for providing carbon-free baseload generation. A nuclear renaissance has been talked about for decades but could never overcome the history of project costs far exceeding budgets. Now, a new approach is on the table: smaller modular reactors (SMRs) built offsite in a factory and delivered to the job site, perhaps adjacent to an existing nuke or fossil-fueled plant.

There is also a race to establish the SMR design that could become the standard for the new era of nukes. GE Vernova, with Hitachi, is promoting a 300 MW SMR and plans to begin operation of unit 1 of 4 in 2029 at an existing nuclear power plant at Darlington (Toronto), Ontario. Other SMR designs by NuScale Corp., Google, and Amazon are focused on design modules in the 80 – 100 MW size, modeled after the U.S. Savannah commercial cargo ship.

## KEEP YOUR EYES ON ALASKA

On the last day of CERAWeek, Alaska Governor Mike Dunleavy described, with great enthusiasm, his outlook for a \$44 Billion LNG export project. The Alaska LNG Project has three major components:

- A 3.5 BCFD gas-gathering and processing plant on the north slope, an 800-mile 42-inch pipeline to Niniski (near Anchorage), and a 20 million MTPA liquefaction near Kenai. The project also includes carbon capture.
- Construction of the gas pipeline would begin in 2026 with gas flowing in 2028.

- The conditioning plant and export facility are scheduled for completion in 2030 - 2031.

While financing is not yet in place, Dunleavy is highly optimistic.

“We have all the permits, feedback from all the court cases, the support of the President of the United States, and Asian allies that need gas,” Dunleavy said.

Unlike the major LNG terminals in Texas and Louisiana, Alaska LNG can be delivered in a straight shot to Japan, Korea, India, and Southeast Asia without traveling through the Panama Canal.

The project, which was approved during Trump’s first term as President, received Federal Energy Regulatory Commission authorization in 2020 and final legal approval in 2022 but was put on hold during the Biden administration. Trump signed an executive order during his first day in office called “Unleashing Alaska’s Extraordinary Resource Potential.” The executive order removed certain restrictions on drilling as well as barriers to the development of mining and timber resources imposed by the previous administration. After more than 10 years of planning and permitting, it looks like the Alaska LNG Project could become a reality. Stay tuned. ■



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# Myth: We Need That Last Percent

The perfection trap is just that: a trap—and often a costly, inefficient trap that leads to delays and even diminished operational flexibility.

BY KLAUS BRUN & RAINER KURZ

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**T**here is a persistent myth in engineering, research, and development: The pursuit of perfection is always necessary. This mindset drives organizations to chase the last fraction of a percent in efficiency or performance. In the turbomachinery industry, this is sometimes called the “Perfection Trap,” which describes how overzealous engineering or regulations can waste time and money with limited benefits in actual efficiency, emissions reduction, power, or other desired machinery performance characteristics. Unfortunately, a relentless push for perfection often leads to project delays, budget overruns, and even diminished operational flexibility.

When managing an R&D budget—whether within a company or when funding third-party research—it is crucial to prioritize investments based on the greatest need and highest impact. Resources are always limited, and not every promising technology can or should be funded. Historically, many R&D initiatives have failed to produce results, which is an accepted risk in innovation. However, there is another category of wasteful spending: research that pushes for extreme,

unnecessary performance improvements far beyond what is technically or commercially reasonable. Engineers and researchers are naturally inclined to push boundaries, squeezing out the last bits of efficiency or performance, even when the cost-benefit ratio no longer makes sense.

A prime example of this was the race in the 1990s and early 2000s to drive NOx emissions from gas turbines into the low single-digit parts per million (ppm) range. The effort toward lower NOx emissions required massive investments over decades (often provided through taxpayer funding) or complicated add-on post-combustion treatment systems. However, the real-world benefits were negligible. Hundreds of millions of R&D dollars were spent on minimal improvements based on a questionable environmental hypothesis. Besides, the available test methods had a larger uncertainty than the required emissions levels. In hindsight, NOx levels of 25 - 40 ppm were perfectly adequate, yet the industry sacrificed operating range, reliability, and overall system operability in the name of achieving an arbitrary perfectionist goal. Ironically, we are reversing course today, often accepting slightly higher NOx levels to reduce CO and CO<sub>2</sub> emissions,

acknowledging that the previous obsession with perfection was misguided.

This pattern is not unique to NOx reduction; the same excessive drive for perfection can be seen across multiple areas of turbomachinery engineering. There are many other examples of the cost of chasing perfection, as demonstrated by over-engineering across our industry.

## FUGITIVE EMISSIONS

For example, fugitive emissions reduction regulations for centrifugal compressors are driving irrational engineering decisions. Some current regulations for methane leakage criteria are set so low that the measurements become arbitrary, and it becomes nearly impossible to verify the levels required by law. Modern rotating machinery dry gas seals have reduced methane fugitive emissions to the point that they do not significantly contribute to global greenhouse gas emissions. They are certainly far lower than many other methane emission sources in the fossil energy industry, such as reciprocating compressor piston leakage, coal bed methane seepage, pipeline process valve leakage, cold stack venting, and, in

particular, emergency or maintenance blowdowns. Yet, there is a push to further reduce methane leakage from centrifugal compressors, leaving few technically viable options to meet permitting requirements for compression stations or require additional equipment such as vent gas re-compressors that increase cost and reduce reliability.

Hermetically sealed compressors are being touted as the solution. However, they are inherently less efficient than conventional machines and, when including all the electrical components required, more costly to purchase and operate than gas turbines or conventional electric motor-driven compressors. They simply add complexity and cost without addressing larger, more impactful sources of emissions. And because they are less efficient, their total (all-in) carbon emissions footprint is usually worse than conventional compressors with dry gas seals.

## PARTICULATE EMISSIONS

Similar trends that exaggerate criteria pollutant regulations can be found for particulate matter exhaust emissions from gas turbine plants. In some strict urban regulatory environments, the plant air emissions permit requires the gas turbine's exhaust air to have a lower particulate matter count than the actual city's air quality on most normal days—i.e., the gas turbine is expected to act like an air filter, with the exhaust air having to be cleaner than the air that enters the machine. Although natural gas-fired plants are a type of fossil-fueled plant, they generally do not produce particulate emissions and should not even be regulated for this criteria pollutant. Subjecting natural gas-fired plants to this regulation makes operation more costly and may even negatively impact total plant efficiency due to added inlet pressure losses. This is clearly another extreme regulatory example that is difficult to justify in terms of real environmental and health impact.

## DRIVERS AND DRIVEN EQUIPMENT

Even the push for efficiency improvements for turbomachinery drivers and driven equipment is sometimes questionable. Clearly, we always want our machines to be more efficient to lower carbon emissions and reduce energy consumption. All major turbomachinery manufacturers spend significant amounts of time and money to improve their equipment's efficiency. However, sometimes higher efficiency is not necessarily better. Achieving fraction-of-a-percent efficiency improvements at one operating point at the cost of load/speed range and operational flexibility can easily result in a net negative impact on the carbon footprint while driving up operating costs and reducing equipment reliability. Specifically, gas turbines, steam turbines, and compressors are sometimes optimized for a single highest efficiency point rather than the best efficiency over their normal operating range. Surge margin may be sacrificed on centrifugal compressors for fractions-of-a-percent peak efficiency improvements. In practice, most machines seldom operate at their best efficiency point, rendering these improvements largely meaningless. And if a compressor is required to recycle to stay out of surge, then efficiency becomes meaningless anyway.

## CARBON CAPTURE

Now we are seeing a similar trend in capture targets for CO<sub>2</sub> power-plant carbon-sequestration applications. Although no fully commercial power plants in the world operate with any meaningful carbon capture, regulatory proposals already require nearly 100% carbon-capture levels for new plants. Carbon capture at the source level (e.g., fossil power plant pre- or post-combustion capture) is currently technically and commercially viable at the 50 - 70% capture level, but anything higher drives up costs dramatically while also decreasing plant availability. Thus, while

capturing 70% of CO<sub>2</sub> emissions is both feasible and financially reasonable, aiming for near-total capture drives costs up exponentially, making large-scale implementation impractical or nearly impossible. It is unclear whether some of these regulations actually aim to encourage carbon capture or simply discourage the construction of new fossil power plants. However, given that nearly 80% of the world's energy is still derived from fossil fuel, promoting a practical and feasible implementation of carbon capture—rather than discouraging it through overzealous regulations—should be the goal.

There are many more such examples in our industry. Engineers are engineers and always strive for the best. However, the real-life practical alternative is that “good enough” is often satisfactory and sometimes even best. Instead of striving for unattainable perfection, the turbomachinery designer should focus on solutions that provide the best balance of cost, practicality, and effectiveness. In many cases, an 80 - 90% solution is sufficient and can be implemented much faster at a fraction of the cost.

The lesson from past decades of engineering is clear: Perfectionism can be a costly distraction. Instead, we should prioritize pragmatic, cost-effective solutions that achieve the desired results without unnecessary complexity. The goal should be a real-world impact, not academic perfection. ■



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