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TURBOMACHINERY INTERNATIONAL

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HANDBOOK 2022 • VOL. 62 NO. 6

HANDBOOK 2022

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Gas Turbines
Steam Turbines
Compressors & Expanders

MARKET ANALYSES
Worldwide Gas Turbines
U.S. Power Outlook

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Manufacturers
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Product Categories

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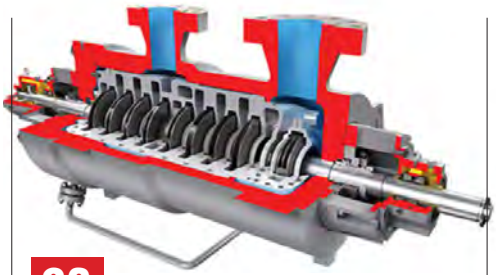

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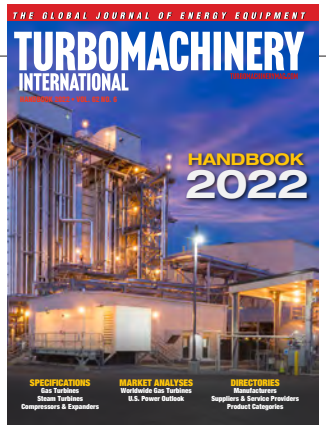

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HOW TO USE THIS HANDBOOK

Here is your 2022 edition of the **Turbomachinery International Handbook**.

The **Features** section provides the U.S. power industry outlook on **p. 18** and the worldwide gas turbine market on **p. 30**.

The alphabetical **Company Directory**, beginning on **p. 44**, provides contact information on every company listed in the handbook. The text of each listing is provided by the company itself.

The **Category Index** on **p. 43** lists the categories within each segment of the industry, and on which page to find them.

The **Categories** section provides a list of specific segments of the turbomachinery market and begins on **p. 69**. Refer back to the Company Directory for more detailed information about each company.

Equipment Specifications for gas turbines, steam turbines, compressors and expanders begins on **p. 80**.

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IS A RECOVERY LOOMING?

Welcome to our Annual Turbomachinery International Handbook for 2022. This is a good time of the year to take stock of where the industry currently stands and where we are heading.

In our cover story by Industrial Info Resources (IIR), the expectation is that renewables will constitute the overwhelming majority of new-build U.S. electric generation projects during the 2022-2026 period. They will account for about 88% of all new electric generation capacity. Gas will comprise 11% over that five-year span.

Such statistics make it unnecessray to compare the various regions. They are all largely on board with what appears to be a renewables-only policy. Some regions have more than 90% of their eggs in the renewable basket. The star of the show is West Coast at 96%. The outliers are the Mid-Atlantic regions with 35% natural gas generation planned, and the Great Lakes Region with 23%.

Despite that apparently grim picture from the standpoint of natural gas-based generation, IIR still estimates that about 35 GW of new-build natural gas-fired generators will commence construction between now and 2026. That's about 10% down on the prediction from last year's IIR report. But the long-term look is more frightening. This year's five-year total is about 60% less than what was planned to kick off construction during the 2019-2023 period. In other words, the industry in the U.S. is being squeezed on several fronts. New plants are becoming more challenging to plan, never mind push through to completion.

But with such a large quantity of renewables flooding onto the grid, this should be good news for the aftermarket. Those natural gas facilities that remain are likely to be subjected to far more starts and stops. As more of these plants are closed, the survivors become steadily more critical as assets that help to balance the grid. They will be needed to provide power when it isn't available elsewhere.

It has been proven in recent years that it is never smart to rely on one source of power. In the North East a few years ago, overreliance on gas caused problems during a cold spell when prices soared. Dependence on wind or solar is likely to produce the same issues.

Worldwide Picture

Beyond a potentially healthy U.S. aftermarket, is there any hope of a recovery? Yes, when viewing the international picture. Forecast International provided us with a worldwide market analysis of gas turbine-powered electrical generation. This year's report projects that sales over the period 2021-2030 will total more than $100 billion. While the last few years for turbine sales have been challenging, and 2021 might be stagnant, a medium-term recovery is projected.

The U.S. market may be tough for turbine sales. But natural gas is forecast to continue to expand its global share of overall power generation in tandem with renewables. CHP, too, is an area where gas generation is enjoying success – and will continue to do so.

Therefore, it looks like the aftermarket will dominate in North America while much of the rest of the world (except Western Europe) continues to embrace gas generation and build new plants.

> **"The aftermarket will dominate in North America while much of the rest of the world continues to embrace gas generation.**

Three years ago, we visited Egypt for a tour of several brand new 4.8 GW combined cycle plants. With China suddenly shifting away from coal and experiencing rolling blackouts, and many Asian nations involved in a bidding war for LNG supplies, more natural gas plants of that magnitude are destined for those areas.

Specs and Listings

A special shoutout to two people for great work compiling material for our annual handbook:

Bob Maraczi did his usual stellar job with the company listings. Each year, he just keeps improving on previous results.

Joe McDonald, our new associate editor, picked up the reins and took care of the many details involved in compiling our vendor specifications pages.

Enjoy the Handbook! ■

Drew Robb

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Doosan Skoda's DST-G20 steam turbine

STEAM TURBINE FOR ENERGY-FROM-WASTE FACILITY

Doosan Škoda Power supplied Acciona with a steam turbine for the Avertas Energy facility in Australia. It is the first of a number of planned energy-from-waste projects for energy recovery in the nation. It will process up to 400,000 tons of waste annually, while exporting approximately 45 MW of baseload renewable electricity to the grid. As well as Doosan's 45 MW DST-G20 single-body turbine, project scope also includes the transmission unit and the power generator. In addition, the company will provide technical assistance during assembly and commissioning.

BAKER HUGHES TO DELIVER SUBSEA COMPRESSION MANIFOLD

Baker Hughes has been awarded a contract from Chevron Australia to deliver subsea compression manifold (SCMS) technology for the Jansz-Io Compression (J-IC) Project. The company will provide Chevron with the SCMS including module and foundation, as well as the latest version of its horizontal clamp connector system and subsea controls.

The Jansz-Io gas field is located around 200 kilometers offshore the north-western coast of Western Australia, at water depths of approximately 1,400 meters. The Jansz-Io field is a part of the Chevron-operated Gorgon natural gas facility, one of the world's largest natural gas developments. Baker Hughes has previously provided 23 subsea trees, 12 subsea manifolds, 45 subsea structures and a subsea production control system for the Gorgon natural gas facility.

JERA'S HYDROGEN DEMONSTRATION PROJECT

JERA will conduct a demonstration project related to hydrogen utilization at an LNG thermal power plant in Japan under the New Energy and Industrial Technology Development Organization's Green Innovation Fund program. The project will switch a portion of the LNG fuel used to generate electricity at JERA's LNG thermal power plant in Japan to hydrogen and evaluate the resulting operational and environmental characteristics over a period of five years.

Based on initial results, JERA aims to construct hydrogen supply and related facilities at its LNG plant, to install combustors capable of co-firing hydrogen and LNG in gas turbines, and to switch approximately 30% of the LNG used for electricity generation (by volume, equivalent to approximately 10% of heating value) to hydrogen by fiscal 2025.

CONCEPTS NREC SOFTWARE INCLUDED IN ENGINEERING CURRICULUM

Concepts NREC's Agile Engineering Design System is now a component of Colorado State University's (CSU) Mechanical Engineering course curriculum on turbomachinery design. The Department of Mechanical Engineering at CSU aims to provide practical engineering experience to complement the theoretical underpinnings of undergraduate and graduate coursework. Co-taught by CSU Mechanical Engineering Professor Dr. Wajid Ali Chishty and turbomachinery aeromechanical design expert Mr. Eric Krivitzky of the independent Thermofluid Research Lab, the course focuses on bridging the gap between foundational knowledge of the classroom and application of that knowledge to engineering problems.

ATLAS COPCO ACQUISITIONS

Atlas Copco has acquired CPC Pumps. The company specializes in the design, manufacturing, and servicing of centrifugal pumps. CPC Pumps has 110 employees and is based in Burlington in Ontario, Canada, with North America as its main market. CPC Pumps will become part of the Gas and Process division within the Compressor Technique business area.

Atlas Copco has also acquired the assets of Natev. The company was founded in 2010 and specializes in position solutions for assembly tools used in industrial production. Natev develops systems for real-time positioning and imaging solutions in close cooperation with key customers in the automotive industry. Products include hardware and software used to monitor and error-proof defined production steps linked to the tightening processes. The business will be integrated into the MVI Tools and Assembly Systems Division in the Industrial Technique Business Area.

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MTU SELLS VERICOR

MTU Aero Engines has sold Vericor Power Systems. This marine and industrial gas turbine OEM is being acquired by US private equity company CSL Capital Management of Houston, Texas. MTU established Vericor Power Systems in 1999 as a joint venture with Allied Signal (now Honeywell). Since 2002, it has been a wholly owned subsidiary of MTU Aero Engines. Vericor has around 50 employees. MTU retains its maintenance business for the LM series of gas turbines, which is operated by MTU Maintenance Berlin-Brandenburg.

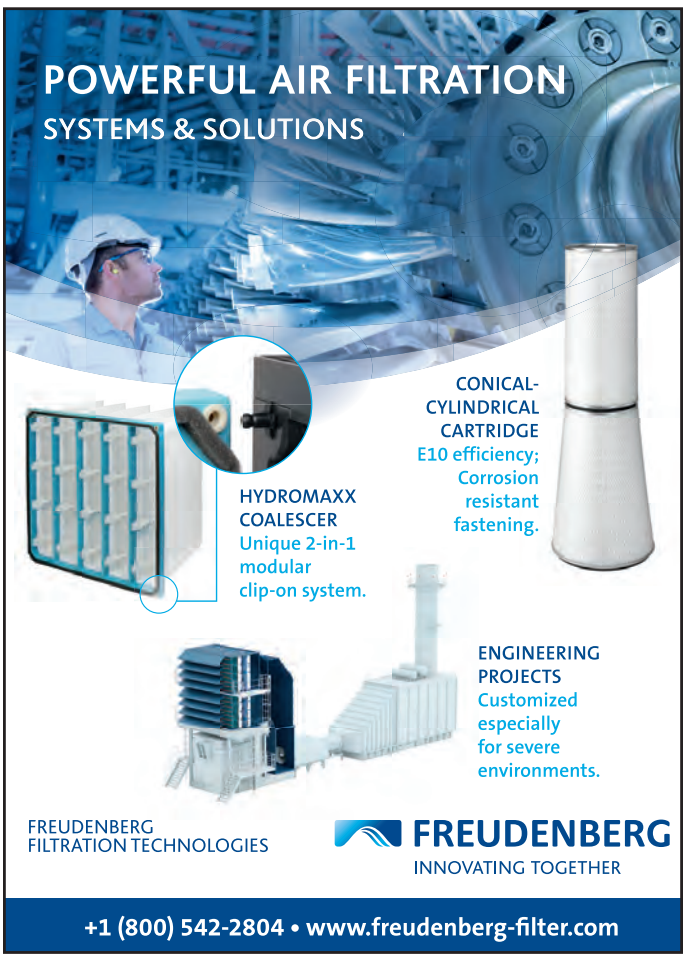
CTCI WINS SUN BA POWER PLANT PHASE 2 CONTRACT

CTCI has won a contract to carry out engineering, procurement, and construction (EPC) work for the Sun Ba Combined Cycle Power Plant Phase 2 Project in southern Taiwan with consortium partner, Siemens Energy. The plant will include a new 1.1 GW generating unit to provide power. As part of plant expansion, CTCI is responsible for the civil works and balance-of-plant. Generated power will be sold to state utility company Taipower.

Siemens Energy's scope of supply includes the plant's power island, consisting of two SGT6-9000HL gas turbines, one SST-5000 steam turbine, three SGen6-2000P generators, two heat recovery steam generators, and the SPPA-T3000 control system. Siemens will also provide long-term service over 25 years.

CALIFORNIA TO INSTALL TEMPORARY GAS GENERATORS

After a decade or more of coal plant shutdowns, and state policy that steadily inhibited gas turbine power plant operations, another summer of rolling blackouts has caused California to have a change of heart. Officials approved a measure to procure five 30 MW gas-fueled generators for "temporary" use to solve the ongoing energy shortfall. Such is the emergency in the state that these units were rushed into immediate operation. A governor's proclamation temporarily eases some of the regulations levied against the energy industry.



BENTLY NEVADA REMOTE MONITORING CENTER

Bently Nevada is opening a new remote monitoring center (RMC) in Singapore to provide remote monitoring and diagnostic services for industrial customers in Asia-Pacific. This will be the first RMC for Bently Nevada in Asia-Pacific and the eighth in the world, supporting services in English, Mandarin, and Malay. The RMC will enable continuous monitoring of assets across offshore oil and gas platforms, liquefied natural gas (LNG) plants, refineries, petrochemical plants and industrial manufacturing sites. Specifically, the RMC's in-house machinery diagnostic engineers will analyze early warning signals for predictive maintenance and provide customers with insights on potential issues and recommended actions.

ASSOCIATED NATURAL GAS PRODUCTION DECLINES

2020 saw a decrease in associated natural gas production amongst the five major U.S. onshore oil producing regions (Permian, Bakken, Eagle Ford, Niobrara, and Anadarko). The Energy Information Administration reports that the share of associated gas in these regions declined by 1.5% year over year and averaged 37.7% of natural gas production. The drop has been attributed to decreased demand. A 9.2% drop in oil production in 2020 led to about 4.1% less associated gas being produced per day – around 14.2 billion cubic feet.

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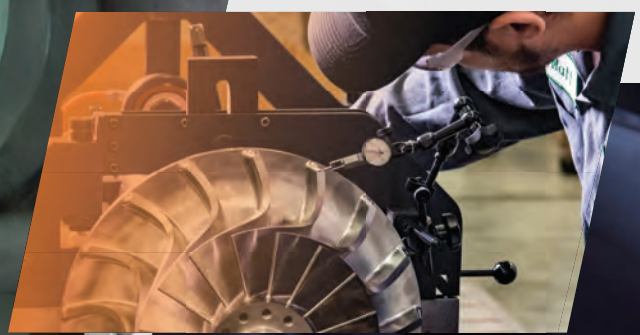

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AUSTRALIAN POWER STATION DECLARED CRITICAL

A proposed $1.3 billion hydrogen-gas turbine power station in Port Kembla, New South Wales (NSW) in Australia has been declared Critical State Significant Infrastructure, given its importance to renewable energy capacity. Minister for Planning and Public Spaces Rob Stokes said the proposed power station would produce up to 635 MW of electricity. The facility had committed to using up to 50% green hydrogen. If approved, the power station could be completed by 2024.

PSEG TO SELL ITS FOSSIL FUEL PORTFOLIO

Public Service Enterprise Group (PSEG) has entered into an agreement to sell its 6,750 MW fossil generating portfolio to a fund controlled by ArcLight Capital Partners. The deal is expected to be completed late in the fourth quarter of 2021 or the first quarter of 2022. The sale comprises 13 generation units in New Jersey, Connecticut, Maryland and New York.

CAPSTONE DIGEST

Capstone Green Energy orders:

- Capstone received a contract for a Capstone Signature Series C1000S system to operate grid-connected on biogas at a wastewater treatment facility in Central America.
- Capstone distributor Lone Star Power Solutions has contracted with a remote data center in Louisiana to provide a long-term rental of a Capstone C1000S microturbine system.
- Capstone distributor Vergent Power Solutions has signed an agreement to provide a 1 MW combined heat and power (CHP) microturbine for a large greenhouse expansion in Ontario, Canada.

NEVADANANO SENSORS IN GAS DETECTION

NevadaNano, announced that Crowcon Detection Instruments uses the Molecular Property Spectrometer (MPS) sensors in its new Gasman flammable gas detection products. A single MPS sensor accurately reports across 19 flammable gases, including hydrogen, with a single factory calibration and no field maintenance. The Gasman allows operators to enter areas where an explosive gas atmosphere is present. In addition, the Gasman with MPS is hydrogen ready. A single MPS sensor accurately detects hydrogen and common hydrocarbons without recalibration in a fail-safe, poison-resistant solution.

MITSUBISHI POWER DIGEST

Mitsubishi Heavy Industries (MHI) and Mitsubishi Power reached an absorption-type split agreement under which Mitsubishi Power will be integrated into MHI. The business operations and employees of Mitsubishi Power were taken over by MHI effective October 1, 2021.

Mitsubishi Power is introducing a global network of Tomoni Hubs that use artificial intelligence to support plant operation and maintenance decision making. They include connected software, hardware and services that provide pre-warning of impending issues or needed corrective action. The network includes hubs in Takasago and Nagasaki, Japan; Orlando, Florida, United States; and Alabang, Philippines, with a fifth Hub to be commissioned in Duisburg, Germany, in the third quarter of 2021. They access secure cloud-based analytics and uses distributed knowledge databases.

Chevron U.S.A. has agreed on a framework to acquire an equity interest in ACES Delta, a joint venture between Mitsubishi Power Americas and Magnum Development. This project will produce, store and transport green hydrogen at utility scale for power generation, transportation and industrial applications in the western United States.

GE DIGEST

GE announced the start of commercial operation for Chia Hui Power's CHP plant in Minxiong Township in Taiwan. GE provided an HA-powered combined cycle plant including power generation equipment, analytics and controls software, and service agreements. The plant adds approximately 535 MW, providing electricity as well as steam for district heating. GE and FieldCore, GE's field services company, collaborated on the project. The power plant is comprised of a single generating block equipped with a GE's 7HA.02 gas turbine powering an H65 generator, a STF-A650 steam turbine powering an H33 generator, and a Heat Recovery Steam Generator (HRSG). GE will provide maintenance services for 10 years.

GE announced that the modernization of Elpedison's Thessaloniki Power Plant in Greece was completed safely and successfully. GE upgraded a GE 9F.03 gas turbine and a Franco Tosi-supplied steam turbine. GE also installed digital solutions to help increase the plant's output by over 20MW (equal to powering 17,000 Greek households) and reduce its start-up costs by 10 percent.

SKF ACQUIRES CONSULTING FIRM

SKF has completed the acquisition of Rubico Consulting, an industrial consultancy firm with 10 employees based in Luleå, Sweden. Rubico specializes in visualization and analysis of signal data. This expertise will be integrated into SKF's offer around the rotating shaft, as well as powering new technology areas such as bearings with fiber-optic sensors.

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MAN DIGEST

MAN Energy Solutions and Woodside Energy have signed a cooperation agreement aimed at commercializing a solution for small-to-mid scale LNG production known as Factory LNG. The concept involves a nominal 0.05 Mtpa unit, the size of 40-foot ISO shipping container, that can be transported via standard heavy-lift shipping and trucking logistics. It also includes MAN's HOFIM high-speed, oil-free, integrated motor-compressor technology as used, for example, in subsea compression-station applications.

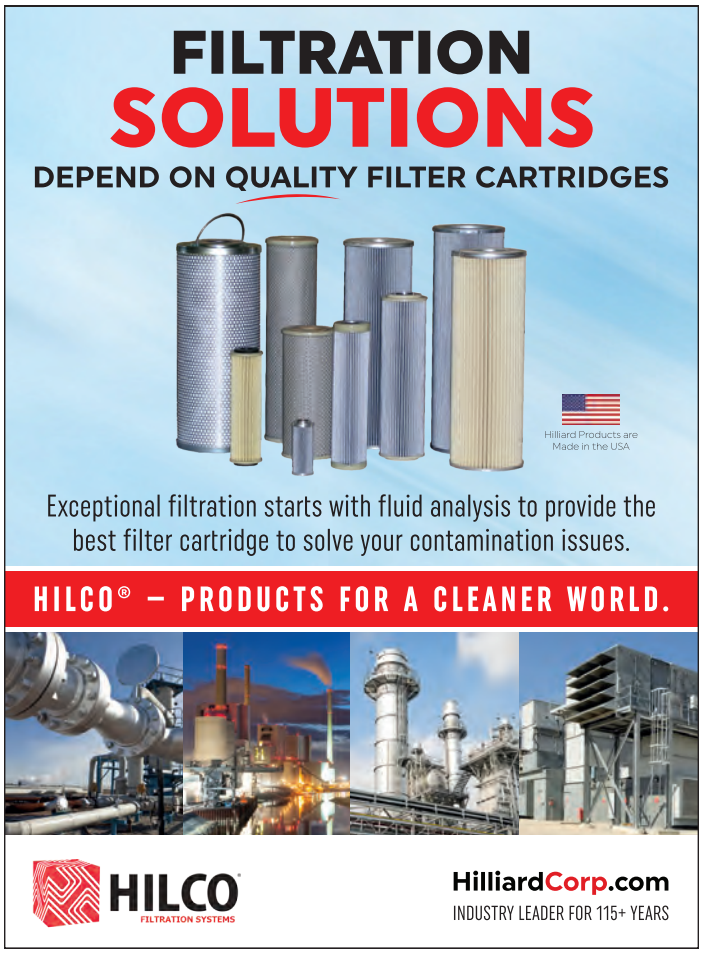
MAN's HOFIM compressor

Aker Solutions has awarded MAN Energy Solutions the contract to supply five subsea compressor units to the Jansz-Io field, located around 200 km off the north-western coast of Western Australia at water depths of approximately 1,400 m. The scope of work comprises the supply of five Subsea HOFIM compressor units, each with compressor frame size RB 45 with integrated MAN motor, size M43. Three compressor systems will be installed into the subsea modules while two further will serve as spare units.

AM PARTS FOR AEROSPACE, OIL & GAS, ENERGY

Vertex Manufacturing has purchased a second additive manufacturing (AM) solution from Velo3D. The first machine processes Inconel 718 and the second is dedicated to Hastelloy-X. As it is not a heat-hardened material, Hastelloy-X doesn't become brittle at high temperatures, and its high oxidation resistance provides durability over many years of continuous use.

Velo3D printer for Hastelloy-X.



ACCELERATING THE LOW-METHANE NATURAL GAS MARKET

Bloom Energy is converting its global natural gas fleet to certified low-leak natural gas to prevent the release of methane emissions stemming from upstream gas production. In addition, Bloom Energy and MiQ will collaborate to test and refine elements of the certified gas marketplace.

Certified natural gas includes verification of methane performance. While progress has been made in recent decades to curb methane emissions, 75% of these emissions from oil and gas production can be eliminated today with little to no net cost. Achieving these reductions in methane emissions is the CO_2 equivalent of replacing 60% of the world's coal-fired power plants with zero-emissions generation.

IHI AWARDED SERVICES CONTRACT

IHI Power Services Corp. (IPSC) has entered into an operations and management (O&M) service agreement with San Francisco-based investment management firm, Panamint Capital to oversee the Nevada Cogeneration Associate No.2 (NCA#2) facility near Las Vegas, and the Cottage Grove Cogeneration plant near Minneapolis. The NCA#2 plant is comprised of an 85 MW 3×1 combined cycle cogeneration facility of three GE LM2500 combustion turbines and one GE steam turbine, supplying waste heat to a neighboring gypsum plant. Cottage Grove is a 245 MW combined cycle cogen facility powered by a Siemens 501FC+ with a Nooter Erickson triple pressure HRSG and a Siemens steam turbine.

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HOW TO SPECIFY TURBOMACHINERY

BY AMIN ALMASI

Before beginning specification, the turbomachinery should be sized. Final sizing will be done by the vendor/manufacturer. But a preliminary sizing is needed for a quality specification: such as specifying a single-stage turbo-compressor when a multi-stage turbo-compressor is not appropriate. There is often more than one turbomachinery type suited to a defined task.

For instance, in many modern compression services both integrally-geared turbocompressors and conventional-type turbocompressors could be used. Once the different turbomachinery types are reviewed, various factors sway the decision. The key point is this: It is quite difficult to write a comprehensive multi-purpose specification. Therefore, some decisions should be made at an early stage such as the type of turbomachinery. The specification can then be written based on these decisions. That specification outlines what the turbomachinery needs to accomplish and how reliable it should be.

UNUSUAL CONDITIONS

Operational conditions should be divided into a set of normal condition(s) and those other than normal (such as alternative, emergency, etc.). Off-design or unusual conditions such as abnormal gas molecular weight (as might be encountered in a startup), a holding period where part of a plant is not in operation, and similar situations should be accurately included and explained. If anything is missed it could lead to future problems.

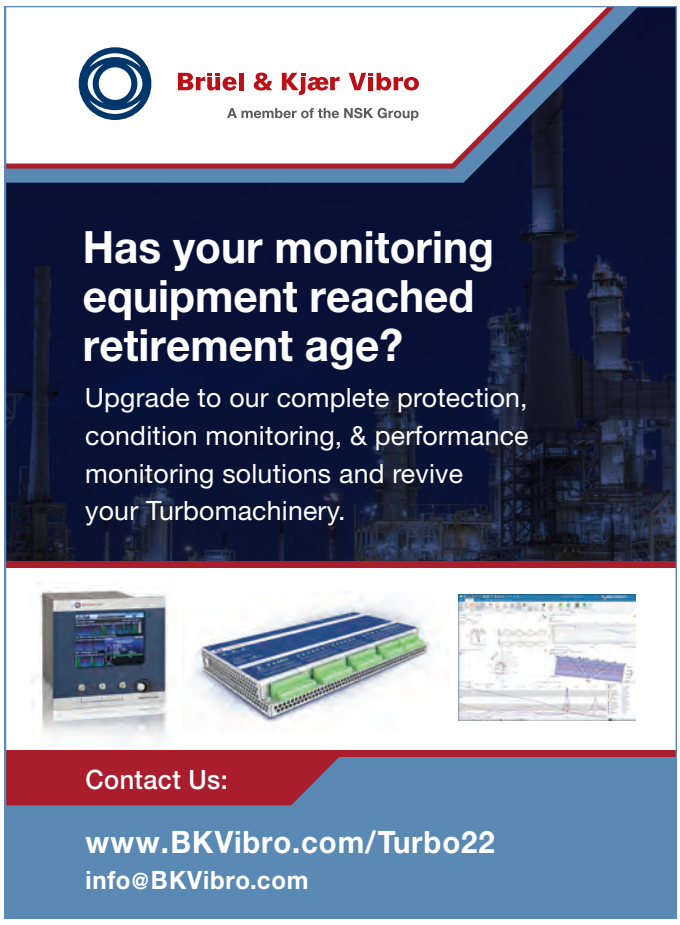
The purchaser generally should know a lot about the plant, the processes involved, and its operation. In particular, the purchaser should be much more aware of unusual conditions, involved risks, and potential upsets. It is unwise to assume that a vendor is completely knowledgeable about the plant or process.

Reference check any previously successful turbomachinery references in similar facilities. However, each plant or unit has its own set of challenges and specific requirements. Note that turbomachinery manufacturers are specialized in machinery design and manufacturing. Their staff, background, structure, and business are not focused on processes or plant operation.

Off-design or unusual conditions should be included in any specification.

If the vendor's engineers have experienced a problem in a process or facility similar to the plant under discussion, they may raise a question. However, this is not often the case. Take fluid temperature runaway potential in hot units. A specification should note some expected maximum temperatures and ask the vendor about the maximum temperature that the turbomachinery can handle.

Past experience of operation could provide guidance concerning requirements such as the material selection. Stating minimum material requirements can help a vendor in part selection. On the other hand, a specification should not be so rigorous that it seriously limits the vendor. Any specification should specify the minimum material requirements and invite manufacturer input based on their experience.



A large number of unscheduled shutdowns are traced back to vendor design, manufacturing, material selection or component selection such as seal problems, bearing issues, excessive fouling, high degradation, corrosion, and erosion. However, many of these issues could be prevented if the purchaser communicated turbomachinery requirements, expected conditions, and technical specifications properly.

One example could be the selection of austenitic stainless steel. This is a premium material, but cannot be used if chlorides are present due to inter-granular corrosion and subsequent cracking problems. All traces of corrosive, sour or problematic materials should be accurately specified by the purchaser to prevent the selection of wrong material.

PRACTICAL GUIDELINES

There have been many discussions whether to install machinery outdoors or indoors. If in doubt, specify an external location without roof or shelter. But later stages can add shelter or a roof if there is a need to increase overall reliability.

Turbomachinery design parameters, such as turbomachinery speed, should be given as the allowable values after enough research and checking into the most recent technologies and modern turbomachinery installations. These maximum allowable values should be insisted upon to keep bidding compatible.

More time is often spent specifying accessories than is spent on the core turbomachinery, mainly because options are so numerous. Some engineers reported that more than 50% of their discussions and communications with vendors have only been about instrumentations, condition monitoring, electrical systems and control items. All items related to electrical, control and instrumentation should be fully specified early in specifications and clarified at the earliest opportunity. Otherwise, lengthy and challenging discussions are to be expected.

Reference: Royce N. Brown, Compressors Selection and Sizing, Third Edition, 2005 (Gulf Publishing, Elsevier).■

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

U.S. POWER INDUSTRY OUTLOOK 2022

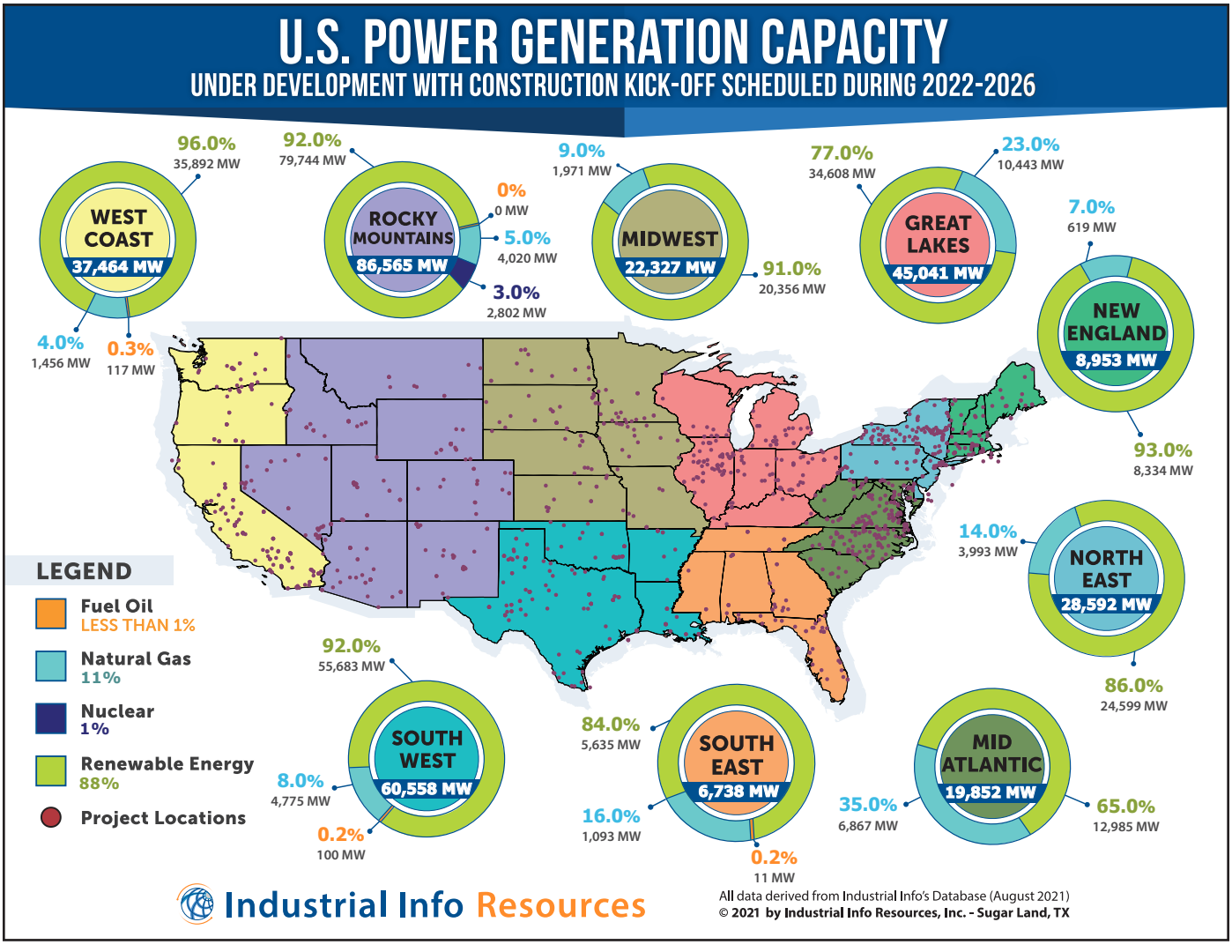
Biden Administration Stresses New-Build Renewables; But Rising Gas Prices Gave New Life to Coal-Fired Generators.

BY BRITT BURT AND BROCK RAMEY

"Elections have consequences," goes the political adage. That was particularly true for the electricity generation business during the first year of the new administration. On Day 1, President Biden issued a flurry of executive orders, including one to make the electric generation business carbon-free by 2035 as a step toward a net-zero carbon economy by 2050.

All federal agencies were instructed to review, with an eye to reversing, all actions taken by the Trump administration that might conflict with or undermine the new president's commitment to decarbonize the electricity business and the broader economy.

"Confronting the carbon crisis" became a catchphrase. In some ways, this follows in the wake of the electricity business, which has been decarbonizing for



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years. That trend has been the product of federal and state tax incentives, state regulatory mandates, and technological gains that have improved the cost competitiveness of renewable energy. A growing preference for no- or low-carbon electricity also continued to gain traction among consumers and businesses during 2021.

A January 20, 2021, executive order revoked several executive orders from his predecessor on energy and electricity. Other Day 1 moves included returning the U.S. to the Paris Agreement and establishing an interagency working group to determine the social cost of greenhouse gases. Former EPA Administrator Gina McCarthy also became the first-ever White House national climate advisor.

"The world must be put on a sustainable climate pathway to protect Americans and the domestic economy from harmful climate impacts, and to create well-paying union jobs as part of the climate solution," the executive order stated.

ENERGY TRANSITION

The U.S. transformation from hydrocarbon-based electric generation to lesser- or non-emitting generation accelerated during 2021, and most experts see further acceleration in the years to come.

Although the COVID-19 pandemic cut overall electricity demand by 3.9% in 2020, the virus did not alter the existing trend to build fewer new power plants that burned coal or gas. For the 2022-2026 period, Industrial Info Resources (IIR) expects renewables will continue to constitute the overwhelming majority of new-build U.S. electric generation projects, accounting for about 88% of all new electric generation capacity. Gas will account for about 11% over that five-year period, with nuclear, fuel oil and coal sharing the remaining 1% of new generation construction (see map).

About 316,000 megawatts (MW) of new-build generation projects are being tracked with a scheduled construction start date between 2022 and 2026. Not all planned projects will be constructed according to their original schedules. Depending on the technologies involved, and developers' ability to secure financing, offtake arrangements, and regulatory support, we typically see between one-quarter and one-half of all announced projects delayed or cancelled. But then again, new projects are announced on a near-daily basis.

While all 316,000 MW of new generation are not expected to be built as announced, the trend for the 2022-2026 period is clear and consistent with long-standing projections: cleaner and greener new-build generation.

And while coal has been out of favor in the new-build market for some time, the black rock certainly came to the rescue of existing electric generators and consumers in 2021.

Once COVID-19 vaccines became readily available, U.S. consumers responded with a vengeance, driving up gross national product (GNP) and with it, electricity demand. For 2021, the U.S. economy is expected to grow 6.6%, and another 5% in 2022, according to mid-year 2021 projections from the U.S. Energy Information Administration (EIA). Based on projected strong economic growth (and assuming COVID is contained), the agency forecasts 2021 electric demand to grow about 2.7%.

Rising electricity demand in 2021 came as natural gas prices were on the upswing, rising about 60% through the first seven months of 2021, to about $4 per million British thermal units (MMBtu). For 2021, the EIA projected gas will average $4.46 per MMBtu.

Generators that could switch fuels increased their use of coal in 2021, driving up coal use about 17% compared with 2020 (Figure 1). The EIA's preliminary estimate of coal use in 2022 by power generators shows a decline of about 9% in 2022, as asset owners switch back to what they assume will be lower-cost gas. But as wave after wave of summer heat drove up electric demand, gas prices similarly went upward while coal stayed relatively flat. Could coal hold onto some of its newfound gains in the electric fuels market in 2022?

Electricity generators drew down on their coal inventories to meet rising demand, according to EIA estimates (Figure 2). Roughly 23% of U.S. electricity was generated by coal in 2021, up from 20% in 2020, the EIA said. In 2022, coal's market share is expected to fall to 21%. Existing coal- and gas-fired generators continued their bare-knuckled fight in the electric fuels market, where a shift of a few pennies per MMBtu can cause generators to swing from one fuel to the other.

New-build coal-fired generation, however, continued to struggle in 2021 and faces a bleak future over the 2022-2026 period. Another recent force increasing King Coal's misery has been the rising influence of environmental,

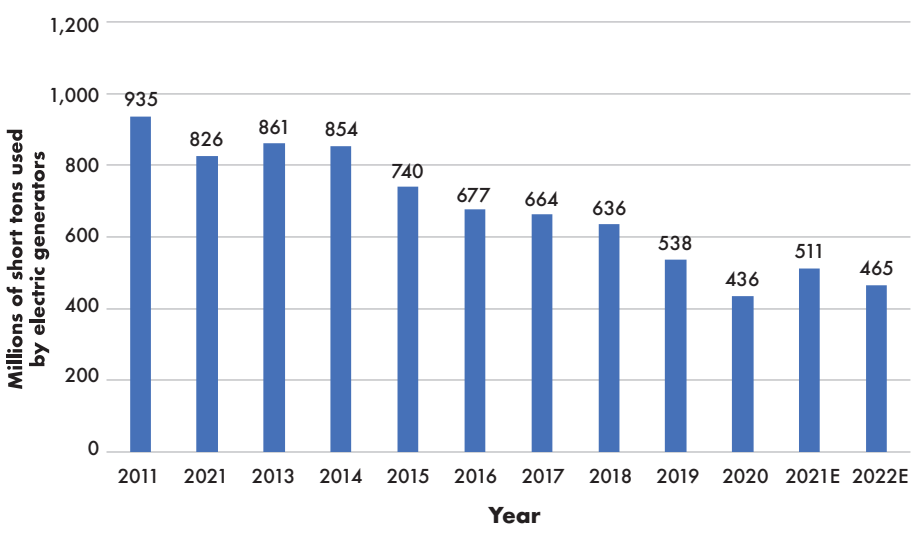

Figure 1: Electric generators expected to increase use of coal in 2021, 2022

Source: Electric Power Monthly and Short-Term Energy Outlook reports, U.S. Energy Information Administration

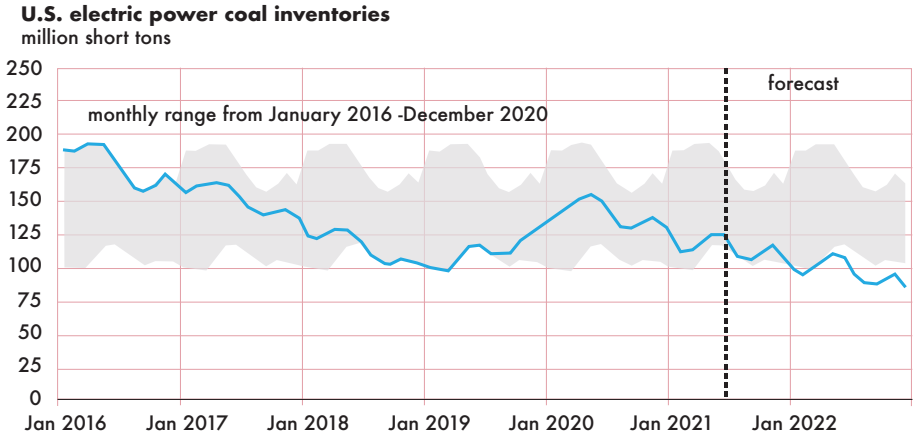

Figure 2: Coal inventories at U.S. generators forecast to fall below five-year average
Source: U.S. EIA Short-Term Energy Outlook (July 2021)

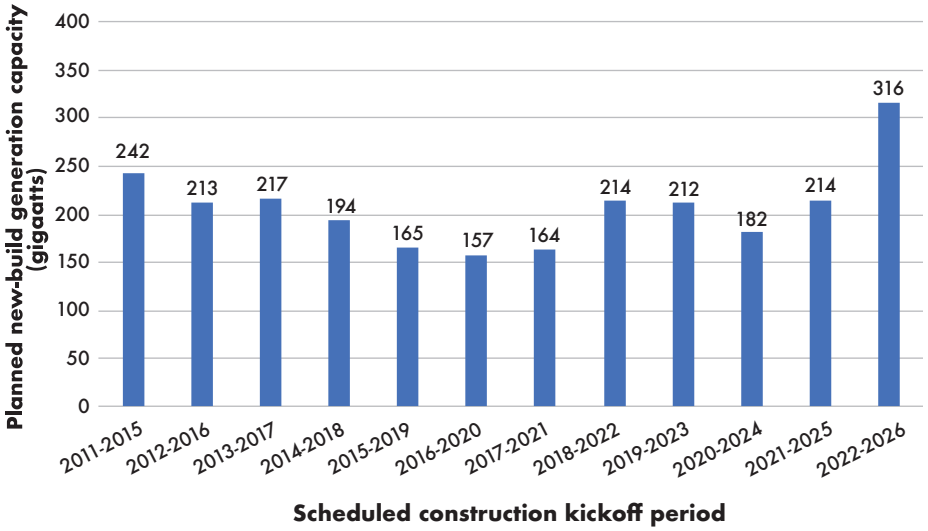

Figure 4: Planned new-build capacity additions jump sharply Source: Industrial Info Resources

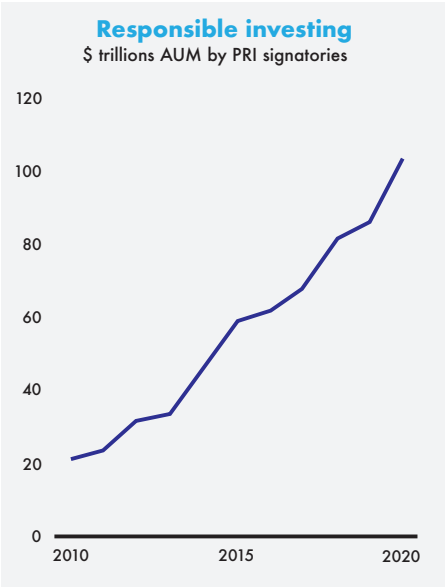

Figure 3: Investors jump onto ESG train
Source: United Nations Principles for Responsible Investment

social and governance (ESG) investing, which effectively bans investment in the coal business. By some calculations, ESG assets under management (AUM) soared to more than $100 trillion by the end of 2020 (Figure 3).

During 2021, generators across the U.S. announced plans to phase out coal in the pursuit of net-zero carbon emissions. That trend is expected to continue in 2022 and beyond.

The Tennessee Valley Authority (TVA), for example, has retired or announced the retirement of about 8,600 MW of coal-fired generation. It is evaluating the impact of retiring the remaining 6,000 MW of its coal fleet by 2035. That retired generation has been replaced by adding nuclear, solar and gas-fired generation as well as upgrading its hydroelectric power stations.

In a mid-year 2021 announcement, TVA said it planned to invest about $1 billion to build new gas-fired combustion turbine generators totaling approximately 1,500 MW. The new facilities will replace aging gas-fired combustion turbines.

In announcing that decision, Jacinda Woodward, senior vice president of power operations at TVA, said, "As we continue to evolve our generation portfolio, natural gas is the right choice at this time because it provides the flexibility and reliability we need to add more solar energy. It's important to remember that solar power is an intermittent generation source, but natural gas delivers reliable electricity even when the sun doesn't shine." TVA will continue to consider natural gas' role in its fuel mix as it studies the closure of its remaining coal fleet by 2035 while adding about 10,000 MW of new solar generation.

TVA's announcement came during a year when asset owners from Oregon to Florida announced plans to accelerate their move away from coal. During 2021, coal plant closure announcements were made by numerous asset owners, including Consumers Energy, Alliant Energy, Vistra, GenOn, Xcel Energy, PPL, Minnesota Power, NRG, Mississippi Power, American Electric Power and Lakeland (Fla.) Electric.

IIR expects a surge in renewable energy construction over the 2022-2026 period, which would push overall new-build generation for that period to nearly 316,000 MW, up nearly 50% from the five-year plans of only one year ago (Figure 4).

COAL OUTLOOK

At mid-year 2021, roughly 42,000 people were working as coal miners, up slightly over the year-earlier number of about 39,700. But the ranks of coal miners have thinned by about 75% since 1985, according to data tracked by the St. Louis Federal Reserve (Figure 5).

In recent decades, employment in industry has been crippled by increased automation of mining, coupled with demand being crushed by ever-more stringent environment regulations, and the rising competitiveness of substitute fuels like gas and renewables.

U.S. generators closed more than 100,000 MW of coal-fired generation between 2010 and 2020, and another 34,000 MW is expected to close during the next five years, according to data tracked by IIR (Figure 6). Though some states, like Wyoming, have tried to erect legal barriers to the closure of coal mines and coal-fired power plants, most observers don't think those laws will be upheld by the courts. Economics more than laws will determine the future of coal and coal-fired generation in the U.S.

Over the 2022-2026 period, construction is unlikely to begin on any new-build coal-fired power plants. Capital spending at coal generators will be for environmental remediation, particularly cleaning up coal ash ponds, and in-plant capital improvements like turbine upgrades.

NATURAL GAS OUTLOOK

Construction on about 35,000 MW of new-build natural gas-fired generators is expected to start during the 2022-2026 period. That's about 11% of the 316,000 MW of new generation that developers plan to begin building during that five-year timeframe (Figure 7). The areas with the greatest amount of planned new-build gas generation are the Great Lakes, the Mid-Atlantic, the Southwest, the Rocky Mountains, and the Northeast. Very little new gas generation is scheduled to be built in the Southeast, Midwest, or West Coast.

Developers and asset owners who have delayed or cancelled gas-fired, new-build generation typically cite "market forces" as the reason for their decision. That covers a wide range of factors, including an inability to obtain financing, reach offtake agreements, or secure transmission rights. As gas pipelines start to run into opposition, stymied gas pipeline projects like the Atlantic Coast Pipeline are another market force with which developers have to contend. Finally, another powerful market force is a state's regulatory regime, and several have turned against gas in recent years.

Renewables will continue to constitute the overwhelming majority of new-build U.S. electric generation projects.

That's certainly the case in California, Arizona and New York, where state commitments to reduce greenhouse gas emissions in the electric sector or increase the percentage of renewable energy in the electric mix work against gas. In addition, methane emissions have emerged as another market force working against natural gas generation. Methane is a much more potent greenhouse gas than carbon dioxide, at least over the short term.

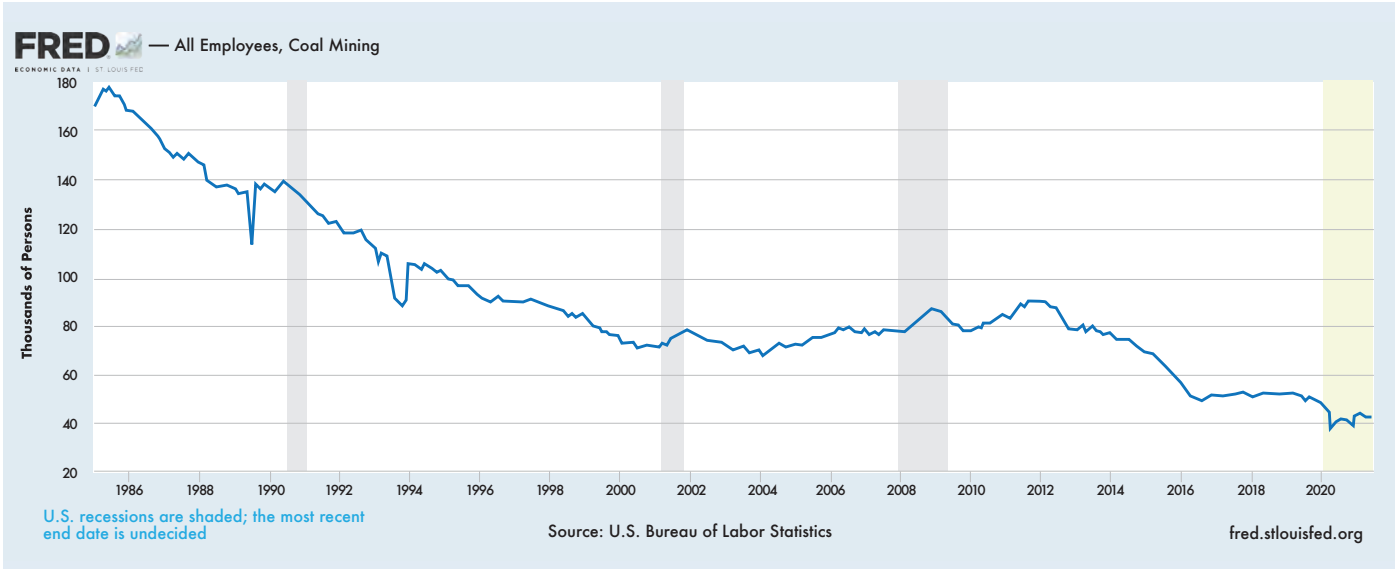

Figure 5: U.S. coal-mining employment rises a bit Source: Federal Reserve Bank of St. Louis

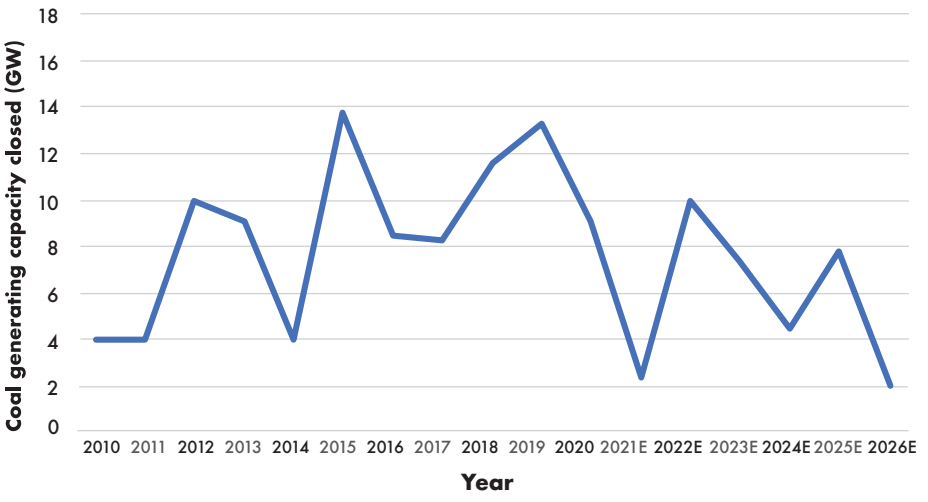

Figure 6: U.S. coal-fired generating capacity retirements, actual and planned
Source: Industrial Info Resources

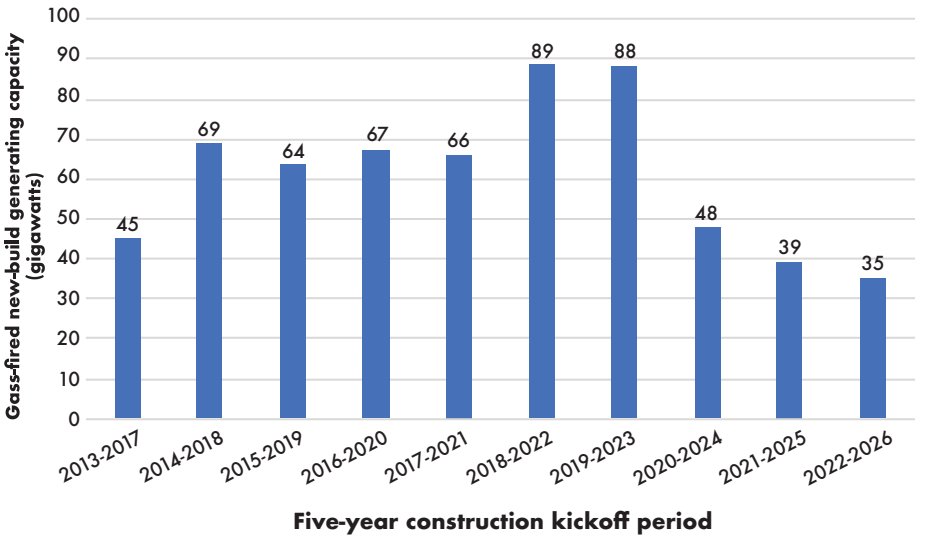

Figure 7: U.S. planned new-build gas generation continues to decline
Source: Industrial Info Resources

The cancellation or delay of approximately 48 new-build gas-fired power plants has been documented in 25 states that were scheduled to begin construction in 2021. The total investment value of those plants was about $12.6 billion. As more states, and possibly the federal government, enact measures that cut against gas-fired generation, the number of new-build generation projects should continue to decline over the 2022-2026 period.

About 35,000 MW of new-build gas-fired generation is scheduled to begin construction between 2022 and 2026. That is down a little over 10% from last year's five-year tally and about 60% less than what was planned to kick off construction during the 2019-2023 period.

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It was not that long ago that the power industry was proclaiming a "dash to gas," as coal plants closed and before sharp declines in renewable energy costs. But recent trends shows a dramatic slowdown in new-build gas generation. Though most U.S. regions show a decline in planned gas-fired project kickoffs, the most dramatic declines are in the West Coast and Southwest (Figure 8).

RENEWABLES OUTLOOK

Gas' loss has been renewables' gain. Renewables are now projected to account for about 88% of all U.S. new-build generation capacity over the 2022-2026 period, roughly eight times the amount of gas-fired generation scheduled to be built over that time (Figure 9).

That gap has widened over time. In 2018 looking at a five-year construction cycle between 2019 and 2023, renewables were scheduled to account for about 57% of all new-build generation scheduled to be built in the U.S compared with 41% for gas. But renewables' improving cost competitiveness stemming from efficiency gains, coupled with a growing embrace by regulators and Corporate America, has widened its lead in the new-build race.

Over the next five years, solar is expected to surpass wind for the first time in utility-scale renewable energy construction (Figure 10). The widespread popularity of rooftop solar, both for residential and commercial settings, is not reflected in Figure 10, so the growing popularity of rooftop solar likely would give that energy source an even larger slice of the renewables' pie.

About 1,450 renewable energy projects are scheduled to begin construction over the next five years. Those projects have a total investment value of about $390 billion.

Again, all of those projects are unlikely to begin construction as scheduled. But over the next five years, the new-build renewable power business looks particularly green in the Rocky Mountains, the Southwest, the Great Lakes and the West Coast (Figure 11).

Nevada and Arizona are the states in the Rocky Mountain region with the largest dollar value of solar projects under development. In the Southwest,

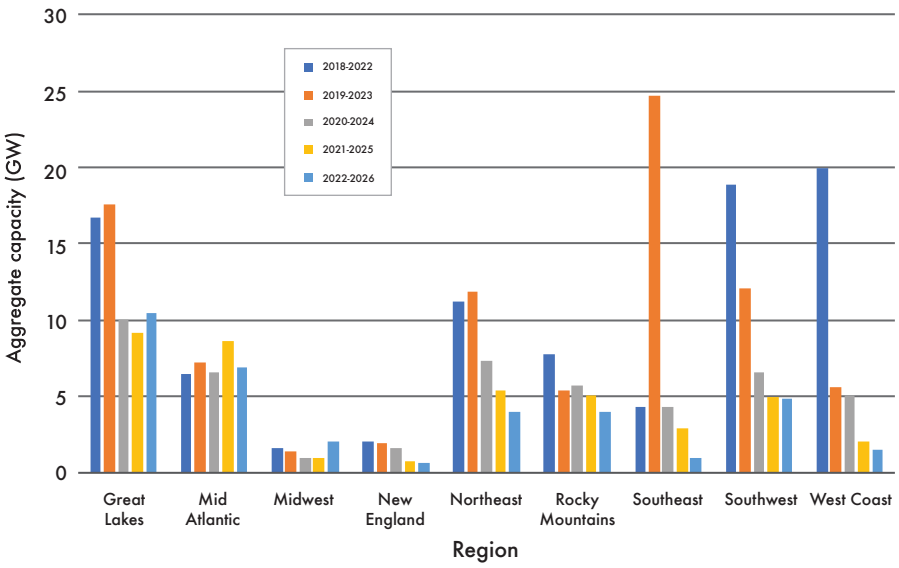


Figure 8: Planned new-build gas-fired generation, by region over five-year periods (GW) Source: IIR

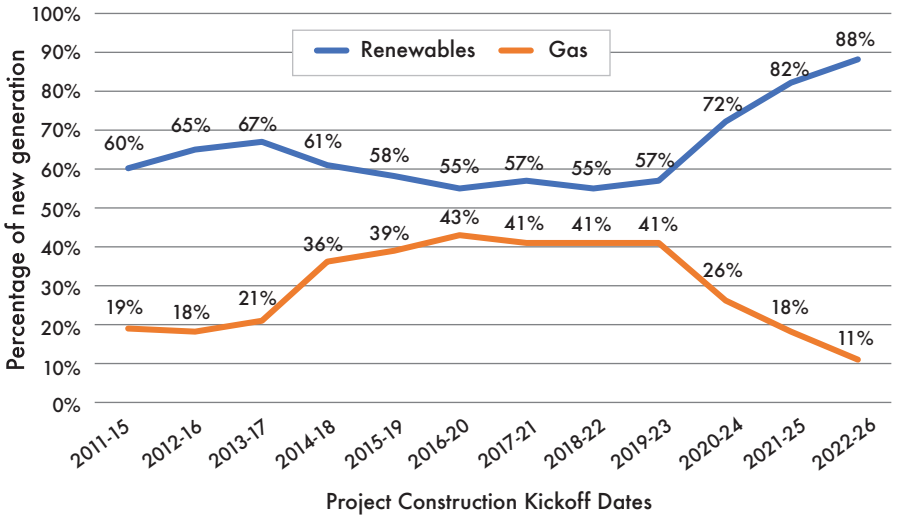


Figure 9: Proposed New-Build Generation, Renewables vs. Gas Source: IIR

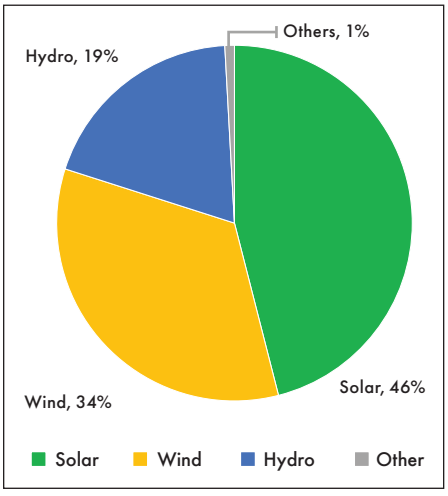


Fig. 10 Planned Renewables Construction, 2022-2026 Source: Industrial Info Resources

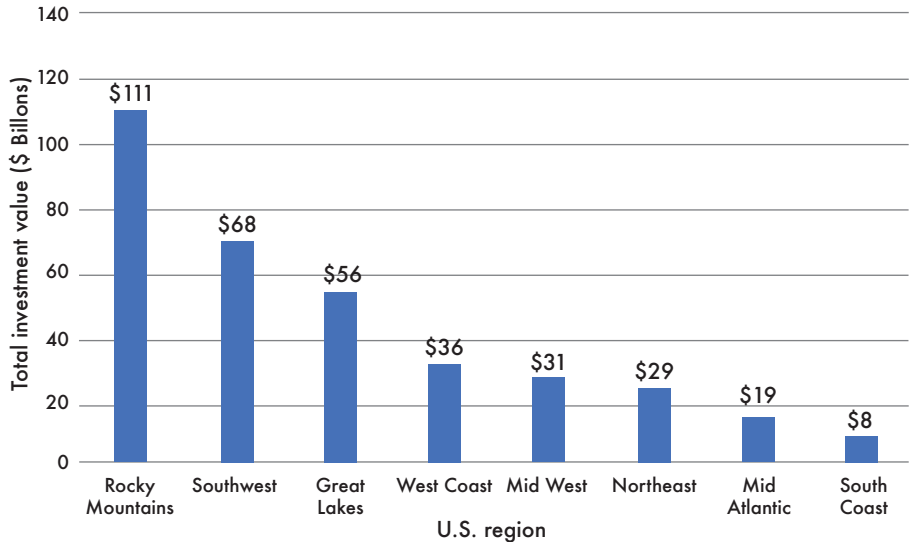


Figure 11: Dollar value of planned new-build renewable energy generation
Source: Industrial Info Resources

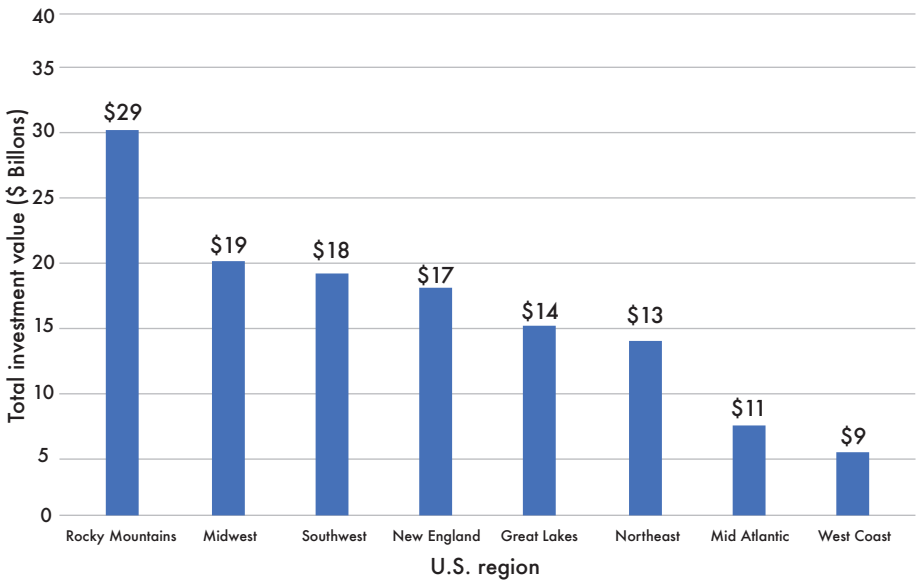


Figure 12: Dollar value of planned new-build windpower, by region
Source: Industrial Info Resources

solar project activity is taking place almost exclusively in Texas. The Great Lakes region also has a robust pipeline of solar projects being developed, with Ohio and Indiana in the lead, followed by Kentucky and Illinois, according to project data being tracked.

Although fewer wind projects are being developed than in prior years, mostly because the areas with the best quality wind resource already have been tapped, the Rockies, Midwest, Southwest and New England are the regions with the largest dollar-value of wind power projects scheduled to begin construction between January 2022 and December 2026 (Figure 12). The Rockies, Wyoming, New Mexico, and Arizona are the regions and states with the largest dollar value of wind projects under development, according to data tracked.

The $390 billion of renewable energy projects under development include 27 offshore wind projects valued at about $39 billion. The Atlantic Ocean is far and away the leading body of water for proposed offshore wind power projects. The Biden administration wants to see as much as 30 gigawatts (GW) of offshore wind power developed in the Atlantic Ocean by 2030.

When politicians try to fight against markets, markets often win. We saw that most clearly in the Trump administration, which unsuccessfully fought against market forces to try to restore coal in the electric fuel mix. But Biden is taking the opposite approach, working to accelerate market-driven changes already well underway.

While in years past renewable energy projects would have had to include the cost of a transmission line to bring the energy to a market hub, several renewable energy projects announced during 2021 plan to be built on or near large shuttered plants to take advantage of existing transmission infrastructure.

Examples are NextEra Energy's plan to construct a 690 MW solar plant next to its closed Duane Arnold nuclear plant in Iowa, and Xcel Energy's plan to build a 460 MW solar plant on the site of its soon-to-be-closed Sherco plant in Minnesota. There should be many more over the next five years. Use of existing transmission lines also enables a developer to fast-track their project around clogged queues in regional markets.

NUCLEAR OUTLOOK

The outlook for new-build nuclear is as bleak as the outlook for renewables is upbeat. The only planned new-build nuclear project, the Blue Castle nuclear power station in Utah, continues to be developed, with a planned construction start date of spring 2025 and a projected start-up date of mid-2032. The Blue Castle project is expected to utilize two 1,100-MW advanced passive reactors from Westinghouse. This project has been on the books for more than a decade, and its projected costs have mounted as its

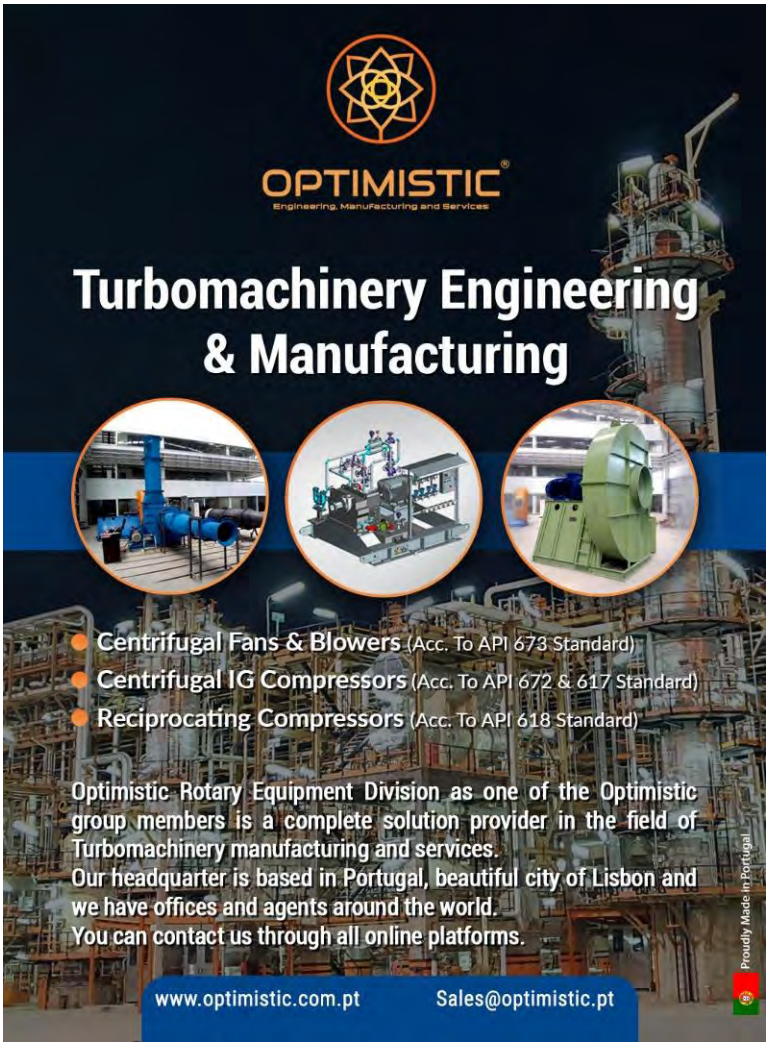
commercial operation date has been pushed back. There is a very low probability of this project ever getting built.

At the other end of the spectrum, a small modular reactor (SMR) project called the Carbon-Free Power Project continues to be developed by the Utah Associated Municipal Power Systems (UAMPS), a group of community-owned electric utilities across the intermountain West.

In 2020, the group received a ten-year, $1.4-billion grant from the U.S. Department of Energy to develop and deploy 720 MW of SMRs in 60-MW modules. Originally, 12 were planned to be built at the Idaho National Laboratory in Eastern Idaho, with construction starting in 2025. But plans for that project were scaled back in mid-2021, as some UAMPS utilities rethought their participation in the project.

Now, the UAMPS project envisions constructing only six modules, but a spokesperson for the group said these modules will be more efficient than previously thought. Instead of 720 MW consisting of 12 60-MW modules, the project now consists of six modules of 77 MW each, for a total of 462 MW.

Across the country in Tennessee, the Tennessee Valley Authority (TVA) is also contemplating SMRs as part of its plan to decarbonize generation. The agency has big hopes for the smaller nuclear generators, but its long-term resource plan does not contemplate construction beginning until 2027 at the earliest.



The only new-build nuclear project still being constructed in the U.S. is the two-unit addition to the Alvin W. Vogtle Nuclear Power Station in Waynesboro, Georgia. Helmed by Southern Company subsidiary Georgia Power, Unit 3 expected to begin operating sometime during 2022. Unit 4 is scheduled to begin operating about one year later.

As the project missed milestone after milestone in recent years, a construction oversight panel filed ever-gloomier reports about the costs and in-service dates of the two new units. A mid-2021 report from that oversight panel cast serious doubt on Georgia Power's projected in-service dates for Units 3 and 4, and said construction costs could be as much as $2.4 billion over the most recent agreed-upon amount.

Whenever those units are finished and whatever their eventual cost, expect a pitched fight at the Georgia Public Service Commission (GPSC) over how much of its investment Georgia Power can recoup from its customers. The unit addition's other three owners, all municipal agencies, are not jurisdictional at the GPSC. But whatever that panel decides about Georgia Power's 45.7% stake in the two new units could cast a long shadow over the other three owners' regulatory decisions about the prudence of that investment, the quality of construction, and the effectiveness of construction management.

The other owners of Vogtle units 3 and 4 are Oglethorpe Power Corporation, a 30% owner, the Municipal Electric Authority of Georgia, which has a 22.7% stake, and Dalton Utilities, a 1.6% owner.

Most of the value of work scheduled to be performed on nuclear plants over the next five years exists at the other end of the product life cycle: dismantling and decommissioning shuttered nuclear plants. A dozen closed nuclear stations are awaiting D&D work totaling about $19 billion.

Roughly two dozen in-plant capital projects for nuclear generators are being tracked, including steam generator replacements, control upgrades, and extended power uprates. The value of this work is about $1.8 billion.

ENERGY STORAGE OUTLOOK

The outlook continues to brighten for battery energy storage systems (BESS) to become a more significant part of today's marketplace (Figure 13). Regulators are providing incentives and allowing it to enter regional markets as a stand-alone generation resource. BESS is utilized for many applications, including: stand-alone generation resource; grid stability; renewable energy utilization; and storage for thermal generation.

Demand for BESS is rising, particularly in areas prone to natural disasters. The fast-paced push in the West Coast and Southwest to integrate these systems into electric markets is another factor creating a boom in this sector.

In ERCOT, there is over 40 GW of BESS in early-to late-stage development being proposed for 2021-2023. This number may decline as projects confront permitting challenges, financing hurdles, and regional transmission constraints.

Another driver for BESS growth is the late-2020 extension of the federal Investment Tax Credit (ITC) for solar energy. The guidelines grant ITCs to BESS assets based on its proximity to solar generation, its ownership, and whether it was being charged at least 75% of the time. The extension of the Production Tax Credit (PTC) for wind energy did not include a BESS provision.

Like many other projects, BESS suffered COVID-19 supply-chain issues. The strong demand growth for lithium may act as a limiting factor in the near term, as projected demand for that metal, used in electric vehicles, cell phones, smart devices as well as battery energy storage projects, far exceeds estimated supply. There have been calls to expand lithium processing facilities in the U.S., but any such project would be years away from commercial operations.

About 3.5 GW of battery energy storage that will become operational in 2021 is being tracked, an 80% increase over the capacity that began operating in 2020. Another 4.3 GW of BESS capacity is slated to come online in the U.S. by the end of 2022. The West Coast and Southwest are the regions with the highest level of project activity for BESS.

U.S. large-scale cumulative battery storage power capacity, 2003-2023

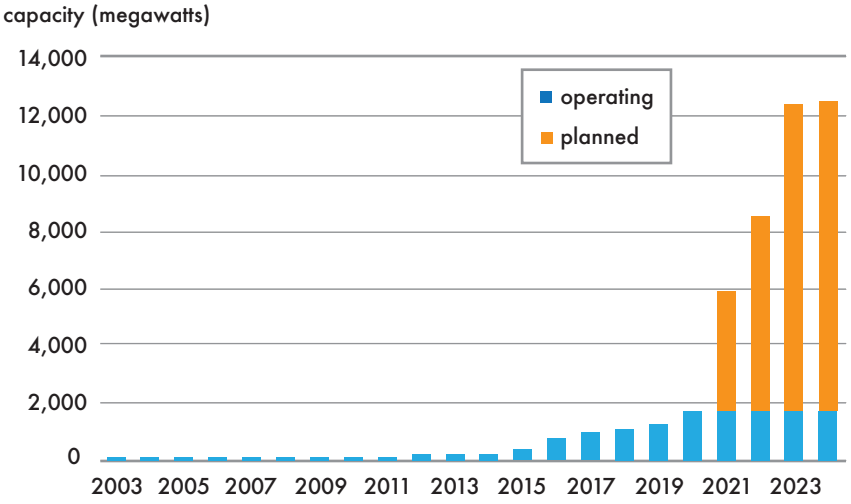


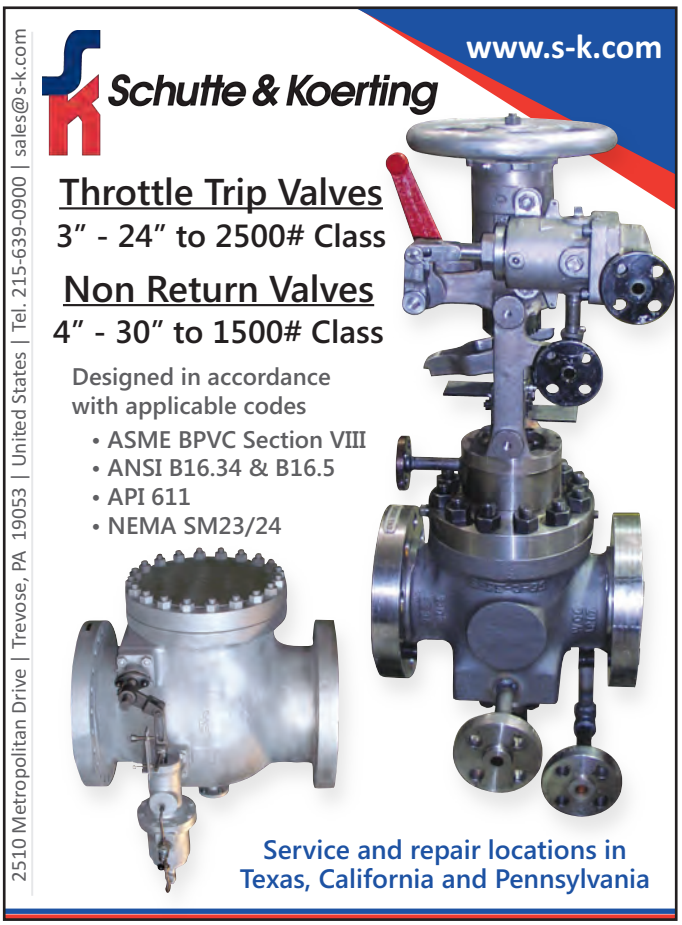
Figure 13. Sharp increase expected in deployment of battery energy storage systems
Source: US EIA

MICROGRIDS OUTLOOK

Currently, the U.S. has 115 operational microgrids that include over 2 GW of generation, according to the EIA. The referenced microgrids range from a segment of 500 kW to more than 100 MW.

Right now, these microgrids are being installed at military bases, universities and colleges, hospitals, police, fire and first responder stations, industrial complexes, government centers, and other settings where a high value is placed on having uninterrupted power. The annual spend to install microgrids is expected to be just below $1 billion in 2021.

The pandemic dramatically slowed the deployment of microgrids in 2020 and 2021, and may not see a rebound until the pandemic and all its variants is conclusively defeated. COVID created a near-term pause in deployments, but growth should resume, possibly by mid-2022. The regions with the highest interest in microgrids are the West Coast and Southwest.



Natural disasters and prolonged power interruptions tend to drive microgrid deployment decisions, and there has been no shortage of natural disasters and power outages in recent years. Years of wildfires in the West, flooding, hurricanes, and the Texas grid breakdown of February 2021 are likely to lead a wider appreciation of the benefits of microgrids that utilize distributed generation such as solar or wind plus BESS.

The cost of a microgrid will not be irrelevant in a company's or agency's planning. But we expect more projects will achieve financial viability when entities sharpen their proverbial pencils and take a closer look at the cost of a microgrid compared to the cost of power interruptions or unreliable power.

Utility-scale microgrid projects, on the other hand, have encountered a variety of headwinds — including regulatory, permitting and financing — in recent years. Those headwinds have caused many projects to stall or be shelved. Construction costs continue to be a high hurdle to overcome at an estimated $2.6 million to $4 million per installed MW of capacity.

State and federal grants for research & development have supported microgrid deployment. Congress is scheduled to consider a clean energy bill that includes up to $1.5 billion for microgrid R&D grants. About $2 billion in planned microgrid spending for 2022 is being tracked, a doubling of planned spending for 2021.

DISTRIBUTED GENERATION OUTLOOK

Over the last several years, distributed energy resources (DER) have become a more important element of the power generation business. As a category, DER includes a wide range of assets in smaller-scale settings, typically less than 10 MW in size. Types of DER include: small combined heat and power (CHP) units; wind; solar; battery storage; flywheel; biomass; waste-to-energy incinerators; small hydropower; fuel cells; reciprocating internal combustion engines (RICE); and generation that is part of a microgrid.

DER also includes onsite power generation located at industrial or institutional sites such as colleges, universities, chemical processing plants, refineries, medical centers, military bases, manufacturing plants, and more.

More than 29 GW of DER generation currently under development across the country is being tracked, with an additional 1.4 GW of generation in the early planning stage, with possible deployment by 2022-2023. The regions with the largest planned spend on DER are the Southwest, Northeast, and Rocky Mountains.

Orders 828 and 842 from the Federal Energy Regulatory Commission (FERC) determined that DERs deserve to be compensated if they provide generation or frequency support. Utility generation owners continue to have some concerns about FERC Order 842.

In September 2020, FERC issued Order 2222, which expanded the definition of DER to include rooftop solar, electric vehicle charging system (EVC), and other micro-generation sources when coupled together. FERC followed that order with 2222-A, issued in March 2021, which removed other barriers to aggregated DERs in wholesale markets.

LOOKING AHEAD

It is unclear whether full decarbonization of the U.S. electricity business can be achieved by 2035. But in the current business climate, decarbonization doubters have largely gone underground. Those advocating cleaner and greener power are driving the narrative. ■

Britt Burt is Vice President of Global Power Industry Research for Industrial Info Resources (IIR), which is headquartered in Sugar Land, Texas, and has six offices in North America and 12 international offices.

Brock Ramey is North American Power Specialist for IIR, which provides global market intelligence for companies in the power, heavy manufacturing and industrial process businesses. For more information see www.industrialinfo.com or email powergroup@industrialinfo.com.

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WORLDWIDE MARKET REPORT

Gas Turbine Sales Forecast for the Coming Decade

BY CARTER PALMER

This Forecast International market analysis of gas turbine-powered electrical generation projects that sales over the period 2021-2030 will total $107.705 billion. The prospect of recovery is convincing; however, 2021 might be stagnant with a similar outlook to 2020 due to the lingering COVID-19 pandemic. The dominant response has been to keep most workers home and severely restricted the movements of the rest. Depending on the geographical region, it remains to be seen if further lockdowns will be implemented.

Yet despite COVID-19, it will be a short-term impact only and is already being quickly absorbed. Some countries will differ in their recovery. Therefore, production in Europe, Asia and the Americas might differ slightly. But a medium-term recovery is projected.

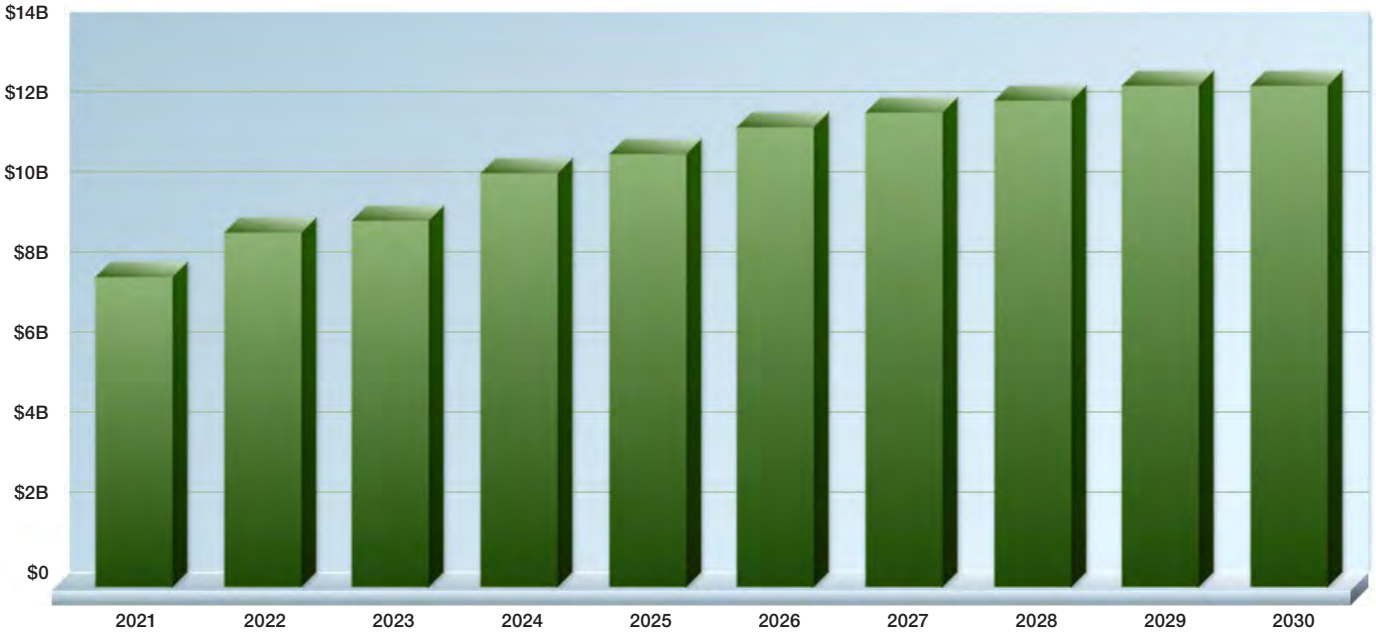
In the power generation sector, the initial result was a significant decline, estimated at between 19 and 21% in energy demand as industrial facilities shut down. These developments have led the U.S. Energy Information Administration (EIA) to project that a total of 4.9 GW of previously planned capacity expansions will be delayed into at least 2021 or 2022. Natural gas consumption in the United States decreased in 2020 with some recovery likely in 2021.

Still, it is apparent from both the EIA analysis and our own data (which largely supports the EIA assessment) that the impact of COVID-19 on the power generation equipment industry is surprisingly limited at this time. It is mostly expressed as a delay of projects rather than a dramatic reduction in demand. It is a shallow, short-term dip in the recovery from the much more severe recession that has afflicted the industry since 2014. This situation may change if there are additional waves of the pandemic.

MARKET RECOVERY

The extent of the market collapse over the last six years is remarkable. The

Gas Turbine Electrical Power Generation
Value Statistics 2021-2030
Forecast



The recovery of gas turbine sales from the current slump will begin slowly and could take another year or two to really become evident. But by 2024, a resurgence in the market will be clearly evident, continuing for the rest of the decade.

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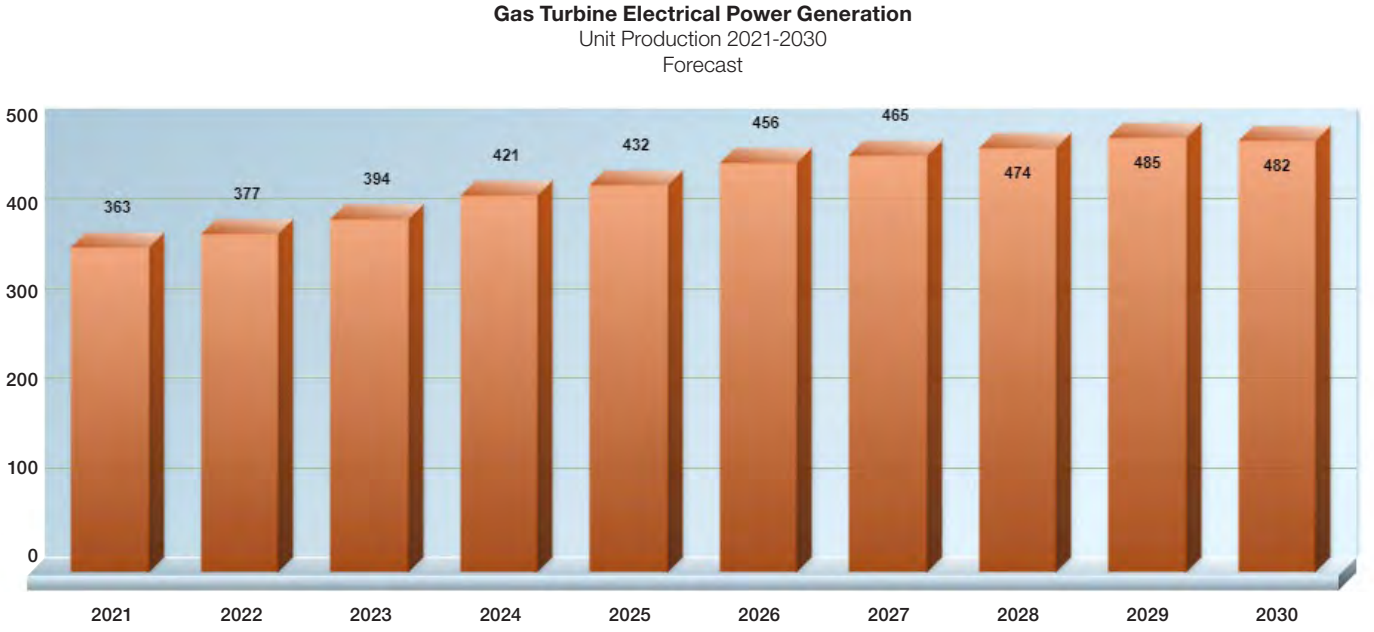

Like dollar value, unit production of gas turbines worldwide is beginning a slow recovery. But by 2024, sales will have jumped significantly from today's level. This is projected to peak around 2027 and remain flat at a higher level for the remainder of the decade.

estimated size of the market in this year's market overview is just 48% of the figure recorded in 2014. When Larry Culp became CEO of GE in October 2018, he quoted a similar figure as part of the reason GE had suffered so severely during this period. Siemens' assessment in 2018 estimated falling sales and industry production overcapacity to be in the same general ballpark.

This sharp fall is a direct result of the spreading crisis caused by overcapacity in the power generation equipment sector and the resulting softness of prices. In short, companies are selling significantly fewer power generation gas turbines than they had predicted and receiving a lower unit price for each sale.

As a direct outcome, all three of the leading companies in the power generation equipment sector – GE, Siemens, and Mitsubishi Power – undertook restructurings to reduce costs and rationalize production. In an inevitable result, these companies announced redundancies. Yet these measures proved of only limited effect; a more fundamental reorganization of the sector appears to be taking place.

General Electric has adopted a different strategy with its former Baker Hughes subsidiary. GE has divested itself from the oil & gas industry whereby Baker Hughes currently supplies gas turbines for compressor drive and power generation for that market. This is evident in that the relatively new LM9000 is marketed solely by Baker Hughes.

The former Mitsubishi Hitachi Power Systems (MHPS) was subject to a different process. It was apparent for some years that the formation of the Mitsubishi-Hitachi joint venture had generated neither the business opportunities nor the technology benefits expected. In addition, the two companies were heading in different directions, with the opportunities for synergistic growth declining quickly. Representatives of Mitsubishi Heavy Industries (MHI) interviewed at trade shows made little effort to hide their disillusionment. In the early months of 2020, MHPS ceased to exist, to be renamed Mitsubishi Power. This has been consolidated further in 2021 into the fold of MHI.

Similarly, Siemens spun off all of gas turbines into Siemens Energy. However, unlike GE, the turbines offered seem to cover both the Power Generation and oil & gas industries as mechanical drive machines are still offered.

It is apparent that the impact of COVID-19 on the power generation equipment industry is surprisingly limited at this time.

Often overlooked within the gas turbine market are the Eurasian countries of Ukraine and Russia. In regard to power generation, this is often attributed to a limited area of sale. Currently, Russia generally sells to Russia with Ukraine selling to

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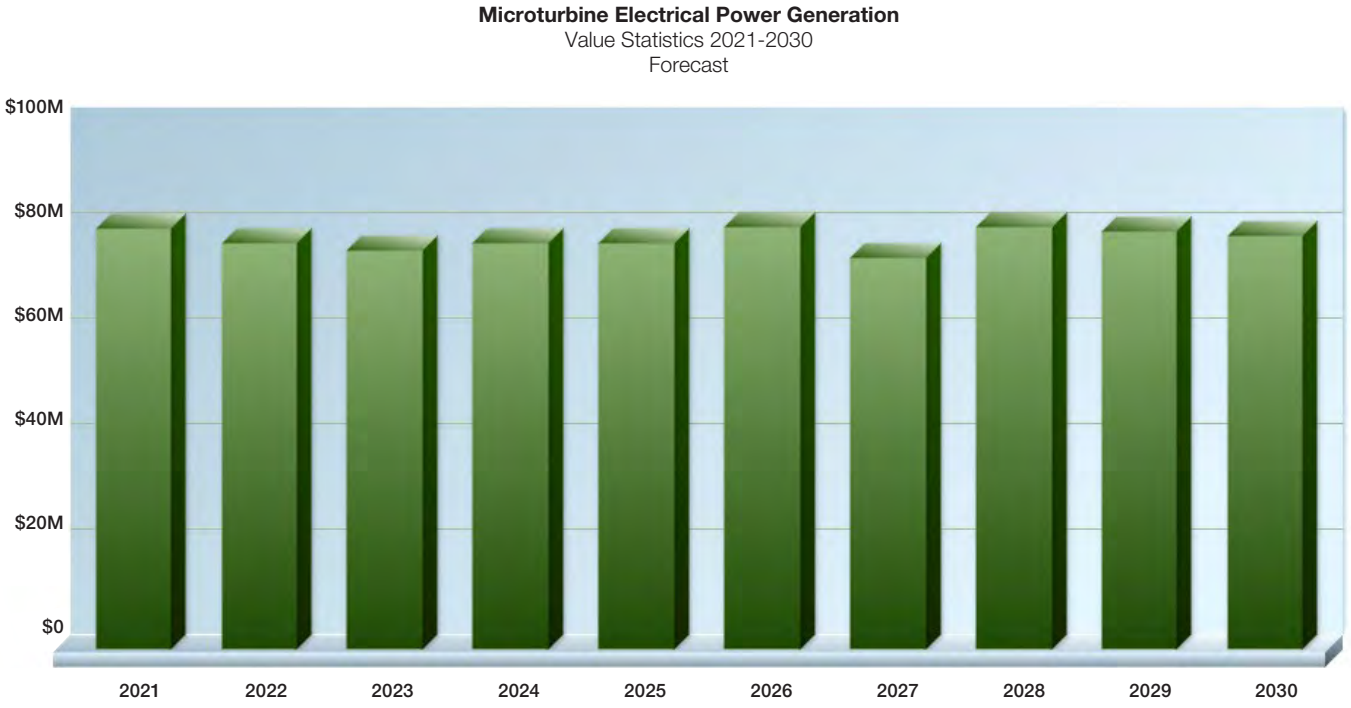

Microturbine revenue is relatively flat, but total units produced has been expanding.

slightly more customers. Licensed production usually takes the place of physically sending turbines to international operators. There is ittle information avaialble from United Engine Corp. of Russia and Zorya-Mashproekt of Ukraine. But it seems that within both countries, maintaining machinery with some limited production in the power generation field is the current state of affairs.

From a global perspective, the impact of reduced demand, overcapacity, and soft prices will slowly work itself out of the market. A recovery will take place. Natural gas and renewables will continue to gain ground over the next ten years thus securing the gas turbine's place in the power market. COVID-19 means this recovery will be later than originally projected, but it will be slightly stronger as delayed projects finally get underway. Once the middle- and far-term periods are reached, the industry will be dominated by large combined-cycle facilities in the industrialized nations, notably Japan and countries in Europe and Asia.

Natural gas and renewables will continue to gain ground over the next ten years thus securing the gas turbine's place in the power market.

MICROTURBINES

In the period 2021 to 2030, Forecast International is projecting a worldwide unit production of 8,446 microturbine electrical power generation units, a significant increase over earlier projections of about 3,800 units. Value of production is projected to be $779 million.

Reference to 2017 is important, as that was a pivotal year in the microturbine market. The increase in unit production and the decrease in average unit price are attributable to new, very small microturbines currently coming to market. Although they do not add much to the 2021-2030 overall value estimates, their production numbers are significant.

Microturbines have generally grown in power output over the years, and that still holds true. When they started to become a significant market factor in 1999, the average unit on sale had a power output of about 35 kW. Ten years later, this had increased to approximately 100 kW, and it is now approaching 150 kW. There is even a 400 kW stand-alone machine; however, it is not in mass production. There is no indication that the trend of power increases is slowing. There are, however, microturbines going in the other direction.

A trend is developing in Europe toward very small turbine applications. There was a time when microturbines were too powerful for a private residence. But times are slowly changing. MTT's EnerTwin produces 3.2 kW of electricity and 15.6 kW of thermal power. This puts the machine in a prime position to be utilized in smaller buildings. These new turbines change the forecast significantly. Between 2017's projection and this current analysis, unit production increases significantly, average unit value decreases significantly, and the total value for the forecast period remains nearly the same.

These new small machines from the likes of MTT and Bladon might change the landscape somewhat, but previous trends still hold true: microturbines have become more powerful, more fuel options are becoming available, and Capstone is still the market leader in terms of value.

Today, microturbines are primarily used for remote power applications in the oil and gas industry and for cooling, heating, and power (CHP) and combined CHP (CCHP) applications in the commercial, industrial, and residential high-rise markets. The success of Bladon's 12 kW machine would add power in remote locations to the list. An increasing energy demand-supply gap, a rise in the adoption of low-emission power generation sources, and the need to generate power cost-efficiently are some of the factors that will hold microturbines' place in the market globally. ■

Carter Palmer is Industrial & Marine Turbine Analyst at Forecast International, a provider of market intelligence forecasting, proprietary research, and consulting services for the Aerospace, Defense and Power Systems industries. Forecast's Platinum 4.4 information and analysis service was used to compile this report. For more information, visit www.forecastinternational.com

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CENTRIFUGAL PUMPS

Failure Investigation, Remedies, and Mitigation of a Centrifugal Pump

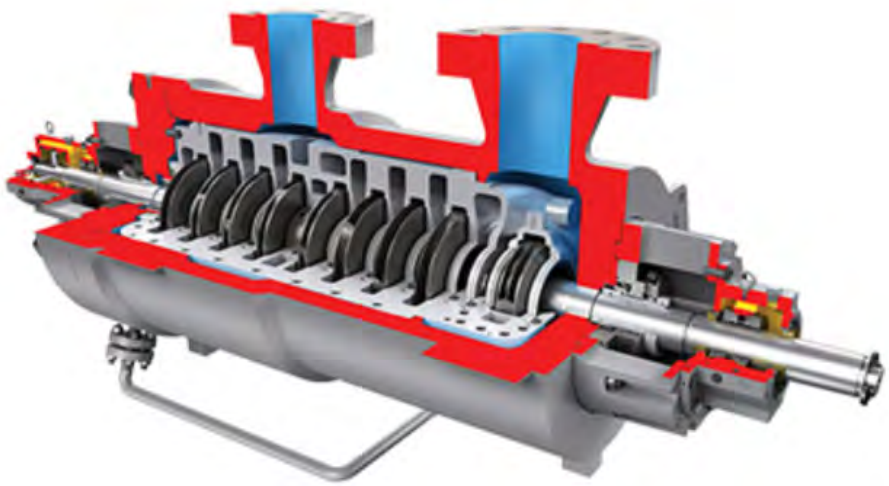
BY LUIS INFANTE & RODOLFO ALVARADO

A high energy pump at a water injection station in El Furrial, Venezuela exhibited extremely high vibration levels prior to an overhaul. It then suffered a catastrophic failure during startup following overhaul. The hydrodynamic bundle, rotor, and drive end (DE) bearing suffered damage.

This centrifugal pump is a 3,000 HP, double-case volute, boiler feed water pump type. It has nine stages, outputs 750 gpm of water with suction pressure 1800 psi and discharge pressure 5250 psi. Rated speed was increased from 6000 to 6600 RPM to enhance the hydraulic performance. However, the pump's actual discharge pressure was about 4,500 psi, well below the target value of 5,000 psi. The coupling was reportedly poorly fitted.

The increased RPM created rotordynamic concerns of getting closer to a critical speed, thus the operator wanted to know about the synchronous regime. The operator also wanted remedial measures and temporary mitigation steps to keep the pump running for 4-6 months until remedies were finally enforced.

The course of action for this investigation was clear since the beginning: conduct an internal clearances analysis and a forced response rotordynamic study.



High energy pump for boiler feed water. Courtesy of Flowserve

A thorough study of internal clearances was conducted. Table1 shows the results from this study featuring a comparison between internal (hydrodynamic bundle) clearances from different data sources, namely: design data, shop measurements, API-610 minimum clearances, and typical clearances for a similar pump with vibratory problems. As a result, the recommended clearance for the center seal, balance piston, eye, and impeller hub seals are shown in the bottom part of Table 1.

Due to the high vibration levels (20 mil DE, 5 mil NDE) reported before the overhaul, a simulation of the pump's forced response rotordynamic behavior was attempted using a trial unbalance weight located in the coupling. A mass-elastic mathematical model incorporating the effect of the internal seals at 1X and 2X design clearance (as suggested by API 610) was used for this purpose.

One can expect a flexible rotor behavior (first critical speed below operating speed) for this high-speed, long slender shaft, but the stiffening effect provided by the internal seals (Lomakin's effect) locates the first critical speed in the

Table 1.- Analysis of internal clearances

	DIAM - INCH						CLEARANCE - MIL				C/D RATIO - MIL/INCH			
	Shaft	Imp.	Piston	Central	Eye	Hub	Piston	Central	Eye	Hub	Piston	Central	Eye	Hub
Design	2.6	9.1	3.8	4.2	6.1	4.5	13	14	15	15	3.5	3.2	2.5	3.3
API - Min							13	15	18	15	3.5	4.0	4.8	4.0
Typical	2.4	9.3	4.1	3.5	5.5	4.5	15	12	19	19	3.7	3.4	3.5	4.2
							Shop Survey ===>		13					
							Shop Survey: ===>		10					
Recomm.:							Piston	Central	Eye	Hub				
Enlarge clear. to API +50% impellers 1 - 4 ==>								23	27	23				
Enlarge clear. to API + 25% impellers 5-9 ==>							16		23	19				

vicinity of 9,000 RPM, well above 6,600 RPM operating speed. Retrofitting the bearing and coupling with the technology presented below raises this first critical speed to approximately 10,000 RPM, thus discarding the likelihood for resonance despite the steep vibration plot obtained during a ramp up vibration survey.

Remedies and Mitigation

Our attention was focused on balancing and the effect on the dynamic stability of the rotor-bearing-support substructure. A bearing and coupling retrofit was recommended with a balancing plane on the coupling and an added mass on the bearing housing. It was discovered that the shaft was excessively long on the DE. Shortening the shaft together with a reduced moment coupling proved to be beneficial in keeping rotor synchronous response away from resonances. Such coupling design has a center of gravity and flex discs moved closer to the bearing.

A tilting pad bearing is a good option for stability and support of this slender high-speed shaft. A pad load distribution analysis showed increased clearances unloading the top pads and the six-pad arrangement offered the best support. Furthermore, a lateral stability analysis revealed six-pad bearing to have the best stability parameters (whirl mode, log dec, amplification factor, undesirable speeds).

Effective mitigation measures that ran for a few months with acceptable vibration levels turned out to be:

1. Add 150 lb to the bearing housing;
2. Increase internal clearances and bearing clearances (max 6 mil);
3. Finning the bearing housing ribs for enhanced heat dissipation;
4. Using the coupling as a balancing plane; adjusting and balancing the coupling; and
5. Correct bearing housing distortion.

Conclusions

The most likely cause of failure was attributable to tight clearances found in the hydrodynamic bundle's internal seals. OEM design and even API clearances were considered to be too tight. Reducing internal clearances below API 610 recommendations exposes these pumps to catastrophic failures during start up. For the impeller eye, we recommend a 50% increase (to 27 mil) over API values for stages 1–4 and a 25% increase (to 23 mil) for stages 5–9. Clearances for other rotor locations are shown in Table 1.

Trimming the shaft in the DE side and installing a reduced moment coupling helps in separating the operating speed from the first critical envelope, thus reducing the amplitude of vibration. ■

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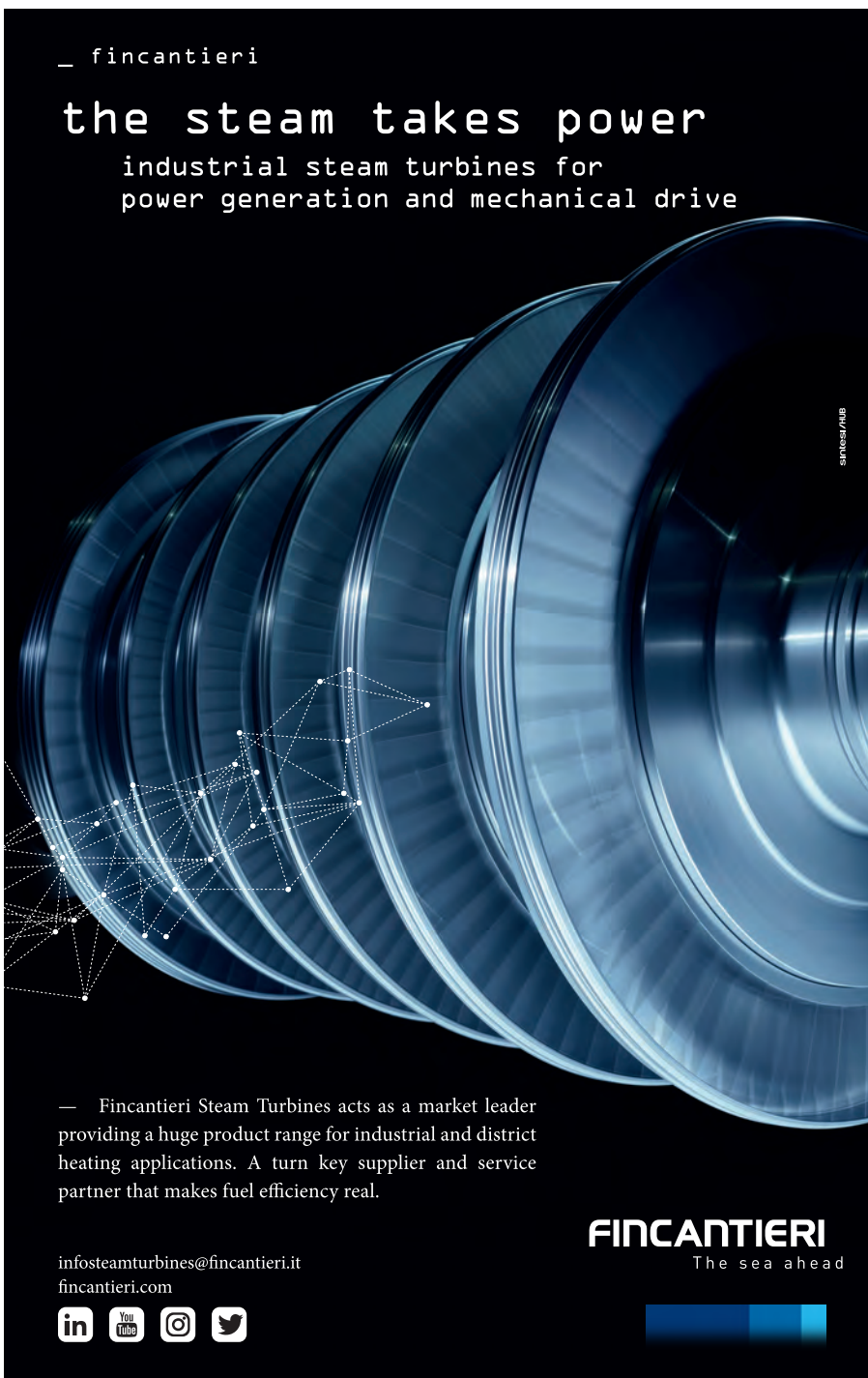

INTEGRALLY GEARED COMPRESSION, DECARBONIZATION, AND EMERGING MARKETS

Ulrich Schmitz, Vice President of Marketing Atlas Copco Gas and Process, discusses integrally geared compression, and how the company is responding to emerging markets for decarbonization, hydrogen, and CCUS.

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Gas and Process is a division within the Sweden-based industrial group Atlas Copco, which has about 40,000 employees. Gas and Process is part of the Compressor Technique business area. We provide centrifugal gas compressors according to API 617 chapter 3, as well as turboexpanders per chapter 4, air compressors according to API 672, API 610 centrifugal pumps, and gas screw compressors.

Gas and Process is active in all segments of hydrocarbon processing, power generation (both conventional and renewable), industrial gases, as well as new energy and circular economy markets. It has production facilities in Germany, the United States, India, China, Canada, and Korea, and offers its corresponding aftermarket services worldwide.

Traditionally, Atlas Copco Gas and Process has deep roots in air separation. We are still very active in this growth market; it is currently fueled by tremendous growth in chip and electronics production, for example, and this industry's need for air and nitrogen. But today, the the majority of our business comes from hydrocarbon processing.

TELL OUR READERS ABOUT YOUR INTEGRALLY GEARED TURBOCOMPRESSORS.

Integrally geared compression (IGC) has been used successfully for more than 70 years. It is the core technology offered by Atlas Copco Gas and Process. IGC was originally developed for air separation and has seen growing use in chemical/petrochemical driven by several factors: Advances in dry gas seal technology, modern aerodynamics, rotor dynamic and thermodynamic knowledge; and advanced manufacturing and testing methods producing accurate rotating parts and complex components at reasonable cost.

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the move towards carbon capture, utilization, and storage (CCUS). These factors drive R&D efforts of turbomachinery OEMs as they advance CO_2 and hydrogen compression.

Hydrogen is challenging because of its physical properties and low molecular weight, as well as possible hydrogen embrittlement. But it provides many new opportunities.

For CO_2, Atlas Copco Gas and Process is focused on: using the existing and available CO_2 molecules such as CO_2 post-combustion processes; and blending CO_2 with hydrogen.

WHAT DO YOU OFFER IN NON-GEARED TURBOCOMPRESSORS?

Our non-geared compressors for polyolefines and main air handle flows up to 65,000 m3/h, with a max. input power of 10 MW and max. pressure of 45 bar. Our non-geared compressors for main air handle flow volumes up to 500,000 m3/h, with a maximum input power of 30 MW. They are a good choice for applications with high flows requirements (we are now seeing requirements of 600,000 m3/h, or power requirements of 40 or more MW. In the hydrogen market, non-geared compressors could be an option for large flows since hydrogen does not require intercooling, and volume changes are minimal.

H&L Instruments Model 900C/CE Edge Profile Comparator ...aids in maintaining peak engine performance

Visually Inspect Fan and Compressor Blade Leading and Trailing Edge Contours

The 900C/CE Edge Profile Comparator is a compact, self-contained optical instrument for comparing airfoils with optimum profile overlays. A rugged hand-held module captures magnified (20x or 40x) bright and sharply defined images that are displayed on a high resolution, flat screen LED monitor. The instrument is used by mechanics during the blending process to greatly reduce rework time. Instrument portability allows use both on the flight line for blade inspection and on the bench during repair. A built-in frame grabber enables before and after documentation of repairs.

Properly contoured blade edges may result in up to 10% thrust improvements, which can mean the difference between passing or failing a test cell run. Used worldwide by carriers and MROs alike, the Model 900C/CE Edge Profile Comparator is an essential maintenance and inspection tool for the CFM56, Pratt & Whitney, Rolls Royce Trent and numerous other engines.

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HOW ABOUT YOUR COMPANDERS?

Companders combine compressor and expander functionalities: they are installed on a single gearbox and skid. Companders are used in several hydrocarbon processing applications, including carrier LNG, small-scale LNG and chemical/petrochemical, as well as sCO_2. A compander is a feasible choice when the process provides an opportunity for energy recovery (process waste heat) or pressure reduction, with compression required from the adjacent processes.

WHAT ARE SOME OF THE CHALLENGES FOR HYDROGEN-RICH TURBOEXPANDERS?

One of the key elements for hydrogen liquefaction is a turboexpander providing efficient refrigeration down to 20 degrees Kelvin. Radial inflow turboexpanders have been used in hydrogen-rich petrochemical applications (ethylene and propane dehydrogenation plants) for off-gas recovery for many years. The process gas for these petrochemical applications contains up to 90% hydrogen. However, the turboexpanders required for hydrogen liquefiers using pure or very high hydrogen mixtures are more challenging. This is due to high isentropic enthalpy drop, low volume, and speed limitation. These turboexpanders need aerodynamic and mechanical designs such as low-flow coefficient turboexpander wheel, high peripheral speed, thermal management,-special materials, and innovative sealing. For standard 10-30 TPD liquefiers, oil-free bearing turboexpanders with hydrogen compressor load are preferred.

WHAT TURBOEXPANDER PRODUCT IS AVAILABLE FOR GLOBAL GAS PROCESSING?

While the oil and gas industry is typically viewed as a custom design market, local gas processing developers require standard package turboexpanders for plant sizes ranging 80-400 MMSCFFD. Early on in the shale gas boom, the market demanded turboexpander-compressors to be standardized for quick delivery. To meet this demand, Atlas Copco developed a product we call ECOTS (Expander Compressor Off The Shelf). Apart from the aero dynamic flow path parts, the package is a standardized and modular design. Our recently released ECOTS Plus has a smaller footprint, improved efficiency, and configurability to suit international gas processing markets.

WHAT NEW AFTERMARKET SERVICES DO YOU OFFER?

We recently added remote servicing and support through our family of connectivity solutions. Turboview enables us to connect to the customer site, identify problems, and provide initial advice remotely. We equip our technicians with Hololens technology, enabling aftermarket back office to better guide and support them at the customer site. ■

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Power Database Global Coverage by Market Region

World Region	Active Projects	Operational Plants	Pre-Commissioned Plants	Generator Drives	Boilers	Outages
North America	6,983	9,377	2,128	31,769	11,665	154,350
Middle America	334	450	98	2,147	295	2,583
South America	4,248	2,354	2,022	14,865	1,825	12,299
Europe	11,059	12,517	5,236	29,999	6,622	58,007
Africa	3,449	1,597	1,287	8,792	961	1,829
Asia	28,910	22,098	14,156	71,222	15,889	20,548
Oceania	1,027	826	577	3,430	379	2,345
Grand Total	56,010	49,219	25,504	162,224	37,636	251,961

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3D PRINTING PARTS WITHOUT SUPPORT STRUCTURES

Metal additive manufacturing (AM) company Velo3D has products that can print zero-degree overhangs, circular holes (up to 100mm), conical surfaces, domes, and thin pins/walls. They can be accomplished without the use of supports. Velo3D targets its AM applications towards microturbines, turbopumps, and heat exchangers. Velo3D's Sapphire printer can print circular holes anywhere between 500µm and 100mm. Tilting the part by a few degrees allows for features to be printed from 300µm to more than 200mm.

The technology allows the creation of domes with an interior diameter up to 150mm without the need for supports. Outward growing conical surfaces that exceed 30 degrees do not require supports, while inward growing cones are stable down to nearly 0 degrees.

Velo3D printers can also produce thin pins and walls. Pins at low angles (around 15 degrees) can be manufactured as thin as 190µm but can be made thinner by being placed at more vertical angles. Leak-tight walls can be produced at 325µm. Non-leak-tight walls can reach 150µm.

Currently, the system works with the following materials:

- Nickel: Inconel 718, Inconel 625, Hastelloy C-22, and Hastelloy X
- Titanium: Ti-6Al-4V Grade 23, and Grade 5
- Aluminum: F357, Scalmalloy

VELO3D.COM

NEW AIR/WATER COOLED CENTRIFUGAL COMPRESSOR

ECO-Turbo compressor

FS-Curtis – part of the Fusheng Industrial family of companies – recently launched its ECO-Turbo centrifugal air compressor. The oil-free, Class 0 compressor uses an FS-Elliott engineered air-end and is suitable for use in industries and applications where 100% oil-free compressed air is required with higher demand, ranging from 185 kW to 250 kW drive power at a final compression pressure of up to 125 psi. The design has been optimized with a wear-free compression principle which results in lower maintenance and fewer downtimes. The ECO-Turbo's design fully encapsulates the compressor's air, lubrication, cooling, and control systems. In addition, the compressor's small footprint saves space and allows for easy installation.

US.FSCURTIS.COM

The NOx Tracker interface.

UCF DEVELOPS NEW ONLINE NOX TRACKER

A new online Power Generation NOx tracker has been developed as part of an industry-education partnership between Mitsubishi Power Americas and UCF. The tracker uses data from the U.S. EPA database as analyzed by UCF's Center for Advanced Turbomachinery and Energy Research (CATER) to show trends over time. The tracker is accessible at no cost.

Experts at UCF's CATER are evaluating and developing technology to address nitrogen oxides as well as other pollutants regulated by the U.S. Clean Air Act and monitored by the EPA. UCF engineers developed the NOx tracker to not only track the cumulative percent change in nitrogen oxide emissions, but also to follow the cumulative change in sulfur dioxide and overall power generated. Kapat and UCF post-doctoral scholar Dr. Ladislav Vesely will be updating the tracker every quarter.

CECS.UCF.EDU/NOX/

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The Metrix ST5484E is a self-contained, loop-powered seismic velocity transmitter that incorporates a piezo-electric accelerometer, signal integrator, RMS peak detector, and 4-20 mA signal conditioner into a single, robust package. It has been evaluated by an independent third-party agency based on IEC61508 Functional Safety standards and is SIL2 capable.

The Metrix ST5484E

METRIXVIBRATION.COM

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m.simco@zeintlplc.com
www.zeintlplc.com
<100kW-1MW Waste2Energy at point of need Electricity, Cogen/Trigen Solutions.
Energy Systems

AFTERMARKET

ALIGNMENT

Optimistic
Lisbon Portugal

ALIGNMENT

Acoem AB
(formerly Fixturlaser AB)
Moelndal Sweden

Acquip, Inc. -
Rotating Equipment Solutions
Miami Beach FL

Di Vita Engineering, LLC
Salt Lake City UT

Howden
Connersville IN

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

S2W Contracting LLC
Tunkhannock PA

BALANCING EQUIPMENT

Hines Industries
Ann Arbor MI

Howden
Connersville IN

Schenck USA Corp.
Deer Park NY

BALANCING EQUIPMENT-AT-OR HIGH-SPEED

BRUSH GROUP
Ashby de la Zouch UK

ElliottGroup
Jeannette PA

EthosEnergy
Houston TX

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Sulzer ManagementLtd
Winterthur ZH Switzerland

BALANCING EQUIPMENT - LOW-SPEED

ElliottGroup
Jeannette PA

IRD Balancing
Louisville KY

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

BLADES

Baker Hughes
Firenze Italy

ElliottGroup
Jeannette PA

Engineered Turbine Components
Ithaca NY

EthosEnergy
Houston TX

FLOWDY
Changwon Gyeongsangnam-do
Korea South

Precision Profiles, LLC
Titusville PA

Revak Keene Turbomachinery, LP
La Porte TX

BLADES - COMPRESSORS

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Precision Profiles, LLC
Titusville PA

Sulzer ManagementLtd
Winterthur ZH Switzerland

BLADES - DIAPHRAGM NOZZLE

ElliottGroup
Jeannette PA

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Precision Profiles, LLC
Titusville PA

BLADES - GRINDING

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Precision Profiles, LLC
Titusville PA

BLADES - TESTING

ElliottGroup
Jeannette PA

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Schenck USA Corp.
Deer Park NY

BLADES - TURBINES

AGL Manufacturing Ltd.
Vancouver BC Canada

De Pretto Industrie Srl
Schio Italy

ElliottGroup
Jeannette PA

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Precision Profiles, LLC
Titusville PA

Stork H&E Turbo Blading
Ithaca NY

Sulzer ManagementLtd
Winterthur ZH Switzerland

Turbine Resources, Inc.
Euless TX

BORESCOPES

ViewTech BorescopesPCE Deutschland GmbH
Meschede Germany

ViewTech Borescopes
Traverse City MI

COATINGS

A&A Coatings
South Plainfield NJ

Baker Hughes
Firenze Italy

Bodycote
Dallas TX

ElliottGroup
Jeannette PA

HFW Industries
Hackensack NJ

Master Bond, Inc.
Hackensack NJ

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Turbine Resources, Inc.
Euless TX

COMBUSTOR PARTS

Baker Hughes
Firenze Italy

COMBUSTOR PARTS

Baker Hughes
Firenze Italy

DEMAGNETIZING PRODUCTS & SERVICES

MPS Gaussbusters - Magnetic Products and Services
Holmdel NJ

Shaft Current Solutions, Inc., DBA Sohre TurbomachineryÂ® Inc.
Florence MA

Turbo Non-Destructive Testing, Inc.
Houston Texas

MAINTENANCE - BOILERS

Agis, LLC
Ambler PA

MAINTENANCE - COMPRESSOR SPECIALIST

Atlas Copco Gas and Process Division
Cologne NRW Germany

Cook Compression
Houston TX

Cook Compression Ltd.
Ellesmere Port UK

De Pretto Industrie Srl
Schio Italy

Dover Precision Components
The Woodlands TX

ElliottGroup
Jeannette PA

Howden
Connersville IN

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Rotating Machinery Services, Inc.
Bethlehem PA

Sulzer ManagementLtd
Winterthur ZH Switzerland

MAINTENANCE - GAS TURBINE SPECIALIST

Eta Technologies. LLC
Coventry CT

Sulzer ManagementLtd
Winterthur ZH Switzerland

TTS
Orlando FL

Turbine Efficiency Group
Lincoln LINCS UK

Turbine Resources, Inc.
Euless TX

MAINTENANCE - GENERAL

Baker Hughes
Firenze Italy

Doosan Škoda Power
Plzen Czech Republic

EthosEnergy
Houston TX

Howden
Connersville IN

MAINTENANCE - STEAM TURBINE SPECIALIST

De Pretto Industrie Srl
Schio Italy

Doosan Škoda Power
Plzen Czech Republic

ElliottGroup
Jeannette PA

Integrated TurboMachinery, Inc.
Montebello CA

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Revak Keene Turbomachinery, LP
La Porte TX

Rotating Machinery Services, Inc.
Bethlehem PA

Steam Turbine Engineering, India Pvt. Ltd.
Ahmedabad Gujarat India

Sulzer ManagementLtd
Winterthur ZH Switzerland

MAINTENANCE PROGRAMS

Atlas Copco Gas and Process Division
Cologne NRW Germany

Baker Hughes
Firenze Italy

De Pretto Industrie Srl
Schio Italy

ElliottGroup
Jeannette PA

EthosEnergy
Houston TX

Howden
Connersville IN

L.A. Turbine
Valencia CA

NRG Energy Services
Houston TX

Sulzer ManagementLtd
Winterthur ZH Switzerland

MATERIALS SUPPLIER

Aerospace Alloys, Inc.
Bloomfield CT

Air Liquide America Specialty Gases,LLC
Houston TX

Fabreeka International, Inc.
Stoughton MA

NOZZLES - FUEL

EthosEnergy
Houston TX

Sulzer ManagementLtd
Winterthur ZH Switzerland

Turbine Resources, Inc.
Euless TX

NOZZLES - TURBINE

ElliottGroup
Jeannette PA

Precision Profiles, LLC
Titusville PA

OPERATIONS & MAINT. - COGENERATION/ RENEWABLE ENERGY

ElliottGroup
JeannettePA

OPERATIONS & MAINT. - GAS TURBINES

Ansaldo Energia S.p.A.
Genoa Italy

MTU Maintenance Berlin-Brandenburg GmbH
Ludwigsfelde Brandenburg Germany

OPERATIONS & MAINT. - STEAM TURBINES

Ansaldo Energia S.p.A.
Genoa Italy

Doosan Škoda Power
Plzen Czech Republic

ElliottGroup
Jeannette PA

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

OPERATIONS & MAINTENANCE

Atlas Copco Gas and Process Division
Cologne NRW Germany

Baker Hughes
Firenze Italy

ElliottGroup
Jeannette PA

EthosEnergy
Houston TX

Howden
Connersville IN

Nord-Lock Group
Clinton PA

PT. Imeco Inter Sarana
Jakarta Indonesia

PARTS - GAS TURBINES

Allied Dynamics
Commack NY

Baker Hughes
Firenze Italy

Maximum Turbine Support
San Bernardino CA

Nordic Turbine Components
Arboga SE Sweden

Recotech
Arboga SE Sweden

Rotating Machinery Services, Inc.
Bethlehem PA

Sulzer ManagementLtd
Winterthur ZH Switzerland

TTS
Orlando FL

PARTS - MANUFACTURERS

Atlas Copco Gas and Process Division
Cologne NRW Germany

Bill McDonald TEK-REPS, Inc.
Cypress TX

BRUSH GROUP
Ashby de la Zouch UK

Glebus Alloys LLC
Stow OH

Howden
Connersville IN

L.A. Turbine
Valencia CA

Precision Profiles, LLC
Titusville PA

PARTS - STEAM TURBINES

Baker Hughes
Firenze Italy

De Pretto Industrie Srl
Schio Italy

ElliottGroup
Jeannette PA

HFW Industries
Buffalo NY

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Precision Profiles, LLC
Titusville PA

Revak Keene Turbomachinery, LP
La Porte TX

Rotating Machinery Services, Inc.
Bethlehem PA

Star & Star Field Fit, Inc.
Marion OH

Sulzer ManagementLtd
Winterthur ZH Switzerland

PARTS - SUPPLIERS

Baker Hughes
Firenze Italy

REAPPLICATION SERVICES

ElliottGroup
Jeannette PA

RECOVERY SYSTEMS

Baker Hughes
Firenze Italy

REPAIR - ACCESSORIES

ElliottGroup
Jeannette PA

Gard Specialists Co., Inc.
Eagle River WI

REPAIR - BEARINGS

American Turbine Bearings
Arlington TX

Atlas Copco Gas and Process Division
Cologne NRW Germany

Bearings Plus
Houston TX

Dover Precision Components
The Woodlands TX

ElliottGroup
Jeannette PA

Miba Industrial Bearings
Laakirchen Austria

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Pioneer Motor Bearing
Kings Mountain NC

Revak Keene Turbomachinery, LP
La Porte TX

Turbine Resources, Inc.
Euless TX

REPAIR - BLADES

ElliottGroup
Jeannette PA

EthosEnergy
Houston TX

Liburdi Turbine Services, Inc.
Dundas ON Canada

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

PAS Technologies Ireland Ltd.
Carrigtwohill County Cork Ireland

Precision Profiles, LLC
Titusville PA

Revak Keene Turbomachinery, LP
La Porte TX

Turbine Resources, Inc.
Euless TX

REPAIR - CASINGS

ElliottGroup
Jeannette PA

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Revak Keene Turbomachinery, LP
La Porte TX

Turbine Resources, Inc.
Euless TX

REPAIR - COUPLINGS

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Riverhawk Company
New Hartford NY

REPAIR - GEARBOXES

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Philadelphia Gear, Power Systems by Timken
King of Prussia PA

Revak Keene Turbomachinery, LP
La Porte TX

Sulzer ManagementLtd
Winterthur ZH Switzerland

The Gear Works
Seattle WA

REPAIR - PUMPS

ElliottGroup
Jeannette PA

Revak Keene Turbomachinery, LP
La Porte TX

Sulzer ManagementLtd
Winterthur ZH Switzerland

REPAIR - ROTORS

Atlas Copco Gas and Process Division
Cologne NRW Germany

ElliottGroup
Jeannette PA

EthosEnergy
Houston TX

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Revak Keene Turbomachinery, LP
La Porte TX

REPAIR - VANES

ElliottGroup
JeannettePA

Liburdi Turbine Services, Inc.
Dundas ON Canada

Precision Profiles, LLC
Titusville PA

Turbine Resources, Inc.
Euless TX

REPAIR & OVERHAUL

Atlas Copco Gas and Process Division
Cologne NRW Germany

Baker Hughes
Firenze Italy

BRUSH GROUP
Ashby de la Zouch UK

Cook Compression
Houston TX

De Pretto Industrie Srl
Schio Italy

Doosan ŠkodaPower
Plzen Czech Republic

Elca Engineering Co. (Pty) Ltd
Vanderbijlpark Gauteng South Africa

ElliottGroup
Jeannette PA

EthosEnergy
Houston TX

ETU i+D S.A. de C.V.
QuerÃ©taro Mexico

FLOWDY
Changwon Gyeongsangnam-do Korea South

Howden
Connersville IN

L.A. Turbine
Valencia CA

Laservorm GmbH
Altmittweida Germany

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

PT Nuscaco Hasteloy Turbine Services
Jakarta Timur Jakarta Indonesia

Rotating Machinery Services, Inc.
Bethlehem PA

Rotoflow, An Air Products Business
Allentown PA

Turbine Resources, Inc.
Euless TX

REPAIR & OVERHAUL - GAS TURBINES

Ansaldo Energia S.p.A.
Genoa Italy

Component Process & Repair
Bognor Regis West Sussex UK

EthosEnergy
Houston TX

Hi-Tech Furnace Systems, Inc.
Shelby Township MI

Liburdi Turbine Services, Inc.
Dundas ON Canada

MAN Energy SolutionsSE
Augsburg Bavaria Germany

Sulzer ManagementLtd
Winterthur ZH Switzerland

RERATES

Atlas Copco Gas and Process Division
Cologne NRW Germany

Cook Compression
Houston TX

ElliottGroup
Jeannette PA

EthosEnergy
Houston TX

Flexware, Inc.
Grapeville PA

Revak Keene Turbomachinery, LP
La Porte TX

SEALING PRODUCTS

Bearings Plus
Houston TX

Dover Precision Components
The Woodlands TX

EthosEnergy
Houston TX

Inpro/Seal
Rock Island IL

SHROUDS - TURBINE

Precision Profiles, LLC
Titusville PA

SPIN TESTING EQUIPMENT

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

TOOLS

LINK Tools International (USA), Inc.
Chicago IL

TOOLS FOR ALIGNMENT

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

AFTERMARKET/ANALYSIS & SOFTWARE/AUXILIARY EQUIPMENT

TOTAL PLANT SERVICE

Baker Hughes
Firenze Italy

EthosEnergy
Houston TX

TURBINE MAINTENANCE TOOLS

Advanced F.M.E. Products, Inc.
Mentor OH

Kipper Tool Company
Gainesville GA

Machida,Inc.
Orangeburg NY

Power House Tool, Inc.
Joliet IL

UPGRADES

Atlas Copco Gas and Process Division
Cologne NRW Germany

Baker Hughes
Firenze Italy

De Pretto Industrie Srl
Schio Italy

Dover Precision Components
The Woodlands TX

ElliottGroup
Jeannette PA

EthosEnergy
Houston TX

L.A. Turbine
Valencia CA

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Petrotech,Inc.
New Orleans LA

Rotoflow, An Air Products Business
Allentown PA

VANES - STATORS

FLOWDY
Changwon Gyeongsangnam-do Korea South

Precision Profiles, LLC
Titusville PA

ANALYSIS & SOFTWARE

DESIGN & ANALYSIS

Baker Hughes
Firenze Italy

CD-adapco
Melville NY

CFturbo, Inc.
Brooklyn NY

KISSsoft AG
Bubikon Switzerland

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Optimistic
Lisbon Portugal

Simulia
Providence RI

TURBOdesign Technology, Inc.
Oakbrook Terrace

FAILURE ANALYSIS

Bearings Plus
Houston TX

ElliottGroup
Jeannette PA

L.A.Turbine
Valencia CA

Laschet Consulting GmbH
Bergisch Gladbach Germany

Liburdi Turbine Services, Inc.
Dundas ON Canada

Lucideon
Schenectady NY

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

R.J. Hill Consulting
Smyrna TN

Rotating Machinery Services, Inc.
Bethlehem PA

Rotoflow, An Air Products Business
Allentown PA

Sulzer ManagementLtd
Winterthur ZH Switzerland

FINITE ELEMENTS ANALYSIS

ElliottGroup
Jeannette PA

PLANT DESIGN

Baker Hughes
Firenze Italy

PROGNOSTICS

Baker Hughes
Firenze Italy

SOFTWARE & ENGINEERING PROGRAMS

Advanced Design Technology
London UK

Applied Flow Technology (AFT)
Colorado Springs CO

Baker Hughes
Firenze Italy

Concepts NREC
White River Junction VT

Engineered Software, Inc.
Lacey WA

Honeywell Process Solutions
Houston TX

Howden
Connersville IN

Liburdi Turbine Services, Inc.
Dundas ON Canada

Mobideo
Houston TX

OpenMindTechnologiesUSA,Inc.
Needham MA

Petrotech,Inc.
New Orleans LA

Siemens Product Lifecycle Management Software, Inc.
London UK

TechNeurons Consulting Solutions Pvt. Ltd.
Kochi Kakkanad India

STRESS ANALYSIS

AmericanStressTechnologies,Inc.
Pittsburgh PA

ElliottGroup
Jeannette PA

Liburdi Turbine Services, Inc.
Dundas ON Canada

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

SONATS, Europe Technologies
Carquefou France

TESTING

Baker Hughes
Firenze Italy

E.T. Balancing Inc.
Los Angeles CA

GTAnalysis, Inc.
Bradenton FL

Howden
Connersville IN

Laboratory Testing, Inc.
Hatfield PA

Liburdi Turbine Services, Inc.
Dundas ON Canada

Optimistic
Lisbon Portugal

TESTING - LUBRICATION

Analysts,Inc.
Hawthorne CA

R&G Laboratories, Inc.
Tampa FL

SGS Herguth Laboratories
Vallejo CA

Under MyHood
Queen Creek AZ

WearCheck USA
Cary NC

TURBINE BLADE STRESS ANALYSIS

ElliottGroup
Jeannette PA

Sensatek Propulsion Technology, Inc.
Daytona Beach FL

VIBRATION ANALYSIS

Baker Hughes
Firenze Italy

Benstone Instruments
St. Paul MN

Diagen Laboratory
Plzen Czech Republic

ElliottGroup
Jeannette PA

Emerson
Knoxville TN

GTI Predicitve Technology
Manchester NH

Howden
Connersville IN

Inertance
Seoul Korea South

Laschet ConsultingGmbH
Bergisch Gladbach Germany

Mid-America Dynamics, Inc.
Lisle IL

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Oros, Inc.
Dulles VA

Schenck USA Corp.
Deer Park NY

AUXILARY EQUIPMENT

ACOUSTIC ENCLOSURES

ARK Noise Control Enginering Center
Pune Maharashtra India

Camfil Power Systems
Boras Sweden

G+H Schallschutz GmbH
Mannheim Germany

SAI
Massy France

Schock Manufacturing
Owasso OK

AIR DRYERS

La-Man Corporation
Mazeppa MN

Sullair A Hitachi Group Company
Michigan City IN

AIR FILTERS

Boll Filter Corporation
Novi MI

Camfil Power Systems
Boras Sweden

Clean Air Company
Fords NJ

Defitec
Waterloo Brabant Belgium

Eagle Filters Ltd.
Kotka Finland

Freudenberg Filtration Technologies SE & Co. KG
Weinheim Germany

G+H Schallschutz GmbH
Mannheim Germany

Nordic Air Filtration A/S
Nakskov Denmark

Sullair A Hitachi Group Company
Michigan City IN

BEARINGS

Baker Hughes
Firenze Italy

Bearings Space
Spring TX

Bearings Plus
Houston TX

Cerobear GmbH
Herzogenrath Germany

Dover Precision Components
The Woodlands TX

ElliottGroup
Jeannette PA

Gleitlagertechnik Weissbacher GmbH
Alpen Nordrhein-Westfalen Germany

GMN Bearing USA Ltd.
Houston TX

Graphite Metallizing Corporation
Yonkers NY

K C Engineering
Consett UK

Kinematics Manufacturing
Phoenix AZ

Kingsbury, Inc.
Philadelphia PA

Miba Industrial Bearings
Laakirchen Austria

Oiltech Bearings Ltd
Newcastle Upon Tyne Tyne & Wear UK

Revak Keene Turbomachinery, LP
La Porte TX

Schaeffler Technologies GmbH & Co. KG
Herzogenaurach Germany

Texas Bearing Services
Houston TX

TRI Transmission & Bearing Corp., Div of Turbo Research, Inc.
Lionville PA

Waukesha Bearings
Pewaukee WI

Waukesha Bearings - Suzhou
Suzhou China

Waukesha Bearings Ltd.
Rickmansworth Hertfordshire UK

Xdot Bearing Technologies
Charlottesville VA

AUXILIARY EQUIPMENT

BEARINGS - MAGNETIC

Calnetix Technologies, LLC
Cerritos CA

CEROBEAR GmbH
Herzogenrath Germany

Dover Precision Components
The Woodlands TX

L.A. Turbine
Valencia CA

Waukesha Bearings - Suzhou
Suzhou China

Waukesha Magnetic Bearings
Worthing West Sussex UK

CLUTCHES

AltraMotion
Erie PA

SSS Clutch Company, Inc.
New Castle DE

COMBUSTION MONITORING

EthosEnergy
Houston TX

Petrotech,Inc.
New Orleans LA

TTS
Orlando FL

COMBUSTION SYSTEMS

TTS
Orlando FL

COMPRESSOR WASHING SYSTEMS

ECT, Inc.
Pottstown PA

ElliottGroup
Jeannette PA

EthosEnergy
Houston TX

FP Turbomachinery B.V.
Zoetermeer Netherlands

Turbo-K Ltd.
Emmendingen Germany

CONDENSERS

Ambassador Heat Transfer Co.
Cincinnati OH

COOLING SYSTEMS

Ecodyne Heat Exchangers
Houston TX

Industrial Cooling Solutions (ICS)
Lakewood CO

Moffitt Corporation
Jacksonville Beach FL

COUPLINGS

Altra Motion
Erie PA

Kile Industries, Inc.
Houston TX

KWD Kupplungswerk Dresden GmbH
Dresden Germany

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

PSC Couplings
Menomonee Falls WI

Regal Beloit Corporation
Florence KY

Riverhawk Company
New Hartford NY

Wuxi TRUMY Transmission Engineering Co. Ltd.
Wuxi Jiangsu China

DAMPERS

Braden Americas, Inc.
Lake Mary FL

Riverhawk Company
New Hartford NY

WES GmbH
Nordkirchen Germany

DEAERATORS

Sterling Deaerator Company
Cumming GA

DISCS

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

EFFICIENCY & PERFORMANCE MONITORING

FlexElement - High Performance Couplings
Houston TX

TTS
Orlando FL

ENCLOSURES

Drake Controls, LLC
Houston TX

EXHAUST SYSTEMS

Braden Americas, Inc.
Lake Mary FL

Durr Universal, Inc.
Stoughton WI

G+H Schallschutz GmbH
Mannheim Germany

Schock Manufacturing
Owasso OK

STF SpA
Magenta (MI) Italy

EXPANSION JOINTS

Braden Americas, Inc.
Lake Mary FL

Isolated SystemsLtd
Heanor Derbyshire UK

Schock Manufacturing
Owasso OK

FANS & BLOWERS

AirPro Fan & Blower Company
Rhinelander WI

Daltec Canadian Buffalo Fan Mfg. Ltd.
Guelph ON Canada

Howden
Connersville IN

Optimistic
Lisbon Portugal

Piller-TSC Blower Corporation
Schenectady NY

FASTENERS (STUDS,NUTS, BOLTS,ETC.)

Belleville International
Butler PA

Boltight Ltd.
Walsall West Midlands UK

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Nord-Lock, Inc.
Carnegie PA

Pilgrim International Ltd
Oldham UK

Power Plant Services
Melrose Park IL

Riverhawk Company
New Hartford NY

FILTERS

Air Filters, Inc.
Houston TX

Baldwin Filters
Kearney NE

Boll Filter Corporation
Novi MI

Contec GmbH Industrieausrüstungen
Bad Honnef Germany

Defitec
Waterloo Brabant Belgium

FRANKE-Filter GmbH
Bad Salzdetfurth Germany

G+H SchallschutzGmbH
Mannheim Germany

HILCO Filtration Division of the Hilliard Corporation
Elmira NY

Hydac Corporation
Bethlehem PA

One Eye Industries, Inc.
Calgary AB Canada

FUEL SYSTEMS, TREATMENT, FILTERS, & PUMPS

Boll Filter Corporation
Novi MI

Roper Pump Company
Commerce GA

GAS TURBINE EXHAUST SYSTEMS

Braden Americas, Inc.
Lake Mary FL

G+H Schallschutz GmbH
Mannheim Germany

Schock Manufacturing
Owasso OK

GAS TURBINES - STARTERS

HILCO Filtration Division of the Hilliard Corporation
Elmira NY

GEARBOXES

Baker Hughes
Firenze Italy

Brevini Power Transmission
Reggio Emilia Italy

Cincinnati Gearing Systems Inc.
Cincinnati OH

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Philadelphia Gear, Power Systems by Timken
King of Prussia PA

RENK-MAAG GmbH
Winterthur Zurich Switzerland

SPX Cooling Technologies, Inc.
Overland Park KS

Turbo Non-Destructive Testing, Inc.
Houston TX

GEARS

Cincinnati Gearing Systems Inc.
Cincinnati OH

Excel Gear, Inc.
Roscoe IL

IGW (Power)
Oostkamp Belgium

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Philadelphia Gear, Power Systems by Timken
King of Prussia PA

HEAT EXCHANGERS

AMSEnergy Corp.
Columbia TN

Baker Hughes
Firenze Italy

Doosan Škoda Power
Plzen Czech Republic

Echogen Power Systems
Akron OH

Enerfin, Inc.
St. Hubert QC Canada

GEA Heat Exchangers GmbH
Bochum Germany

Hubei Defon Heat Exchanger Co. Ltd.
Daye City Hubei China

Kelvion Holding GmbH
BOCHUM Germany

Lytron
Woburn MA

Modine Grenada, LLC
Grenada MS

Oeltechnik
Waghaeusel Baden-Württemberg Germany

Tech Solutions International Group, LLC
Chicago IL

TMEC - Thermal & Mechanical Equipment Co.
Houston TX

UNIVERSAL HYDRAULIK USA CORP.
Perrysburg OH

HEATERS

Gaumer Process
Houston TX

Power House Tool, Inc.
Joliet IL

Tutco SureHeat
Exeter NH

INTAKE FILTERS

Advanced Filtration Concepts, Inc.
Norwalk/Los Angeles CA

Camfil Power Systems
Boras Sweden

Clarcor Industrial Air
Overland Park KS

Donaldson Company, Inc.
Bloomington MN

Freudenberg Filtration Technologies L.P.
Hopkinsville KY

G+H Schallschutz GmbH
Mannheim Germany

Schock Manufacturing
Owasso OK

Veotec (Americas) LLC
Lakeville MN

LUBE OIL SYSTEM ACCUMULATORS (LOSA)

Fluid Energy Controls, Inc.
City of Industry CA

LUBRICANTS

American Chemical Technologies
Fowlerville MI

Lubrication Engineers, Inc.
Fort Worth TX

Sullair A Hitachi Group Company
Michigan City IN

AUXILIARY EQUIPMENT/ BOILERS - SUPPLIERS/ COGENERATION & COMBINED CYCLE

LUBRICATION SYSTEMS

Cobey, Inc.
Buffalo NY

Cook Compression
Houston TX

ElliottGroup
Jeannette PA

Lube-Power, Inc.
Shelby Township MI

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Sicelub Lubritech
Mexico Distrito Federal Mexico

Worcester FluidsTechnology
Auburn MA

LUBRICATION SYSTEMS - FILTERS

Boll Filter Corporation
Novi MI

Contec GmbH Industrieausrüstungen
Bad Honnef Germany

Donaldson Company, Inc.
Bloomington MN

HILCO Filtration Division of the Hilliard Corporation
Elmira NY

OilKleen, LLC
Anthem AZ

NOISE & VIBRATION SUPPRESSION EQUIP.

Acoustiblok, Inc.
Tampa FL

Kinetics Noise Control - Heavy Industrial Division
Cambridge ON Canada

OIL PURIFICATION EQUIPMENT

General Atomics Electromagnetic Systems (GA-EMS)
San Diego CA

HILCO Filtration Division of the Hilliard Corporation
Elmira NY

Isopur Fluid Technologies, Inc.
North Stonington CT

Kleentek, a division of United Air Specialists, Inc.
Cincinnati OH

Meiji Corporation
Itasca IL

PACKING RINGS

Cook Compression
Houston TX

Cook Compression - Suzhou
Suzhou China

Cook Compression Ltd.
Ellesmere Port UK

Dover Precision Components
The Woodlands TX

EthosEnergy
Houston TX

FLOWDY
Changwon Gyeongsangnam-do Korea South

PIPES

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Permanent Steel Manufacturing Co.,Ltd
Changsha Hunan China

Ritinox Overseas
Mumbai Maharashtra India

Yaang Pipe Industry Co.
Wenzhou Zhejiang China

SEALS

Bal Seal Engineering, Inc.
Foothill Ranch CA

Bearings Plus
Houston TX

Dover Precision Components
The Woodlands TX

ElliottGroup
Jeannette PA

EthosEnergy
Houston TX

Greene Tweed
Houston PA

Houston Dynamic Service, Inc.
Houston TX

Inpro/Seal
Rock Island IL

JetSeal,Inc.
Spokane WA

Miba Industrial Bearings
Laakirchen Austria

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Planet Asia Pte. Ltd.
#07-108 Singapore

Power Generation Services GmbH
Berlin Berlin Germany

WaukeshaBearings
Pewaukee WI

Waukesha Bearings Ltd.
Rickmansworth Hertfordshire UK

SEALS - GAS

ElliottGroup
Jeannette PA

SEALS- MECHANICAL

ElliottGroup
Jeannette PA

Erie Bronze & Aluminum Co.
Erie PA

Sichuan Sunny Seal Co., Ltd.
Chengdu Sichuan China

SEALS - OIL

ElliottGroup
Jeannette PA

SHAFT CURRENT CONTROL EQUIPMENT

Dover Precision Components
The Woodlands TX

Inpro/Seal
Rock Island IL

SHIMS

Accushim, Inc.
Lyons IL

Machinery Mounting Solutions,Inc.
Virginia Beach VA

SILENCERS

Braden Americas, Inc.
Lake Mary FL

Camfil Power Systems
Boras Sweden

Freudenberg Filtration Technologies L.P.
Hopkinsville KY

Schock Manufacturing
Owasso OK

Stoddard Silencers, Inc.
Grayslake IL

SKIDS

CP International, Inc.
Houston TX

STARTERS

HILCO Filtration Division of the Hilliard Corporation
Elmira NY

TORQUE CONVERTERS

Regal Beloit Corporation
Florence KY

TRANSMISSIONS

Baker Hughes
Firenze Italy

TURBINE COOLING - CHILLING SYSTEMS

Donaldson Company, Inc.
Bloomington MN

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

TURBINE COOLING - FOGGING

ECT, Inc.
Pottstown PA

EthosEnergy
Houston TX

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

TURBINE COOLING - INLET COOLING

Camfil Power Systems
Boras Sweden

EthosEnergy
Houston TX

Everest Sciences
Tulsa OK

Freudenberg Filtration Technologies L.P.
Hopkinsville KY

Marlo Heat Transfer Solutions
High Ridge MO

TURBINE COOLING - MEDIA BASED

Donaldson Company, Inc.
Bloomington MN

Munters Corporation
Selma TX

TURBINE COOLING - OVERSPRAY

ECT, Inc.
Pottstown PA

VACUUM EQUIPMENT

High Tech Services
Richardson TX

Oerlikon Leybold Vacuum GmbH
Köln Germany

VALVES

Baker Hughes
Firenze Italy

Checkfluid
London Ontario Canada

Cook Compression
Houston TX

Cook Compression - Suzhou
Suzhou China

Cook Compression Ltd.
Ellesmere Port UK

Copes-Vulcan
McKean PA

Dover Precision Components
The Woodlands TX

Drake Controls, LLC
Houston TX

HILCO Filtration Division of the Hilliard Corporation
Elmira NY

JASC-Controls
Tempe AZ

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

MSA, a.s.
Dolni Benesov Czech Republic

Schutte & Koerting
Trevose PA

ThermOmegaTech
Warminster AL

Xiamen Weldon Valves Import and Export Co., Ltd.
Xiamen China

BOILERS - SUPPLIERS

BOILERS

Rentech Boiler Systems, Inc.
Abilene TX

COGENERATION & COMBINED CYCLE

COGENERATION ENG. & CONSULTINGSERVICES

Delve Energy Group
Minneapolis MN

HCS Group, Inc.
Humble TX

COGENERATION SYSTEMS

Petrotech,Inc.
New Orleans LA

COMBINED CYCLE PLANTS

Ansaldo Energia S.p.A.
Genoa Italy

Baker Hughes
Firenze Italy

BRUSH GROUP
Ashby de la Zouch UK

B-Tech Valve, LLC
Palmyra NJ

Cheng Power Systems, Inc.
Mountain View CA

Doosan Škoda Power
Plzen Czech Republic

EthosEnergy
Houston TX

COGENERATION & COMBINED CYCLE/ COMPRESSORS & EXPANDERS/ ELECTRIC EQUIPMENT/ ENERGY RESOURCES

COOLING TOWERS

SPX Cooling Technologies, Inc.
Overland Park KS

HRSG

Rentech Boiler Systems, Inc.
Abilene TX

MACHINERY FOR COGENERATION

Baker Hughes
Firenze Italy

Beltservice Corporation
St. Louis MO

Schutte & Koerting
Trevose PA

COMPRESSORS & EXPANDERS

COMPRESSORS

Atlas Copco Gas and Process Division
Cologne NRW Germany

Baker Hughes
Firenze Italy

BORSIG ZM Compression GmbH
Meerane Saxony Germany

CompMaster, LLC
Houston TX

Cryostar SAS
Hesingue France

ElliottGroup
Jeannette PA

Enerproject SA
Mezzovico Ticino Switzerland

FLOWDY
Changwon Gyeongsangnam-do Korea South

FLSmidth, Inc.
Bethlehem PA

Graco Air
Pinehurst TX

HYUNDAI HEAVY INDUSTRIES TURBOMACHINERY
ULSAN Dong-gu Korea South

IHI Corporation
Tokyo Japan

Ingersoll-Rand Industrial U.S., Inc.
Davidson NC

Integrated TurboMachinery, Inc.
Montebello CA

Mitsubishi Heavy Industries Compressor International (MCO-I)
Hiroshima Japan

Optimistic
Lisbon Portugal

Precision Profiles, LLC
Titusville PA

Rotoflow, An Air Products Business
Allentown PA

Turbo Non-Destructive Testing, Inc.
Houston TX

Universal Turbomachinery Equipment
Lodz Poland

York Process Systems (Johnson Controls)
Waynesboro PA

COMPRESSORS - AXIAL

Baker Hughes
Firenze Italy

ElliottGroup
JeannettePA

MAN Energy SolutionsSE
Augsburg Bavaria Germany

Rotating Machinery Services, Inc.
Bethlehem PA

COMPRESSORS - CENTRIFUGAL

Atlas Copco Gas and Process Division
Cologne NRW Germany

Baker Hughes
Firenze Italy

Bharat Forge Ltd.
Pune Maharashtra India

ElliottGroup
Jeannette PA

EthosEnergy
Houston TX

FIMA Maschinenbau GmbH
Obersontheim Germany

FS-Elliott
Export PA

Hitachi America Ltd.
Tarrytown NY

Howden
Connersville IN

Ingersoll-Rand Company
Davidson NC

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

PillAerator GmbH
Moringen Lower Saxony Germany

Revak Keene Turbomachinery, LP
La Porte TX

Rotating Machinery Services, Inc.
Bethlehem PA

Shenyang Blower Works Group Corporation
Shenyang China

Sullair A Hitachi Group Company
Michigan City IN

York Process Systems (Johnson Controls)
Waynesboro PA

COMPRESSORS - PACKAGERS

ABB sp. z o.o.
Warsaw Poland

Cobey, Inc.
Buffalo NY

Eltacon Engineering B.V.
Waddinxveen Netherlands

GEA
York PA

COMPRESSORS - RECIPROCATING

Baker Hughes
Firenze Italy

CPI - Worldwide Headquarters
Stafford TX

Gas & Air Systems, Inc.
Hellertown PA

Howden
Connersville IN

Ingersoll-Rand Company
Davidson NC

Neuman & Esser GulfFZE
Dubai United Arab Emirates

Shenyang Blower Works Group Corporation Shenyang China

COMPRESSORS - SCREW

Aerzen USA Corporation
Coatesville PA

Atlas Copco Gas and Process Division
Cologne NRW Germany

Howden
Connersville IN

Ingersoll Rand OEM Solutions
Davidson NC

Ingersoll-Rand Industrial U.S., Inc.
Davidson NC

Rotating Machinery Services, Inc.
Bethlehem PA

Sullair A Hitachi Group Company
Michigan City IN

York Process Systems (Johnson Controls)
Waynesboro PA

EXPANDERS

Atlas Copco Gas and Process Division
Cologne NRW Germany

Baker Hughes
Firenze Italy

Calnetix Technologies, LLC
Cerritos CA

CryostarUSA
Bethlehem PA

ElliottGroup
Jeannette PA

L.A.Turbine
Valencia CA

Optimistic
Lisbon Portugal

Rotating Machinery Services, Inc.
Bethlehem PA

Rotoflow, An Air Products Business
Allentown PA

ELECTRIC EQUIPMENT

ELECTRICAL SYSTEMS

Nidec IndustrialSolutions
Cinisello Balsamo (MI) Italy

PEMCO
Bluefield VA

GENERATORS & ALTERNATORS

BRUSH GROUP
Ashby de la Zouch UK

Calnetix Technologies, LLC
Cerritos CA

IDEAL Electric Company (formerly Hyundai Ideal ElectricCo.)
Mansfield OH

Kato Engineering, a Nidec Brand
North Mankato MN

Mega-Watt Consulting, LLC
Klein TX

Philadelphia Gear, Power Systems by Timken
King of Prussia PA

MOTORS - ELECTRIC

ATB Laurence Scott (Wolong Group)
Norwich UK

ATBMotors
The Woodlands TX

Baker Hughes
Firenze Italy

Brook Crompton USA, Inc.
Cleveland OH

Calnetix Technologies, LLC
Cerritos CA

General Atomics Electromagnetic Systems (GA-EMS)
San Diego CA

Phase USA Inc.
Lombard IL

Philadelphia Gear, Power Systems by Timken
King of Prussia PA

TMEIC Corporation Americas
Houston TX

Wolong Americas, LLC
Chicago IL

Wolong Group
Norwich Norfolk UK

Yaskawa Environmental Energy / The Switch
Helsinki CO

VARIABLE FREQUENCY DRIVES

Calnetix Technologies, LLC
Cerritos CA

General Atomics Electromagnetic Systems (GA-EMS)
San Diego CA

Philadelphia Gear, Power Systems by Timken
King of Prussia PA

TMEIC Corporation Americas
Houston TX

Yaskawa Environmental Energy / The Switch
Helsinki CO

ENERGY RESOURCES

COMBINED HEAT & POWER PLANT (CHP)

Baker Hughes
Firenze Italy

EthosEnergy
Houston TX

Howden
Connersville IN

Renewable Energy Institute
Cathedral City CA

POWER PLANTS

Baker Hughes
Firenze Italy

Combustion Associates, Inc.
Corona CA

EthosEnergy
Houston TX

Optimistic
Lisbon Portugal

Turboden SpA
Brescia Italy

ENERGY RESOURCES/ ENVIRONMENTAL SERVICES/ GAS TURBINES/ INSTRUMENTATION & CONTROL

POWER PLANTS- BIOMASS

Howden
Connersville IN

POWER PLANTS- STEAM

Howden
Connersville IN

POWER SERVICES

Baker Hughes
Firenze Italy

Power Generation Consulting, LLC
Madison NJ

ENVIRONMENTAL SERVICES

ANTI-ICING

Braden Americas, Inc.
Lake Mary FL

Camfil Power Systems
Boras Sweden

TUTCO SureHeat
Exeter NH

ASH CONTROL

TUTCO SureHeat
Exeter NH

CATALYSTS

Braden Americas, Inc.
Lake Mary FL

EmeraChem
Knoxville TN

TUTCO SureHeat
Exeter NH

CONTINUOUS EMISSION MONITORING SYSTEMS

Loccioni
Angeli di Rosora Ancona Italy

EMISSIONS REDUCTIONS

Braden Americas, Inc.
Lake Mary FL

Cook Compression
Houston TX

Cook Compression - Suzhou
Suzhou China

Cook Compression Ltd.
Ellesmere Port UK

Cormetech, Inc.
Durham NC

Dover Precision Components
The Woodlands TX

EthosEnergy
Houston TX

HAUG Sauer Kompressoren AG
St. Gallen Switzerland

TTS
Orlando FL

TUTCO SureHeat
Exeter NH

UT 99 AG Oil Mist Eliminators
Andelfingen Switzerland

NOX CONTROL

Braden Americas, Inc.
Lake Mary FL

EthosEnergy
Houston TX

TUTCO SureHeat
Exeter NH

POLLUTION CONTROLS

Miratech
Tulsa OK

SCR

Braden Americas, Inc.
Lake Mary FL

TUTCO SureHeat
Exeter NH

WASTEWATER TREATMENT

Allen Filters, Inc.
Springfield MI

Howden
Connersville IN

Regal Beloit Corporation
Florence KY

Songpo Hightech
Siheung Korea South

WATER TREATMENT

Boll Filter Corporation
Novi MI

DEWA (Dubai electricity and water authority)
Dubai United Arab Emirates

GAS TURBINES

GAS TURBINES

AddQual
Derby DS UK

Ansaldo Energia S.p.A.
Genoa Italy

Baker Hughes
Firenze Italy

EthosEnergy
Houston TX

FLOWDY
Changwon Gyeongsangnam-do Korea South

Great River Energy
Elk River AL

Ibrahim & Associates LLC
Los Angeles CA

Kale Research & Development Inc.
Istanbul Turkey

Meggitt Control Systems
North Hollywood CA

Mitsubishi Power Americas
North Hollywood CA

Rotation Solutions
Perth WA Australia

Shin Nippon Machinery Co., Ltd.
Osaki 2-Chome Shinagawa-Ku, Tokyo Japan

Siemens Energy Global GmbH & Co. KG
Munich Germany

Skyline Turbine Services b.v.
Poeldijk Selecteer een gebied, St Netherlands

TechnipFMC
Zoetermeer Netherlands

TTS
Orlando FL

Turbine Consulting & Spare Parts Supplier
Balsorano AQ Italy

Turbo Non-Destructive Testing, Inc.
Houston TX

U.S. Bolt Manufacturing, Inc.
Houston TX

GAS TURBINES - AERODERIVATIVES

Air New Zealand - Gas Turbines
Manukau Auckland New Zealand

Baker Hughes
Firenze Italy

Mitsubishi Power Aero LLC
Glastonbury CT

Vericor Power Systems
Alpharetta GA

GAS TURBINES - COMBINED CYCLE

Baker Hughes
Firenze Italy

Tecnicas Reunidas
Madrid Spain

GAS TURBINES -ELECTRICAL GENERATION

Ener-Core,Inc
Irvine CA

GAS TURBINES - INDUSTRIAL

Baker Hughes
Firenze Italy

Kraft Power Corp., USA
Pompton Plains NJ

Reintjes GmbH
Hamelin Germany

GAS TURBINES - MECHANICAL DRIVE

Baker Hughes
Firenze Italy

MUC Oil & Gas Engineering Consultancy
Sharjah United Arab Emirates

GAS TURBINES - PACKAGERS

AFGlobal Corporation
Houston TX

Baker Hughes
Firenze Italy

Greengold Energy Ltd.
Kuala Lumpur WP Malaysia

GAS TURBINES -POWER GENERATION

Baker Hughes
Firenze Italy

BraytonEnergy
Hampton NH

Energy Experts Now
Juan Dolio Dominican Republic

G+H Schallschutz GmbH
Mannheim Germany

Industrial Motor Power Corporation
Los Angeles CA

Major Tool & Machine, Inc.
Indianapolis IN

PrecisionAir & LiquidSolutions,LLC
Hammond LA

Turbine Resources, Inc.
Euless TX

GAS TURBINES - POWER TURBINES

Rotating Machinery Services, Inc.
Bethlehem PA

GAS TURBINES - REFURBISHED

Baker Hughes
Firenze Italy

GENERATOR SETS - GAS TURBINES

Baker Hughes
Firenze Italy

MICROTURBINES

Ansaldo Energia S.p.A.
Genoa Italy

Capstone Turbine Corporation
Chatsworth CA

Flex Energy Solutions
Greenwood Village CO

INSTRUMENTATION & CONTROL

ACTUATORS

Drake Controls, LLC
Houston TX

ANALYZERS

OROS
Meylan Cedex France

AUTOMATION

KEB America, Inc.
Shakopee MN

TTS
Orlando FL

CONDITION MONITORING

Baker Hughes
Firenze Italy

BK Virbo America Inc.
Gardnerville NV

BRUSH GROUP
Ashby de la Zouch UK

Drake Controls, LLC
Houston TX

Emerson
Knoxville TN

EthosEnergy
Houston TX

Poseidon Systems, LLC
Rochester NY

Pruftechnik Dieter Busch AG
Ismaning Germany

Schenck USA Corp.
Deer Park NY

Shinkawa Electric Co. Ltd.
Chiyoda-ku Tokyo Japan

Veros Systems, Inc.
Austin TX

CONTROL SYSTEMS - OPTIMIZATION

Baker Hughes
Firenze Italy

CCC (Compressor Controls Corporation)
Des Moines IA

Energy Control Tecchnologies (ECT)
Urbandale IA

EthosEnergy
Houston TX

Honeywell Process Solutions
Houston TX

INSTRUMENTATION & CONTROL/MANUFACTURING

Mauell GmbH
Velbert NRW Germany

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Philadelphia Gear, Power Systems by Timken
King of Prussia PA

TTS
Orlando FL

Xiamen Make Locks Manufacturer Co., Ltd.
Xiamen China

CONTROL SYSTEMS - RETROFIT

Baker Hughes
Firenze Italy

BRUSH GROUP
Ashby de la Zouch UK

CCC (Compressor Controls Corporation)
Des Moines IA

Drake Controls, LLC
Houston TX

Elliott Group
Jeannette PA

Honeywell Process Solutions
Houston TX

HPI, LLC
Houston TX

L.A. Turbine
Valencia CA

Philadelphia Gear, Power Systems by Timken
King of Prussia PA

Rockwell Automation
Milwaukee WI

TTS
Orlando FL

CONTROL SYSTEMS & GOVERNORS

Baker Hughes
Firenze Italy

BRUSH GROUP
Ashby de la Zouch UK

De Pretto Industrie Srl
Schio Italy

Drake Controls, LLC
Houston TX

Governor Control Systems, Inc.
Fort Lauderdale FL

SSE - Sirio Sistemi Elettronici S.p.A.
Prato Italy

TurboMachinery Controls
Haywards Heath West Sussex UK

Veinfurt s.r.o.
Plzen Czech Republic

DATA LOGGERS & RECORDERS

PCE Deutschland GmbH
Meschede Germany

DETECTION SYSTEMS

Environment One Corporation
Niskayuna NY

General Atomics Electromagnetic Systems (GA-EMS)
San Diego CA

Spectronics Corporation
Westbury NY

FLOW METERS

ATO Automation, Inc.
Diamond Bar CA

Cook Compression
Houston TX

Cook Compression Ltd.
Ellesmere Port UK

Hoffer Flow Controls
Elizabeth City NC

Honeywell Process Solutions
Houston TX

PCE Deutschland GmbH
Meschede Germany

Tek-Trol LLC
Crystal Lake IL

Universal Flow Monitors, Inc.
Hazel Park MI

Wyatt Engineering, LLC
Lincoln RI

GAS ANALYZERS

Control Instruments Corporation
Fairfield NJ

Enerac
Holbrook NY

Honeywell Process Solutions
Houston TX

MKS Instruments, Inc.
Andover MA

GAUGES & INDICATORS

Clark-Reliance
Strongsville OH

INSTRUMENTATION - TELEMETRY

Accumetrics
Schenectady NY

INSTRUMENTATION & CONTROLS

Automation Products, Inc. - DYNATROLÂ® Division
Houston TX

Baker Hughes
Firenze Italy

Drake Controls, LLC
Houston TX

Elliott Group
Jeannette PA

GE Oil & Gas - Measurement & Control
Billerica MA

Honeywell Process Solutions
Houston TX

Kytola Instruments
Alpharetta GA

Petrotech,Inc.
New Orleans LA

Reuter-Stokes, a Baker Hughes business
Twinsburg OH

Spectro Scientific
Chelmsford MA

Temp-Pro,Inc.
Northampton MA

TMEIC Corporation Americas
Houston TX

TTS
Orlando FL

Weschler Instruments
Cleveland OH

WIKA Instrument, LP
Lawrenceville GA

MONITORS

Alber
Pompano Beach FL

REMOTE MONITORING & DIAGNOSTICS

Baker Hughes
Firenze Italy

Camfil Power Systems
Boras Sweden

EthosEnergy
Houston TX

Honeywell Process Solutions
Houston TX

Regal Beloit Corporation
Florence KY

Schenck USA Corp.
Deer Park NY

TTS
Orlando FL

SENSORS

Baker Hughes
Firenze Italy

NewTek Sensor Solutions
Pennsauken NJ

Palmer Wahl Instruments, Inc.
Asheville NC

SENSORS - PRESSURE

Honeywell Process Solutions
Houston TX

Kistler Instrument Corp.
Amherst NY

SENSORS - TEMPERATURE

AMETEK Power Instruments
Rochester NY

Honeywell Process Solutions
Houston TX

Pyromation, Inc.
Fort Wayne IN

Sensor Coating Systems Ltd.
London UK

The Sensor Connection
Troy MI

SHAFT GROUNDING & CONDITION MONITORING

Inpro/Seal
Rock Island IL

Magnetic Products and Services
Holmdel NJ

Shaft Current Solutions, Inc., DBA Sohre TurbomachineryÂ® Inc.
Florence Italy

TESTING EQUIPMENT

Baker Hughes
Firenze Italy

Capture 3D, Inc.
Costa Mesa CA

Durlmark Industrial, Inc.
Jinagsu China

H&L Instruments, LLC
North Hampton NH

PCE Deutschland GmbH
Meschede Germany

The L.S. Starrett Co.
Athol MA

UE Systems, Inc.
Elmsford NY

TORQUEMETERS

Riverhawk Company
New Hartford NY

Torquemeters Ltd.
Ravensthorpe Northampton UK

TURBINE CONTROL SYSTEMS

Baker Hughes
Firenze Italy

Compressor Controls Corporation
Des Moines IA

Drake Controls, LLC
Houston TX

Elliott Group
Jeannette PA

EthosEnergy
Houston TX

Holland-Controls BV
Hengelo Overeijssel Netherlands

Honeywell Process Solutions
Houston TX

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Revak Keene Turbomachinery, LP
La Porte TX

TTS
Orlando FL

VIBRATION MONITORING EQUIPMENT

Alta Solutions, Inc.
Poway CA

Baker Hughes
Firenze Italy

Balmac,Inc.
Plain City OH

BK Vibro America Inc.
Gardnerville NV

DeWal Industires
Narragansett RI

Drake Controls, LLC
Houston TX

Emerson
Knoxville TN

IfTA GmbH
Puchheim Germany

Instrumart
South Burlington VT

Meggitt Sensing Systems
Fribourg Switzerland

PCE Deutschland GmbH
Meschede Germany

Riverhawk Company
New Hartford NY

SEC of America, Inc.
Durham NC

Sensonics Ltd.
Berkhamsted Hertfordshire UK

Tern Technologies, Inc.
Anchorage AK

Voyager Instruments
Fort Collins AL

MANUFACTURING

3D PRINTING

Baker Hughes
Firenze Italy

C-Mac 3D Printing Service Sydney
Girraween New South Wales Australia

EthosEnergy
Houston TX

Hoosier Pattern, Inc.
Decatur IN

Sintavia, LLC
Fort Lauderdale FL

Sulzer Management Ltd
Winterthur ZH

The ExOne Company
North Huntington PA

MANUFACTURING/ MATERIALS/ PUMPS/ RENEWABLE ENERGY/ SAFETY EQUIPMENT/ SERVICES

CASTINGS

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

FABRICATORS

LAI International, Inc.
Tempe AZ

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Paradigm Precision
Burnley Lancashire UK

Penn Iron Works,Inc.
Wyomissing PA

SAS Global Corporation
Warren MI

FORGINGS

Ellwood City Forge
Ellwood City PA

GRINDING

Abrasive-Form, Inc.
Bloomingdale IL

Niche Tools & Abrasives
Orlando FL

Precision Profiles, LLC
Titusville PA

IMPELLERS

Baker Hughes
Firenze Italy

Champion Aviation Dynamic Technology (Xi'an) Co. Ltd.
Xi'an Shaanxi China

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Sulzer Management Ltd
Winterthur ZH

MACHINE TOOLS

DFC Tank Pressure Vessel Manufacturer Co., Ltd
Shijiazhuang China

Leistritz Advanced Technologies
Shijiazhuang China

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Prima Power Laserdyne
Champlin MN

Weingartner Maschinenbau GmbH
Kirchham Austria

MACHINING

Ace Wire Spring & Form Co., Inc.
McKees Rocks PA

Adron EDM Specialists
Menomonee Falls WI

Aerospace Alloys, Inc.
Bloomfield CT

AGL Manufacturing Ltd.
Vancouver BC Canada

AIKOKU ALPHA
Inazawa Ai Japan

Alexander Comley Ltd.
Wolverhampton West Midlands UK

EDM Department, Inc.
Bartlett IL

General Atomics Electromagnetic Systems (GA-EMS)
San Diego CA

GOIMEK
Itziar-Deba Guipuzcoa Spain

HFW Industries
Buffalo NY

Just In Time CNC Machining
Rochester NY

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Precision Profiles, LLC
Titusville PA

Ushers Machine & Tool
Greenville SC

MANUFACTURERS

Lucifer Furnaces, Inc.
Warrington PA

Optimistic
Lisbon Portugal

Thermal Structures, Inc.
Corona CA

MILLING

Emuge Corp.
West Boylston MA

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Precision Profiles, LLC
Titusville PA

WELDING

ArcProducts
San DiegoCA

Custom Engineering Company
Erie PA

HFW Industries
Buffalo NY

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

PTR-Precision Technologies, Inc.
Enfield CT

MATERIALS

ALLOYS

Aerospace Alloys, Inc.
Bloomfield CT

BGH Specialty Steel Services, Inc.
Macedonia OH

United Performance Metals
Hamilton OH

CARBON & CARBON PRODUCTS

Metcar
Ossining NY

HIGH TEMPERATURE METALS

Aerospace Alloys, Inc.
Bloomfield CT

Gloria Material Technology Corp.
Tainan Taiwan

United Performance Metals
Hamilton OH

INSULATION

AB TechGroup
Ogdensburg NY

PLASTICS

R. Blaine Industries, Inc. (RBI)
Reading PA

PUMPS

PUMPS

ACCA Pumps
Katy TX

ATO Automation Inc
Los Angeles CA

Baker Hughes
Firenze Italy

Blackmer- part of PSG, A Dover Company
Grand Rapids MI

Gorman-Rupp Company
Mansfield OH

Hammelmann Corporation
Dayton OH

HYUNDAI HEAVY INDUSTRIES TURBOMACHINERY
UISAN Dong-gu Korea South

Iwaki America / Iwaki AIR
Holliston MA

Leistritz Advanced Technologies
Allendale NJ

LEWA-Nikkiso America, Inc.
Holliston MA

Rotoflow, An Air Products Business
Allentown PA

Sulzer Management Ltd.
Winterthur ZH Switzerland

Tri-Rotor Pump
Torrington CT

Turbo Non-Destructive Testing, Inc.
Houston TX

PUMPS - CENTRIFUGAL

Carver Pump Company
Muscatine IA

Gorman-Rupp Company
Mansfield OH

Sulzer Management Ltd.
Winterthur ZH Switzerland

PUMPS - SCREW

Leistritz Corporation
Allendale NJ

RENEWABLE ENERGY

ENERGY SYSTEMS

BASF
Shakopee MN

General Atomics Electromagnetic Systems (GA-EMS)
San Diego CA

Iren SpA
Torino Switzerland

LPP Combustion, LLC
Columbia MD

Nel Hydrogen
Wallingford CT

ZE Europe Ltd.
Salisbury Wilts UK

GEOTHERMALPOWER

BRUSH GROUP
Ashby de la Zouch UK

EthosEnergy
Houston TX

L.A. Turbine
Valencia CA

HYDRO TURBINES

Petrotech,Inc.
New Orleans LA

SOLAR ENERGY

Topper Floating Solar PV Mounting Manufacturer Co. Ltd.
Xiamen China

WIND TURBINES

PCB
Depew NY

SAFETY EQUIPMENT

EMERGENCY SHUTDOWN

Drake Controls, LLC
Houston TX

Emerson
Knoxville TN

Honeywell Process Solutions
Houston TX

FIRE DETECTION EQUIPMENT

Allestec Corporation
Kingwood TX

Honeywell Process Solutions
Houston TX

FIRE PROTECTION & SUPPRESSION

Victaulic
Easton PA

SAFETY CLOTHING & EQUIPMENT

Honeywell Process Solutions
Houston TX

SERVICES

ASSET MANAGEMENT SERVICES

Baker Hughes
Firenze Italy

Emerson
Knoxville TN

EthosEnergy
Houston TX

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Soluciones de Ingeniería y Mantenimiento - SIM, S.L.
Madrid Spain

ASSOCIATIONS

ASME International Gas Turbine Institute
Houston TX

CLEANING SERVICES

Rico Industrial Services Ltd.
Tenbruy Wells Worcestershire UK

COATING SERVICES

Bodycote S3P
London UK

HFW Industries
Buffalo NY

Liburdi Turbine Services, Inc.
Dundas ON Canada

Sifco ASC
Independence OH

Sulzer Management Ltd
Winterthur ZH Switzerland

SERVICES

CONSTRUCTION CONTRACTORS

Petrochem Insulation, Inc.
Vallejo CA

CONSULTING SERVICES

Baker Hughes
Firenze Italy

Business Exploration
Milan Italy

BWD Turbines Ltd.
Hamilton ON

CCC (Compressor Controls Corporation)
Des Moines IA

EnEx Advisors,LLC
Plano TX

Foster Cove Engineering, Inc.
Davenport FL

Gas Electric Partnership
Houston TX

Global Turbomachinery Consulting Group
League City TX

Heat Transfer Technologies
Saint Lizier France

Honeywell Process Solutions
Houston TX

Jonas,Inc.
Pomfret MD

Kotra Zurich
Zurich Switzerland

Lahmeyer International GmbH
Bad Vilbel Germany

Link4Success
Kowloon Hong Kong

PCA Engineers Ltd.
Lincoln Lincs UK

Peter Baldwin Consulting Services
Winchester MA

Rotating Machinery Services, Inc.
Bethlehem PA

SHL Consulting
Vernon CT

Straits Research
New York NY

Workforce Group
Baton Rouge LA

CORROSION DETECTION & PREVENTION

Honeywell Process Solutions
Houston TX

DIMENSIONAL INSPECTION & RE-ENGINEERING

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

ENGINEERING SERVICES

Accurate Engineering, LLC
East Lansing MI

Alden
Holden MA

B&B-AGEMA
Aachen DE Germany

Baker Hughes
Firenze Italy

Compressor Controls Corporation
Des Moines IA

ENPPI
Cairo Egypt

Hoerbiger Service - Middle East
Dubai United Arab Emirates

Honeywell Process Solutions
Houston TX

KnightHawk Engineering, Inc.
Houston TX

Laschet ConsultingGmbH
Bergisch Gladbach Germany

Liburdi Turbine Services, Inc.
Dundas ON Canada

Macek Power & Turbomachinery Engineering
Friendswood TX

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

MTU Aero Engines North America
Rocky Hill CT

Omara Engineering, PC
Williamsville NY

Petra Resources Sdn Bhd
Petaling Jaya Selangor Malaysia

Precision Profiles, LLC
Titusville PA

Rotor Bearing Technology& Software (RBTS)
Phoenixville PA

Shaft Current Solutions, Inc., DBA Sohre TurbomachineryÂ® Inc.
Florence MA

TTS
Orlando FL

EPC

Ansaldo Energia S.p.A.
Genoa Italy

KBR Power and Industrial
Birmingham AL

EQUIPMENT - LEASING

Rental Power Solutions
Miami FL

EQUIPMENT - USED

EthosEnergy
Houston TX

Exchangium
Orlando FL

FIELD SERVICE

AST Turbo AG
Altendorf Switzerland

Baker Hughes
Firenze Italy

BRUSH GROUP
Ashby de la Zouch UK

Cook Compressions
Houston TX

Donaldson Company, Inc.
Bloomington MN

Dover Precision Components
The Woodlands TX

Drake Controls, LLC
Houston TX

ElliottGroup
Jeannette PA

EthosEnergy
Houston TX

Howden
Connersville IN

Integrated TurboMachinery, Inc.
Montebello CA

L.A. Turbine
Valencia CA

Maintenance Technologies International, LLC
Milford CT

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Nord-Lock Group
Clinton PA

PEC Ltd. (Machinery Service)
Singapore

Rotating Machinery Services, Inc.
Bethlehem PA

Roteq Switzerland Ltd.
Freienbach SZ Schwyz Switzerland

Rotoflow, An Air Products Business
Allentown PA

S2W Contracting LLC
Tunkhannock PA

Shaft Current Solutions, Inc., DBA Sohre TurbomachineryÂ® Inc.
Florence MA

Sulzer Management Ltd.
Winterthur ZH Switzerland

GROUTING

S2W Contracting LLC
Tunkhannock PA

HEAT TREATING - FURNACES

EFD Induction
Madison Heights MI

Vac Aero International, Inc.
Oakville ON Canada

INSPECTION

American Efficiency Services
Woodbine MD

Baker Hughes
Firenze Italy

BRUSH GROUP
Ashby de la Zouch UK

Donaldson Company, Inc.
Bloomington MN

Turbo Non-Destructive Testing, Inc.
Houston TX

INSTALLATION

Baker Hughes
Firenze Italy

ElliottGroup
Jeannette PA

Machinery Mounting Solutions, Inc.
Virginia Beach VA

S2W Contracting LLC
Tunkhannock PA

MARKET RESEARCH

Essential Resources,LLC
Morristown NJ

Global Market Insights, Inc.
Selbyville DE

Industrial Info Resources, Inc.
Sugar Land TX

PLANT OPERATION & MANAGEMENT

Baker Hughes
Firenze Italy

BHEL
New Delhi India

EthosEnergy
Houston TX

PROJECT ENGINEERING

Scansonic GSM GmbH
Berlin Germany

Sulzer Management Ltd.
Winterthur ZH Switzerland

RECRUITERS & EMPLOYMENT AGENCIES

DB Consulting
Virginia Beach VA

System One
Pittsburgh PA

RESEARCH & DEVELOPMENT

Baker Hughes
Firenze Italy

Cook Compression
Houston TX

Creare, LLC
Hanover NH

Dover Precision Components
The Woodlands TX

Southwest Research Institute
San Antonio TX

Waukesha Bearings
Waukesha WI

RESEARCH & DEVELOPMENT-SEALS

Greene Tweed
Houston TX

Inpro/Seal
Rock Island IL

SERVICE FOR TURBINES & GENERATORS

Baker Hughes
Firenze Italy

Boyd Machine & Repair
Kimmell IN

BRUSH GROUP
Ashby de la Zouch UK

De Pretto Industrie Srl
Schio Italy

Doosan Škoda Power
Plzen Czech Republic

ElliottGroup
Jeannette PA

EthosEnergy
Houston TX

Lambda Technologies Group
Cincinnati OH

Optimistic
Lisbon Portugal

Sulzer Management Ltd.
Winterthur ZH Switzerland

The Balancing Company
Vandalia OH

TST-TurboService&TradingGmbH
Moers NRW Germany

TURBOMACHINERY SHIPPING & STORAGE CONTAINERS

Crowley Logistics Inc.
Houston TX

Dixie Cullen Interests, Inc.
Houston TX

STEAM TURBINES/ TRAINING & EDUCATION

STEAM TURBINES

GENERATOR SETS - STEAM TURBINES

De Pretto Industrie Srl
Schio Italy

Doosan Škoda Power
Plzen Czech Republic

ElliottGroup
Jeannette PA

WEG Steam Turbines
Duluth Georgia

STEAM TURBINES

Ansaldo Energia S.p.A.
Genoa Italy

Baker Hughes
Firenze Italy

De Pretto Industrie Srl
Schio Italy

Doosan Škoda Power
Plzen Czech Republic

ElliottGroup
Jeannette PA

EthosEnergy
Houston TX

FLOWDY
Changwon Gyeongsangnam-do Korea South

Franco Tosi Meccanica S.p.A.
Legnano Milano Italy

Howden
Connersville IN

M+M Turbinen-Technik GmbH
Bielefeld Germany

Precision Profiles, LLC
Titusville PA

Revak Keene Turbomachinery, LP
La Porte TX

Rotating Machinery Services, Inc.
Bethlehem PA

Skinner Power Systems
Erie PA

TGM Steam Turbines
Sertaozinho - SP Sao Paulo Brazil

Turbo Non-Destructive Testing, Inc.
Houston TX

STEAM TURBINES - ELECTRICAL, INDUSTRIAL

ElliottGroup
Jeannette PA

HYUNDAI HEAVY INDUSTRIES TURBOMACHINERY
ULSAN Dong-gu Korea South

STEAM TURBINES - ELECTRICAL, NUCLEAR

RelaDyne Reliability Services
Cincinnati OH

STEAM TURBINES - MECHANICAL

ElliottGroup
Jeannette PA

Frontken (Singapore) Pte. Ltd.
Singapore

Rotating Machinery Services, Inc.
Bethlehem PA

STEAM TURBINES - MECHANICAL MARINE

HYUNDAI HEAVY INDUSTRIES TURBOMACHINERY
ULSAN Dong-gu Korea South

STEAM TURBINES - MECHANICAL, PROCESS

ElliottGroup
Jeannette PA

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

STEAM TURBINES - PACKAGERS

Cobey, Inc.
Buffalo NY

ElliottGroup
Jeannette PA

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

STEAM TURBINES - REFURBISHED

De Pretto Industrie Srl
Schio Italy

Doosan Škoda Power
Plzen Czech Republic

ElliottGroup
Jeannette PA

Integrated TurboMachinery, Inc.
Montebello CA

Mitsubishi Heavy Industries Compressor International (MCO-I)
Houston TX

Revak Keene Turbomachinery, LP
La Porte TX

Rotating Machinery Services, Inc.
Bethlehem PA

TRAINING & EDUCATION

ASME CERTIFICATION

Optimistic
Lisbon Portugal

BOOKS & MAGAZINES

COMPRESSORtech2 - KHL Group
Waukesha Wi

TURBOMACHINERY INTERNATIONAL
Islin, NJ

EDUCATION

International Generator Technical Community
Columbus OH

TRAINING

Baker Hughes
Firenze Italy

Camfil Power Systems
Boras Sweden

Compressor Controls Corporation
Des Moines IA

ElliottGroup
Jeannette PA

Flexware, Inc.
Grapeville PA

Global Training Solutions Inc.
Mississauga ON Canada

Laschet Consulting GmbH
Bergisch Gladbach Germany

Vibration Institute
Oakbrook IL

TRADEMARKS

AeroBlock Standardized integrally-geared main air compressor for industrial gas applications • Atlas Copco, Cologne, Germany

BoostToReduce Upgrading GT-filtration is the easiest way to reduce carbon emissions • Camfil Power Systems, Boras, Sweden

CamGT 3V-600 Game changing high efficiency filter for non-stop performance • Camfil Power Systems, Boras, Sweden

COMS Contec Oil Mist Separators • Contec GmbH, Bad Honnef, Germany

COMS Contec Oil Mist Separators and high-performance filter systems • Contec GmbH, Bad Honnef, Germany

ECOMAX Fully customizable solution for automated combustion tuning • EthosEnergy, Alpharetta GA

ExVel Turbo Fans Specializing in Mechanical Vapor Recompression MVR • Howden, Connersville, IN

FSR Full Solution Rejuvenation Proprietary Heat Treatments to restore turbine blades/buckets to as-new strength • Liburdi Turbine Services, Inc., Dundas Ontario Canada

Gas Connectivity Suite of digital connectivity solutions for turbomachinery service • Atlas Copco, Cologne, Germany

Howden Global leader in air and gas handling solutions since 1854 • Howden, Connersville, IN

Icon Control Systems Proven solution replaces legacy GE controls for Mark I to Mark VI • EthosEnergy, Alpharetta GA

MSG Centac Multi-stage geared (MSG) centrifugal air compressors • Ingersoll-Rand Co., Davidson,NC

MSG Turbo-Air Multi-stage geared (MSG) centrifugal Air & Gas Compressors • Ingersoll-Rand Co., Davidson, NC

NovaLT Gas Turbines family Gas turbines for 5-20MW in power-generation and mechanical-drive • Baker Hughes, Firenze, Italy

PNEUTRIP Highest performing pneumatic trip valve solution 1002 and 2003 • Drake Controls, Houston, TX

PolyBlock Standardized direct-driven centrifugal compressor for PP/PE applications • Atlas Copco, Cologne, Germany

PowerEye: real-time monitoring of key inlet system and GT metrics • Camfil Power Systems, Boras, Sweden

Roots Rotary positive displacement blowers since 1854 • Howden, Connersville, IN

Sohre Turbomachinery Inc. Shaft riding brushes invented by John S. Sohre, P.E. • Sohre Turbomachinery Inc., Florence, MA

Turblex World-leading efficient compressors and steam turbines • Howden, Connersville, IN

TurboBlock Standardized, integrally- geared centrifugal compressor for the power generation market • Atlas Copco, Cologne, Germany

TurboLink Digital connectivity solution for Operating Data Analysis • Atlas Copco, Cologne, Germany

Combined Cycle Plant Specifications

ANSALDO ENERGIA, Genoa, Italy

MODEL	POWER RATING Net plant power output (MW)	EFFICIENCY Net plant efficiency %	GAS TURBINES Number	Model	Frequency (Hz)
1AE64.3-CC1S	120.0	55.7	1	AE64.3A	50/60
1AE94.2-CC1M	287.0	55.8	1	AE94.2	50
1AE94.3-CC1S	495.0	60.0	1	AE94.3A	50
1GT26-CC1S	540.0	61.0	1	GT26	50
1GT36-S5-CC1M	760.0	62.6	1	GT36-S5	50
1GT36-S6-CC1M	520.0	62.3	1	GT36-S6	60
2AE64.3-CC1M	243.0	56.4	2	AE64.3A	50/60
2AE94.2-CC1M	578.0	56.2	2	AE94.2	50
2AE94.3-CC1M	992.0	60.3	2	AE94.3A	50
2GT26-CC1M	1083.0	61.2	2	GT26	50
2GT36-S5-CC1M	1525.0	62.8	2	GT36-S5	50
2GT36-S6-CC1M	1046.0	62.6	2	GT36-S6	60

Note: Reference Conditions: ISO conditions (Amb. temp. = 15°C, amb. press.= 1.013 bar, amb. R.H. = 60%; natural gas methane), direct cooling, 3RH cycles, 100% CH4 natural gas fuel

MITSUBISHI POWER, LTD

MODEL	POWER RATING ISO Base Load At Generator Terminals (MW)		GROSS HEAT RATE Lower Heating Value (LHV) (Btu/kWh)	GAS TURBINES			
	Gas Turbines	Steam Turbine		Number	Model	Frequency (Hz)	Efficiency (%)
MPCP1 (M501DA)	112.1	55.3	6,635	1	M501DA	60	51.4
MPCP2 (M501DA)	224.2	112.0	6,610	2	M501DA	60	51.6
MPCP3 (M501DA)	336.3	169.9	6,585	3	M501DA	60	51.8
MPCP1 (M501F)	182.7	102.4	5,976	1	M501F	60	57.1
MPCP2 (M501F)	365.4	206.8	5,955	2	M501F	60	57.3
MPCP1 (M501G)	264.4	134.5	5,843	1	M501G	60	58.4
MPCP2 (M501G)	528.8	271.7	5,823	2	M501G	60	58.6
MPCP1 (M501GAC)	280.8	146.2	5,640	1	M501GAC	60	60.5
MPCP2 (M501GAC)	561.6	294.4	5,622	2	M501GAC	60	60.7
MPCP3 (M501GAC)	842.4	442.6	5,622	3	M501GAC	60	60.7
MPCP1 (M501J)	326.2	157.8	5,504	1	M501J	60	62.0
MPCP2 (M501J)	652.4	318.6	5,486	2	M501J	60	62.2
MPCP1 (M501JAC)	431.9	198.1	<5,332	1	M501JAC	60	>64
MPCP2 (M501JAC)	863.8	399.2	<5,315	2	M501JAC	60	>64.2
MPCP1 (M701DA)	142.1	70.4	6,635	1	M701DA	50	51.4
MPCP2 (M701DA)	284.2	142.4	6,610	2	M701DA	50	51.6
MPCP3 (M701DA)	426.3	218.7	6,585	3	M701DA	50	51.8
MPCP1 (M701G)	325.7	172.3	5,755	1	M701G	50	59.3
MPCP2 (M701G)	651.4	348.0	5,735	2	M701G	50	59.5

Combined Cycle Plant Specifications

MITSUBISHI POWER, LTD

MODEL	POWER RATING ISO Base Load At Generator Terminals (MW)		GROSS HEAT RATE Lower Heating Value (LHV) (Btu/kWh)	GAS TURBINES			
	Gas Turbines	Steam Turbine		Number	Model	Frequency (Hz)	COMMENTS
MPCP1(M701F)	379.3	186.7	5,504	1	M701F	50	62.0
MPCP2 (M701F)	758.6	376.4	5,486	2	M701F	50	62.2
MPCP1 (M701J)	472.3	228.7	5,477	1	M701J	50	62.3
MPCP1 (M701JAC)	570.9	269.1	<5,332	1	M701JAC	50	>64
MPCP1 (M701JAC)	441.7	208.3	<5,332	1	M701JAC	50	>64
MPCP1 (H-25)	39.6	20.5	6,319	1	H-25	50/60	54.0
MPCP2 (H-25)	79.2	42.2	6,261	2	H-25	50/60	54.5
MPCP1 (H-100)	112.7	58.3	5,945	1	H-100	50	57.4
MPCP2 (H-100)	225.4	120.6	5,884	2	H-100	50	58.0
MPCP1 (H-100)	102.5	47.5	6,193	1	H-100	60	55.1
MPCP2 (H-100)	205.0	100.7	6,083	2	H-100	60	56.1

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

MITSUBISHI POWER AERO, LLC, Glastonbury, Connecticut, U.S.A. aero.power.mhi.com

MODEL	POWER RATING ISO Base Load At Generator Terminals (MW)		HEAT RATE Lower Heating Value (LHV) (Btu/kWh)	GAS TURBINES			
	Gas Turbines	Steam Turbine		Number	Model	Frequency (Hz)	COMMENTS
FT8 SWIFTPAC 30	42.1	12.0	7333	1	FT8-3	50/60	
FT8 SWIFTPAC 60	85.1	24.6	7257	2	FT8-3	50/60	
FT4000 SWIFTPAC 60	89.3	18.4	7106	1	FT4000	50/60	2P, non reheat, unfired
FT4000 SWIFTPAC 120	179.9	37.8	7051	2	FT4000	50/60	2P, non reheat, unfired

Combined Cycle Plant Specifications

SIEMENS ENERGY

MODEL	POWER RATING ISO Base Load At Generator Terminals (MW) Gas Turbines	Total power	HEAT RATE Lower Heating Value (LHV) (kJ/kWh)	GAS TURBINES Number	Model	Frequency (Hz)	COMMENTS
SCC5-9000HL Single Shaft	870		<5,714	1	SGT5-9000HL	50	(2)
SCC5-9000HL 2x1	1,740		<5,714	2	SGT5-9000HL	50	(2)
SCC6-9000HL Single Shaft	595		<5,714	1	SGT6-9000HL	60	(2)
SCC6-9000HL 2x1	1,190		<5,714	2	SGT6-9000HL	60	(2)
SCC6-8000H Single Shaft	460		5,920	1	SGT6-8000H	60	(2)
SCC6-8000H 2x1	930		5,910	2	SGT6-8000H	60	(2)
SCC6-5000F 1x1	325		6,050	1	SGT6-5000F (215 MW)	60	(2)
SCC6-5000F 2x1	650		6,040	2	SGT6-5000F (215 MW)	60	(2)
SCC6-5000F 1x1	387		6,040	1	SGT6-5000F (260 MW)	60	(2)
SCC6-5000F 2x1	775		6,030	2	SGT6-5000F (260 MW)	60	(2)
SCC5-8000H Single Shaft	665		5,890	1	SGT5-8000H	50	(2)
SCC5-8000H 2x1	1,335		5,880	2	SGT5-8000H	50	(2)
SCC5-4000F Single Shaft	475		6,030	1	SGT5-4000F	50	(2)
SCC5-4000F 2x1	950		6,030	2	SGT5-4000F	50	(2)
SCC5-2000E 1x1	275		6,679	1	SGT5-2000E	50	(2)
SCC5-2000E 2x1	551		6,679	2	SGT5-2000E	50	(1)
SCC6-2000E 1x1	174		6,893	1	SGT6-2000E	60	(1)
SCC6-2000E 2x1	347		6,901		SGT6-2000E	60	(1)

Site conditions = 59°F, 14.7 psia, 60% RH (15°C, 1.013 bar).
1 dual pressure, no reheat
2 triple pressure, reheat
Net plant performance shown above includes auxiliary power consumption. All ratings on natural gas with LHV

Combined Cycle Plant Specifications

SIEMENS ENERGY

MODEL	POWER RATING ISO Base Load At Generator Terminals (MW) Gas Turbines	Total power	HEAT RATE Lower Heating Value (LHV) (kJ/kWh)	GAS TURBINES Number	Model	Frequency (Hz)	COMMENTS
SCC-600 1x1	36.5		6734	1	SGT-600	50/60	(1)
SCC-600 2x1	74.2		6616	2	SGT-600	50/60	(1)
SCC-700 1x1	46.7		6301	1	SGT-700 33MW	50/60	(1)
SCC-700 2x1	92.6		6354	2	SGT-700 33MW	50/60	(1)
SCC-700 1x1	49.8		6264	1	SGT-700 35MW	50/60	(1)
SCC-700 2x1	100		6233	2	SGT-700 35MW	50/60	(1)
SCC-750 1x1	52.1		6336	1	SGT-750	50/60	(1)
SCC-750 2x1	104.8		6304	2	SGT-750	50/60	(2)
SCC-800 (50 MW) 1x1	71.9		6.239	1	SGT-800 (50 MW)	50/60	(3)
SCC-800 (50 MW) 2x1	145.3		6.175	2	SGT-800 (50 MW)	50/60	(3)
SCC-800 (50 MW) 3x1	217.9		6.175	3	SGT-800 (50 MW)	50/60	(3)
SCC-800 (54 MW) 1x1	78.1		6.261	1	SGT-800 (54 MW)	50/60	(3)
SCC-800 (54 MW) 2x1	157.9		6.196	2	SGT-800 (54 MW)	50/60	(3)
SCC-800 (54 MW) 3x1	236.7		6.196	3	SGT-800 (54 MW)	50/60	(3)
SCC-800 (56 MW) 1x1	80.0		6.218	1	SGT-800 (56 MW)	50/60	(3)
SCC-800 (56 MW) 2x1	162.1		6.143	2	SGT-800 (56 MW)	50/60	(3)
SCC-800 (56 MW) 3x1	243.1		6.143	3	SGT-800 (56 MW)	50/60	(3)
SCC-800 (57 MW) 1x1	81.5		6.154	1	SGT-800 (57 MW)	50/60	(3)
SCC-800 (57 MW) 2x1	164.8		6.091	2	SGT-800 (57 MW)	50/60	(3)
SCC-800 (57 MW) 3x1	247.5		6.091	3	SGT-800 (57 MW)	50/60	(3)
SCC-800 (62 MW) 1x1	89		6.040	1	SGT-800 (62 MW)	50/60	(3)
SCC-800 (62 MW) 2x1	182		5.941	2	SGT-800 (62 MW)	50/60	(3)
SCC-800 (62 MW) 3x1	273		5.941	3	SGT-800 (62 MW)	50/60	(3)
SGT-A35 DLE 1x1 (Ind. RB211-G62 DLE)	37.7		7,175	1	SGT-A35	50/60	(1)
SGT-A35 DLE 1x1 (Ind. RB211-GT62 DLE)	39.8		7,005	1	SGT-A35	50/60	(1)
SGT-A35 DLE 1x1 (Ind. RB211-GT61 DLE)	42.6		6,820	1	SGT-A35	50/60	(1)

All ratings on natural gas with LHV.
1 dual pressure, no reheat
2 triple pressure, reheat
3 triple pressure, no reheat
All combined cycle performance data shown above are gross values at ISO ambient conditions

Electrical Generation Specifications

ANSALDO ENERGIA, Genoa, Italy

MODEL	POWER RATING ISO Base Load (MW)	EFFICIENCY %	POWER SHAFT SPEED (RPM)	PRESSURE RATIO	NUMBER OF COMBUSTORS	AT ISO BASE LOAD Grid Frequency	Exhaust Flow (kg/sec)	Exhaust Temp (°C)
AE64.3A	80	36.4	*3,000/3,600	18.3	1 (annular)	*50/60 Hz	215	580
AE94.2	190	36.3	3,000	12.0	2 (silo)	50 Hz	555	550
AE94.2K	170	36.5	3,000	12.0	2 (silo)	50 Hz	540	545
AE94.3A	340	40.3	3,000	19.5	1 (annular)	50 Hz	755	593
GT26	370	41.0	3,000	35.0	2 (annular)	50 Hz	741	625
GT36-S5	538	42.8	3,000	26.0	1 (cannular)	50 Hz	1,020	621
GT36-S6	369	42.3	3,600	24.0	1 (cannular)	60 Hz	710	630
AE-T100	0.1	30.0	70,000	4.5	1 (silo)	50/60 Hz	1	270

Notes: Reference conditions: ISO, i.e., Amb. temp. = 15°C, amb. press.= 1.013 bar, amb. R.H. = 60%;
Natural gas methane, except low heating value gas for AE94.2K
GT Inlet pressure loss = 0 mbar, GT Exhaust pressure loss = 0 mbar
*with gear (gas turbine 90 Hz)

BAKER HUGHES

MODEL	POWER OUTPUT (MW)	HEAT RATE Lower Heating Value (LHV)(Btu/kWh)	POWER SHAFT SPEED (RPM)	PRESSURE RATIO	NUMBER OF COMBUSTORS	AT ISO BASE LOAD Turbine Inlet Temp. (°C)	Exhaust Flow (kg/sec)	Exhaust Temp (°C)
OIL & GAS								
NovaLT5-1	5.5	11606	16630	14.8	1 anular	20.4	580	580
NovaLT12	12.5	9666	8900	19	1 anular	42.3	496	496
NovaLT16	16.9	9374	7800	19	1 anular	54.6	495	495
PGT25 DLE	22.5	9452	6500	17.9	1 anular	68.9	524	524
PGT25+ DLE Xtend 9 ppm	25.1	8909	6100	21.5	1 anular	84.3	480	530
PGT25+ DLE High Power	30	8727	6100	21.5	1 anular	84.3	500	480
PGT25+G4 DLE	32.5	8727	6100	23.2	1 anular	89.7	510	
PGT25+G5 DLE Xtend 15ppm	32.8	8840	6100	24.9	1 anular	92.5	550	500
PGT25+G5 DLE High Power	36.9	8617	6100	24.9	1 anular	92.5	550	510
LM2500	22.7	9348	3600	18.7	1 anular	69	530	550
LM2500+	31.2	8749	3600	23.7	1 anular	87	516	516
LM2500+G4	33.6	8660	3600	24	1 anular	91	527	527
LM2500+G5 Xtend 15ppm	33.6	8573	3600	25	1 anular	92	530	540
LM2500+G5 DLE High Power	37.6	8425	3600	25	1 anular	92	555	454
LM6000PC	43.3	8302	3600	28.8	1 anular	126.2	454	457
LM6000PF	43.3	8282	3600	29.1	1 anular	125.5	457	496
LM6000 PF+	52.5	8322	3930	32.3	1 anular	136.8	496	560
Frame5/1	25.5	12318	5100	10.6	10 cans	122.5	560	551
Frame6/1B	44	10185	5163	12.7	10 cans		551	518
Frame5/2E	32.8	9531	5714	17.3	6 cans	102.5	518	535
Frame7/1EA	91	10065	3600	13	10 cans	296	535	
LM9000	73	7844	3000	33	1 anular	182	456	456
LMS100 PB+	108	7935	3000	44	1 anular	230	412	412
Frame9/1E	132	10006	3000	12.7	14 cans	410	540	540

Electrical Generation Specifications

KAWASAKI HEAVY INDUSTRIES, LTD., Akashi, Japan

MODEL	POWER RATING ISO Base Load (MW)	EFFICIENCY %	POWER SHAFT SPEED (RPM)	PRESSURE RATIO	NUMBER OF COMBUSTORS	AT ISO BASE LOAD Turbine Inlet Temp. (°C)	AT ISO BASE LOAD Exhaust Flow (kg/sec)	AT ISO BASE LOAD Exhaust Temp (°C)
M1A-13A	1.49	14,104	1,500/1,800	9.4	1	—	8.1	531
M1A-13D	1.49	14,246	1,500/1,800	9.6	1	—	8.0	531
M1T-13A	2.93	14,312	1,500/1,800	9.4	1×2	—	16.2	521
M1A-17D	1.81	12,160	1,500/1,800	10.5	1	—	8.1	522
M1T-13D	2.93	14,445	1,500/1,800	9.6	1×2	—	16.0	531
M5A-01D	4.71	10,450	1,500/1,800	15.4	6	—	17.4	511
M7A-01	5.53	11,510	1,500/1,800	13.1	6	—	21.7	545
M7A-01D	5.47	11,550	1,500/1,800	13.1	6	—	21.7	542
M7A-02	6.80	11,250	1,500/1,800	16.0	6	—	27.0	516
M7A-02D	6.74	11,270	1,500/1,800	16.0	6	—	27.0	513
M7A-03D	7.80	10,190	1,500/1,800	15.8	6	—	27.2	523
L20A	18.52	9,948	1,500/1,800	18.6	8	—	59.8	541
L30A	34.38	8,460	1,500/1,800	25.8	8	—	92.6	502

MITSUBISHI POWER, LTD

MODEL	POWER RATING ISO Base Load (MWe)	HEAT RATE Lower Heating Value (LHV)(Btu/kWh)	POWER SHAFT SPEED (RPM)	PRESSURE RATIO	NUMBER OF COMBUSTORS	AT ISO BASE LOAD Inlet Temp. (°C)	AT ISO BASE LOAD Exhaust Flow (kg/sec)	AT ISO BASE LOAD Exhaust Temp (°C)	AT ISO BASE LOAD Efficiency (%)
M501DA	114.0	9,780	3,600	14	14	—	354	543	34.9
M501F	185.4	9,230	3,600	16	16	—	468	613	37
M501G	267.5	8,730	3,600	20	16	—	612	601	39.1
M501GAC	283.0	8,531	3,600	20	16	—	618	617	40.0
M501J	330.0	8,105	3,600	23	16	—	620	645	44
M501JAC	435	7,755	3,600	25	16	—	764	645	44
M701DA	144.1	9,810	3,000	14	18	—	453	542	34.8
M701G	334.0	8,630	3,000	21	20	—	755	587	39.5
M701F	385.0	8,144	3,000	21	20	—	748	630	41.9
M701J	478.0	8,067	3,000	23	22	—	896	630	42.3
M701JAC	574	7,862	3,000	25	22	—	1024	646	43.4
M701JAC	448.0	7,755	3,000	25	18	—	765	663	44
H-25	41.0	9,432	7,280	17.9	10	—	114	569*	36.2
H-100	116.5	8,909	3,000	18	10	—	296	586*+	38.3
H-100	105.8	8,930	3,600	18.4	10	—	293	534*++	38.2

Notes: All other specifications are for natural gas fuel with inlet and exhaust losses. * without inlet and exhaust losses. +50Hz, ++60Hz

Electrical Generation Specifications

OPRA GAS TURBINES, The Netherlands

MODEL	POWER RATING ISO Base Load (MW)	HEAT RATE Lower Heating Value (LHV) (Btu/kW-hr)	POWER SHAFT SPEED (RPM)	PRESSURE RATIO	NUMBER OF COMBUSTORS	AT ISO BASE LOAD		
						Turbine Inlet Temp. (°C)	Exhaust Flow (lb/sec)	Exhaust Temp (°C)
OP16-3A	1.88	13,585	26,000	6.7	4	—	19.8	573
OP16-3B*	1.88	13,585	26,000	6.7	4	—	19.8	573
OP16-3C**	1.88	13,585	26,000	6.7	4	—	19.8	573

* DLE combustors NOx <15PPMV
** Ultra low caloric fuel, down to 5 MJ/kg

MITSUBISHI POWER AERO, LLC, Glastonbury, Connecticut, U.S.A. aero.power.mhi.com

MODEL	POWER RATING ISO Base Load (MWe)	HEAT RATE Lower Heating Value (LHV) (Btu/kWh)	POWER SHAFT SPEED (RPM)	PRESSURE RATIO	NUMBER OF COMBUSTORS	AT ISO BASE LOAD		
						Turbine Inlet Temp. (°C)	Exhaust Flow (lbs/sec)	Exhaust Temp (°F)
MITSUBISHI POWER AERO (50 HZ)								
FT8 SWIFTPAC 60 *	61.6	9 366		3000	21.3	18	405	922
FT8 SWIFTPAC 30 *	30.7	9 383		3000	21.3	9	202	922
FT8 SWIFTPAC 50 DLN	50.9	8 970		3000	19.5	2	373	863
FT8 SWIFTPAC 25 DLN	25.3	9 016		3000	19.5	1	186	863
FT8 MOBILEPAC **	28.5	9 834		3000	21.2	9	203	924
FT4000 SWIFTPAC 140 ***	140.5	8 431		3000	37.9	2	808	808
FT4000 SWIFTPAC 70 ***	70.2	8 443		3000	37.9	1	404	808
MITSUBISHI POWER AERO (60 HZ)								
FT8 SWIFTPAC 60 *	62.1	9 281		3600	21.3	18	404	916
FT8 SWIFTPAC 30 *	30.9	9 327		3600	21.3	9	202	916
FT8 SWIFTPAC 50 DLN	51.1	8 938		3600	19.5	2	372	861
FT8 SWIFTPAC 25 DLN	25.4	8 993		3600	19.5	1	186	861
FT8 MOBILEPAC **	30.9	9 312		3600	21.3	9	202	916
FT4000 SWIFTPAC 140 ***	144.2	8 209		3600	37.9	2	808	791
FT4000 SWIFTPAC 70 ***	71.9	8 232		3600	37.9	1	404	791

Estimates are for natural gas fuel. Zero installation losses.
*combustor water injection **combustor water injection, transportable ***combustor water injection, wet compression, inlet fogging

Electrical Generation Specifications

SIEMENS ENERGY (50/60 HZ)

MODEL	POWER RATING ISO Base Load (MW)	HEAT RATE Lower Heating Value (LHV) (Btu/kWh)	POWER SHAFT SPEED (RPM)	PRESSURE RATIO	NUMBER OF COMBUSTORS	AT ISO BASE LOAD		
						Turbine Inlet Temp. (°C)	Exhaust Flow (lbs/sec)	Exhaust Temp (°F)
SGT-800 (62 MW)	62.5	8.302	6.600	21.1	—	—	298.7	1.104
SGT-800 (57 MW)	57	8.502	6.600	22	—	—	301.1	1.049
SGT-800 (56 MW)	55.6	8.647	6.600	22	—	—	303.6	1.047
SGT-800 (54 MW)	54	8.725	6.600	21.6	—	—	298.7	1.045
SGT-800 (50 MW)	49.9	8.670	6.600	19.8	—	—	274.9	1.041
SGT-750	39.8	8,456	6,100	24.3	—	—	254.4	875
SGT-700	32.8	9,170	6,500	18.7	—	—	209.4	991
SGT-600	24.5	10,161	7,700	14	—	—	179.2	1,009
SGT-400 (15 MW)	14.3	9,647	9,500	18.9	—	—	97.7	1,004
SGT-400 (13 MW)	12.9	9,815	9,500	16.8	—	—	86.8	1,031
SGT-400 (11 MW)	10.4	9,802	11,500	16	—	—	74.5	946
SGT-300	7.9	11,158	14,010	13.7	—	—	66.6	1,008
SGT-100 (5.4 MW)	5.4	11,006	17,384	15.6	—	—	46	1,006
SGT-100 (5.1 MW)	5.1	11,291	17,384	14	—	—	43	1,013
SGT-A35 (GT30 38 MW) 50 Hz	36.6	8,813	3,000	25.4	—	—	244.7	912
SGT-A35 (GT30 34 MW) 50 Hz	32.2	9,109	3,000	22.9	—	—	220	937
SGT-A35 (GT30 34 MW) DLE 50 Hz	31.9	9,140	3,000	22.6	—	—	218.7	939
SGT-A35 (GT30 38 MW) 60 Hz	37.4	8,600	3,600	25	—	—	240.5	909
SGT-A35 (GT30 34 MW) 60 Hz	33.2	8,873	3,600	22.7	—	—	218	934
SGT-A35 (GT30 34 MW) DLE 60 Hz	32.5	8,906	3,600	22.3			215.8	932
SGT-A35 (GT61) DLE	32.1	8,681	4,850	21.6			207	950
SGT-A05 (KB7HE)	5.8	10,281	14,600	14			47.1	972
SGT-A05 (KB7S)	5.4	10,570	14,600	13.9			47	921
SGT-A05 (KB5S)	4	11,504	14,200	10.3			34	1,040
KG2-3E	1.9	18,956	1,500/1,800	4			33.1	1,020
KG2-3G	2	13,124	1,500/1,800	5	—	—	20.9	1,080

Note: EG ratings at generator terminals. Specifications are for natural gas fuel.

SOLAR TURBINES, San Diego, California, U.S.A.

MODEL	POWER RATING ISO Base Load (MWe)	HEAT RATE Lower Heating Value (LHV) (Btu/kWh)	POWER SHAFT SPEED (RPM)	PRESSURE RATIO	NUMBER OF COMBUSTORS	AT ISO BASE LOAD		
						Turbine Inlet Temp. (°C)	Exhaust Flow (lbs/sec)	Exhaust Temp (°F)
Centaur 50	4.6	11,630	1,800	10.6	1 (annular)	—	41.8	950
Mercury 50	4.6	8,865	1,800	9.9	1 (annular)	—	39	690
Taurus 60	5.7	10,830	1,800	9.9	1 (annular)	—	48	950
Taurus 65	6.5	10,295	1,800	15	1 (annular)	—	47.1	1000
Taurus 70	8.2	9,920	1,800	17.6	1 (annular)	—	59.2	970
Mars 100	11.4	10,365	1,800	17.7	1 (annular)	—	93.1	905
Titan 130	16.5	9,605	1,800	17.1	1 (annular)	—	124	915
Titan 250	23.1	8,775	1,800	24.1	1 (annular)	—	153.9	865
MOBILE POWER UNIT								
Taurus 60 MPU	5.7	10,830	1,800	9.9	1 (annular)	—	48	950
Titan 130 MPU	16.5	9,605	1,800	17.1	1 (annular)	—	124	915
MODULAR POWER PLANT								
Taurus 60 MPP	5.7	10,830	1,800	9.9	1 (annular)	—	48	950
Taurus 130 MPP	16.5	9,605	1,800	17.1	1 (annular)	—	124	915

Note: Specifications are for natural gas fuel. MPP stands for Modular Power Plant

Mechanical Drive Specifications

BAKER HUGHES

MODEL	POWER RATING ISO Base Load (HP)	HEAT RATE Lower Heating Value (LHV)(Btu/hp-h)	POWER SHAFT SPEED (RPM)	PRESSURE RATIO	NUMBER OF COMBUSTORS	AT ISO BASE LOAD		
						Turbine Inlet Temp. (°C)	Exhaust Flow (kg/sec)	Exhaust Temp (°C)
NovaLT12	17433	6914	8900	19	1 annular		42.1	496
NovaLT16	23468	6785	7800	19	1 annular		54.6	495
PGT25 DLE	31246	6785	6500	17.9	1 annular		68.9	524
PGT25+ DLE Xtend 9 ppm	35001	6425	6100	21.5	1 annular		84.3	480
PGT25+ DLE High Power	41706	6283	6100	21.5	1 annular		84.3	500
PGT25+G4 DLE	45192	6283	6100	23.2	1 annular		89.7	510
PGT25+G5 DLE Xtend 15 ppm	45595	6361	6100	25.1	1 annular		91	512
PGT25+G5 DLE High Power	51361	6191	6100	25.1	1 annular		91	540
LM2500	31246	6803	3600	18.7	1 annular		69	530
LM2500+	41706	6524	3600	23.7	1 annular		87	516
LM2500+G4	45058	6458	3600	24.3	1 annular		91	527
LM2500+G5 Xtend 15ppm	45058	6393	3600	25	1 annular		92	530
LM2500+G5 High Power	50422	6073	3600	25	1 annular		92	540
Frame5/2C	37951	8714	4670	9	12 cans		123	543
Frame5/2D	45595	8342	4670	11	12 cans		139.6	560
Frame5/2E	45327	6877	5714	17.3	6 cans		102.5	518
Frame6/1B	59005	7595	5163	12.7	10 cans			551
Frame7/1EA	122033	7506	3600	13	10 cans		296	535
LM6000PC	59675	6029	3600	28.8	1 annular		126.2	454
LM6000PG	70806	6044	3930	32.3	1 annular		140.7	470
LM6000PF	59139	6146	3600	29.1	1 annular		125.1	463
LM6000 PF+	72147	6058	3930	32.3	1 annular		136.9	498
LM9000	98565	5783	3429	33	1 annular		182	455
LMS100 PB+	147512	5783	3429	44	1 annular		230	410
Frame9/1E	177015	7354	3000	12.7	14 cans		410	540

KAWASAKI HEAVY INDUSTRIES, LTD., Akashi, Japan

MODEL	POWER RATING ISO Base Load (hp)	HEAT RATE Lower Heating Value (LHV) (Btu/hp-hr)	POWER SHAFT SPEED (RPM)	PRESSURE RATIO	NUMBER OF COMBUSTORS	AT ISO BASE LOAD		
						Turbine Inlet Temp. (°C)	Exhaust Flow (kg/sec)	Exhaust Temp (°C)
L30A	47,660	6,100	5,600	25.8:1	8	—	92.6	502

MITSUBISHI POWER SYSTEMS, LTD

MODEL	POWER RATING ISO Base Load (hp)	HEAT RATE Lower Heating Value (LHV) (Btu/hp-hr)	POWER SHAFT SPEED (RPM)	PRESSURE RATIO	NUMBER OF COMBUSTORS	AT ISO BASE LOAD		
						Turbine Inlet Temp. (°C)	Exhaust Flow (kg/sec)	Exhaust Temp (°C)
H-100	144,350	6,542	3,600	18.4	10	—	293	534
H-100	160,780	6,549	3,600	20.1	10	—	315	552

Note: All ratings are at the gas turbine shaft end and based on the natural gas fuel.

Mechanical Drive Specifications

MITSUBISHI POWER AERO, LLC, Glastonbury, Connecticut, U.S.A.

MODEL	POWER RATING ISO Base Load (hp[1])	HEAT RATE Lower Heating Value (LHV) (Btu/hp-hr)	POWER SHAFT SPEED (RPM)	PRESSURE RATIO	NUMBER OF COMBUSTORS	AT ISO BASE LOAD Turbine Inlet Temp. (°F)	Exhaust Flow (lbs/sec)	Exhaust Temp (°F)
FT8	37,940	6,580	5,500	20.2	9	—	193.4	857

1 shp base. Note: Estimates are for natural gas fuel.

SIEMENS ENERGY

MODEL	POWER RATING ISO Base Load (hp)	HEAT RATE Lower Heating Value (LHV) (Btu/hp-hr)	POWER SHAFT SPEED (RPM)	PRESSURE RATIO	NUMBER OF COMBUSTORS	AT ISO BASE CONTINUOUS Turbine Inlet Temp. (°C)	Exhaust Flow (lbs/sec)	Exhaust Temp (°C)
SGT-750 (41 MW)	54,994	6,121	3,050–6,100–6,405	24.3	—	—	245.4	845
SGT-750 (34 MW)	45,595	6,299	3,050–6,100–6,405	21.9	—	—	236.9	821
SGT-700	45,151	6,661	3,250–6,500–6,825	18.7	—	—	209.4	991
SGT-600	33,847	7,344	3,850–7,700–8,085	14	—	—	179.2	1,009
SGT-400 (15 MW)	20,006	6,908	4,750–9,500–9,975	18.9	—	—	97	1,004
SGT-400 (13 MW)	18,000	7,028	4,750–9,500–9,975	16.8	—	—	86.8	1,031
SGT-400 (11 MW)	14,470	7,019	5,750–11,500–12,075	16	—	—	74.5	946
SGT-300 (9 MW)	12,257	7,191	5,750–11,500–12,075	14.5	—	—	67.3	954
SGT-300 (8 MW)	11,216	7,315	5,750–11,500–12,075	13.8	—	—	65.5	925
SGT-100	7,640	7,656	6,500–13,000–13,650	14.9	—	—	43	1,013
SGT-A35 (GT30 38 MW)	51,092	6,317	2,400–3,429–3,600	25.2	—	—	241.8	910
SGT-A35 (GT30 34 MW)	45,245	6,516	2,400–3,429–3,600	22.8	—	—	218.9	934
SGT-A35 (GT30 34 MW) DLE	44,374	6,541	2,400–3,429–3,600	22.3	—	—	216.5	933
SGT-A35 (GT61)	45,316	6,299	3,153–4,850–5,093	22.1	—	—	209	949
SGT-A35 (GT61) DLE	44,230	6,307	3,153–4,850–5,093	21.6	—	—	207	949
SGT-A35 (GT62)	41,495	6,599	3,120–4,800–5,040	22	—	—	211.9	938
SGT-A35 (GT62) DLE	41,084	6,602	3,120–4,800–5,040	21.7	—	—	209	938

SOLAR TURBINES, San Diego, California, U.S.A.

MODEL	POWER RATING ISO Base Load (hp)	HEAT RATE Lower Heating Value (LHV) (Btu/hp-hr)	POWER SHAFT SPEED (RPM)	PRESSURE RATIO	NUMBER OF COMBUSTORS	AT ISO BASE LOAD Turbine Inlet Temp. (°C)	Exhaust Flow (kg/sec)	Exhaust Temp (°C)
Centaur 40	4,700	9125	15,500	10.3	1 (annular)	—	18.9	445
Centaur 50	6,150	8,485	16,500	10.3	1 (annular)	—	18.9	515
Taurus 60	7,700	7,950	13,950	12.2	1 (annular)	—	21.7	510
Taurus 70	11,110	7,190	11,605	16.5	1 (annular)	—	26.8	500
Mars 90	13,220	7,655	9,400	16.3	1 (annular)	—	40.2	465
Mars 100	15,900	7,395	9,500	17.1	1 (annular)	—	42.6	485
Titan 130	23,470	6,800	8,855	16.1	1 (annular)	—	56.2	480
Titan 250	31,900	6,725	7,000	24.1	1 (annular)	—	70.4	460

Steam Turbine Specifications

ANSALDO ENERGIA, Genoa, Italy

MODEL	Power Rating (MW)	Thermal Cycle Type	Application	Configuration	Grid Freq. (Hz)	Inlet Temp. (°C)	Inlet Pressure (bar)
GT series	15–150		Geothermal	1 to 2 cylinder	50/60	Up to 240	Up to 20
MT10	40–250	Non-Reheat	Combined Cycle, Fossil, Solar	1-cylinder	50/60	Up to 565	Up to 140
MT20	100–350	Non-Reheat	Combined Cycle, Fossil, Cogeneration	2 to 3 cylinder	50/60	Up to 565	Up to 140
MT15	100–300	Reheat	Combined Cycle, Fossil, Solar	2-cylinder	50/60	Up to 600/585	Up to 170
RT30	150–1000	Reheat	Combined Cycle, Fossil, Cogeneration	3 to 5 cylinder	50/60	Up to 600/620	Up to 280

1 shp base. Note: Estimates are for natural gas fuel.

BAKER HUGHES, Steam Turbine—Reaction Technology (Florence, Italy)

MODEL	POWER RATING (MW)	SPEED RANGE (RPM)	RATED INLET PRESSURE (BAR A)	RATED INLET TEMPERATURE (°C)	INLET CONTROL TYPE	CONTROLLED EXTRACTIONS (#)	EXHAUST
SC/SAC	2 - 150	3,000–15,000	140	565	Sliding/Fixed Pressure	0–2	Radial/Axial
SNC/SANC	2–100	3,000–15,000	140	565	Sliding/Fixed Pressure	0–2	Radial, Max 60 BARA
A5/A9	20–100	3,000–3,600	140	565	Sliding/Fixed Pressure	—	Axial
SG	5–40	3,000–3,600	30	300	Sliding/Fixed Pressure	—	Radial/Axial
SDF	10–80	3,000–3,600	30	300	Sliding/Fixed Pressure	—	Double Flow

SC = Condensing Type, SAC = Condensing Type with Controlled Extractions, SNC = Backpressure Type, SNC = Backpressure Type with Controlled Extractions, A5/A9 = Single Casing Reheat, SG = Geothermal Applications, SDF = Double Flow

BAKER HUGHES, Steam Turbine—Impulse Technology (Le Creusot, France)

MODEL	POWER RATING (MW)	SPEED RANGE (RPM)	RATED INLET PRESSURE (BAR A)	RATED INLET TEMPERATURE (°C)	INLET CONTROL TYPE	CONTROLLED EXTRACTIONS (#)	EXHAUST
MP	2–30	3,000–13,000	140	525	Sliding/Fixed Pressure	0–1	Radial
MC	2–45	3,000–13,000	140	525	Sliding/Fixed Pressure	0–1	Radial/Axial
BFPT	5–45	4,000–15,000	170–280	565–575	Sliding/Fixed Pressure	—	Radial
P	1–6	5,000–13,000	90	480	Sliding/Fixed Pressure	0–1	Radial, Max 20 BARA
C	1–6	5,000–13,000	90	480	Sliding/Fixed Pressure	0–1	Radial

MP = Multivalves—Backpressure Type, MC = Multivalves—Condensing Type, BFPT = Boiler Feed Pump Turbine, P = Single valve—Backpressure Type, C = Single valve—Condensing Type

Steam Turbine Specifications

DOOSAN ŠKODA POWER, Czech Republic

ELECTRIC POWER GENERATION			ELECTRIC POWER GENERATION		
ELECTRIC UTILITY MW RANGE		INDUSTRIAL	COMBINED CYCLE	MARINE	OTHER
Fossil Fueled	Nuclear	MW Range	MW Range	hp Range	hp Range
up to 900	up to 1,200	up to 350	up to 400	—	3,000 - 12,000

Doosan Škoda Power is part of a strong group of companies united under the Doosan Group, which supplies leading technologies and services of the highest quality and value to customers all over the world.

Doosan Škoda Power is a leading global manufacturer and supplier of power plant equipment, especially steam turbine/generator sets with outputs between 3 and 1,200 MW. The company has extensive experience and references in applications for steam such as fossil power plants, CHP plants, nuclear power plants and solar power plants (CSPs), biomass incineration plants etc.

Wide range of aftermarket services includes retrofits and modernization (R&M) of existing installed OEM and non-OEM equipment, commissioning and long-term service including spare parts delivery. Annual research and development investments guarantee high quality products that meet specific customer requirements.

www.doosanskodapower.com

ELLIOTT GROUP, Jeannette, Pennsylvania, U.S.A. and Sodegaura, Chiba, Japan

ELECTRIC POWER GENERATION			MECHANICAL DRIVE		
ELECTRIC UTILITY MW RANGE		INDUSTRIAL	COMBINED CYCLE	MARINE	OTHER
Fossil Fueled	Nuclear	MW Range	MW Range	hp Range	hp Range
0.05–50	—	0–130	1–175,000 hp	—	1–175,000 hp

Elliott designs, manufactures, tests, installs, services and repairs steam turbines for industrial power generation and mechanical drive service. Dependable, versatile turbomachinery is essential for today's refinery and chemical processes, industrial applications, and power generation use. Elliott steam turbines yield proven reliability and high efficiency which make them a key element of successful mechanical drive or power generation services. Elliott offers a complete line of steam turbines ranging up to 175,000 HP (130,000 kW) capable of inlet steam conditions up to 2,200 PSIG 151 (BarG) and 1050°F (565°C). Elliott's steam turbines are available in multiple configurations including condensing and back pressure designs, single and multiple valve designs, and multiple controlled and uncontrolled extractions or inductions. Elliott steam turbines can operate at speeds up to 16,000 RPM making them suitable as drivers for equipment such as pumps, fans, compressors, and generators. With manufacturing headquarters in Sodegaura, Japan and Jeannette, Pennsylvania along with an extensive networkof service shops strategically located worldwide Elliott is exclusively situated to provide design, manufacturing, testing, installation, and service to steam turbines for global industrial power.

Turbocompressor Specifications

ATLAS COPCO GAS AND PROCESS (www.atlascopco-gap.com)

CENTRIFUGAL COMPRESSORS

MODEL	INLET VOLUME (M3/hr)	DISCHARGE PRESSURE P_2 (BAR)	POWER REQUIREMENT (hp)	NUMBER OF STAGES	MAXIMUM RPM	TYPE OF CASING SPLIT	TYPE OF SEALS	TYPE OF GAS COMPRESSOR CAN HANDLE	TYPE OF DESIGN
GT	250–500,000	up to 205	40,000	1 to 8	52,000	V	all	all gases	C,I
RT	320,000–500,000	up to 7	46,500	3	6,500	H	C	Air	C,R
T	15,000–65,000	up to 43	13,300	1	3,600	V	D	all gases	C

Note: The T-Series is a direct-driven compressor

CENTRIFUGAL COMPRESSORS

MODEL	NUMBER OF THROWS	MAXIMUM POWER (kW)	MAXIMUM DISCHARGE PRESSURE (bar)	MAXIMUM FLOW (Nm3/h)	APPLICATIONS	TYPE OF CASING SPLIT
GB	NA	560	35	2400	LNG—BOG, FGB, Refrigeration, Biomethane	Oil-injected, screw
GZ	NA	1000	27	9000	LNG—BOG, CO2 liquefaction, Refrigeration	Oil-free screw

BAKER HUGHES, Florence, Italy

MODEL	INLET VOLUME (M^3/hr)	DISCHARGE PRESSURE P_2 (BAR)	POWER REQUIREMENT (hp)	NUMBER OF STAGES	MAXIMUM RPM	TYPE OF CASING SPLIT	TYPE OF SEALS	TYPE OF GAS COMPRESSOR CAN HANDLE	TYPE OF DESIGN
BCL, 2BCL	125,000	900	—	2–10	20,000	V	D,L,O	2	C
MCL, 2MCL	600,000	60	—	2–10	20,000	H	D,L,O	3	C
DMCL	700,000	25	—	2–8	10,000	H	D,L,O	3	C
3MCL	400,000	60	—	2–10	15,000	H	D,L,O	3	C
SRL	450,000	200	—	1–10	40,000	V	D,L,O	2	C
DBCL	250,000	100	—	2–8	18,000	V	D,L,O	3	C
PCL	100,000	130	—	1–4	18,000	V	D,L,O	natural gas	C
AN	600,000	25	—	up to 20	10,000	H	D,L,O	3	A+C
AX	600,000	15	—	up to 20	10,000	H	D,L,O	3	A
BlueC 400	180,000	205	16,763	3–5	10,670	V	—	natural gas	C
RA	4,500	220	10,700	1–7	20,000	V	D,L,O	process gas	C
ICL	35,000	350	20,000	1–9	30,000	V	Sealless	non-acid gas	C

2 Air, steam and process gases. 3 Air and process gasses. S - API 619

Baker Hughes manufactures a complete range of compressors for all major compression services. Key locations include: Florence, Italy; Houston, Texas, U.S.A.; Le Creusot, France

Turbocompressor Specifications

BAKER HUGHES, Florence, Italy

RECIPROCATING COMPRESSORS

MODEL	NUMBER OF THROWS	MAX POWER (@max speed) (KW)	ROD LOAD (lbs)	Maximum RPM	Application	Type of Design
OA	1	435	26,325	800	Process (1) / Natural Gas	Horizontal
HA	2 TO 4	2,120	32,557	1,000	Process (1) / Natural Gas	Horizontal
HB	2 TO 6	5,520	53,055	800	Process (1) / Natural Gas	Horizontal
HD	2 TO 8	10,400	72,562	700	Process (1) / Natural Gas	Horizontal
HE	2 TO 10	28,700	150,750	800	Process (1) / Natural Gas	Horizontal
HF	2 TO 10	34,600	256,500	514	Process (1) / Natural Gas	Horizontal
HG	2 TO 10	66,820	445,500	400	Process (1) / Natural Gas	Horizontal
SHM	2 TO 6	7,980	80,565	1,200	Natural Gas	Horizontal
SHM-B	2 TO 4	5,320	80,565	1,200	Natural Gas	Horizontal
PH	4 TO 24*	36,000	326,250	310	LDPE	
PK	4 TO 24*	72,000	652,500	310	LDPE	Horizontal

* # of cylinders
1 Refinery & Petrochemical

ELLIOTT GROUP, Jeannette, Pennsylvania, U.S.A. and Sodegaura, Chiba, Japan

MODEL	INLET VOLUME (M^3/hr)	DISCHARGE PRESSURE P_2 (BAR)	POWER REQUIREMENT (hp)	NUMBER OF STAGES	MAXIMUM RPM	TYPE OF CASING SPLIT	TYPE OF SEALS	TYPE OF GAS COMPRESSOR CAN HANDLE	TYPE OF DESIGN
SINGLE STAGE									
PH	1,200–125,000	55	—	1	13,500	V	L,C,G,O,W,D	all	C
TC	600–150,000	50	—	1	10,000	V	L,C,G,O,W,D	all	C
MULTISTAGE									
M-Line	1,700–1,522,200	69	—	10	20,000	H	L,C,G,O,D	all	C
MB-Line	1,700–540,000	690	—	12	20,000	V	L,C,G,O,D	all	C
AXIAL									
A	705,000	6	—	18	8,025	H	L	air	A

Notes: Elliott Group designs, manufactures, tests, installs, services and repairs centrifugal and axial compressors for the petrochemical, refining, oil & gas as well as general industrial markets. Features and stand alone products include: • Proprietary EDGE centrifugal designs • High efficiency and exceptional reliability • Advanced impellers • Low maintenance • Wide range of inlet volume and pressure capability • Elliott control systems • Superior casing design • Lubrication oil systems • Auxiliary systems are available ON and OFF skid. • Full load testing • Wide complement of coatings are available to extend unit life • High speed balancing • Elliott-designed bearings are included for optimum running • Dry gas seal and buffer gas systems • Integrated bundle, end-walls and housings for quick turn around of barrel centrifugal
* Inquire with Elliott Group for volume flows greater than 680K m3/hr.

Turbocompressor Specifications

FS-ELLIOTT CO. LLC (www.fs-elliott.com)

MODEL	INLET VOLUME (M3/hr)	DISCHARGE PRESSURE P_2 (BAR)	POWER REQUIREMENT (hp)	NUMBER OF STAGES	MAXIMUM RPM	TYPE OF CASING SPLIT	TYPE OF SEALS	TYPE OF GAS COMPRESSOR CAN HANDLE	TYPE OF DESIGN
PAP PLUS ENGINEERED AIR COMPRESSORS									
S1	3,600	12.1	160-500	1–3	70,000	H	C	air, N	C,I
A1	6,000	15.2	260-800	1–3	52,000	H	C	air, N	C,I
BH	11,700	14.9	540-1,560	1–3	40,000	H	C	air, N	C,I
CH	18,600	14.3	875-2,600	1–3	30,000	H	C	air, N	C,I
DH	31,500	31	1,125-5,500	1–4	53,000	H	C,L	air, N	C,I
EH	41,700	25.2	1,750-6,000	1–4	47,000	H	H	air, N	C,I
POLARIS + INDUSTRIAL AIR COMPRESSORS									
P300 +	3,600	10.5	250–450	2–3	68,320	H	C	air, N	C,I
P400 +	6,000	10.5	260–800	2–3	51,930	H	C	air, N	C,I
P500 +	7,800	10.5	600–1,000	2–3	43,450	H	C	air, N	C,I
P600 +	10,800	10.5	540–1,560	2–3	39,140	H	C	air, N	C,I
P700 +	19,800	10.5	875–2600	2–3	29,770	H	C	air, N	C,I

FS-Elliott designs, manufactures, tests, installs, services and repairs intergrally geared centrifugal compressors. Design benefits and features follow: • High base-load and part-load efficiency • Optimized operational efficiency throughout the year • Professional Service • Minimum number of moving parts • Superior package design • Lowest life-cycle cost • Robust and reliable design • Simple and low-cost installation •Ease of maintenance • Industrial to API 672 applications • Ease of operation • Genuine OEM parts

Turbocompressor Specifications

INGERSOLL RAND

MODEL	INLET VOLUME (M^3/hr)	DISCHARGE PRESSURE P_2 (BAR)	POWER REQUIREMENT (hp)	NUMBER OF STAGES	MAXIMUM RPM	TYPE OF CASING SPLIT	TYPE OF SEALS	TYPE OF GAS COMPRESSOR CAN HANDLE	TYPE OF DESIGN
INTEGRALLY GEARED CENTRIFUGAL COMPRESSORS									
MSG PRODUCT LINE: Applications engineered with many configurations to efficiently provide oil-free air and gas									
MSG LMAC 20	20,000–35,000	9	up to 4,000	1 to 3	26,000	V	L	Air & Nitrogen	C,I
MSG LMAC 30	35,000–50,000	9	up to 6,000	1 to 3	21,000	V	L	Air & Nitrogen	C,I
MSG LMAC 50	50,000–90,000	9	up to 15,000	1 to 3	12,000	V	L	Air & Nitrogen	C,I
MSG-2/3	4,250–17,000	100	up to 5,500	1 to 6	50,000	V	D,C,L	all except O_2	C,I
MSG-4/5	12,000–30,000	100	up to 9,500	1 to 6	40,000	V	D,C,L	all except O_2	C,I
MSG-8/9	28,000–60,000	100	up to 10,000	1 to 6	35,000	V	D,C,L	all except O_2	C,I
MSG-12/14/16	51,000–100,000	100	up to 19,000	1 to 6	35,000	V	D,C,L	all except O_2	C,I
MSG-18	77,000–136,000	41	up to 20,000	1 to 6	23,000	V	D,C,L	all except O_2	C,I
MSG-25	85,000–230,000	20	up to 22,000	1 to 4	13,000	V	D,C,L	all except O_2	C,I
TURBO-AIR PRODUCT LINE: Packaged on a common base for easy installation and available in many configurations to efficiently provide oil-free oil and gas									
TA-2000	900–2,900	10	up to 350	1 to 3	75,000	V	L	Air & Nitrogen	C,I
TA-2040	2,500–3,100	42	up to 800	1 to 4	75,000	V	L	all except O_2	C,I
TA-3000	3,400–6,800	10	up to 800	1 to 3	60,000	V	L	Air & Nitrogen	C,I
TA-6000	6,800–13,600	10	up to 1,750	1 to 3	44,000	V	L	Air & Nitrogen	C,I
TA-NX 8000	8,500–17,000	40	up to 3,250	1 to 5	45,000	V	L	Air & Nitrogen	C,I
TA-NX 12000	12,700–31,500	40	up to 5,650	1 to 5	33,000	V	L	Air & Nitrogen	C,I
TA-20000	31,000–42,000	80	up to 5,500	1 to 6	50,000	V	L	Air & Nitrogen	C,I
CENTAC PRODUCT LINE: Packaged on a common base for easy installation and available in many configurations to efficiently provide oil-free oil air									
C400	2,700–4,000	8.6	up to 500	2	64,700	V	C	Air & Nitrogen	C,I
C700	3,200–7,100	10	up to 800	2 to 3	52,300	V	C	Air & Nitrogen	C,I
C800	3,500–7,600	13	up to 1,100	2 to 3	40,100	V	C	Air & Nitrogen	C,I
5CII	27,000–51,400	10	up to 6,000	2 to 3	25,000	V	C	Air & Nitrogen	C,I
C750	3,400–4,000	40	up to 900	3 to 4	65,500	V	C	Air & Nitrogen	C,I
C1050	6,450	40	up to 1,250	4	55,500	V	C	Air & Nitrogen	C,I

Turbocompressor Specifications

KAWASAKI HEAVY INDUSTRIES, LTD., Akashi, Japan

MODEL	INLET VOLUME (M^3/hr)	DISCHARGE PRESSURE P_2 (BAR)	POWER REQUIREMENT (hp)	NUMBER OF STAGES	MAXIMUM RPM	TYPE OF CASING SPLIT	TYPE OF SEALS	TYPE OF GAS COMPRESSOR CAN HANDLE	TYPE OF DESIGN
CENTRIFUGAL COMPRESSORS: HORIZONTALLY SPLIT									
MSG LMAC 20	20,000–35,000	9	up to 4,000	1 to 3	26,000	V	L	Air & Nitrogen	C,I
MSG LMAC 30	35,000–50,000	9	up to 6,000	1 to 3	21,000	V	L	Air & Nitrogen	C,I
MSG LMAC 50	50,000–90,000	9	up to 15,000	1 to 3	12,000	V	L	Air & Nitrogen	C,I
MSG-2/3	4,250–17,000	100	up to 5,500	1 to 6	50,000	V	D,C,L	all except O_2	C,I
MSG-25	85,000–230,000	20	up to 22,000	1 to 4	13,000	V	D,C,L	all except O_2	C,I
VERTICALLY SPLIT									
TA-2000	900–2,900	10	up to 350	1 to 3	75,000	V	L	Air & Nitrogen	C,I
TA-2040	2,500–3,100	42	up to 800	1 to 4	75,000	V	L	all except O_2	C,I
TA-3000	3,400–6,800	10	up to 800	1 to 3	60,000	V	L	Air & Nitrogen	C,I
TA-6000	6,800–13,600	10	up to 1,750	1 to 3	44,000	V	L	Air & Nitrogen	C,I
C1050	6,450	40	up to 1,250	4	55,500	V	C	Air & Nitrogen	C,I

D = Dry gas, C = Centrifugal, L = Labyrinth, A = Axial, O = Oil, I = Integral gear, W = Water, R = Radial inflow, C = Carbon ring, S = Screw, G = Gas

KOBELCO / KOBE STEEL LTD.
KOBELCO COMPRESSORS AMERICA, INC.

MODEL	INLET VOLUME (M^3/hr)	DISCHARGE PRESSURE P_2 (PSI)	POWER REQUIREMENT (hp)	NUMBER OF STAGES	MAXIMUM RPM	TYPE OF CASING SPLIT	TYPE OF SEALS	TYPE OF GAS COMPRESSOR CAN HANDLE	TYPE OF API DESIGN
API CENTRIFUGAL COMPRESSORS									
VH Series	500–100,200	5,000	28,000	Multi	18,000	V	D, C, L	all	617 Part 2
VGS/VGSP/VGS7	800–450,000	3620	67,000	1 to 8	40,000	V	D, C, L, O	all	617 Part 3
Process gas VG/ VGP/VG7	800–450,000	1,500	67,000	1 to 8	60,000	V	D, C, L	air, N2	617 Part 3, 672
DH series	800–150,000	1,300	33,500	single	18,000	V	D, C, L, O	all	617 Part 2
V-VS-VSS Series	800–340,000	700	21,000	multi	18,000	H	D, C, L, O	all	617 Part 2
API RECIPROCATING COMPRESSORS									
	150–30,000	15,000	30,000	1 to 8		V	various	all gases & cold LNG BOG	618
API 100% OIL-FREE SCREW COMPRESSORS									
100% oil-free design	400–145,000	650		1 to 3	~16,000	H/V	D, C, L, O	all	C,I
API OIL-INJECTED SCREW COMPRESSORS									
< 0.5 ppm/ wt. oil carryover	150–35,000	1,500		1 & 2	~5,200	V	O, D	all	C,I

API 617 = Centrifugal
API 618 = Reciprocating
API 619 = Rotary Screw
Seals: D = Dry gas, L = Labyrinth, O = Oil/Mech, C = Carbon Ring

Turbocompressor Specifications

MITSUBISHI HEAVY INDUSTRIES COMPRESSOR CORPORATION, HIROSHIMA, JAPAN
MITSUBISHI HEAVY INDUSTRIES COMPRESSOR INTERNATIONAL, HOUSTON, TX, U.S.A.

Model #	Inlet Volume (Ms/hr)	Discharge Pressure P2 (Bar)	Power Requirement (hp)	Number of stages	Max RPM	Type of Casing Split	Type of Seals	Type of Design
INTEGRALLY GEARED COMPRESSOR SPECIFICATIONS								
2C	5000	200	2000	6	43000	V	D, L, A	C, I
3C	12000	200	4500	6	29000	V	D, L, A	C, I
4C	30000	200	10000	8	21000	V	D, L, A	C, I
6C	60000	200	23000	8	14000	V	D, L, A	C, I
8C	200000	200	40000	8	11000	V	D, L, A	C, I
12C	600000	200	120000	8	7000	V	D, L, A	C, I
14C	900000	200	135000	8	6000	V	D, L, A	C, I
16C	1200000	200	135000	8	5500	V	D, L, A	C, I
CENTRIFUGAL COMPRESSOR SPECIFICATIONS								
3V	20,000	1,000	-	up to 9	40,000	V	D, L, O	C
4V	40,000	300	-	up to 9	20,000	V	D, L, O	C
5V	100,000	300	-	up to 9	15,000	V	D, L, O	C
7V	150,000	200	-	up to 9	12,000	V	D, L, O	C
9V	500,000	100	-	up to 9	8,000	V	D, L, O	C
11V	700,000	100	-	up to 9	6,000	V	D, L, O	C
4H	40,000	70	-	up to 9	20,000	H	D, L, O	C
5H	100,000	70	-	up to 9	15,000	H	D, L, O	C
7H	150,000	70	-	up to 9	12,000	H	D, L, O	C
9H	500,000	60	-	up to 9	8,000	H	D, L, O	C
11H	700,000	60	-	up to 9	6,000	H	D, L, O	C

1 The first number in the “Model” column represents the “Model size”.
2 The letter of “W” in the “Model” column represents “Double flow type”.
3 Type of Casing Split: H = Horizontal, V = Vertical
4 Type of Seals: C = Carbon ring, D = Dry gas, L = Labyrinth, O = Oil, W = Water Seal
5 Type of Design: A = Axial, R = Radial, C = Centrifugal, I = Integral gear, S = Screw

Turbocompressor Specifications

SIEMENS ENERGY

MODEL	INLET VOLUME (M^3/hr)	DISCHARGE PRESSURE P_2 (BAR)	POWER REQUIREMENT (hp)	NUMBER OF STAGES	MAXIMUM RPM	TYPE OF CASING SPLIT	TYPE OF SEALS	TYPE OF GAS COMPRESSOR CAN HANDLE	TYPE OF DESIGN
SINGLE SHAFT AXIAL									
STC-SX	50,000–1,300,000	up to .48	as required	up to 19	9,000	H	D, L, O	air & clean gases	C
AXIAL-RADIAL									
STC-SR	50,000–1,300,000	up to 1.1	as required	up to 13	9,000	H	L, G	air	A-R
RADIAL									
STC-SH	250–600,000	up to 6.89	as required	up to 10	20,000	H	D, L, C	all	C
STC-SV	250–480,000	up to 68.95	as required	up to 10	20,000	V	D, L, C	all	C
PIPELINE CENTRIFUGAL COMPRESSORS									
RFA24/36	43,000–102,800	up to 7.1	20,000– 50,000	1	9,500– 14,500	V	D	natural gas	C
RFBB20/24/30/36/42	21,600–106,500	up to 10.69	25,000– 75,000	1–5	6,667– 14,500	V	D	natural gas	C
INTEGRALLY GEARED									
STC-GV	1,500–1,000,000	up to 13.79	as required	up to 8	45,000	V	L, G, C	all	I-C
STC-GC	10,000–400,000	up to 1.38	as required	up to 4	44,000	H	L	air & N_2	I-C
STC-GVT	1,500–480,000	up to 4.14	400–15,000	up to 6	45,000	V	L,D,C	process gas, air	A
DATUM									
Radial split	up to 440,000	up to 68.95	as required	up to 12	26,500	V	D, L, C, O	all	C
INTERCOOLED									
CVM	187,000	.83	as required	4	10,400	H	L	air	C

Note: figures acc. US spelling
D = Dry gas, C = Centrifugal, L = Labyrinth, A = Axial, O = Oil, I = Integral gear, W = Water, R = Radial inflow, C = Carbon ring, S = Screw, G = Gas

SOLAR TURBINES, San Diego, California, U.S.A.

MODEL	INLET VOLUME (M^3/hr)	DISCHARGE PRESSURE P_2 (BAR)	DISCHARGE PRESSURE P_2 (kPag)	NUMBER OF STAGES	MAXIMUM RPM	TYPE OF CASING SPLIT	TYPE OF SEALS	TYPE OF GAS COMPRESSOR CAN HANDLE	TYPE OF DESIGN
C16	3,600	310	31,025	10	23,800	V	D	natural gas	C
C31	8,520	344	34,475	9	16,000	V	D	natural gas	C
C33	16,200	186	18,620	10	19,000	V	D	natural gas	C
C40M	15,300	172	17,235	6	14,300	V	D	natural gas	C
C40P	18,000	186	11,030	2	15,500	V	D	natural gas	C
C41 (1)	30,600	259	25,855	10	14,300	V	D	natural gas	C
C45	31,500	124	15,513	3	12,000	V	D	natural gas	C
C50	33,900	103	10,350	5	14,000	V	D	natural gas	C
C51 (1)	42,600	207	20,685	10	12,000	V	D	natural gas	C
C61	59,400	207	20,685	10	10,200	H	D	natural gas	C
C65	40,800	110	11,030	2	10,500	H	D	natural gas	C
C75	51,000	155	15,510	3	8,860	V	D	natural gas	C
C85	76,500	110	11,030	2	7,000	V	D	natural gas	C

1 Pressure Ratios are higher for the C41/C51/C61. Dual Compartment compressors depending on cooling capability.

Turbocompressor Specifications

YORK (BY JOHNSON CONTROLS), Waynesboro, Pennsylvania, U.S.A.

MODEL	INLET VOLUME (M3/hr)	DISCHARGE PRESSURE (barg)	POWER REQUIREMENT (KW)	NUMBER OF STAGES	MAXIMUM RPM	TYPE OF CASING SPLIT	TYPE OF SEALS	TYPE OF GAS COMPRESSOR CAN HANDLE	TYPE OF DESIGN
CENTRIFUGAL COMPRESSORS									
M 25 & 26 Series	600–9,000	up to 41.3	4,000	1–8	22,000	H	O	(1)	C
M 38 Series	7,000–20,000	up to 41.3	5,600	1–8	9,000	H	O	(1)	C
M 55 Series	15,000–40,000	up to 31.7	11,200	1–8	5,000	H	O	(1)	C
SCREW COMPRESSORS									
RXF (XJS) Series	120–1,000	up to 24.1	225	1	3,600	V	O	(1)	S
RWFII (SGC) Series	1,000–14,000	up to 41.4	3,700	1	4,500	V	O	(1)	S
HPSH 1510	100–600	up to 76	400	1	6,000	V	O	(1)	S
HPSH 270	350–2200	up to 68	1,300	1	4,500	V	O	(1)	S
HPSH 407	1,500-7,240	up to 76	4500	1	3,600	V	O	(1)	S

(1) Hydrocarbons, mixed gases, sour gas. CO2.
Note: Applications include refrigeration and gas compression. Steel or cast iron casings.

Turboexpander Specifications

ATLAS COPCO GAS AND PROCESS (www.atlascopco-gap.com)

MODEL	INLET PRESSURE (BAR A)	INLET TEMPERATURE (°C)	NUMBER OF STAGES	RPM	POWER (kW)	TYPE OF CASING SPLIT	TYPE OF SEALS	TYPE OF GAS COMPRESSOR CAN HANDLE	TYPE OF DESIGN
EC/ECM/ETB	up to 200	–260 to +200	1	up to 100,000	up to 23,000	V	L/C/D	(1)	R, (2)
EG/EGI/ETG	up to 200	–260 to +510	1 to 4	up to 50,000	up to 25,000	V	L/C/O/D	(1)	R, (3), (4)
EHB, ETF	up to 200	–260 to +120	1	up to 105,000	below 250	V	L/F	(1)	R, (5)

1 All industrial gases and hydrocarbon gas mixtures, including condensing streams. Hydrogen and hydrogen rich gas, super critical CO2, ammonia, etc.
2 EC and ETB have compressor load with oil bearings. ECM has Compressor load with active magnetic bearings.
3 EG has electric generator load with external gearbox. EGI has electric generator load with integral gearbox.
4 ETG has electric generator load with gearbox
5 EHB and ETF have oil brake load.
6 Seal types: L=Labyrinth, C=Carbon Ring, D=Dry gas, O=Oil
7 Type of casing Split: H=Horizontal, V=Vertical

BAKER HUGHES, Radial Expanders (Florence, Italy)

MODEL	FRAME (1)	INLET PRESSURE (Bar A)	INLET TEMP. (°C)	INLET FLOW (m^3/h)	NUMBER OF STAGES	RPM	TYPE OF CASING SPLIT (2)	TYPE OF SEALS (3)	TYPE OF GAS EXPANDER CAN HANDLE (4)	TYPE OF DESIGN (5)	TYPE OF BEARING (6)
HIPER	25	15 to 85	0 to 100	40,000	1	30,000	V	NA	HC	IN	M
EC/EG	10	2 to 230	–270 to 315	300	1–4	110,000	V	D,L,O	HC,S,I	R,C,I	M,P,0
EC/EG	15	2 to 230	–270 to 315	500	1–4	70,000	V	D,L,O	HC,S,I	R,C,I	M,P,0
EC/EG	20	2 to 230	–270 to 315	2,000	1–4	60,000	V	D,L,O	HC,S,I	R,C,I	M,P,0
EC/EG	25	2 to 230	–270 to 315	3,000	1–4	35,000	V	D,L,O	HC,S,I	R,C,I	M,P,0
EC/EG	30	2 to 230	–270 to 315	5,000	1–4	25,000	V	D,L,O	HC,S,I	R,C,I	M,P,0
EC/EG	40	2 to 230	–270 to 315	7,000	1–4	22,000	V	D,L,O	HC,S,I	R,C,I	M,P,0
EC/EG	50	2 to 140	–270 to 315	11,000	1–4	20,000	V	D,L,O	HC,S,I	R,C,I	M,P,0
EC/EG	60	2 to 140	–270 to 315	15,000	1–4	16,000	V	D,L,O	HC,S,I	R,C,I	M,P,0
EC/EG	80	2 to 90	–270 to 315	20,000	1–4	12,000	V	D,L,O	HC,S,I	R,C,I	M,P,0
EC/EG	100	2 to 90	–110 to 315	35,000	1–4	10,000	V	D,L,O	HC,S,I	R,C,I	P,0
EC/EG	130	2 to 50	–110 to 315	50,000	1–4	8,500	V	D,L,O	HC,S,I	R,C,I	P,0
EC/EG	160	2 to 50	–110 to 315	80,000	1–4	7,000	V	D,L,O	HC,S,I	R,C,I	P,0
EC/EG	180	2 to 20	–110 to 315	110,000	1–4	6,000	V	D,L,O	HC,S,I	R,C,I	P,0

1 Model: EC = Expander Compressor, EG = Expander Generator, ED = Expander Dyno
2 Type of Casting Split: H = Horizontal, V = Vertical
3 Type of Seals: C = Carbon ring, D = Dry gas, L = Labyrinth, O = Oil, W = Water
4 Type of Gas: HC = Hydrocarbons, S = Steam, I = Industrial gasses, incl. Air, Nitrogen, CO, CO2, Waste, NH3, etc., F = Flue Gas
5 Type of Design: A = Axial, R = Radial, C = Centrifugal / Centripetal, I = Integral gear, S = Screw
6 Type of Bearings: M = Magnetic, P = Pressurized oil bearings, O = Oil bearings

BAKER HUGHES, Hot Gas Expanders (Florence, Italy)

MODEL	INLET VOLUME (BAR A)	INLET TEMPERATURE (°C)	INLET FLOW (kg/hr)	NUMBER OF STAGES	RPM	TYPE OF CASING SPLIT (2)	TYPE OF SEALS (3)	TYPE OF GAS EXPANDER CAN HANDLE (4)	TYPE OF DESIGN (5)
FEX-81	4.4	760	up to 130,000	1	7,500	V	L	F	A
FEX-97	4.4	760	up to 230,000	1	6,500	V	L	F	A
FEX-107	4.4	760	up to 360,000	1	5,100	V	L	F	A
FEX-125	4.4	760	up to 470,000	1	4,000	V	L	F	A
FEX-142	4.4	760	up to 750,000	1	3,600	V	L	F	A
NAE	11	500	up to 300,000	7	4,500	H	L	I	A

1 Model: EC = Expander Compressor, EG = Expander Generator, ED = Expander Dyno
2 Type of Casting Split: H = Horizontal, V = Vertical
3 Type of Seals: C = Carbon ring, D = Dry gas, L = Labyrinth, O = Oil, W = Water
4 Type of Gas: HC = Hydrocarbons, S = Steam, I = Industrial gasses, incl. Air, Nitrogen, CO, CO2, Waste, NH^3, etc., F = Flue Gas
5 Type of Design: A = Axial, R = Radial, C = Centrifugal/Centripetal, I = Integral gear, S = Screw
6 Type of Bearings: M = Magnetic, P = Pressurized oil bearings, O = Oil bearings.

Turboexpander Specifications

ELLIOTT GROUP, Jeannette, Pennsylvania, U.S.A. and Sodegaura, Chiba, Japan

MODEL	INLET VOLUME (BAR A)	INLET TEMPERATURE (°C)	INLET FLOW (kg/hr)	NUMBER OF STAGES	RPM	TYPE OF CASING SPLIT	TYPE OF SEALS	TYPE OF GAS EXPANDER CAN HANDLE	TYPE OF DESIGN
TH-85	4.5	760	220,000	1–2	7,500	V	L	(1)	A
TH-100	4.5	760	330,000	1–2	5,800	V	L	(1)	A
TH-120	4.5	760	505,000	1	4,700	V	L	(1)	A
TH-140	4.5	760	772,000	1	3,960	V	L	(1)	A

Notes: Elliott designs, manufactures, tests, installs, services and repairs FCC flue gas power recovery expanders. Our proven designs and technology result in rugged, reliable machines with millions of hours of operation in the field and up to 10 years of blade life from a single row of blades. Product features include: • Aerodynamic design to eliminate secondary erosion • Integral expansion joint • Superior materials technology • Overspeed protection • After burn protection
1 FCC, blast furnace, coal gas

L.A. TURBINE, Valencia, California, U.S.A.

MODEL	INLET VOLUME (BAR G MAX.)	INLET TEMPERATURE (°C)	NUMBER OF STAGES (2)	RPM (MAX.)	TYPE OF BEARINGS (6)	TYPE OF CASING SPLIT (3)	TYPE OF SEALS (4)	TYPE OF GAS EXPANDER CAN HANDLE	TYPE OF DESIGN (1)
L1000	up to 206	–195 to 260	1	105,000	Oil	V	L	(5)	EC/EG/ED (7)
L2000	up to 206	–195 to 260	1 to 2	52,000	Oil/AMB	V	L	(5)	EC/EG/ED
L3000	up to 206	–195 to 260	1 to 2	31,000	Oil/AMB	V	L/D	(5)	EC/EG/ED
L4000	up to 206	–195 to 260	1 to 2	29,000	Oil/AMB	V	L/D	(5)	EC/EG
L5000	up to 206	–195 to 260	1 to 2	18,000	Oil/AMB	V	L/D	(5)	EC/EG
L6000	up to 206	–195 to 260	1 to 2	15,000	Oil/AMB	V	L/D	(5)	EC/EG

1 Model EC = Expander-Compressor, EG = Expander-Generator, ED = Expander-Dyno (Oil Brake)
2 Number of Stages: Multi-Stage is only applicable to the EC model
3 Type of Casting Split: V = Vertical
4 Type of Seals: L = Labyrinth Seal, D = Dry Gas Seal
5 Type of Gas: Hydrocarbons, Industrial Gases, Refrigerant, Steam
6 Type of Bearings: AMB = Active Magnetic Bearing, Oil = Oil Bearing. AMB is only applicable for EC model. Skid-Mounted AMB Control Panel is available for NEC area classifications or non-hazardous areas.
7 High Pressure/High Power does not apply on ED equipment. A maximum of 105,000 RPM is only applicable to the ED model.

Turboexpander Specifications

ROTOFLOW, An Air Products Business

MODEL (1)	FRAME/ SIZE	INLET PRESSURE (Bar A)	INLET TEMP. (°C)	NUMBER OF STAGES	RPM	POWER (kW)	TYPE OF CASING SPLIT (2)	TYPE OF SEALS (3)	TYPE OF GAS EXPANDER CAN HANDLE (4)	TYPE OF DESIGN (5)	TYPE OF BEARING (6)
ETAC	3R	up to 100	–200 to +100	1	up to 70,400	up to 210	V	L	HC, I	R, C	O
ETAC	5R	up to 100	–200 to +100	1	up to 50,000	up to 620	V	C, D, L	HC, I	R, C	M, O
ETAC	7R	up to 100	–200 to +100	1	up to 41,000	up to 1,170	V	C, D, L	HC, I	R, C	M, O
ETAC	8R	up to 100	–200 to +100	1	up to 30,000	up to 1,970	V	L	HC, I	R, C	M, O
ETAC	10R	up to 100	–200 to +100	1	up to 23,000	up to 2,480	V	C, D, L	HC, I	R, C	M, O
ETAC	12R	up to 100	–200 to +100	1	up to 21,000	up to 4,470	V	L	HC, I	R, C	M, O
ETAC	13R	up to 100	–200 to +100	1	up to 20,000	up to 8,000	V	C, D, L	HC, I	R, C	M, O
ETAC	16R	up to 100	–200 to +100	1	up to 13,500	up to 12,000	V	C, D, L	HC, I	R, C	M, O
ETAG/ ETAGG	3DF	up to 100	–270 to 315	1	up to 20,000	up to 520	V	L	HC, I	R, C, I, E	M, O
ETAG/ ETAGG	5DF	up to 100	–270 to +100	1	up to 14,000	up to 1,570	V	L	HC, I	R, C, I, E	P, O
ETAG/ ETAGG	10	up to 100	–270 to +100	1	up to 31,000	up to 3,360	V	C, D, L	HC, I	R, C, I, E	P, O
ETAG/ ETAGG	16	up to 20	–200 to +100	1	up to 15,000	up to 1,000	V	C, D, L	HC, I	R, C, I, E	P, O
ETAG/ ETAGG	21	up to 20	–200 to +100	1	up to 12,000	up to 1,490	V	C, D, L	HC, I	R, C, I, E	P, O
ETAG/ ETAGG	25	up to 20	–200 to +100	1	up to 10,000	up to 1,860	V	C, D, L	HC, I	R, C, I, E	P, O
ETFO	2He	up to 100	–270 to +100	1	up to 110,000	up to 30	V	L	Helium	R, C	P, O
ETAO	3H	up to 100	–270 to +100	1	up to 65,000	up to 190	V	L	Hydrogen	R, C	P, O
ETAO	3PL	up to 50	–200 to +100	1	up to 57,500	up to 180	V	L	HC, I	R, C	P, O
ETAO	5PL	up to 50	–200 to +100	1	up to 31,000	up to 180	V	L	HC, I	R, C	P, O
ETAO	7PL	up to 50	–200 to +100	1	up to 26,000	up to 180	V	L	HC, I	R, C	P, O
ETAO	9PL	up to 50	–200 to +100	1	up to 21,000	up to 230	V	C, D, L	HC, I	R, C	M, P, O
EC/EG/ ED	10	up to 210	–270 to +300	1	up to 105,000	up to 1,360	V	C, D, L	HC, I	R, C, I, E	M, P, O
EC/EG/ ED	15	up to 210	–270 to +300	1	up to 65,000	up to 560	V	C, D, L	HC, I	R, C, I, E	M, P, O
EC/EG/ ED	20	up to 210	–240 to +340	1	up to 57,000	up to 1,450	V	C, D, L	HC, I	R, C, I, E	M, P, O
EC/EG/ ED	30	up to 210	–200 to +300	1	up to 48,000	up to 2,990	V	C, D, L	HC, I	R, C, I, E	M, P, O
EC/EG/ ED	40	up to 210	–200 to +300	1	up to 29,000	up to 5,410	V	C, D, L	HC, I	R, C, I, E	M, P, O
EC/EG/ ED	50	up to 140	–200 to +300	1	up to 19,500	up to 7,570	V	C, D, L	HC, I	R, C, I, E	M, P, O
EC/EG/ ED	60	up to 140	–200 to +300	1	up to 14,700	up to 22,570	V	C, D, L	HC, I	R, C, I, E	M, P, O
EC	100	up to 10	–200 to +300	1	up to 4,000	up to 7,360	V	L	HC, I	R, C	P, O

Notes:

1 Model: ETAC = Expansion Turbine Active Nozzles Compressor Loaded, ETAG = Expansion Turbine Active Nozzles Generator Loaded, ETAGG = Expansion Turbine Active Nozzles Geared Generator Loaded, ETFO = Expansion Turbine Fixed Nozzles Oil Brake Loaded, ETAO = Expansion Turbine Active Nozzles Oil Brake Loaded, EC = Expander Compressor, EG = Expander Generator, ED = Expander Dyno

2 Type of Casting Split: H = Horizontal, V = Vertical

3 Type of Seals: C = Carbon ring, D = Dry gas, L = Labyrinth

4 Type of Gas: HC = Hydrocarbons, I = Industrial gases, incl. Air, Nitrogen, Oxygen, CO, CO2, Waste, NH3, etc.

5 Type of Design: R = Radial, C = Centrifugal, I = Integral gear, E = External gear

6 Type of Bearings: M = Magnetic, P = Pressurized oil bearings, O = Oil bearings

Turboexpander Specifications

SIEMENS ENERGY

MODEL	INLET PRESSURE (BAR A)	INLET TEMPERATURE (°C)	INLET FLOW (kg/hr)	NUMBER OF STAGES	RPM	TYPE OF CASING SPLIT	TYPE OF SEALS	TYPE OF GAS EXPANDER CAN HANDLE	TYPE OF DESIGN
STC-GT	15	up to 550	9,000–600,000	up to 3	25,000	V	L	all	I-C
E-516/520/522/526	15	760	45,000–165,000	5	7,100–10,930	H	L	(1)	A
E-132/232	3.3–5	760	165,000–200,000	1–2	7,500–8,400	V	L	(1)	A
E-138/238	3.3–5	760	345,000–350,000	1–2	6,000	V	L	(1)	A
E-148/248	3.3–5	760	450,000–555,000	1–2	4,000	V	L	(1)	A
E-156	3.3	760	730,000	1	3,600	V	L	(1)	A

1 Nitric acid, ethylene oxide, FCC, coal gas, blast furnace gas

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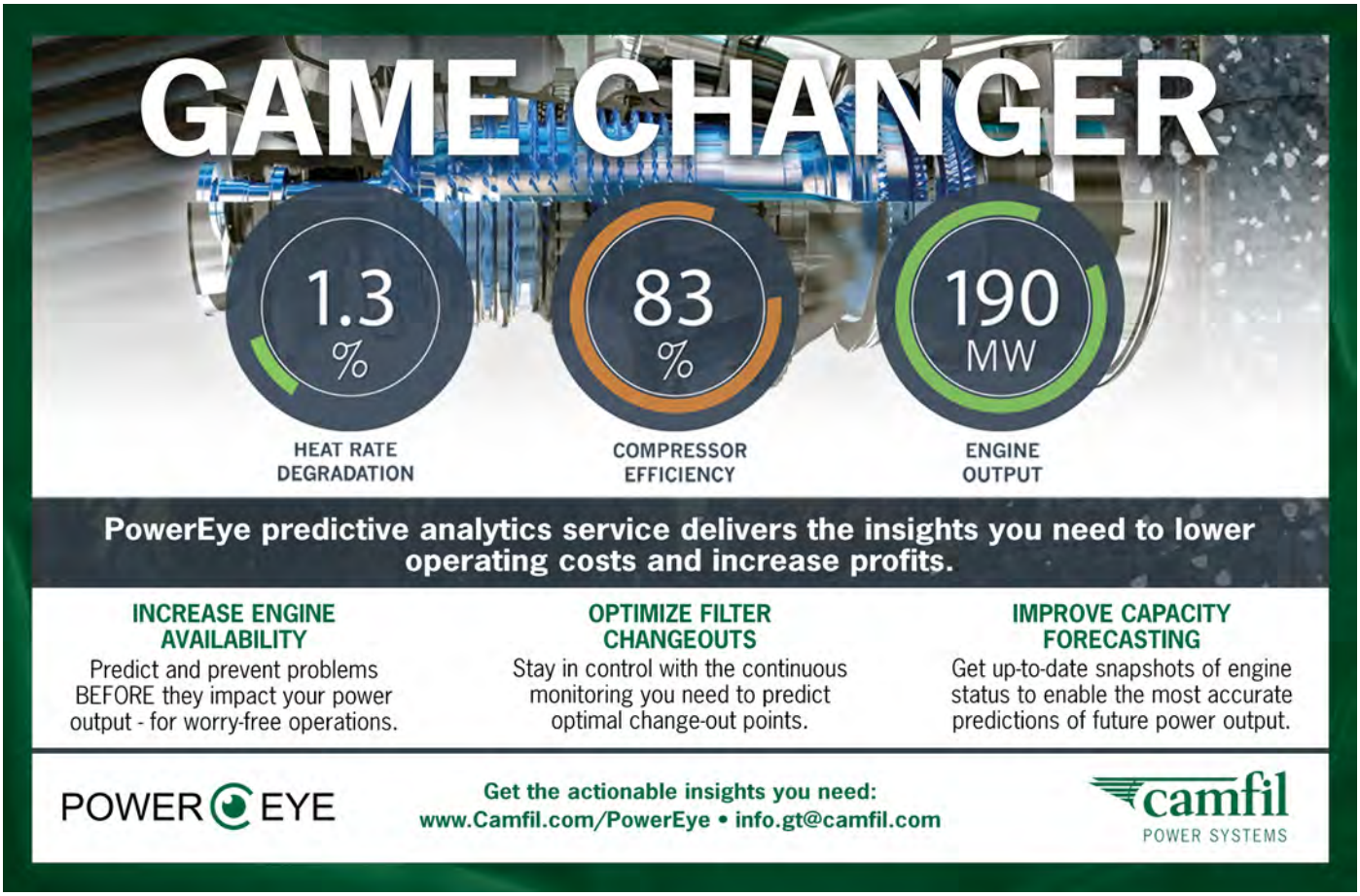

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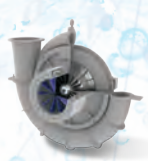
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Revolving Around You™

THE COLORS OF HYDROGEN: WHY DO WE CARE?

Hydrogen is a colorless, odorless gas that burns with a near invisible flame. So why do we constantly hear about green, blue, grey and other colors of hydrogen? What are these colors for?

Hydrogen "colors" colloquially refer to the way the hydrogen is generated. We have a rainbow of colors including brown, grey and black that are not part of the rainbow. For the most part, turbomachinery that either utilizes or transports hydrogen doesn't care where and how the hydrogen originated. But it is still important to understand the basic nomenclature.

Green hydrogen is produced without any greenhouse gas emissions. It is made by using electricity from renewable sources, like photovoltaics or wind power, to electrolyze water. Electrolyzers use an electrochemical reaction to split water into its components, hydrogen and oxygen.

Blue hydrogen is produced from natural gas using a process known as steam reforming, where natural gas and steam react to form hydrogen, but also carbon dioxide. To make hydrogen "blue," the carbon dioxide must be captured and sequestered. If the same process is used, but the carbon is not captured, it is called *grey* hydrogen.

Black and *brown* hydrogen are made through partial oxidation gasification from black coal or brown coal (lignite). This is the type of hydrogen that creates the largest amount of environmentally damaging by-products.

Red (also known as *pink* or *purple*) hydrogen is generated using electricity from nuclear energy. Just like green hydrogen, an electrolysis process is used. The difference is that the nuclear waste is created as a by-product of these processes. There are also some ideas to use the high-temperature reactors or available steam.

Turquoise (or *cyan*) hydrogen is made by a process called methane pyrolysis. The by-product is solid carbon. Depending on the thermal process that is used for pyrolysis — for example, whether it comes from renewable sources — and the capability to store the solid carbon permanently, this can be a low- or no-carbon process.

Yellow hydrogen is produced by electrolysis directly from solar energy without the intermediate step of creating electricity. In some publications, the term 'yellow' hydrogen is used when the electricity for the electrolysis process comes from multiple sources, some of them renewable, some of them conventional.

And lastly, *white* hydrogen, is naturally occurring geological hydrogen. Yes, there is a process that involves drilling a hole in the ground to get to hydrogen, with some fracking involved; however, there is currently no large-scale exploitation of this relatively rare resource.

Why do we care about these colors of hydrogen, especially since the machinery is agnostic to its source? There are two areas where the production source can make a difference: the pressure at which the hydrogen is available and the composition of the hydrogen gas.

Why are these features so important? Both relate to the fact that hydrogen compression is energy intensive. For a given mass flow, the amount of work to get a certain pressure ratio with pure hydrogen is almost 10 times higher than that of natural gas. Of course, hydrogen has a much higher energy density on a mass basis than natural gas (the lower heating value of hydrogen on a mass basis is 2.5 times that of natural gas), but even for the same energy flow, the compression work for hydrogen is four times higher.

On the other hand, even a small amount of composition impurity of the hydrogen, such as 4-5% carbon dioxide, can substantially lower the compression work by a factor of two. Therefore, it makes a big difference at what pressure and composition the hydrogen is made available in various compression processes. Also, both the combustion characteristics and the compression work change if other components (such as carbon dioxide or methane) are part of the hydrogen produced. Lastly, the capability of hydrogen to cause material issues (such as hydrogen embrittlement) can be influenced by the presence of other substances in the gas composition.

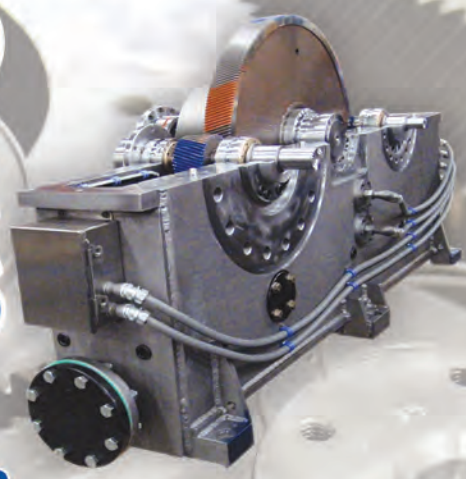
A third consideration of the source of hydrogen has less to do with the gas itself and more with the by-products of its generation process. Specifically, in processes that produce hydrogen from fossil fuels, carbon dioxide usually also is generated. For example, if blue hydrogen is produced from natural gas using steam reforming, about 10 kilograms of carbon dioxide are produced for every kilogram of hydrogen. In these cases, the separation, transport, and sequestration of carbon dioxide is necessary to maintain greenhouse gas neutrality — and that requires additional compression infrastructure. ■

Klaus Brun is the Director of R&D at Elliott Group. He is also the past Chair of the Board of Directors of the ASME International Gas Turbine Institute and the IGTI Oil & Gas applications committee.

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

PRECISION GEAR MANUFACTURING AND DESIGN ENGINEERING

TURBO GEAR UNITS



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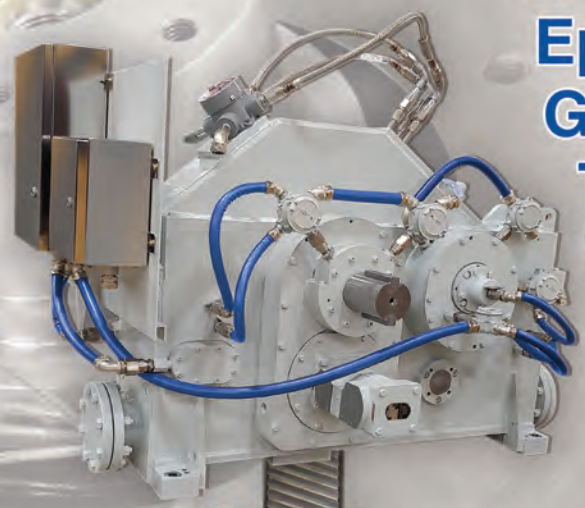

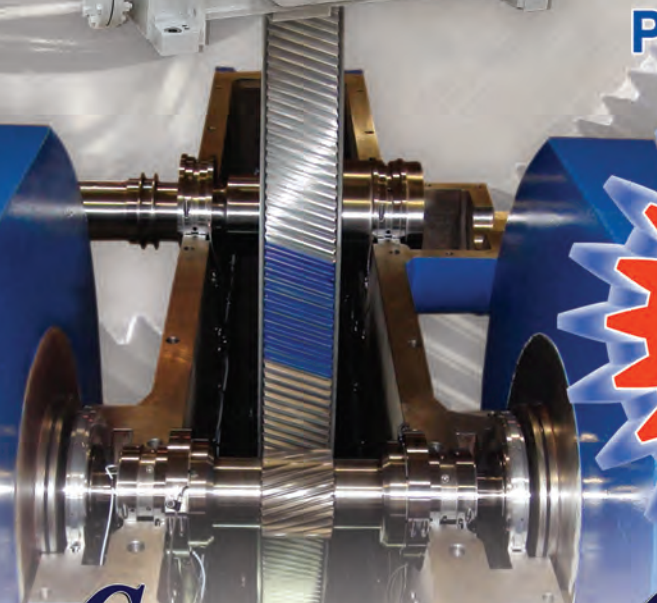

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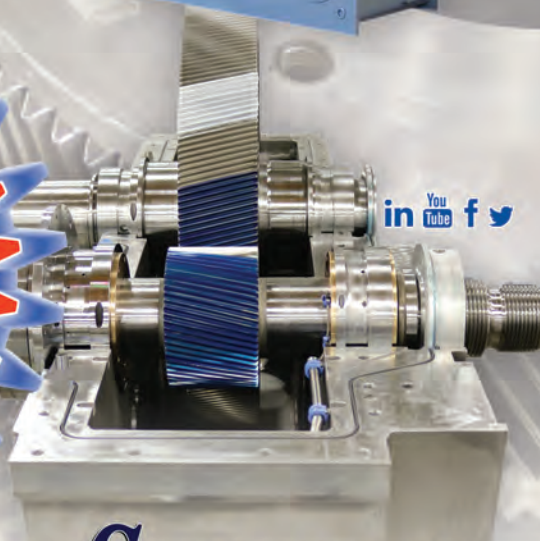

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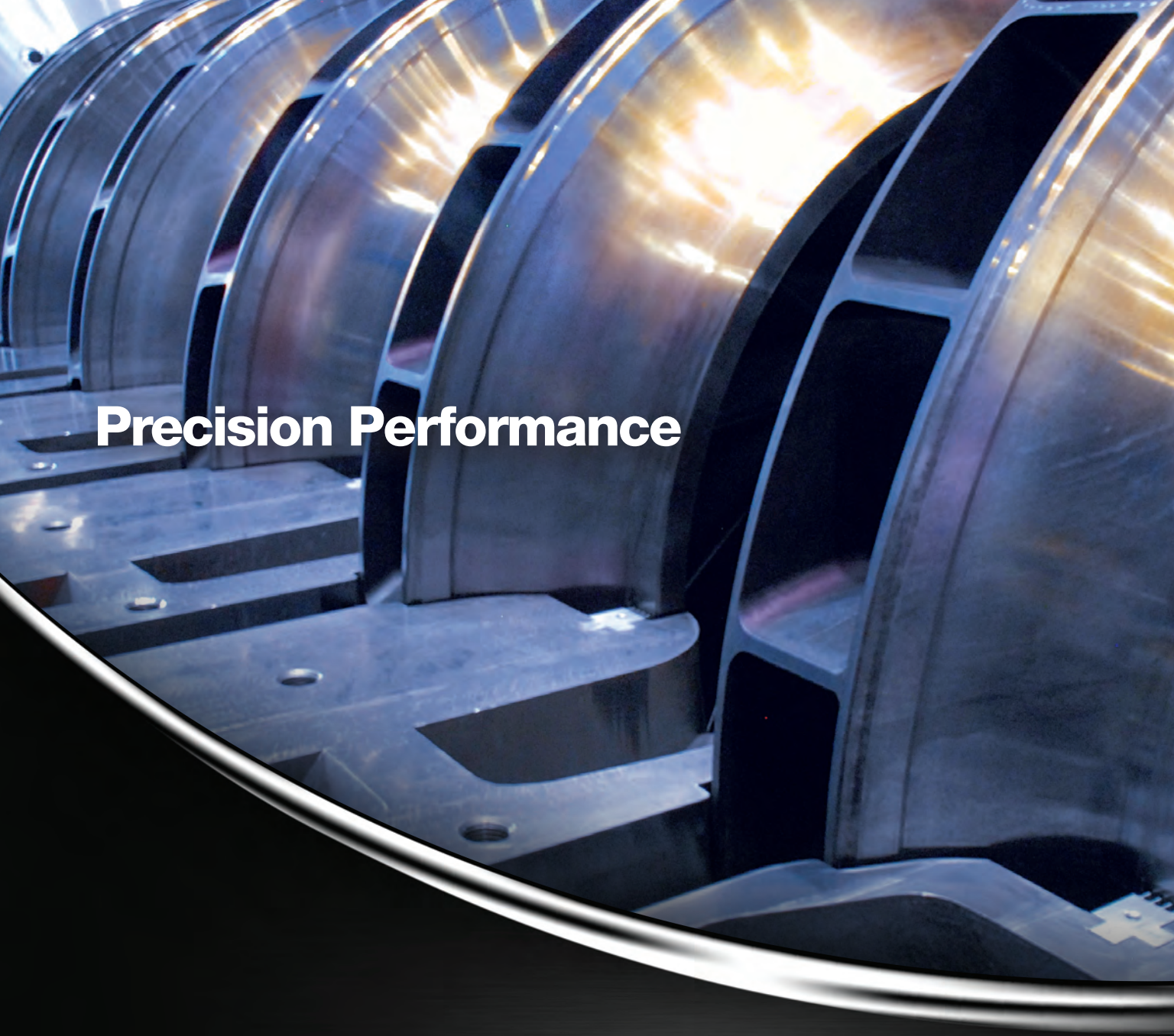

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