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COMMENT

# The unforeseen consequences of war

It's rare that bare-knuckle geopolitics align with the long-term demand for alternative energy sources, but we seem to be living in one of those times.

Russia's invasion of Ukraine, and the world's response to it, have led to an abrupt decline in natural gas exports from Russia. It's hard to estimate the number of lives lost and uprooted because of the conflict. Those are obvious – and tragic.

There are less obvious consequences of this war and those unforeseen consequences will likely stay with us for a long time.

The world is scrambling for alternative supplies of just about every kind of energy, including natural gas. China's Sinopec recently signed a 27-year supply agreement with QatarEnergy and has pledged to help the country develop the Northern gas field. Although specifics of the agreement were not made public, the long-term nature of the agreement raised a few eyebrows.

A year ago, the trend was the opposite. Natural gas buyers did not want to be tied into long-term contracts with a single supplier. Sellers recognized this and started offering more flexible, and shorter, contracts.

That was before Ukraine. Now, demand centers in Asia and elsewhere are looking to secure supplies from anywhere they can find them and are willing to make long-term commitments. Price is a secondary consideration – at least for now.

The conflict has had other unforeseen consequences as well. The crisis has sparked keen interest in alternative sources of energy and is likely to speed up the transition away from fossil fuels.

The conflict, according to a study from the International Energy Agency, has also forced some countries to rely more on coal and nuclear sources, but that effect is expected to be short-lived. Europe is planning to install as much as 50 gigawatts of renewable power in the next two years, which the agency said could be enough to offset the higher use of coal.

Meanwhile, Russia's previous gas exports are not likely to find alternative markets soon. The agency predicted worldwide demand for fossil fuels will peak in the coming years and that energy producers will turn instead to wind turbines, solar, electric vehicles, hydrogen and electric heat pumps. That effect is expected to be more long-term than the sudden reliance on coal.

**Keefe Borden**
Editor
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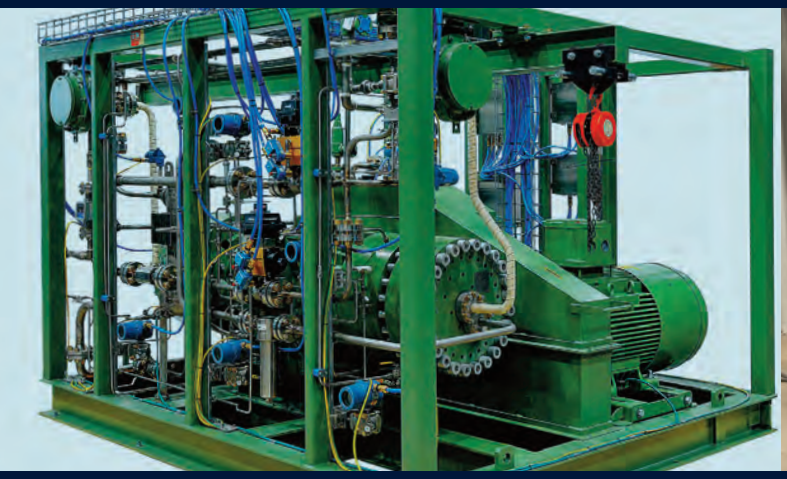
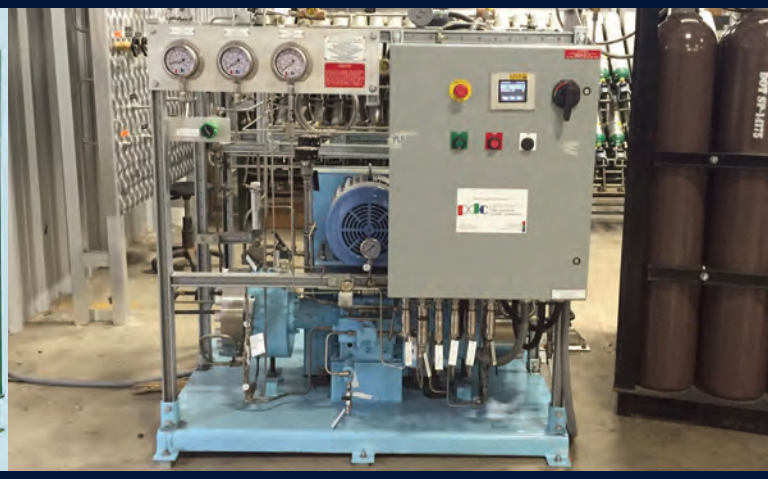
Hydrogen Refueling Stations


*Photo Credit*"Toyota Industries Corporation (TICO) Takahama Factory, Aichi Prefecture, Japan

SimpleFuel: On Site Hydrogen Generation



Petrochemical



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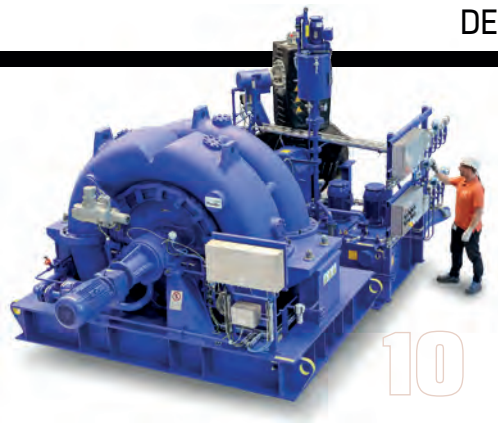


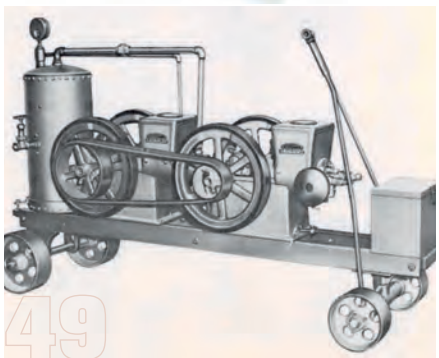


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## COMPRESSION YEARBOOK



## OUTLOOK




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## DEPARTMENTS



## OUTSIDE

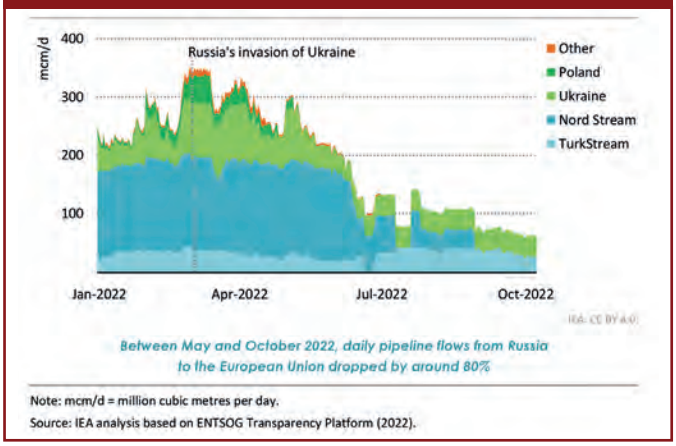
# Natural gas markets facing unprecedented trouble

Russia's invasion of the Ukraine earlier this year has shaken international natural gas markets and will leave consumers worldwide exposed to higher energy bills and supply shortages, according to a recent report from the International Energy Agency.

The current crisis is broader and more complex than anything the world has seen before, the IEA stated in its latest World Energy Outlook.

"Today, the world is in the midst of the first truly global energy crisis, with impacts that will be felt for years to come," said Fatih Birol, IEA executive director. "Russia's unprovoked invasion of Ukraine in February has had far-reaching impacts on the global energy system, disrupting supply and demand patterns and fracturing long-standing trading relationships."

**NATURAL GAS PIPELINE FLOWS FROM RUSSIA TO THE EUROPEAN UNION AND TÜRKIYE SINCE JANUARY 2022**




Note: mcm/d = million cubic metres per day.
Source: IEA analysis based on ENTSOG Transparency Platform (2022).

GRAPH: INTERNATIONAL ENERGY AGENCY

**The interruption of natural gas pipeline flows from Russia to the Ukraine has shaken world gas markets.**

The high prices caused by the crisis have led to a huge transfer of wealth from consuming nations to producing nations. The crisis has led to inflationary pressures and created fears of a global recession. It has also led to a $2 trillion windfall for fossil fuel producers above their 2021 net income, the IEA reported.

The rising prices of energy mean that the number of people worldwide without access to modern energy is rising for the first time in a decade. About 75 million people worldwide who now have access to electricity will probably not have the ability to pay for it, the IEA reported.

At the end of September Russia's exports of gas to the European Union had fallen by 80% when compared with historical levels. Europe demands more gas in the winter for heating and it is unclear how it will make up the shortfall, the IEA reported. The crisis has driven spot prices for natural gas to levels never seen before and has driven up oil and

## Norway strengthens importance as European gas supplier

Norway has emerged as a significant supplier of natural gas to the European Union since Russia's invasion of Ukraine earlier this year. As Russian gas exports to Europe have declined, Norway has strengthened its importance to the region's gas supply chain, a recent study has shown.

Norway is not a formal member of the European Union, but is an important trading partner and a member of the European Economic Area. The country is one of the top 10 natural gas-producing nations in the world and has always been an important source of natural gas to the European Union (EU).

Earlier this year, the Norwegian government authorized an increase of about 0.14 Bcf/d of natural gas production by the end of the year, primarily from two producing fields. Last year, Norway produced 11.1 Bcf/d of natural gas, making it the third largest exporter of gas in the world, after Russia and the U.S.

On average, Norway exports about 94% of the gas it produces. In 1990, the country exported 92% of the 2.7 Bcf/d it produced. Most of Norway's natural gas exports are shipped through its extensive export pipeline infrastructure, although smaller volumes are exported as LNG.

In June, Norway reopened its Hammerfest LNG facility, which was closed after a fire in September 2020. The additional production from the facility could enable an increase in natural gas exports of about 0.7 Bcf/d in 2022, according to a recent report from the U.S. Energy Information Administration.

Hammerfest processes natural gas from the nearby Snøhvit field in the Barents Sea. In 2019, the last year the liquefaction facility was fully operational, 5% of Norway's natural gas exports were shipped as LNG. During normal operations, the facility produces about 6.5 Bcm of natural gas annually, Equinor said. In addition to Equinor, the operator of the project, Hammerfest partners include TotalEnergies (18%), Petoro (30%), Neptune Energy (12%), and Wintershall DEA (3%.)

coal prices as well.

The global supply crisis has led to record price levels in multiple markets around the world and the IEA said it does not expect balance to return until the middle of the decade, when large new LNG export projects come into production.

The higher prices have slowed demand growth in Asian markets and has accelerated European efforts to reduce gas demand and led to a faster increase in the deployment of renewables. Global gas demand is expected to fall by 750 bcm by 2050 because of the lower expected GDP growth and the stronger gas prices.

"Europe's scramble to reduce reliance on Russian fossil fuel imports takes centre stage, but the repercussions of Russia's invasion of Ukraine are being felt much more broadly across a deeply interconnected global energy system," the report stated.

### Three scenarios

The World Energy Outlook from the IEA does not make a single forecast for the future of energy. Instead, it explores three alternatives of what might happen depending on how world policy makers respond to the gradual warming of the planet.

In the net zero emissions (NZE) scenario, the global energy sector would achieve net zero $CO_2$ emissions by 2050. The announced pledges scenario (APS) shows the extent of the world's ambition to tackle climate change as of mid 2022. The stated policies scenario (STEPS) explores where the energy industry might go without additional policy changes.

Under the STEPS scenario, the high price of energy is expected to restrict the growth in energy demand worldwide to around 1% annually through 2030. In all scenarios examined, the era of rapid growth in natural gas is coming to an end. In STEPS, the most optimistic for the natural gas industry, demand rises by less than 5% between 2021 and 2030 and then holds flat around 4.4 tcm through 2050. This is about 750 bcm lower in 2050 than the IEA had foreseen in previous annual outlooks. In the IEA's STEPS analysis, the demand for natural gas is expected to rise at an average rate of 0.4% per year between 2021 and 2030. CT2

**MONTHLY U.S. HENRY HUB NATURAL GAS SPOT PRICE (JAN 2018 - DEC 2023)**
DOLLARS PER MILLION BRITISH THEMRAL UNITS


Source: EIA

# U.S. natural gas price forecasts decline

The U.S. Energy Information Administration has lowered its forecast for natural gas spot prices in response to slower overall expected economic growth and better than expected inventories for the winter.

The average spot price for natural gas at Henry Hub is expected to reach $6.49/MMBtu for all of 2022, down from a previous forecast of $6.88/MMBtu. For 2023, the EIA has forecast spot prices of $5.46/MMBtu, down from a previous forecast of $5.77/MMBtu.

The agency's latest Short Term Energy Outlook lowered the forecast for natural gas prices after the S&P Global macroeconomic model has predicted that U.S. GDP will fall 0.1% in 2023, which will contribute to a decline in total energy consumption next year.

The EIA estimated U.S. natural gas inventories ended October at more than 3.5 trillion cubic feet (Tcf), which is 4% below the five-year average, but higher than the agency had previously forecast.

The EIA saw stronger than average injections of natural gas into storage in September and October, which contributed to a decline in gas prices in those months. The natural gas spot price at Henry Hub averaged $8.80 per million British thermal units (MMBtu) in August but declined to an average of $5.66/MMBtu in October.

Because the U.S. is headed into winter with inventory levels higher than previously expected, the EIA has lowered its forecast natural gas prices for the winter. The most recent forecast calls for natural gas spot prices to average around $6/MMBtu in 4Q22 and 1Q23, a level that is more than $1/MMBtu lower than the agency forecast in its previous outlook.

"We expect natural gas prices will decline after January as the deficit to the five-year average in inventories decreases," the agency wrote.

The EIA has forecast that consumption will draw down inventories over the winter by 2.1 Tcf to 1.4 Tcf by the end of March 2023. That level would be about 8% below for the five-year average for that time of year.

Natural gas inventories play an important role in price formation. Inventory levels below the five-year average are often correlated with higher natural gas prices, while inventory levels above the five-year average are often correlated with lower natural gas prices, the EIA said.

U.S natural gas production has increased steadily throughout 2022 and dry natural gas production will average around 100.4 Bcf/d in November, the agency predicted.

"We expect declines in natural gas production during the winter months due to the possibility of extreme weather, which can cause production shut-ins," the agency wrote.

# Canadian gas provides buffer for U.S. markets

Natural gas imports from Canada into the U.S. have generally fallen over the last 15 years, but trade between the two countries remains an important element in balancing North American gas markets, a recent study has shown.

The U.S. Energy Information Administration published a report that showed natural gas imports from Canada fluctuated wildly over the interim, but the supply from Canada has regularly ensured access to gas during periods of peak demand in the U.S.

Because of sufficient pipeline capacity and storage facilities, Canadian supplies can rapidly increase during times when demand surges in the U.S., a key stabilizing factor during periods of supply and demand, particularly during the cold winter months, the study shows.

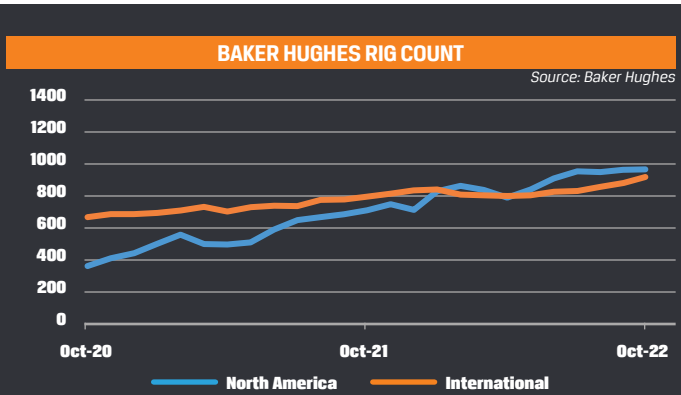
In 2005, 17% of total U.S. supply of dry natural gas came from Canada. Since then, Canada's share of imported dry natural gas supply to the United States has declined as U.S. gas production has grown.

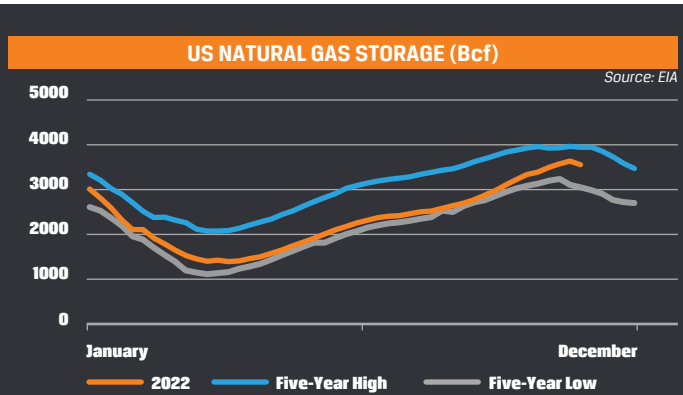
As of the end of August, gross imports of dry natural gas from Canada accounted for, on average, 8% of U.S. supply, and U.S. natural gas production averaged 92%, or 97.0 billion cubic feet per day (Bcf/d), according to figures from the EIA.

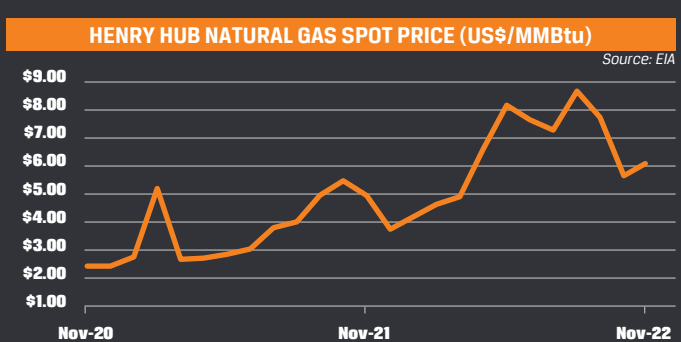
During the same period, U.S. pipeline exports of natural gas to Canada have increased. In 2000, U.S. exports averaged 2% of all pipeline natural gas trade with Canada. In 2005, that share increased to 9%. Through August of this year, it averaged 24%, the EIA reported.

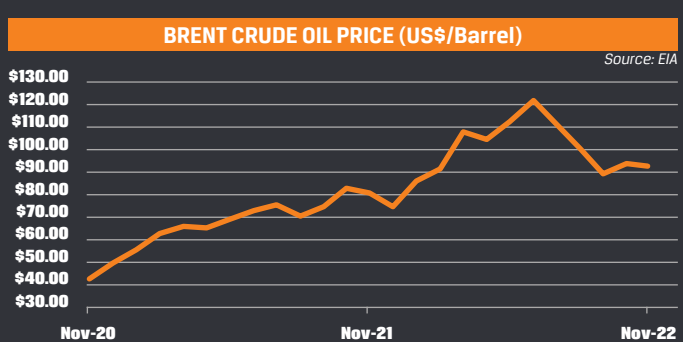
The flow of gas across the border between the two countries is not uniform. Natural gas imports from Canada to the western United States have provided a steady source of supply and have generally increased. So far this year, they have increased 4.1% compared with the same period a year ago. The border-crossing points at Sumas, Washington, and Eastport, Idaho, principally supply metropolitan areas in the Pacific Northwest and California.

Demand for gas to produce electric power has climbed in response to sustained high temperatures and an extreme heat wave. Drought across large portions of the western U.S. has lowered the amount of hydroelectric capacity and forced power producers to use more gas. Meanwhile, pipeline constraints from the Permian Basin have reduced natural gas flows to the western U.S. In the eastern U.S., gas pipeline capacity has expanded and the region is typically a net export of gas to Canada for large portions of the year. CT2



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# Chart buys Howden

KPS Capital Partners plans to sell its portfolio company, Howden, to Chart Industries for $4.4 billion. By **Keefe Borden**

PHOTO: HOWDEN

Howden manufactures a complete portfolio of rotating equipment products, including compressors, blowers, fans, rotary heaters and steam turbines. Headquartered in Renfrew, Scotland, Howden employs more than 6500 associates globally in 35 countries, including over 750 engineers.

KPS acquired Howden in 2019 from Colfax Corporation in a highly complex global corporate carve-out transaction. KPS assembled an accomplished management team, led by Chief Executive Officer Ross Shuster, to lead the transformation of Howden into a large scale, leading global air and gas handling platform.

In just over three years of ownership, KPS, in partnership with management, successfully transformed Howden into a fully independent, fast-growing company focused on innovation.

KPS and Howden's management team executed an aggressive growth strategy that repositioned Howden towards sustainability-linked end-markets and applications.

## Hydrogen compression

Under KPS' ownership, Howden entered or expanded its presence in end-markets that are critical to the future of the industrial economy, including hydrogen compression, carbon capture, utilization and storage, wastewater treatment and energy recovery, KPS said.

KPS made significant investments in the Howden platform, including completing seven highly-synergistic add-on acquisitions, supporting new product development and technology innovation, investing in manufacturing capacity expansions and executing operational improvements.

As a result of these actions, Howden achieved record orders, revenue and profitability under KPS' ownership.

"Howden exemplifies the KPS investment strategy of seeing value where others do not, buying right and making businesses better, across decades, economic and business cycles, geographies and industries," said Raquel Palmer, Co-Managing Partner of KPS. "Howden demonstrates our ability to partner with world-class management teams to build industry-leading manufacturing companies on a global basis."

Howden CEO Ross Shuster said that Howden has a stronger team and superior financial profile than it did prior to KPS.

"Howden's business and growth strategies are aligned with a number of

# COMPRESSORTECH² to sponsor hydrogen summit

**COMPRESSOR**TECH² magazine has issued a call for papers for the first **COMPRESSOR**TECH² Hydrogen Summit, on April 25, 2023, in Houston, TX.

COMPRESSOR TECH² HYDROGEN SUMMIT
HOUSTON, TX APRIL 25, 2023

The one-day summit – which will include an evening networking reception – will address the technical challenges faced by operators in decarbonizing the energy industry.

We are looking for technical papers on topics such as hydrogen blending, compression, green hydrogen, transportation and storage.

Speakers could be representatives of producers, midstream operators and original equipment manufacturers (OEMs), but we are open to proposals from academics, consultants and others active in the hydrogen economy.

The target audience at the Summit will be mid and senior-level executives at midstream operators, original equipment manufacturers, packagers, suppliers, component makers and service companies who provide and service equipment used to process, transport and store gas.

For more information on the Summit, and to send proposals, please contact Keefe Borden, Editor, **COMPRESSOR**TECH². E-mail: keefe.borden@khl.com or tel (713) 254 5329.

Registration for the conference is now open. See the website www.ct2summit.com for more details. For sponsorship opportunities, contact Daniel Brindley: E-mail: daniel.brindley@khl.com.

global macro-trends including the energy transition, decarbonization of industry, and electrification," he said.

Howden and Chart have worked together in the recent past, including on a handful of key projects for joint customers. In 2021, Howden signed a Memorandum of Understanding that resulted in cooperating on a number of ground-breaking projects, including the construction of a new hydrogen liquefaction plant in Canada.

The success of our relationship gives me great confidence that Chart's acquisition of Howden will enable the combined company to offer customers a broader set of innovations, solutions and services."

## New preferred stock

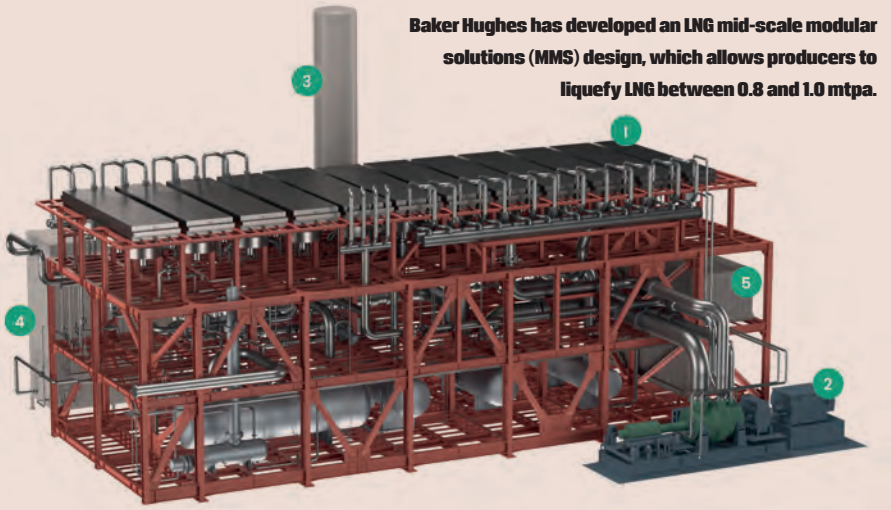
Chart Industries, Inc. is an independent global manufacturer of highly engineered equipment servicing multiple applications in the energy and industrial gas markets. Its product portfolio is used in every phase of the liquid gas supply chain, including upfront engineering, service and repair.

Chart said the purchase will be funded through a combination of cash and shares of a newly created class of preferred stock. The acquisition is subject to the receipt of certain regulatory approvals and other customary closing conditions and is expected to close in the first half of 2023. The acquisition will result in estimated combined revenue of approximately $3.4 billion. **CT2**

**COMPRESSED NEWS**

■ The 13th **INTERNATIONAL CONFERENCE ON COMPRESSORS AND THEIR SYSTEMS** will be held from Sept. 11 – 13, 2023 at City, University of London.

The conference is designed to give participants a forum to discuss developments in air, gas and refrigeration compressors, vacuum pumps, expanders and related systems and components. The program will contain a keynote address, high quality research and technical papers, podium presentations and industry sessions. The theme for the conference will be "Compressors and Expanders in Future Energy Systems."




**Baker Hughes has developed an LNG mid-scale modular solutions (MMS) design, which allows producers to liquefy LNG between 0.8 and 1.0 mtpa.**

# Technip, Baker Hughes sign LNG agreement

Technip Energies and Baker Hughes plan to jointly develop modular LNG liquefaction plants with capacities that range from 1 to 2 million tonnes per annum (mtpa.)

A memorandum of understanding between the two companies states the plans for the plants will fall between the ranges of modularized LNG liquefaction plants that the two companies already have in place.

Baker Hughes has developed an LNG mid-scale modular solutions (MMS), which allows producers to liquefy LNG between 0.8 and 1.0 mtpa. Technip, for its part, has a separate LNG liquefaction plant that gives producers the capacity to produce 2 to 3 mtpa of LNG.

The collaboration is based on the growing market demand for modular LNG options, the companies said.

"Cooperating in advancing technology in LNG with our long-term partner Baker Hughes is an important step for the energy industry and for our clients. The combination of our expertise, modular approach and references will enable shorter delivery times and better affordability," said Arnaud Pieton, CEO of Technip Energies. "Importantly, it reflects Technip Energies' commitment to deliver low-emission liquefaction solutions through electrification and the elimination of fugitive emissions to accelerate the energy transition."

"This agreement is a milestone in our relationship with Technip Energies, and it is mutually beneficial to both companies, leveraging our respective technology expertise and proven track record in the LNG space while maximizing benefits for our customers," said Lorenzo Simonelli, chairman and CEO of Baker Hughes. "LNG will continue to play a key role to solve the energy trilemma, and the ability to accelerate time-to-production through modularized solutions can be a differentiator."

Technip Energies' portfolio already includes SnapLNG, a modularized compact and fully electrified solution for the 2 to 3 MTPA. It covers the liquefaction as well as the necessary pre-treatment and utilities units. SnapLNG highlights Technip Energies' experience of more than a decade in successfully designing and delivering LNG modular projects and is particularly suited for low-to-zero carbon footprint LNG developments.

Baker Hughes has designed LNG plants for over 10 years, catering to different sized projects. Its LNG Mid-scale Modular Solution (MMS) provides a flexible, standardized, and scalable solution for lowering the carbon footprint of the liquefaction process.

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# Power questioned

Concerns about New England energy reliability in winter spark debate. By **Brian Ford**

There was a lot of talk this year among government and utility circles regarding the ability of New England's power system to respond to a particularly harsh winter.

So much so that the chief executive officer of a New England energy company wrote a letter to President Joe Biden urging him to consider implementing an array of emergency actions aimed at ensuring the region has an adequate amount of natural gas and other power sources should the need arise this winter.

In an October 27 letter, Eversource Energy Chief Executive Officer Joseph Nolan asked the Biden administration to "swiftly address the growing concerns about winter electric reliability in New England."

## Offshore wind projects

Eversource and other utilities have increased spending on "large-scale clean energy resources including offshore wind and hydropower that will reduce dependency on natural gas for electric generation, but many of these projects will not be bringing power to the grid for several years," Nolan wrote.

New England relies in part on liquefied natural gas (LNG) imports during the winter months, he noted.

"Pipeline deliveries are routinely supplemented by shipments of foreign-sourced LNG delivered to the LNG import facility in Everett, Massachusetts, on foreign flagged vessels. However, because of the war in Ukraine, imported LNG is not available to the New England region in the volumes necessary to meet this winter's needs without causing further stress on European markets and the American economy," he wrote.

Nolan urged Biden to implement a number of measures to deal with the potential gas shortfall. Among other things, he urged the suspension of the Jones Act, which requires goods moved between U.S. ports to be carried by U.S.-flagged and staffed ships. Suspending the act would allow foreign-flagged vessels to carry LNG and other types of energy from one U.S. port to another in order to alleviate the situation.

In September, the Federal Energy Regulatory Commission conducted a forum in Burlington, Vermont to concentrate on potential long-term solutions to New England's winter energy problems, during which commission Chairman Richard Glick deemed New England's reliance on imported LNG as unsustainable.

## Dependence on natural gas

Following the forum, FERC Commissioner Allison Clements opined, "We know that the root of New England's winter electric system reliability challenge is the significant dependence on natural gas in these extreme conditions, along with gas-supply constraints during extreme winter weather."

She continued: "Shoring up or adding more natural gas supply capability is one way to address these constraints. It is only one way. The region can also diversify away from reliance on natural gas for electric generation and can reduce both electric and gas demand during these extreme weather conditions."

On November 7, Interstate Natural Gas Association of America (INGAA) President Amy Andryszak also wrote Biden, offering a response to Nolan's letter.

"I encourage your Administration to pursue a long-term solution that addresses the root cause of the region's long-standing electric reliability problems--a lack of adequate natural gas infrastructure--rather than focus only on short-term, "emergency" solutions that were neither intended nor designed to address systemic issues like those present in New England," Andryszak wrote.

"The experience of our member companies across the country demonstrates that growing renewable penetration in the electric sector requires greater deliverability of natural gas to backstop the inherent intermittency of renewable resources," she continued. "Unfortunately, there is insufficient infrastructure connecting New England to domestic natural gas supplies and recent attempts to expand existing infrastructure at the request of local utilities and other energy users have been thwarted by misguided policies and vocal opponents to new infrastructure development. New England is facing a perilous winter season because of this stifling of new infrastructure development over the past decade."

## Reliance on LNG imports

Andryszak added that "the negative consequences of overreliance on imported LNG can be avoided with additional natural gas pipeline infrastructure. This solution is especially compelling considering the region's proximity to the Marcellus shale production area, one of the most prolific natural gas supply basins in the world."

Whether New England will experience a particularly cold winter remains to be seen, but Andryszak warned the region does not need a long cold spell to face significant problems. "Just a few days of cold weather could wreak havoc on the region's power grid, and in New England, cold weather is to be expected." CT2

THE AUTHOR

**BRIAN FORD is editor in chief for Industrial Info Resources, which provides up-to-date project information on a wide range of industries across the globe. He has worked as a reporter and editor for newspapers and other publications since 1979.**

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# Shale play-by-play

**James Willis** highlights the latest news from the major North American shale plays

## MARCELLUS/UTICA

### Range likes rock quality in northeast Pa.

Range Resources produced an average of 2.13 Bcfe/d, with approximately 70% of it as natural gas and the rest NGLs, in 3Q22. Range only spent $138 million to drill, but cash flow from operations was a staggering $550 million–the highest in company history. The company drilled seven wells and completed 22 wells during 3Q. Range brought 12 wells online to sales in the southwestern part of PA, and six wells online to sales in northeastern PA.

Range's COO Dennis Degner said the company is "still evaluating how future northeast Pennsylvania activity could find its way into future development programs" of the company. He added, "We like the rock quality there [in northeastern Pennsylvania], we like the results we're seeing." Range recently returned to drilling on its northeast PA acreage in Clinton and Lycoming counties after a five-year hiatus. The company is evaluating whether money invested in northeast PA drilling can compete with drilling in the southwestern part of the state, where it gets big money for NGLs. CEO Jeff Ventura said while his company has concentrated only on the Marcellus rock layer to date, it owns the rights to drill in two other layers–the Utica and Upper Devonian–and plans to do so in the future.

### Shell Pa. cracker plant is officially online

In March 2012, Shell announced the selection of a site in Beaver County, PA, as the future location for an ethane cracker plant. Marcellus/Utica ethane and other NGLs (propane and butane) are found in abundance in the

## BAKKEN/WILLISTON

### Hamm takes Continental private

Continental Resources, the largest oil and gas producer in the Bakken shale, is going private once again. The company announced it had accepted an offer by company founder Harold Hamm to sell those shares not already owned by the Hamm family. The Hamm family collectively owns approximately 83% of Continental's common stock. Harold Hamm founded Continental as Shelly Dean Oil Company in 1967 and ran it as a private firm until 2007. Hamm's stated reason for taking the company private again is that public markets no longer support oil and gas companies. He wants to grow the company's drilling program without concern for shareholder pushback. The deal, which is expected to close by the end of December, does not require shareholder approval.

### Hess brings second compressor station online

Hess Midstream owns oil, gas, and produced water handling assets that are primarily located in the Bakken and Three Forks Shale plays in the Williston Basin area of North Dakota. In September, Hess Midstream brought online the second of two new greenfield compressor stations planned for 2022. Combined, the new stations provide an additional 85 MMcf/d of installed capacity and can be expanded up to 130 MMcf/d in the future. The company's Bakken throughput volumes increased 24% for gas processing and 20% for gas gathering in 3Q22 compared with 3Q21.

## ROCKIES POWDER RIVER BASIN, DENVER-JULESBURG BASIN, NIOBRARA)

### Summit buys two midstream operations in DJ

Summit Midstream Partners announced two deals, one to acquire Outrigger DJ Midstream LLC, the other to acquire Sterling Investment Holdings LLC's Grasslands Energy Marketing and Centennial Water Pipelines (collectively, Sterling DJ), for a combined $305 million in cash. The Outrigger DJ assets, located in Weld County, Colorado, are comprised of a 60 MMcf/d cryogenic natural gas processing plant, approximately 70 miles of low-pressure natural gas gathering lines, 90 miles of high-pressure natural gas gathering lines, 12,800 horsepower of field and plant compression, and 30 miles of crude oil gathering pipelines. The Sterling DJ assets, located in Weld, Morgan, and Logan Counties, Colorado, and Cheyenne County, Nebraska, are comprised of three cryogenic processing plants with a capacity of 100 MMcf/d, approximately 450 miles of natural gas gathering lines, 8,500 horsepower of field compression, freshwater rights, and 40 miles of subsurface freshwater delivery infrastructure. The two transactions are expected to close in 4Q22.

### Jonah Energy deal to provide responsible gas

Jonah Energy's assets and operations are located in the Greater Green River Basin in Sublette County, WY, and consist of 2,400+ producing wells and over 130,000 net acres located in the Jonah Field and surrounding area. In 2020, Jonah Energy became the first U.S. operator to sign onto OGMP 2.0 (the United Nations Oil and Gas Methane Partnership 2.0), and in 2021 Jonah was the first U.S. operator to achieve OGMP's gold standard rating for low emissions.

"wet gas" region of western Pennsylvania, eastern Ohio, and the northern panhandle of West Virginia. It took more than a decade from that initial announcement to build it, but in November, Shell announced the $6-$10 billion plant, now called Shell Polymers Monaca (SPM), is fully operational and shipping polyethylene pellets.

## PERMIAN (DELAWARE)

### Diamondback buying Lario Permian

Diamondback Energy, Inc. has agreed to buy the assets of Lario Permian, LLC, a subsidiary of Lario Oil & Gas Company, for approximately $1.5 billion in stock and cash. The Lario assets include 25,000 gross (15,000 net) acres in the Northern Midland Basin, producing 18,000 BPD of oil equivalent. Diamondback expects to reduce the rig count currently operating on the Lario assets from two to one (or less) in 2023. The primary targets are the Middle Spraberry, Jo Mill, Lower Spraberry, Wolfcamp A, and Wolfcamp B formations.

### ProPetro acquires Silvertip Completion

ProPetro Holding Corp., an oilfield services company providing completions services to upstream oil and gas companies, announced it acquired Silvertip Completion Services Operating, LLC, a provider of wireline perforating and pumpdown services in the Permian Basin. Silvertip owns and operates 23 wireline units and a pumpdown fleet, providing operators with logging, perforating, and pressure control. The transaction was valued at $150 million.

### Stakeholder expands San Andres processing

Stakeholder Midstream, LLC announced a final investment decision (FID) on the installation of a second treating and processing train (Train II) at its Campo Viejo facility. Train II will double the current gas processing capacity from approximately 80 MMcf/d to approximately 160 MMcf/d. Train II will support the continued development of the horizontal San Andres play in Yoakum County, Texas, Lea County, New Mexico, and other surrounding counties.

### HEP gathering pipeline gets Canadian owner

Howard Energy Partners (HEP) is a midstream company that owns and operates more than 600 miles of natural gas gathering pipelines in multiple states, with some 100+ of those miles located in the Pennsylvania Marcellus. In November, Alberta Investment Management Corporation (AIMCo) announced it is the new owner of HEP, having purchased an 87% controlling interest. The announcement does not mention how much AIMCo spent to acquire its controlling interest. AIMCo, one of Canada's largest and most diversified institutional investment managers, said it does not plan to make any major changes to HEP and its asset portfolio. CT2

## HAYNESVILLE

### Southwestern expands transport on two pipes

Southwestern Energy announced it has secured two deals for an additional combined 500 MMcf/d of pipeline capacity in the Haynesville shale. The deals will allow Southwestern to flow more gas to Gulf Coast LNG markets in 2024. Southwestern secured capacity on Momentum Midstream's planned 1.7 Bcf/d Haynesville gas gathering system (not yet built), which will deliver gas to Gulf Coast markets and LNG export terminals. Momentum is due to begin operation in 2Q24. Southwestern also secured additional capacity on DT Midstream's existing 1 Bcf/d Leap pipeline, which flows gas from the Haynesville to the Gulf Coast, linking to the Gillis hub near the Louisiana coast.

### TC Energy sanctions 1.5 Bcf/d Gillis Access project

In November 2022, Canada-based TC Energy sanctioned the development of the Gillis Access project, a 1.5 Bcf/d greenfield pipeline system that will connect supplies from the Haynesville basin at Gillis to markets elsewhere in Louisiana.

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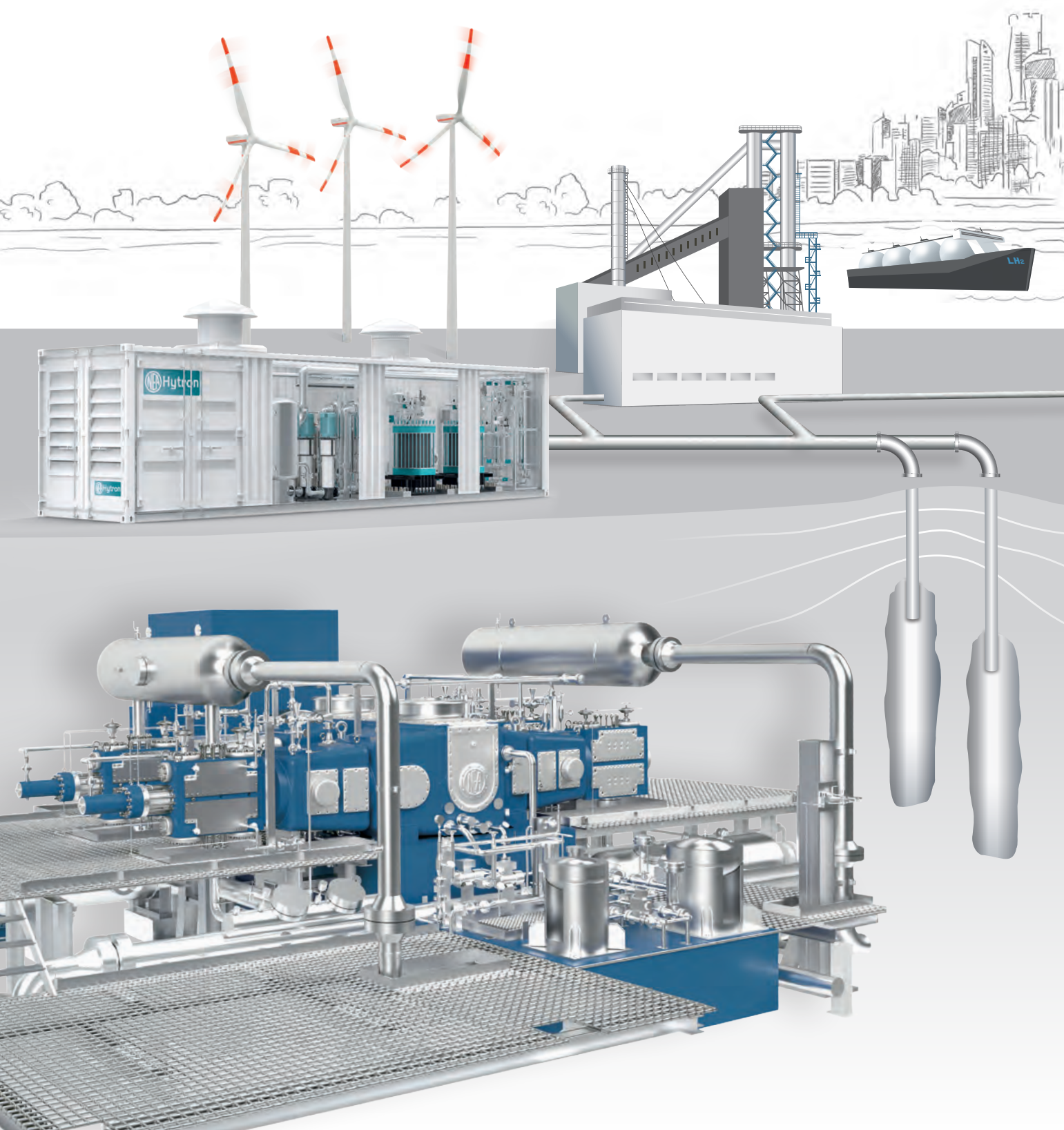

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Whitehawk Capital Partners provided $55 million.

Industry veteran returns with fresh capital.

By **Keefe Borden**

# CherCo sees opportunity for contract compression

New ventures can be risky, but with experienced managers and ample capital backing them up, there are clear opportunities for growth. Chet Erwin, the new chief executive at the recently formed contract service provider CherCo, is betting a growing natural gas industry can provide steady returns for contract services providers.

Although CherCo itself may be a new player, Erwin, has more than 35 years of experience starting and expanding successful companies in the energy sector. He co-founded Hanover Compression Company, which started as a four-person Texas operation in 1990 and grew to more than 5,000 employees worldwide by 2001.

In 2004, he co-founded Valerus Compression Services, which grew its revenues in five years to become the second-largest gas-handling, service company worldwide.

Whitehawk Capital Partners saw potential in CherCo and recently provided $55 million of financing into the company along with CherCo's investors which enable expansion in the U.S. Southwest.

In addition to compression equipment, CherCo offers service guarantees, mechanical availability and timely service from some of the top mechanics in the industry. Comprised of the latest-model Caterpillar and Waukesha engines with Ariel and GE compressors, CherCo's fleet of equipment is suited for gas lift and gas sales in addition to midstream gathering, gas processing and treating.

The firm's warehouses and operating locations are strategically located to provide customers fast response times. CherCo technicians are dedicated to its customers' aftermarket service needs. state-of-the-art training and parts distribution throughout the company's operating footprint.

**COMPRESSOR**TECH$^2$ recently sat down with Erwin and its chief financial officer Braden Norris to discuss the opportunities in the coming years for gas compression service providers.

### CAN YOU TELL US A BIT ABOUT CHERCO AND HOW IT CAME TO BE?

**CHET ERWIN:** I've been in the gas compression business since about 1985 and there was a company in east Texas called CherCo Compression. They were one of original adopters of the contract compression space. I liked the name and I set up a company called CherCo several years ago, just as a personal company.

Braden and I when we went down

this path to look at opportunities in the compression space we used CherCo as a placeholder as we were thinking we would buy somebody and assume their name, but ultimately we ended up with CherCo.

Our very first day of business was September 1 of this year. Braden and I teamed up in 2020 to start looking at opportunities in the infrastructure service contract compression space. We looked at a lot of companies and several regional companies.

Ultimately, our transaction was a carve out of operating and idle assets from one of the large publics in our space. Then we acquired a small regional compression company based in Longview, Texas and the owner has since come on board to be part of the CherCo team.

Then as part of the general strategy we bought a lot of idle assets from a large midstream company. So at closing, we had about 210,000 hp in our fleet.

It's a nice start, a great operating footprint starting in South Texas, Central Texas, East Texas and Louisiana.

We are developing our Permian Basin strategy. We will take a lot of our large horsepower gas lift equipment to the Permian Basin in the later part of this year and in 2023.

**BRADEN NORRIS:** The way I like to think about it is if you look at a map and draw a line down half of Texas the Eastern half of Texas and the state of Louisiana was the active operating footprint that we acquired.

**CE:** With the transaction, we have just under 100 customers. That was part of the attraction to the operating assets, which came with great customers. Our strategy is to work with new and existing customers to further develop those relationships and help increase the utilization of our fleet.

### WHAT DID YOUR AGREEMENT WITH WHITEHAWK PROVIDE?

**CE:** It allowed us to complete those acquisitions and to provide some additional financing for future transactions. We put ample cash on the balance sheet, to allow us some flexibility to transact on other opportunities or to modernize our fleet. We have a lot of opportunities.

### WHAT LONG-TERM TRENDS DO YOU SEE IN THE INDUSTRY?

**CE:** The base case for gas compression hasn't changed in 100 years. That is taking gas from the wellhead, through the gathering system and ultimately into the pipeline. So as the infrastructure around the country continues to be developed, the demand for gas compression will remain strong for decades to come.

### WHAT IS DIFFERENT?

**CE:** There are a couple of things that stand out. First and foremost, the demand for large horsepower gas compression is a trend that has been very meaningful over the last five years, particularly in the Permian but also in other areas. These multi-well pads are very common in the gas compression space.

When I think about the future of the natural gas business, there is about 10 Bcf/d of LNG capacity, which makes up about 8% of the 118 Bcf/d produced in the U.S. today.

So just under 10% of U.S. production today is going to LNG. Within five years, with the existing plants that are permitted, that will double. The demand for LNG will go from 10 Bcf/d to 20 Bcf/d and who knows what the total volume of domestic consumption will be, but it is a game changing event for the natural gas industry. We are at the heart of the production and transportation of natural gas. We are very excited about the future of the infrastructure services space.

**BN:** To add to that, these export facilities have changed the natural gas industry. Historically we have been focusing on supplying the domestic consumption of natural gas. With these export facilities, it takes supply to a global market. Look across to European gas prices today. They are four and five times what we see domestically.

What holds the U.S. from helping to lower that cost overseas is our export capacity or lack thereof to fully participate in a global marketplace. On question we constantly monitor is 'Will these export facilities allow the U.S. the capacity to play a larger role in the global market and what will that do for domestic prices?

We feel that the growth of LNG will help create more stability in gas prices in the long term. The chances that we see gas prices return to where they were in 2016 levels is unlikely.

We're doing what we can, but we're operating at peak capacity. There is an equilibrium that we will hit at some point on a global level which makes us excited for the long-term outlook for natural gas.

> "There is always room for someone who can provide a quality service. The demand for horsepower grows every year as consumption grows."
>
> **CHET WRWIN, CherCo chief executive officer.**

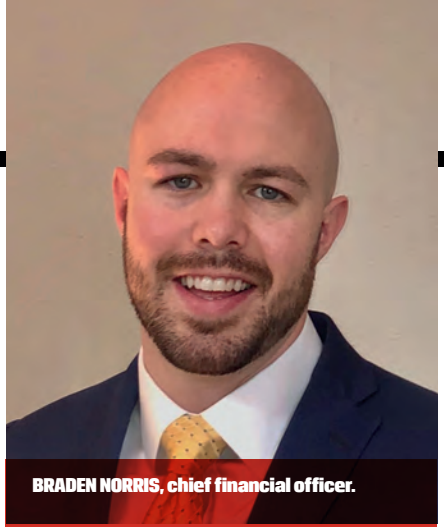
### WHAT OTHER NEW TRENDS?

**CE:** There is a clear trend for gas compression fleets to move to larger horsepower. In the mid 1980s, the average horsepower was 120 to 150 horsepower. My general sense across the board is that it is around 500 horsepower. The large players like Archrock, USA Compression and Kodiak are focused solely on large horsepower. So the one thing that is different about our strategy is that we want to be able to provide compression services from the wellhead to the pipeline.

Our smallest unit is 100 hp and our largest is just under 1700 hp. We want to be able to provide our customers compression services up and down the horsepower spectrum. One day they will need 100 hp and another day, they will need a 1600 hp machine. We want to provide them that service from the wellhead to the pipeline.

### DO YOU THINK THE CONTRACT COMPRESSION SPACE HAS GOTTEN MORE CROWDED OR IS THERE STILL ROOM FOR NEW PLAYERS?

**CE:** There is always room for someone who can provide a quality service. The demand



BRADEN NORRIS, chief financial officer.

**"These LNG export facilities have changed the natural gas industry."**

for compression horsepower grows every year as consumption grows. So whether it's a new company like CherCo or a large one of the large publics in our space, the demand for horsepower is very consistent and predictable. We are bringing significant horsepower to the market over the next couple of years, so we think that will be very well received with the service component that CherCo brings to the market.

**WHAT ADVICE WOULD YOU HAVE FOR A YOUNG PERSON INTERESTED IN THE GAS COMPRESSION INDUSTRY?**

I tell young people in general that this is an industry that will be in demand for decades to come. Don't be concerned about the volatility of the energy space because natural gas infrastructure and natural gas infrastructure services have proven to be resilient. The industry as a whole needs young people to come in and replace my generation of people who have now retired. There is a long successful future here.

You have to think about the business differently than in 1985 when I started. ESG and compliance around emissions are paramount to our success. This is the future of the industry and we need to embrace it. Cherco will certainly be a part of that. We think about safety and operations first and foremost. There is a lot of change in the industry, but it is change in the industry that has been very consistent over the years.

**WHAT KEEPS YOU UP AT NIGHT?**

**CE:** Supply chain issues are very real. We can't take for granted some of the most simple products that we used over the years. Engine deliveries from Caterpillar take 52 to 56 weeks -- and up to 70 weeks on specific models.

There is a tremendous series of supply chain issues for new packages. The daily items that we've always had at our fingertips, you can't take those for granted anymore.

Our equipment runs 24/7 as our culture is committed to our customer's success. We're always trying to grow and upgrade our team with the most accomplished field operators possible.

**BN:** From a supply chain perspective, even the most simple of items have become difficult. Think about trucks, for example. Before, I could go down to a dealership and get a truck. Today, if I want a truck, I may have to search 20 dealerships and still not be able to find one, you have to plan well in advance of your needs. And that's just one example.

**WHERE ARE WE HEADED IN THE NEXT COUPLE OF YEARS?**

**CE:** The pandemic put a lot of projects on hold. Over the next two or three years, we expect pipeline companies to bring those projects forward. The industry is now reacting to that and I think we will play catch up for the next couple of years.

In addition, LNG has been part of our market for several years, but one news item that caught my attention was an LNG supply contract for 20 years. And I thought "These people are locking into a 20-year agreement." LNG was something that was usually traded on the spot market. That contract put a lot of focus on the long-term. In addition, you have these new LNG projects that are coming online. This is not a flash in the pan.

The industry has been waiting for this for a long time. Each one of those plants will export 1 Bcf/d or 2 Bcf/d. Now we're up to 10 Bcf/d with more coming. The trend around LNG and the positive noise is finally here and it will stabilize our natural gas industry, our country and our economy. CT2

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# Euro gas report

**Anna Kachkova** provides information on the latest gas compression news from Europe

## ITALY

### Snam plans to boost Italian gas

Italy's Snam is planning more investments in the country's natural gas network in an effort to improve transportation infrastructure from the south to the north and boost supplies from Africa.

The Italian government has turned to long-standing partnerships with Algeria and Egypt to secure more gas and replace some of its imports from Russia in the wake of the war in Ukraine. Snam has also received permission in recent weeks to set up a floating storage and regasification unit (FSRU) at Piombino by early 2023 and a second off Ravenna by 2024.

In Snam's third-quarter earnings call, the company's CEO, Stefano Venier, discussed the Adriatic pipeline, which he said would take five years to be built, starting up at the end of 2027. The total cost of the pipeline, which runs from the south to the north of Italy, is estimated at EUR2.7bn ($2.8bn). Venier said the pipeline could allow for additional flows from the Trans Adriatic Pipeline (TAP) as well as providing greater flexibility and capacity to accommodate extra volumes from Algeria, Libya and a new gas development offshore Sicily.

Snam reported a 9% in natural gas consumption by industrial users over the first nine months of 2022. This was attributed to high gas prices, which are causing some buyers to scale back usage or switch to alternative fuel sources.

## EUROPEAN UNION

### EU proposed price cap draws mixed response

The European Commission unveiled a proposal to cap natural gas prices across the European Union at EUR275 ($285) per megawatt hour for month-ahead derivatives on the Netherlands' Title Transfer Facility (TTF) exchange.

The proposal is part of an instrument to protect EU businesses and households from excessively high gas prices as the bloc pivots away from Russian gas imports and battles an energy supply crisis. In its announcement, the Commission noted the "extreme" gas price spike over two weeks in August that had a knock-on effect on electricity prices and inflation.

"The Commission is proposing to prevent the repetition of such episodes with a temporary and well-targeted instrument to automatically intervene on the gas markets in case of extreme gas price hikes," it stated.

Under the proposal, the mechanism would be triggered automatically when two conditions are met – the front-month TTF derivate settlement price exceeds EUR275 for two weeks and TTF prices are EUR58 ($60) higher than the LNG reference price for 10 consecutive trading days within those two weeks.

However, the proposal has received a mixed response from EU member states, and opinion has been so divided that energy ministers have thus far failed to reach a compromise, despite agreeing in late October to a limit on gas prices. A further emergency meeting to continue discussions on the topic is scheduled for mid-December.

## NETHERLANDS

### Porthos CCS project set to be delayed by Dutch court ruling

The Netherlands' highest administrative court, the Council of State, ruled that nitrogen emissions from the proposed Porthos carbon capture and storage (CCS) project would need to be taken into account. The developers of the Porthos project had been hoping to make use of an exemption granted by the Dutch government for construction activities. However, the court said in an interim ruling that this would violate European law and that it will need more time in order to decide whether construction of Porthos can proceed.

The consortium developing Porthos – comprising the Port of Rotterdam Authority, Gasunie and EBN – said in a statement that the interim ruling would delay the project. The group had been aiming for a final investment decision (FID) by the end of 2022, with the

PHOTO: REUTERS

**An aerial view of the SNAM underground gas storage facility in Minerbio, Italy.**

THE AUTHOR

**ANNA KACHKOVA is an independent oil and gas writer based in Edinburgh, Scotland. She has over 13 years' experience of covering the energy industry, including five years in Houston, Texas, as NewsBase's North America editor. Her email address is:** aikachkova@gmail.com

PHOTO: EUROPEAN UNION

## POLAND-SLOVAKIA

### Poland-Slovakia interconnector enters service

Poland's Gaz-System and Slovakia's Eustream said that the Poland-Slovakia gas interconnector was set to enter service, with capacity on the new interconnection point available by auction from the following day.

**The gas interconnector between Poland and Slovakia connects the gas networks of the two countries and strengthens gas transportation between the Baltic Sea, the Adriatic and Aegean Seas, the eastern Mediterranean Sea and the Black Sea. The pipeline, with a total length of approximately 165 km, received more than €100 million of EU funding, which represents around 40% of the project costs.**

The pipeline has the capacity to carry up to 201.3 Bcf/y (5.7 × 109 $m^3$/y) towards Poland and 166.0 Bcf/y (4.7 × 109 $m^3$/y) towards Slovakia. On the Polish side, the pipeline connects with the national transmission system at the recently built gas distribution and metering hub at Strachocina, where pipelines that are part of Poland's North-South Gas Corridor converge.

The project forms part of a broader effort to increase security of supply in the region and enhance access to non-Russian sources of natural gas in the wake of the war in Ukraine. Through Slovakia, Hungary and Romania, Poland gains access to gas arriving at LNG import terminals in Greece, Turkey and Croatia, as well as to gas production in the Mediterranean Sea and the Caucasus. Meanwhile, Slovakia gains access to supplies arriving in Poland via the Baltic Pipe and the Świnoujście LNG terminal, as well as volumes from Lithuania's Klaipėda LNG facility.

system then due to be operational by 2024 or 2025. Now, though, the timeline will have to be pushed back.

The project includes a pipeline running through the Rotterdam port area to a compressor station that would receive and pressurize carbon dioxide ($CO_2$). From the compressor station, the $CO_2$ will be transported via an offshore pipeline to a platform around 20 km (12 miles) off the coast and injected into an empty gas field.

The Porthos consortium said it had already conducted an ecological test, which showed that nitrogen emissions from construction of the project would be "minor and one-off" and would not have a significant impact on Natura 2000 nature protection areas in the region. However, it now has to wait for the Council of State to deliver its final verdict before deciding how best to proceed.

The Dutch government has also expressed its concern over the potential impact of the court ruling.

"It now seems that this ruling will delay projects necessary for the energy transition by about six months to two years," said Dutch Minister for Climate and Energy Policy Rob Jetten. "That's a bitter pill because many sustainable projects – after they have been built – actually reduce nitrogen emissions."

## UKRAINE

### Russia backs off threat to restrict gas flows through Ukraine

Russia threatened in late November to restrict gas supplies to Western Europe via Ukraine – the only route connecting the regions along which natural gas is still flowing. Russia's state-owned Gazprom accused Ukraine of taking gas that was meant for Moldova from pipelines crossing the country, and said that it could reduce supplies from November 28. However, that day Gazprom opted not to cut flows after all.

While volumes being shipped to Moldova only comprise a small percentage of those transiting Ukraine, any further disruption in gas flows from Russia to Europe would spell a worsening of the continent's energy crisis and would be expected to unsettle markets. And there is no guarantee that further disruptions can be avoided as well.

Around 1.5 Bcf/d (4.3 × 107 $m^3$/d) of Russian gas has been transiting Ukraine in recent weeks en route to Western Europe. Gazprom has claimed that Ukraine had "accumulated" around 1.8 Bcf (5.2 × 107 $m^3$) of gas that had been bound for Moldova over an unspecified period.

Ukraine rejected Gazprom's allegations, and analysts cited by the Financial Times said Moldova had been storing some of its gas in Ukraine ahead of the coldest winter months.

According to a statement on Gazprom's Telegram channel, a payment issue between the company and Moldova had been resolved. As a result, flows via Ukraine have not been curbed.

Separately, Russia's Kommersant newspaper reported that Gazprom had decided to preserve gas-pumping equipment at the Portovaya and Slavyanskaya compressor stations that supply the Nord Stream 1 and Nord Stream 2 pipelines instead of moving it to other sites, according to sources familiar with the matter. CT2

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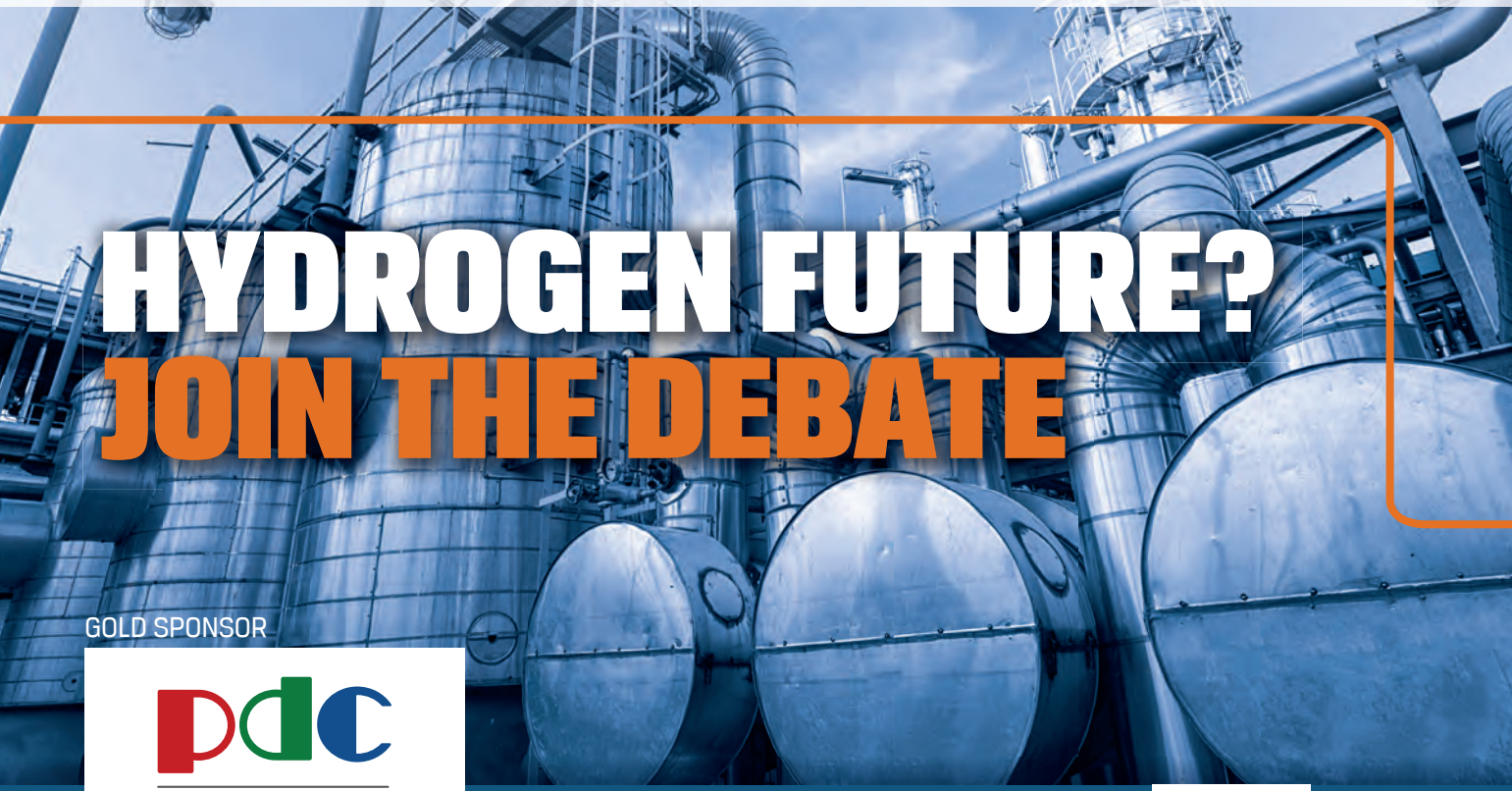

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# Expansion joints limit cracking in grout pours

Foundation cracks can develop as grout hardens. By **Charlie Rowan**, president of Robt. L. Rowan & Assoc., Inc.

Expansion joints are very important in epoxy grout pours as they serve to limit the cracking that can often occur in the grout. Cracks are the result, generally, of a curing stress that develops in the grout as it hardens.

Grouts generate heat after they are mixed and the chemical reaction starts. The hotter the exothermic chemical reaction (necessary to develop a high compressive strength grout) and the more heat there is from external sources (such as direct sunlight) the greater the stress that will develop in the grout.

If the stress does not exceed the tensile strength of the grout, no crack develops. However, if additional stress is added, as is very possible with a change in temperature, then the higher total stress is enough to cause a crack. That is why cracks sometimes develop months after installation. With a coefficient of expansion of more than twice that of concrete or steel, it is easy to see that temperature changes, such as a cold snap, can trigger enough additional stress to allow a crack to develop. Expansion joints will serve to break up the grout pours into smaller sections, thus reducing the probability of a crack.

Even with expansion joints, cracks can start from a stress concentration point, such as a sharp corner, so in addition to the use of expansion joints, elimination or treatment of all sharp corners should be called for. How to install expansion joints and reduce stress concentrations is the subject of this issue of the Grouting Technology Newsletter.

## Location

Expansion joints, perpendicular to the crank shaft or long dimension of the block, should be laid out looking at a plan view of the foundation. An obvious point, such as a change in block width, could serve as a starting point, and additional joints could be added to break the pour into 3' to 4' sections.

The exact locations should be dictated by the equipment configuration rather than a rigid adherence to 3' to 4' distance criteria. Do not call for an expansion joint that will intercept a load bearing area such as a sole plate or chock, but instead move it over so the loaded section is equidistant between expansion joints. If in doubt, add an extra expansion joint. Ends of long metal rails are a logical place to put an expansion joint, since a rail that spans two or three anchor bolts needs to have room to grow thermally.

## How to construct

There are three ways commonly used to construct expansion joints in epoxy grout pours:

- Waxed wooden strips that are pulled out after the grout hardens and the gap then filled with an oil resistant elastomeric compound
- Styrofoam strips that are partially dissolved after the grout hardens and then sealed with an oil resistant elastomeric compound
- Closed cell oil resistant foam.

All three systems are easy to install if added at the time the forms are being constructed.

Expansion joints, in conjunction with full bed epoxy grouting, need only go from the edge of the block, across the grout shoulder and 2" to 3" back under the equipment frame. If the frame is elevated on metal, epoxy chocks or Rowan Tri- Chocks, the expansion joints should go the full width of the grout pour.

With fabricated steel bases (skids) that are epoxy grouted to a concrete slab, common field practice has been to put expansion joints only in the shoulders, even if the grout bed extends 8' to 10' to the other

ABOUT **ROBT. L. ROWAN & ASSOC., based in Houston, Texas, has solved foundation and grouting problems for compressors and other critical alignment equipment in the oil and gas industry for nearly 70 years.**

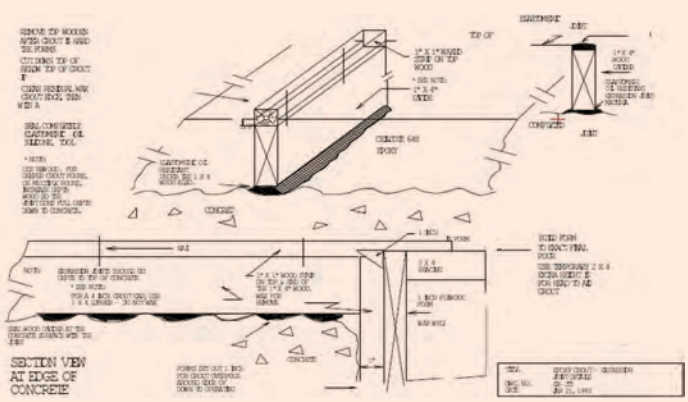


**FIGURE 1 Regardless of which method is used, some grout suppliers suggest a layer of oil-resistant elastomeric material at the bottom of the expansion joint as a "secondary seal."**

side, unless there is access to the interior areas to install the elastomeric seal. Cracking is more likely to occur in the shoulder areas.

Pump bases are usually grouted without any expansion joints because of their smaller size and configuration.

## Wooden strips

Today, the most popular method of installing joints in epoxy grout caps is to use 1" - wide wood strips (redwood is preferred). The strips are attached to the forms and extend to the full depth of the epoxy grout pour, or pours if there is more than one pour.

The top 1/2" at the final grout elevation should be removable, although the 1/2" depth required for the oil resistant elastomeric seal can be chiseled out with difficulty. The wood should be sealed to the chipped concrete substrate elastomeric seal.(See Figure 1).

If the epoxy grout is going to be placed on the vertical edge of the concrete face (overpour) as well, the removable wooden strip should go down the sides. This will enable the elastomeric seal to go down the sides as well, completing the seal. (See Figure 2). After the epoxy grout has hardened, the 1/2" deep removable wood strip is pulled out and any wax cleaned from the edges of the grout. A new, single-package caulking tube of oil- resistant silicone (Rowan Blue™) is a good sealing compound. After cleaning the sides of the grout, put a piece of masking tape on the top of the remaining wood as a bond breaker and on either side of the grout cap to aid in clean up. For the best possible adhesion, prime the edges of the epoxy grout that will be in contact with the elastomeric silicone with an approved primer.

Next, seal the joint with the elastomeric sealer, carrying the seal down the vertical edge of the foundation as well. The single-package, oil-resistant silicone will tool off smoothly by using a little water on the trowel or putty knife. The above provides an optimum expansion joint design where the elastomeric seal has a cross section with the depth being 1/2 of the width and a bond breaker on top of the wood left in place. Such a properly installed expansion joint will allow for proper expansion and contraction of the grout without pulling loose.

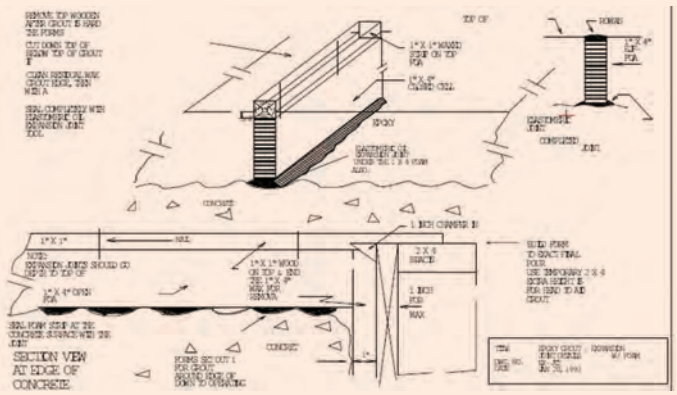


**FIGURE 2**
**The layer of oil-resistant, elastomeric material needs to be applied when installing the expasion joint at the form building stage.**

## Styrofoam strips

This really is a variation of the step above. However, since styrofoam can be dissolved readily with acetone or other solvents, the top 1/4" or so can be dissolved and the joint sealed with an appropriate elastomeric compound as described in the step above. A word of caution, though: some epoxy grout formulations contain solvents themselves and so cannot be used with this method. Be sure to check the compatibility of the epoxy grout and styrofoam ahead of time.

A better variation of the design is to set the foam 1/2" low using a removable wooden strip as in Method 1 and then completing the joint with an oil-resistant, elastomeric silicone.

This method is falling out of favor, as the styrofoam below can crush when someone steps on the joint, causing the seal to tear loose. **We do not recommend using this method.**

## How to install closed cell oil resistant foam

Suitable foam materials of neoprene or urethane are available in 3/4" to 1" width stock. The depth should be approximately that of the grout depth and the length cut to fit the distance from the form edge to where the grout terminates at the equipment oil pan area.

The foam will tend to "snake" after installation. To control this, the foam should be fastened to a wooden strip that is nailed securely into the form. (See Figure 2). The top of the foam should be at the finished elevation of the grout with any excess being neatly trimmed.

An alternative is to use foam a 1/2" low with a removable wooden strip on top of the foam as in Method 1 and then completing the joint with an oil resistant elastomeric silicone.

A thicker 2" x 2" strip of foam works very well for skid mounted equipment. The foam strips should be sealed to the sharp corners of the equipment frame, if full bed grouted, or of a sole plate or rail can cause a crack to start. Good design calls for a 1 1/2" radius, or larger, to help alleviate the stress concentration. Metal plates that will be encased in the grout pour, such as a jackscrew landing plates, should be circular in design or have well rounded corners. If a sharp corner or edge is found during the pregrouting check, electrical putty or duct seal can be used to encase the sharp corner.

With a single pour of epoxy grout, rebar dowels should terminate 2" below the top surface. With a multiple pour, the rebar dowels should extend through the bottom layers and terminate 2" below the top surface of the final pour. Horizontal rebar should also have 2" of grout cover over them. Formed interior corners, for example between compressor cylinders, should also have a generous 1 1/2" contour or radius in the grout. A piece of 3" PVC pipe can be cut and used at the forming stage to create the contour.

Finally, while not directly related to cracking from stress concentrations, the forms should also have a chamfer strip to break the sharp edges of the final grout pour.

Following the above recommendations will not guarantee that cracks will not develop but certainly will greatly reduce cracking no matter what brand of grout is used. **CT2**

# 2022: A year of intensity

## Industry turns to LNG, experiments with hydrogen blends. By **Keefe Borden**

PHOTO: ENI

bp loaded the first LNG cargo from Mozambique's offshore Coral Sul FLNG facility.

It's been a head-spinning year that has changed us and forced major adaptations to the natural gas industry. A war has started that (in addition to the vast toll on human lives), has altered natural gas trading patterns and power, potentially for years to come.

The conflict in the Ukraine has made LNG exports and imports more important than ever worldwide and policymakers have looked for ways to boost both import and export capacity to deliver and receive more supply.

Qatar continues to take steps to regain its dominance the LNG market as it expands production from the North Field. It plans to boost liquefaction capacity from 77 million tonnes per year (mtpa) to 110 mtpa. A second project would boost expansion again to 126 mtpa.

LNG buyers are stepping up to sign long-term contracts as supplies are less certain than before. QatarEnergy, for example, has signed a 27-year contract with China's Sinopec to ship 4 million tonnes per year (mtpa) of LNG to China.

For its part, Williams is trying to sign a 20-year LNG supply agreement with Sempra Infrastructure that would include about 3 mtpa from one of Sempra's LNG facilities on the U.S. GulfCoast.

INEOS, meanwhile, signed a separate agreement with Sempra Infrstructure to buy up to 1.4 mtpa of LNG from North America for 20 years.

More recently, bp loaded the first LNG cargo from Mozambique's offshore Coral Sul FLNG facility, the country's first LNG project and first floating LNG facility ever deployed in the deep waters of the African continent. Under a long-term contract, bp will purchase 100% of LNG output from Coral Sul FLNG which has the capacity to produce up to of 3.4 million tonnes of LNG per year.

Baker Hughes signed a contract with Driftwood Pipeline LLC for the Tellurian pipeline project that will feed their LNG plant. Baker Hughes will supply four ICL trains each powered by 19-MW motors.

New Fortress Energy Inc. (NFE) awarded a contract to Fluor Corp. for its Fast LNG 2 project, a nominal 1.4 mtpa LNG gas treating and liquefaction plant that will be placed on fixed offshore platforms.

As the demand for LNG continues to surge, many OEMs like Howden are seeing a surge in demand for boil-off-gas compressors. Howden's experience with hydrogen lead a subsidiary of INEOS to grant a contract to Howden to supply a low pressure piston compressor and a high pressure diaphragm compressor for a hydrogen production facility in Runcorn, UK.

Howden customised its solution to fit the needs of INOVYN, an INEOS subsidiary, while reducing the total cost of ownership of its operations. The compressors will enable INOVYN to supply compressed fuel-cell quality hydrogen to the transport and industrial sectors.

GE Gas Power and Shell Global Solutions signed a development agreement to pursue potential pathways aiming to reduce the carbon intensity of Shell's LNG supply projects around the world. With global LNG demand projected to almost double by 2040, Shell said decarbonization is crucial in helping the company meet the world's growing energy needs.

Elliott Group this year announced an impulse-type, two-phase cryogenic expander that allows for the expansion of liquefied gases into two-phase mixtures. Harnessing the energy of two-phase expansion increases the expander's generator output, reduces boil-off losses and improves the overall liquefaction and cooling processes. Each expander is custom-designed and built for use in LNG liquefaction, refrigeration, and separation processes, as well as to improve overall efficiency, Elliott said.

The worldwide trend for the year is clear: buyers were looking to secure supplies and sellers were seeking to expand export facilities. Importing countries, meanwhile, were working to boost regasification capacity. Both buyers and sellers were looking for expertise from OEMs to build out their infrastructure, leading to a surge in revenue and new orders for those companies.

IMAGE: HRS

**HRS designs and manufactures hydrogen refueling stations. The stations have a capacity of over one ton per day and can meet the needs of heavy transport, which includes bus, trucks and ports, as well as lighter vehicles.**

## Alternative energy

The world also remains focused on alternative energies, even as it remains dependent on fossil fuels, including natural gas. Right now, one of the best alternatives is hydrogen, which means an important evolution in the gas compression industry.

By many standards, the number of hydrogen projects worldwide is staggering. A report from the Hydrogen Council shows 680 large-scale project proposals have been announced, requiring a direct investment of US$240 billion between now and 2030 – an increase of 50% since November 2021 alone.

To that end, Burckhardt Compression launched an oil-free hydrogen compressor for applications that require high mass flows and a discharge pressure of 550 bar.

Earlier this year, Burckhardt announced it will supply several diaphragm compressors to HRS to be used in hydrogen refueling stations. The compressors will be integrated into HRS hydrogen refueling stations with a capacity of over one ton per day.

The aim is to provide refueling solutions for intensive market use, with a capacity of over one ton per day to meet the market demand for heavy transport, which includes bus, trucks and ports, and light commercial vehicles such as taxi fleets. Burckhardt also signed a global distribution agreement with valve and components maker KB Delta, which took effect at the start of the year.

More recently, Burckhardt delivered its first MD10-L diaphragm compressor unit in Europe to a green hydrogen production facility in St. Gallen, Switzerland.

Southern Star Central Gas Pipeline and Cooper Machinery Services have spent most of the last year testing the effects of hydrogen on a large bore slow-speed integral engine. After extensive tests, the two companies found it could successfully run a blend of 30% hydrogen on a large bore Cooper-Bessmer BMVH-12 at a compressor station owned by Southern Star.

Separately, INNIO announced it will acquire green hydrogen from a subsidiary of energy utility TIWAG. As part of the project, INNIO will install an electrolysis unit on the premises of TIWAG's Achensee power plant that will convert green electricity into green $H_2$. In turn, TINEXT will construct the compression and storage terminals, from which the $H_2$ will be transported via pipeline from TINEXT to INNIO'S Jenbach operations.

Sweden's Hynion selected PDC Machines to supply compressors for new hydrogen filling stations Hynion will build in Västerås and Jönköping. The stations represent a new generation with a refueling capacity of dozens of trucks per day, necessitating powerful and robust compressors, which PDC Machines will provide. The stations will deliver hydrogen at both 35 and 70 MPa for light and heavy-duty vehicles.

Howden announced plans to standardize a design for hydrogen compressors based on the specific needs of renewable fuel plants developed by Raven SR. In addition, the two companies agreed to reduce lead times by providing inventories of dedicated compressor parts.

Baker Hughes has seen an ongoing interest in hydrogen compression and plans to use its experience in the refining industry to meet that growing need. The company also recently produced and shipped four HG compressors to the Sriracha oil refinery operated by Thai Oil, a subsidiary of the state-held PTT Group.

Ariel Corporation and Hoerbiger announced a partnership to provide hydrogen compressors used in public transportation, large fleet vehicles, private trucking companies, trains, boats and other transportation markets. The two companies have worked closely together for more than a year using combined research, development, design, material science, manufacturing, and assembly capabilities to develop compressors needed by high volume, high pressure projects.

Wärtsilä, WEC Energy Group (WEC), the Electric Power Research Institute (EPRI), and Burns & McDonnell (B&McD), plan to test hydrogen fuel blends at the A.J. Mihm power plant in Michigan, USA. The 55 MW plant currently operates with three Wärtsilä 50SG engines running on natural gas. The companies plan to test fuel blends of up to 25% by volume hydrogen mixed with natural gas.

SIAD Macchine Impianti opened an hydrogen compressor test facility at its Osio plant, near the company's headquarters in Bergamo, Italy. A dedicated compressor for oil-free hydrogen compression applications was announced serve the further development of sealing technologies and solutions for hydrogen refueling stations for heavy vehicles. **CT2**

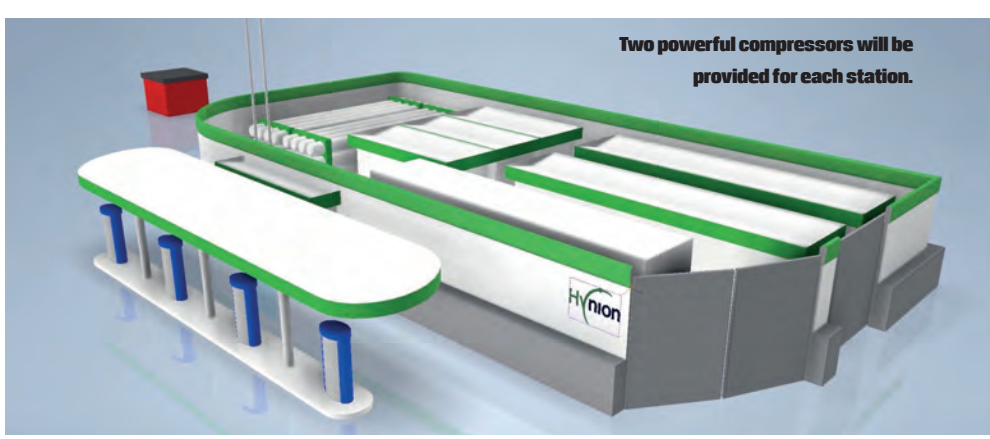


IMAGE: HYNION

**Two powerful compressors will be provided for each station.**

# WPI's focus helps customers to meet ESG goals

## Range of services stretches into every major U.S. operating basin

Know your customers and what they value is a common refrain in almost any business. Waukesha Pearce Industries has applied that adage to its oil and gas customers who remain increasingly focused on ESG goals.

"We are aligning ourselves with suppliers that are as conscious about ESG as we are," said Steve Iwersen, director of sales & marketing at WPI. "We are also talking to our customers about how we can help them meet their ESG goals and how we can make ourselves more ESG friendly."

The company has been servicing engines used in gas compression, drilling rigs and power generation since 1924 and has noticed an ongoing interest among oil and gas operators about how best to improve ESG records.

### Compressor electronics

Some factors have held constant in the engine compression business. One, for example, is the ongoing interest in the evolution of compressor electronics. Oil and gas operators have wanted the latest in electronic technology on their assets. That interest has transferred to electronic gauges that enable remote monitoring of assets.

"That technology allows them to manage equipment from an I-phone or a desktop computer," he said.

The remote monitoring technology also enables predictive maintenance, which allows service companies like WPI to dispatch manpower with the right repair equipment to the location before a failure occurs.

The company is a Waukesha distributor, but is brand agnostic and can work on Caterpillar engines as well. Servicing engines is an essential component of an ESG strategy because it allows a company to rebuild rather than simply buy a new unit. "We save a lot of weight, a lot of iron, aluminum and steel that would otherwise have to be replaced," he said.

An existing engine that has a field life of as much as 20 years can be rebuilt and serve for another five years before it is serviced again.

A full rebuild for a 1400 hp engine that runs at 1200 to 1400 rpm can take four to five weeks to disassemble, clean, inspect, rebuild and then reassemble. WPI puts the unit on a dynometer and tests it under load for several hours to detect any potential issues before it is shipped back to the field.

Operators who do not have compression redundancy on site can temporarily lease replacement units from WPI while their own packages are under service. WPI has the largest fleet of exchange engines in the U.S. and can replace any engine while it rebuilds an existing one.

> **"We are aligning ourselves with suppliers who are as conscious about ESG as we are."**
>
> **STEVE IWERSEN, director of sales & marketing.**

WPI offers emissions testing services.

### In-frame overhauls

In addition to a full rebuild, the company can do in-frame overhauls in the field for any unit that does not need a crankshaft removal or any machine work on the engine block. That service takes about four days from start to finish, Iwersen said.

In addition to in-the-field and in-house rebuilds, WPI can help customers meet ESG goals with emissions testing services. The company has several customers who have asked them to do emissions testing. It sends certified technicians with mobile testing units the size of a suitcase that enable them to measure carbon monoxide, oxygen and NOx


**WPI has six major overhaul centers in North America, including a facility in Houston, TX.**

emissions from units operating in the field.

The field service requires a technician to go out to the unit, place a hose down the stack to monitor the emissions for about an hour. WPI technicians can help a customer troubleshoot an issue if it finds any anomalies in the emissions. If, for example, there is a high amount of oxygen in an exhaust stream, WPI can troubleshoot the combustion process, he said.

The company can also repower an engine, a process that boosts horsepower of some existing engines and eliminates the need to replace them in some cases. For a Waukesha VHP 5794 engine, for example, WPI can expand the bore of the cylinder and boost horsepower for the unit.

## Six overhaul centers

WPI has six major overhaul centers in North America: Houston; Oklahoma City, Bloomfield, NM; Odessa, Texas; Broussard, LA; Bentleyville, PA and two in Canada. IT also has a larger number of distribution centers that can get replacement parts to customers operating in virtually every major basin.

"Our footprint is huge. We try to have a facility in every major operating shale plays," Iwersen said.

The company has more than 800 employees, about 50% of which are focused on services for oil and gas customers. It is also a distributor for Generac for industrial units in Texas. The company also supports both standby and prime power for Waukesha generation units.

"We can put a Waukesha engine on location to power a gas plant if need be," he said.

As a privately held company with a forward-looking supply chain group, WPI has not experienced any significant supply chain issues that has affected multiple industries over the last two years. It keeps the largest inventory of Waukesha parts in the world and has the largest inventory of Ariel spare parts in the U.S., which has also helped.

"We've been pretty fortunate," Iwersen said. CT2

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# IEA sees gas shortfall ahead of 2023-2024 winter

## Renewed demand from China, limited growth in supplies could limit imports into Europe. By **Keefe Borden**

Europe could have a shortfall of as much as 30 billion cubic meters of natural gas next summer, the key period for refilling its gas storage sites ahead of the 2023 – 2024 winter, a recent study has shown.

The study "Never too early to prepare for next winter: Europe's gas balance for 2023 – 2024," was written by the International Energy Agency and stresses the need for urgent action by policy makers to reduce consumption amid the global energy crisis.

The report was released as gas storage in the European Union is now 95% full, and about 5% above the five-year average for this time of year. The IEA stressed against complacency despite the optimistic cushion provided by current inventories, modestly lower prices (of late) and mild temperatures.

Several key factors helped efforts to fill gas storage sites ahead of the upcoming winter. But those factors may not be repeated in 2023. Those factors include Russian pipeline gas deliveries that were relatively close to "normal" levels for a large part of the first half of this year.

### Pipeline supplies

Total pipeline supplies from Russia to the European Union in 2022 is likely to be around 60 bcm and it is unlikely that Russia will delivery that much pipeline gas in 2023. In fact, pipeline deliveries of natural gas could halt entirely next year, the IEA warned.

For all of 2022, the IEA expects Russia's gas exports to fall by more than 55%, a drop of 80 bcm, which has put "unprecedented pressure" on European and global gas markets.

In addition, China imported less LNG in the first 10 months of the year than it usually did, which in turn has enabled additional LNG for Europe to compensate for the decline in gas deliveries from Russia. If China's LNG imports recover to the levels seen in 2021, it would take more than 85% of the expected increase in global LNG supply, the IEA has said.

Additionally, the IEA expects global LNG supply to increase by only 20 bcm in 2023, with about on-third of that coming from the U.S. That expected additional supply next year is about half of the average increase in the four-year period starting in 2016 and significantly less than the expected decline in Russian pipeline deliveries to the EU next year.

If Russia halts entirely its pipeline gas exports to the EU and Chinese demand for LNG recovers to 2021 levels, the IEA said it expects Europe could fall short of about 30 bcm from what it traditionally requires.

That shortfall will likely come in the summer of 2023, when the region traditionally stocks up supplies for th coming winter.

### Danger of complacency

That gap of 30 bcm represents almost half the supplies needed to refill European storage to the current levels by the start of the 2023 – 2024 heating season, the IEA said.

"With the recent mild weather and lower gas prices, there is a danger of complacency creeping into the conversation around Europe's gas supplies, but we are by no means out of the woods yet," said IEA Executive Director Fatih Birol. "When we look at the latest trends and likely developments in global and European gas markets, we see that Europe is set to face an even sterner challenge next winter."

Government need to immediately accelerate improvements in energy efficiency and accelerate the deployment of renewables and heat pumps. That, and take additional steps to reduce gas demand.

"This is essential for Europe's energy security, the wellbeing of its citizens and industries, and its clean energy transition," Birol said.

In March, the IEA released a 10-point plan to reduce Europe's reliance on Russia's natural gas and plans to present a similar plant to secure Europe's gas balance for next winter. **CT2**

**"Europe is set to face an even sterner challenge next winter."**

**FATIH BIROL, IEA Executive Director.**

**IEA analysts have forecast a significant natural gas shortfall in Europe for the coming summer.** IMAGE: ADOBE

# Laser welding for Turbomachinery rotor restoration

By **Michael W. Kuper**, PhD., Materials Engineer, Elliott Group and **Michael J. Metzmaier**, Welding Engineer IV, Materials Engineering, Elliott Group

Laser cladding is gaining acceptance for restoration of turbine and compressor shafts, which has resulted in increased customer demand for laser cladding options, and an increased number of laser welding suppliers who are offering a variety of solutions. Therefore, it is important to understand the basic capabilities, limitations, and potential pitfalls of the laser cladding process, and how the process should be qualified to ensure that laser weld repairs meet requirements for the given application.

As with any welding process, the desired outcome is a metallurgically sound deposit that meets or exceeds the minimum application design criteria. Filler material alloy selection, form, and delivery methods can have a significant impact on the quality and suitability of the weld deposit.

One of the most critical components of turbomachinery equipment is the rotor. These precision assemblies rotate at extremely high speeds and must withstand significant stresses for extensive service times. To achieve this level of reliability, manufacturers must ensure that the components are suitable for the application. Tight controls on composition, mechanical properties, and processing ensure that the parts are acceptable. These inspections, verifications, and safeguards maximize the usable service life while minimizing the risk of catastrophic failure.

However, wear and tear from normal operation will eventually cause sufficient damage that requires repair or replacement. Accumulated damage is generally superficial, and repair offers a cost and time advantage, as compared to replacing the entire rotor, while adding minimal risk related to the repair process. Typical repair processes include spray coating, plating, arc welding, plasma welding, and laser welding. Each of these processes has advantages and disadvantages, depending on a variety of factors, including the location and extent of damage, operating conditions, service environment, the substrate and desired repair material, and customer acceptance. This article focuses specifically on laser welding repairs and how the laser welding process can be beneficial for compressor and turbine shaft repairs, including considerations to be addressed. The discussion includes the most commonly repaired shaft areas, the risks associated with laser welding in these locations, and the types of tests that should be required to qualify the procedure.

## Laser beam welding

Before the advent of laser beam welding (LBW), the most common process for shaft repair was submerged arc welding (SAW), mainly because the process is robust and offers a high deposition rate. However, this process involves high heat input, which can cause distortion of the shaft and high residual stress. Because of distortion, SAW repairs tend to require removal of all protruding features from the repair area, rebuilding of those features, and extensive overlaying to ensure sufficient machining stock to restore dimensions. Also, because of the high residual stress from welding, repairs always require a post weld heat treatment (PWHT) before final machining, which relieves residual stresses that minimize shaft

THE AUTHORS

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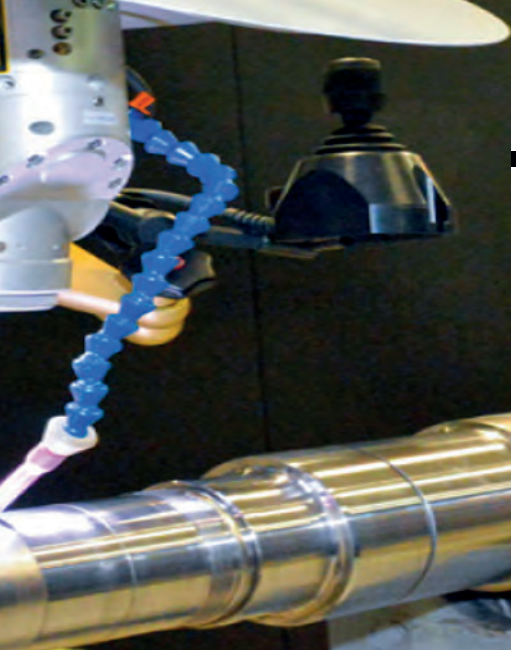

FIGURE 1 Laser welding setup.

movement (distortion) during the machining operation.

Access to a focused laser allows for welding (including cladding), cutting, and heat treatment. Although LBW has existed since the 1970s, improvements in technology and affordability have expanded its range of industrial applications which now include turbomachinery rotor restoration. The main advantage of LBW is that it is a high energy density process, and is therefore capable of welding with very low heat input, which minimizes base metal degradation, the size of the heat affected zone (HAZ), residual stress, and distortion, while also enabling very fast welding speeds. Meanwhile, the smaller HAZ is also beneficial in that less of the shaft volume has the potential for detrimental properties caused by the heat from the fusion process. This is particularly important in the case of heat treatable alloys such as quenched and tempered steels, which are commonly used for turbomachinery rotors. An example laser welding setup is shown in Figure 1.

In addition to low heat input, the LBW process produces high quality fusion welds with a metallurgical bond (no delamination, which can occur in coatings based on adhesion), is easily automated for consistency and repeatability, and has high geometric precision. For example, the spot size of the laser used for this study can range from 0.2 mm in diameter for small welds, to 2.0 mm in diameter for higher deposition rate overlays. To capitalize on the advantages of the LBW process, the process capabilities must be matched with the application, and additional considerations, outlined below, must be explored before implementing LBW for rotor restoration.

## Filler metal delivery

There are two distinct laser welding processes. One uses powder-based filler metal (LBW-P), and one that uses wire-based filler metal (LBW-W). In LBW-P, powder is delivered from a powder feeder through tubing and one or more nozzles by a jet of inert gas, which delivers the powder into the weld pool. In LBW-W, the filler metal is delivered by feeding the wire into the weld pool, either by hand or by a mechanized wire feeder. These two methods have metallurgical as well as logistical differences that must be considered when determining the most appropriate process for a given repair. This is especially true considering that these differences are not yet accounted for in ASME BPVC.

Variables for welding procedure specifications (WPS) for laser beam welding are covered by ASME BPVC Section IX Table QW-264 and QW-264.1. Among the essential variables are specifics related to the powder filler metals, including powder metal size, density, and feed rate. However, there is no mention of filler wire parameters. This indicates that the current code only considers powder-based laser welding applications. It follows that procedure qualification would then also only be relevant for powder based laser welding. This is one reason why additional procedure qualification

**"Access to a focused laser allows for welding, cutting and heat treatment."**

requirements may be necessary for laser beam welding.

## The laser source

A variety of laser sources can be used for laser welding. This article focuses on two of the most common laser sources for welding on Nd:YAG lasers and fiber lasers. Nd:YAG lasers consist of a neodymium doped yttrium aluminum garnet crystal that is excited by a xenon flashlamp to produce the laser beam, while fiber lasers consist of an array of diodes that excite an optical fiber doped with rare earth elements to produce the laser beam. While either of these laser sources can be used for rotor restoration, each of them offers tradeoffs, including beam quality, beam size, beam frequency, lifespan, cost, and efficiency.

Choosing the best laser depends on the application. When ASME BPVC compliance is a concern, however, the fiber laser is the better choice. The reason for this is the difference in the way that the laser beam is generated, and its stability over time. Within the Nd:YAG laser, the xenon flashlamp bulb degrades over time and becomes dimmer as it ages. The dimmer bulb results in lesser excitation of the Nd:YAG crystal, which decreases the intensity of the laser beam produced. The effect is that the power output for a given laser setting decreases throughout the lifetime of the flashlamp, though the rate of degradation will likely be unknown. This is problematic for compliance, since according to ASME BPVC Section IX Table QW-264, laser power is a critical variable that may not be changed for a given weld procedure. Maintaining this requirement would be nearly impossible for an Nd:YAG laser, although this fact is not mentioned in the code. In contrast to Nd:YAG sources, fiber laser sources do not have this problem, since excitation is performed by diodes. Therefore, fiber lasers are vastly superior, and arguably necessary, in situations that require code compliance.


**FIGURE 3 Typical defects that occur in laser welding. These defects were found in a weld made using powder based filler metal delivery. Porosity can be seen speckling each image.**

## Continuous or pulsed laser

Some laser systems now have the ability to operate in both a pulsed mode and a continuous operating mode. The advantage of using a pulsed laser is that the heat input can be reduced to minimize the size of the HAZ, the amount of residual stress, and the amount of distortion. Aside from the general advantages, pulsing is also useful in specific instances, such as welding on a finish-machined part, where a PWHT is not possible. This is because pulsed power has a lower heat input than continuous power. Pulsed laser operation, however, is mostly limited to LBW-W, as LBW-P systems operate most effectively using continuous power. This is because in powder-based applications, the powder is delivered continuously, which would result in a large amount of wasted powder or lack of fusion caused by insufficient heat between pulses. For wire-based systems, the wire feeder is precisely controlled by the equipment to maintain stable welding conditions. It is worth noting that weld mode as a standalone variable can also have an effect on the deposition rates of the welding process, but this is largely dependent on the type of system, as well as the conditions of the repair. Overall, the weld mode should be chosen based on the type of filler metal delivery, but also based on the type of repair and desired weld properties.

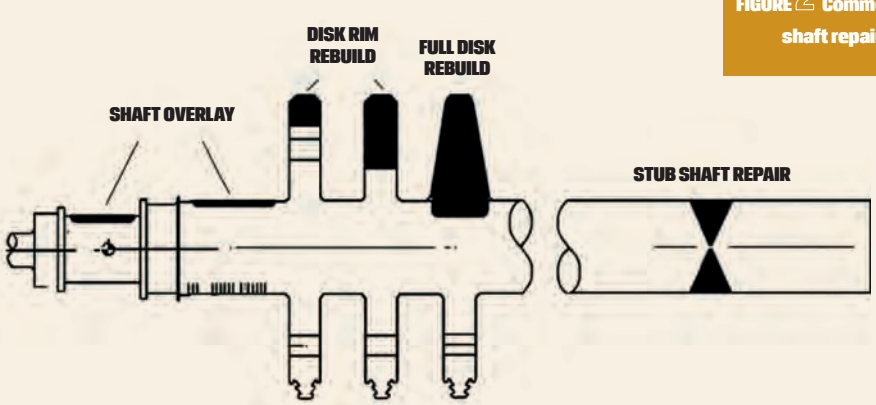


**FIGURE 2 Common shaft repairs.**

## Joint design

To minimize the potential for defects, the joint design must be suitable for the type of welding system used. Wire-based welding systems are typically more tolerant of sharp corners and deep grooves than powder systems. This is due to the fact that wire systems do not require a gas transport system to deliver the filler material to the weld zone. In powder-based welding systems, turbulence in the carrier gas used to deliver powder to the melt pool caused by the substrate geometry, such as a v-groove, can lead to poor powder delivery rates and poor shielding. Poor powder delivery rates result in low welding efficiency and excess heat reaching the substrate, while poor


FIGURE 4 Post weld heat treatment setup.

shielding can result in porosity and the formation of oxide inclusions. Additionally, for LBW-P, excess unfused powder can accumulate in the joint as well. Welding over this loose powder can cause significant defects, including lack of fusion, porosity, or cracking. As a result, powder based filler metal delivery in a groove requires a wider groove angle, which creates more access to the weld joint, but also increases the volume of the groove. Therefore, the volume of the v-groove necessary for extracting test specimens when using LBW-P is very large compared with the typical size of a laser weld bead, making the manufacture of test specimens for procedure qualification impractical.

In the case of wire-based filler metal delivery, the angled wall of the groove creates geometric challenges for shielding gas and wire delivery, which increases the likelihood of porosity and increases the susceptibility for lack of fusion defects. However, groove welding is possible with LBW. Additionally, for most shaft repairs where LBW is applicable, the repairs tend to be weld overlays, which do not require groove welding. Figure 2 shows common shaft repair types including overlays, buildups, and stub repair. Although stub repair would require groove welding, it would not generally be performed using LBW, since other processes have a higher deposition rate. Regarding filler material type, LBW-P and LBW-W will be acceptable for general shaft repairs, though caution should be taken when welds will be close to steps or features that could cause turbulence with a powder process. However, weld procedure qualification requirements may be impossible or impractical for LBW-P, and LBW-P may also struggle where porosity is unacceptable.

## Filler metal cost and availability

The ability to choose a filler metal is dependent on the availability of the material in question. Generally, both wire and powder versions are available for a variety of materials. However, wire-based materials tend to be limited to commonly welded alloys, while powder materials tend to be geared toward higher alloy steels and specialty alloys. This is because one of the key drivers for powder production is powder-based additive manufacturing, which has the highest cost-benefit ratio for the more exotic materials. Because of this, it is difficult to find carbon and low-alloy steel in powder form, since these materials are cheap enough that the use of powder form is not cost effective for most industrial applications. Since carbon and low alloy steels are used heavily in the turbomachinery industry, wire-based laser welding systems tend to be a better option due to better availability of these materials. Additionally, filler metal in wire form is also generally less expensive than powder form.

## Defects

From an applications standpoint, one major difference between powder-based and wire-based laser welding is the type of defects and the likelihood of forming defects during welding. LBW-W is capable of producing fully dense, defect-free welds, while LBW-P usually has a small amount of porosity at a minimum. Regardless, suboptimal welding parameters, joint geometry, or conditions can generate defects for either process. Typical defects that occur in laser welding include the following, with examples shown in Figure 3, which shows defects in an LBW-P overlay.

- Porosity
- Lack of fusion
- Unfused particles
- Cracking

Porosity is characterized by voids that occur within the weld deposit, created by escaping gases that become trapped during solidification. For LBW, there are several methods by which gasses can be introduced into the weld pool, but the main theories include trapping shielding gas or metal vapors, cavitation caused by unstable keyhole welding, and gasses that were entrapped in the powder particles during the atomization process and released during welding. In addition, porosity can occur from poor shielding gas coverage during welding, which is usually caused by an improperly aligned gas lens or turbulence near the weld pool. This may occur because of the turbulence created by rapid oxidation of the solidifying weld pool, or from gasses created from burning the oxygen found in air. Lastly, lack of base metal and filler material cleanliness can also contribute to porosity. Welding over organic matter (oil, grease, dirt, oxides, etc.) causes outgassing during welding that becomes trapped in the weld pool as it solidifies.

Lack of fusion is characterized by locations where the filler metal did not fuse with the base metal. This occurs when the heat source generates insufficient heat to coalesce the filler and base metals. The typical causes for this include poor welding angle, excessive filler material feed rate, and/or inadequate laser power. Similar to lack of fusion, unfused particles are characterized by remnants of unmelted powder being present in the weld. This type of defect is exclusive to LBW-P because it involves powder while LBW-W does not. The cause of unfused particles is similar to lack of fusion, where there is insufficient heat to fully melt and fuse the filler material with the base material. This generally occurs because the laser did not have the time, power, and/

or correct positioning to melt all of the filler metal in the weld area.

Cracking is characterized by weld metal fracture because of stress. Cracking can be caused by a multitude of factors, though common examples include highly restrained joint design, rapid cooling rates, filler metal susceptibility, contamination, weld bead profile, and/or incorrect welding parameters.

## Laser beam welding for rotor restoration

### Powder vs wire filler metal delivery

For shaft repairs, LBW-W is generally more applicable than LBW-P. The first reason for this is that LBW-W has a lower probability of forming defects, namely porosity, which may result in rejectable surface indications after final machining. Second, the ability to use a pulsed laser source in LBW-W reduces heat input, which helps minimize distortion, residual stress, and the size of the HAZ [8]. Third, wire filler metal is cheaper and more readily available than powder in general, and it may be the only option available for the carbon and low alloy steels commonly used as turbomachinery shaft materials.

### The post weld heat treatment

For rotor repair using conventional arc welding, a PWHT is generally required. First, residual stress from arc welding is large enough to cause shaft movement after final machining, particularly during the heat stability test that is required for turbine rotors. The PWHT relieves residual stress to minimize shaft movement during machining. Also, because rotors are typically quenched and tempered martensitic steels, welding creates hard and brittle untempered martensite in the weld deposit and HAZ. Untempered martensite reduces impact toughness, potentially below the base material requirements, especially for low-temperature service. The PWHT tempers the fresh martensite that formed during welding, which restores the impact toughness of the shaft. Unfortunately, the PWHT can also over-temper the base material, which may result in a loss of strength in some cases.

Post weld heat treatment is also a costly and time-consuming operation. Figure 4 shows the setup for a PWHT applied to a rotor. For this process, the shaft must be suspended vertically to minimize distortion. In other words, if the rotor were heat treated horizontally, the rotor would bow and sag between supports that would become permanent after the heat treatment. After suspending the shaft vertically, heating blankets and thermocouples are added which must provide intense, yet precise heat (generally over 1000 °F), and this heat must be evenly distributed. If heat is added non-uniformly, then stress will be relieved non-uniformly, which could result in detrimental distortion. Heating/cooling rates and hold times must be controlled and monitored carefully. Overall, the process is relatively complex, time-consuming, and costly.

Often, laser weld applicators make the assertion that a PWHT is not required with their process because the weld deposit and HAZ created by laser welding are small enough that their presence has a negligible effect on the overall shaft properties. However, little academic research has been performed on mechanical properties of laser weld repairs in turbomachinery applications. While the weld deposit and HAZ may be small, it is dangerous to assume that they will not affect the shaft's fitness for service, particularly when the shaft material is quenched and tempered steel, which is the most commonly used shaft material. In order to avoid the PWHT, precautions must be made to ensure that the repair will meet the required properties without the PWHT. These precautions include the testing recommended later in this article, as well as considering compatibility with the erosion and corrosion requirements of the operating environment.

| HARD FACING OVERLAYS | CORROSION RESISTANT OVERLAYS | GROOVE WELDS |
|---|---|---|
| ■ Liquid penetrant testing | ■ Liquid penetrant testing | ■ 2 tensile tests |
| ■ 3 hardness readings per specimen | ■ Four transverse side bend tests (or two transverse and two longitudinal bend tests) | ■ 4 transverse side bends |
| ■ Macro test | | |

**TABLE 1 Procedure qualification test requirements for overlays and groove welding per ASME BPVC Section IX.**

### Current qualification requirements

As mentioned above, current ASME BPVC does not distinguish between LBW-P and LBW-W, nor does it account for the inevitable change over time in output power for Nd:YAG lasers. This will need to be remedied in the future to account for the differences in the typical applications for and qualification of these processes. Regarding procedure qualification, groove welds would be qualified to ASME BPVC Section IX Table QW-451.1. However, for rotor restoration, LBW repairs are typically performed on superficial damage, and would therefore be considered weld overlays. The procedure qualification requirements for overlays from ASME BPVC Section IX Table QW-453 can be found in Table 1 below along with the requirements for groove welds.

Although hardness readings are required for hard facing overlays, ASME does not list acceptance criteria. Therefore, hardness limits should be applied based on the application and service environment conditions on a case-by-case basis.

As mentioned before, most rotor repairs qualify as weld overlays, but in addition to the above requirements, further testing may be necessary for laser beam welding in some

**"Laser cladding is gaining acceptance for restoration of turbine and compressor shafts."**

instances. In general, the critical design factors for shafts should also be considered, which are dependent on which portion of the shaft requires repair.

## Critical properties based on weld repair location

The most common locations for damage on a shaft undergoing restoration include the coupling fits, journals, probe areas, seal areas, and the main body. Because of the nature of the repair process (fusion of the weld deposit and the formation of the HAZ), it is understood that the properties of the repaired areas will not match the properties of the original shaft material. Additionally, each part of a shaft has its own set of design criteria. Therefore, it is important to ensure that the restored areas meet the minimum design requirements at each repair location. With that in mind, below is a discussion of the critical properties that should be considered for each region of the shaft. A summary of this information is found in Table 2.

### Shaft main body

Main shaft body repairs are usually located in the lowest stress areas, where matching the shaft material composition and properties is generally unnecessary. In these locations, the intent of the repair is to restore dimensions without creating distortion elsewhere. Because the main body of the shaft is in contact with the process gas, weld repairs made on equipment used for hydrogen service (over 100 psig partial pressure of hydrogen) must be constrained to a maximum yield strength of 120 ksi and a hardness of 34 Rockwell C to meet the requirements of API 617. Accordingly, further analysis is required to determine if and how LBW may be applied for rotor repair that will operate in hydrogen service.

### Journals, seals, and probe areas

Journals, seals, and probe areas are generally smaller in diameter compared to the main body of the shaft, so stresses in these locations are moderately high and should be accounted for when selecting a repair method. Tensile strength and toughness should be part of repair evaluation in these areas. Journal areas must also be capable of meeting surface roughness requirements after final machining and grinding (typically 32 micro-inch or better), meaning porosity could be a concern in these locations. Repairs located in probe areas must have uniform microstructures to prevent erratic electrical runout readings. Probe areas are typically ground and burnished to maximize probe precision and accuracy. The filler material must also act as a target material for the eddy-current probe and changes to probe calibration may need to be considered. Although hardness is not a major concern for journals and probe areas, seal areas will be in contact with the process gas and must meet the maximum strength and hardness requirements mentioned above if the rotor operates in hydrogen service.

### Couplings

The coupling area is usually one of the smallest diameters on the entire shaft, which means it experiences some of the highest stresses. This area may also contain additional stress concentrators such as keyways, grooves, or compression fits. Unless there are other highly stressed integral features on the rotor such as turbine disks, the strength of the entire shaft is selected based on this feature. This portion of the shaft may also experience high alternating stresses, which can be induced by the equipment that drives the rotor, meaning the endurance limit must be considered. Care should be taken when determining the endurance limit since surface treated material may exhibit reduced endurance limits up to 50% as compared to the base material. Therefore, direct testing of the fatigue characteristics is necessary in addition to tensile properties. Fatigue considerations of coupling repair is complex and requires additional considerations and testing that go well beyond ASME BPVC guidelines. Because of the criticality and complexity of coupling repair design and assessment, repairs in this area are not be considered in this article.

Based on the critical properties identified in this section, the testing required by ASME BPVC Section IX alone is inadequate to assess the suitability of the repair for all common repair locations, except for the main body of the shaft. To remedy this discrepancy, it is recommended to perform supplemental tensile testing and impact testing, at a minimum, for all repair qualifications made in the journal, probe, and seal areas. Hardness measurements must also be taken for main body and seal repairs in cases where hydrogen service limits the rotor yield strength. In addition, coupling areas require additional considerations related to fatigue testing that are outside the scope of this article.

Laser welding, when applied correctly, is an effective method for the restoration of turbomachinery shafts. However, the requirements of wire-based and powder-based filler metal delivery in LBW, and recognition of the differences between these two types of laser welding, need to be addressed by Section IX of ASME BPVC to ensure compliance to these practices as an industry standard. **CT2**

*To read the entire article, including details and conclusions of mechanical testing and actual laser welding repairs, visit* ***www.compressortech2.com/longer-reads***

| CRITICAL PROPERTY | COUPLINGS | JOURNALS | PROBE AREAS | SEALS | MAIN BODY |
|---|---|---|---|---|---|
| TENSILE STRENGTH | X | X | X | X | |
| IMPACT TOUGHNESS | X | X | X | X | |
| HARDNESS (FOR HYDROGEN SERVICE) | | | | X | X |
| CAPABILITY OF FINELY FINISHED SURFACES | X | X | X | X | |
| ELECTRICAL RUNOUT | | | X | | |
| HIGH CYCLE FATIGUE | X | | | | |

**TABLE 2 Critical material properties based on the repair location.**

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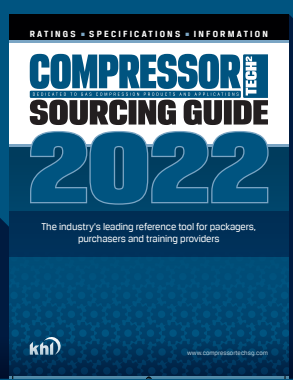


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# Schramm portable compressors

Company produced many firsts in the portable air compressor industry.

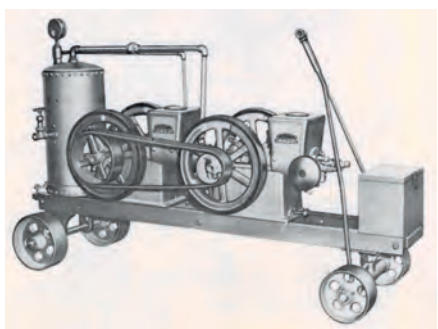
By **Norm Shade**

The Schramm & Maerky Co. was founded on January 2, 1900 on the premise of servicing gas engines. Christian D. Schramm, after immigrating from Germany in 1883, had worked for companies making safes and surgical instruments. Emil Maerky, after immigrating from Switzerland about the same time, had worked for the Scheicher, Schumm & Co of Philadelphia, PA which operated the Otto Gas Engine Works. There, Maerky learned their strong and weak points. In 1901, he developed a make-and-break spark ignition head conversion for Otto slide-valve flame ignition engines. The patented invention increased the power, efficiency and dependability of the Otto engines, and the partnership found a ready market all along the East coast.

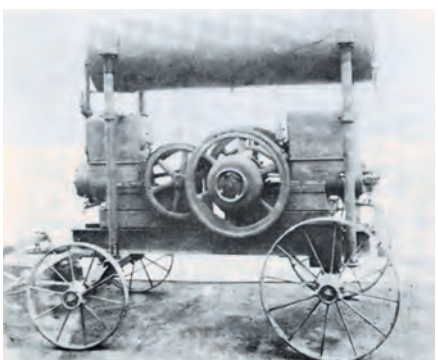
Chris' son, Henry, joined the company in 1901, and in 1902, Schramm bought out Maerky's share of the partnership and moved the growing company into expanded manufacturing space. In 1905, Schramm also started selling gas engines and related equipment, serving as a distributor for engine companies White & Middleton, Middletown (Miami) and Domestic. Growth continued. In 1907, Henry Schramm was made a partner and the company became Chris D. Schramm & Son.

## Portable air compressor

In 1908, an inquiry from a customer set the course on which Schramm would embark for more than six decades. A monument carver wanted an air compressor that he could use both in his shop and in cemeteries to avoid having to remove and haul heavy head stones back to his shop when a date or name had to be changed. Schramm took two 1.5 hp (1.1 kW) Miami engines out of stock and built the first commercial self-contained gasoline engine-driven portable air compressor. Both engines were mounted on a steel cart with a battery box and vertical air tank. One engine was converted to a compressor, driven by a flat belt from the first engine. It produced an unknown air flow at 100 psig (6.7 bar). The invention was an immediate hit, and demand quickly exceeded Middletown's production capacity. Since Schramm also sold Domestic engines and their factory was closer to Philadelphia, Schramm contracted with Domestic to supply all the components in lots of 50. The Schramm Domestic conversions, which were mounted back-to-back and gear driven, produced more air than the earlier Miami units, and production grew, reaching 220 units per year in 1910.



**Schramm built the first commercial gasoline engine-powered portable air compressor, belt-driven by a Miami gasoline engine, 1908.**



**Schramm's second generation portable compressor, which utilized a Domestic gasoline engine and Schramm Domestic compressor mounted back-to-back and gear driven, produced more air than the earlier units.**

With demand for more air capacity, Schramm went to the drawing boards with Domestic and came up with an entirely new design having the four-cycle engine cylinder and air compressor cylinder on the same frame. Three different models produced capacities of 9 to 24 cfm (0.25 to 0.68 $m^3$/min) at 100 psig (6.7 bar). These units remained popular until about 1918.

**An entirely new c. 1911 design had a four-cycle engine cylinder and an air compressor cylinder on the same frame. This Schramm Domestic portable air compressor was popular through 1918.**

## New Pennsylvania facility

World War I production consumed Domestic's capacity, forcing Schramm & Son in 1917 to incorporate and to start manufacturing its own engines and compressors in a new facility in West Chester, PA. Schramm

**Increasing the speed to 500 rpm, Schramm developed a 100 cfm (2.83 m³/min) compressor using two side-by-side air cylinders with a two-throw crankshaft driven by another source. This compressor was mounted on the then very popular Fordson tractor, becoming the first self-propelled portable air compressor, c.1919.**

redesigned the engines to be incorporated into a heavier compressor with more capacity than the Domestic machines. With the speed increased to 500 rpm, capacity grew to 80 cfm (2.26 m³/min). A 100 cfm (2.83 m³/min) compressor was also developed with two side-by-side air cylinders with a two-throw crankshaft driven by another source. This compressor was mounted on the then very popular Fordson tractor, becoming the first self-propelled portable air compressor. Several hundred of these unique machines were sold.

Schramm portable air compressors found their way into more and more applications. In 1926, Schramm built the first portable compressor with vertical engine and compressor cylinders, using four-cylinder Buda engines and two-cylinder Gardner compressors. A Schramm-designed clutch allowed the engine to start with no compressor load, another first. Gardner's compressors were designed to operate at 500 rpm, but Schramm redesigned the valves and ran them at 800 rpm to better match the engines. The resulting unit produced 118 cfm (3.34 m³/min), making it the largest portable compressor at the time.

## Smaller engines

In c.1928, Schramm developed a light-weight two-cylinder compressor that was the first portable that was not simply a stationary compressor speeded up for portable use. It was so successful, that three- and four-cylinder models were soon introduced, producing up to 360 cfm (10.19 m³/min). The largest model became a standard in the industry for many years.

Schramm continued developing compressors that could take advantage of the smaller, higher speed engines that were emerging. Some of these were also applied with electric motors at 1200 rpm for stationary applications.

Schramm portable high-pressure two- and three-stage compresssors re-emerged in the mid-1950s, built around Gardner-Denver W-type frames for air drilling of oil and gas wells.

Over time, other large Schramm models were developed using Buda, Domestic, Hercules, Continental, Wisconsin and Ford engines. All of these used Schramm's mechanically operated compressor intake valves and patented valve unloaders that were first introduced in 1917. Beginning as early as c.1920, Schramm applied its engine-compressors with various trucks, tractors and tracked crawlers to provide self-powered portable air compressors for construction, drilling and other applications. Schramm's success in the portable air compressor industry continued for three more decades after World War II. However, by the 1970s their focus had moved to mobile rotary drilling equipment, which continues today.

**In 1928, Schramm developed a light-weight two-cylinder compressor that was the first portable that was not simply a stationary compressor speeded up for portable use. It was so successful, that three- and four-cylinder models were soon introduced. Shown here are the smallest and largest Schramm portable compressors. The largest model became a standard in the industry for many years, c.1930.**


**In the mid-1930s, Schramm introduced the "Utility" series, which was the first portable compressor that was "styled" to improve its appearance.**

## New intake valve

Schramm was pioneering in the field of portable compressors and many of their improvements were adopted by the entire industry. Some firsts claimed by Schramm include the portable engine-driven compressor (not just a stationary compressor put on wheels), a mechanically operated poppet type compressor intake valve, use of the en-bloc engine-compressor principle, the multi-cylinder compressor driven by a multi-cylinder engine, a clutch between the engine and compressor, a self-propelled portable compressor, a diesel engine-driven portable compressor, standard electric engine starting on portable compressors, and the streamlining (styling) of portable compressors to improve their appearance. **CT2**

**1900**
**Schramm & Maerky Co. was founded on the premise of servicing gas engines.**

**1905**
**Schramm started selling gas engines and related equipment.**

**1907**
**Henry Schramm was made a partner and the company became Chris D. Schramm & Son.**

**1926**
**Built first portable compressor with vertical engine and compressor cylinders.**

**1928**
**Developed a light-weight two-cylinder compressor that was the true first portable.**

**1970s**
**Focus shifted to mobile rotary drilling equipment.**

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# FOR YOUR MOST AMBITIOUS DECARBONIZATION GOALS

As the world embraces the energy transformation, companies struggle with the demands of lowering emissions to meet regulations or corporate ESG goals. COOK CLEAN products can help you forge your path to net zero.

COOK CLEAN packing cases combine proven BTUU uncut ring technology with engineering expertise to deliver a sealing system proven to lower fugitive emissions in reciprocating compressors to near-zero levels.*

If you want a proven system to reduce emissions, make COOK CLEAN part of your decarbonization strategy.

***Learn more at www.cookcompression.com/cookclean**

COOK® COMPRESSION

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*China +86 21 24112600*

***cookcompression.com***

*Cook Compression is a proud part of Dover Precision Components*

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COOPER | MACHINERY SERVICES

# REDUCE METHANE OUTPUT UP TO 40%

# CLEANBURN PLUS™

The reduction of greenhouse gases is a key element of Cooper's emissions reduction technology offerings. To improve the environmental impact of engine-compressors operating within our industry, Cooper introduces CleanBurn Plus™, an emissions reduction solution tailored to reduce not only current regulated emissions constituents such as NOx, CO, and VOC, but also methane in the form of unburned hydrocarbons with additional fuel consumption benefits.

Cooper's CleanBurn Plus™ upgrade package is a comprehensive solution that can reduce methane in the exhaust by up to 40% in most of the industry's engine-compressors. Our CleanBurn Plus™ upgrades are offered across the entire engine-compressor product line to include AJAX®, Cooper-Bessemer®, Clark, Enterprise®, Ingersoll Rand, Superior®, and Worthington. Visit our website to learn more about CleanBurn Plus™ and engines operating with CleanBurn Plus™ elements.

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