

2023 hydrogen report

The US hydrogen market – slow growth in the face of headwinds

By Maura D. Garvey



In January 2021, US annual hydrogen capacity was approximately 3.7 billion cubic feet per year (bcf/yr). Of this, 68% was used in petroleum processing, according to the US Department of Energy (DOE). Capacity was flat over the previous year, while in the rest of the world production declined by 0.3%. About 21% of the hydrogen produced was used in making fertilizer. Most of the hydrogen produced in the United States currently comes from steam methane reforming. There are 1,600 miles of hydrogen pipeline in the US and large hydrogen production facilities in almost every state. New innovations, applications and blue and green sourcing channels continue to emerge, and our view of hydrogen markets continues to evolve as a result.

Let's remind ourselves of the recent history. The Covid-19 pandemic hit the refinery hydrogen business in 2020, with significantly reduced population mobility that reduced demand for petroleum products. In 2022, Russia's invasion of Ukraine drove demand for energy to cover the lost Russian supply, causing skyrocketing Brent and WTI crude prices. In 2023, the average Brent crude price was \$83/barrel (b) compared with \$101/b in 2022 and \$71/b in 2021. This decline in oil prices in 2023 reflects a darkening global economic backdrop and Covid-19 flare-ups in China, threatening demand growth and offsetting the impact of supply shortfalls caused by sanctions on Russia, which have the effect of pushing up prices.

Despite these fluctuating uncertainties, hydrogen is a long-term solid growth platform for the industrial gas industry. In large volumes, industrial gas companies continue to supply hydrogen through their on-site pipeline (OSP) businesses to oil and gas refineries, basic and specialty chemical manufacturers, and

food processors. In smaller volumes, merchant liquid hydrogen is supplied via tube trailer and cylinder and used in a wide range of applications including metallurgy, electronics, aerospace, food hydrogenation, glass, electrical power generation, and fuel cells, which is experiencing the fastest growth. Hydrogen fuel cells are slowly gaining momentum as cost and performance have improved. In this report, we bring you up to date on the OSP business and the merchant hydrogen business, where liquid hydrogen for stationary and mobile fuel cell technology is growing.

On-site supply

Most hydrogen is supplied via pipeline to large users. There are over 1,600 miles of US pipelines for hydrogen delivery currently available from the major industrial gas companies. These pipelines are located near large petroleum refineries and chemical plants in the Gulf Coast, California, and Illinois. In the US, OSP represents 85% of hydrogen supply. Steam methane reforming (SMR) of natural gas is the technology of choice for on-site hydrogen production and is currently the least expensive way to produce hydrogen. This process is used by most large users, like refineries, fossil fuel processors, and ammonia producers, and it is used by the major gas companies to fill demand for OSP hydrogen. Steam reforming of natural gas is an efficient, economical, and widely used process for hydrogen production, and provides near- and mid-term energy security and environmental benefits.

The oil refining industry leads hydrogen production in the US, especially in the Gulf Coast, where half the US refineries operate. The major hydrogen-producing states are Texas, Louisiana, and California. About 90% of hydrogen is sold to oil refining

“There are over 1,600 miles of US pipelines for hydrogen delivery currently available from the major industrial gas companies”

through sale of gas deals by industrial gas companies. Hydrogen demand has increased substantially over time because environmental regulations require the removal of sulfur from motor vehicle fuels and the processing/hydrocracking of heavier crudes. At the same time, the evolution of the shale gas industry, especially in the past decade, has slowed the demand for oil and therefore the need for hydrogen to process heavier crudes.

Air Products, Linde Plc, and Air Liquide are all major producers of on-site/pipeline and merchant hydrogen in the North American market and together operate over 100 plants. Air Liquide, Air Products, and Linde Plc all operate hydrogen pipelines in Texas, Louisiana, California, and Indiana to supply hydrogen to customers. All consider hydrogen a worldwide strategic growth platform. Matheson, through its recent acquisition of Linde's divested HyCO (Hydrogen and carbon monoxide) business, becomes the new fourth player in the US hydrogen on-site/pipeline business.

Natural gas is the main methane source for hydrogen production by industrial facilities and petroleum refineries. Landfill gas/biogas is also a source of hydrogen for several fuel cell power plants in the US. Biofuels and petroleum fuels are also potential methane sources.

SMR splits natural gas into hydrogen and carbon dioxide (CO₂). ▶

- ▶ But the CO₂ byproduct makes this a carbon-intensive process and is why hydrogen produced this way is called “gray” hydrogen as it is the least environmentally friendly of the three types.

Air Products announced in 2021 it will build, own, and operate a first-of-its-kind megaproject, which will produce over 750 mmcf/d of “blue” hydrogen in Ascension Parish, Louisiana. Blue products are produced utilizing hydrocarbons as a feedstock, with the CO₂ in the production process captured for permanent sequestration. At \$4.5bn, it represents Air Products’ largest-ever investment in the US. The megaproject is expected to be operational in 2026.

As its name suggests, the cleanest type of hydrogen is “green” hydrogen. It is produced by splitting water (H₂O) into hydrogen and oxygen via a process of electrolysis powered by renewable energy. This means that no CO₂ is created during production.

The Inflation Reduction Act of 2022 (IRA) includes clean energy tax credits and other provisions that should increase domestic renewable energy production. The IRA’s clean energy incentives include many provisions for clean hydrogen and fuel cell technologies, either extending many existing federal tax credits, increasing existing federal tax credits, or creating new federal tax credits.

Refinery hydrogen

Hydrogen plays a vital role in a whole host of refining operations, from hydrocracking, which is the reduction of heavy gas and gas oils to lower molecular weight components, to the treatment of gas streams and to catalytic reforming. In the latter, the gas is also used to prevent carbon from reacting with the catalyst to maintain the production of lighter hydrocarbons and extend the life of the catalyst.

“The oil refining industry leads hydrogen production in the US, especially in the Gulf Coast”

According to data reported by Oil and Gas Journal, between January 2021 and January 2022, worldwide crude oil refining capacity increased from 91.1 million barrels per calendar day (MMb/cd) to 93.2 MMb/cd, for an increase in the average annual growth rate (AGR) of 2.2%. A decline of 0.9% was experienced for the US while the rest of the world increased by 3.0% per year. The average annual growth over the past five years worldwide increased by 0.4% while the US growth for the same period declined by 1.2% per year. The US comprises 18.7% of global crude oil refining capacity. As of January 2022, the US had 130 of the world’s nearly 700 operating refineries.

The US Energy Information Administration (EIA) May 2023 Short-Term Energy Outlook (STEO) flags heightened levels of uncertainty resulting from factors including Russia’s full-scale invasion of Ukraine. The STEO bases US macroeconomic forecasts on S&P Global’s macroeconomic model. This STEO estimates that US real GDP will average 1.6% growth throughout 2023 and 1.8% in 2024.

The Brent crude oil spot price fell from an average of \$85 per barrel (b) in April to close at \$73/b on May 4. At the beginning of April, OPEC and partner countries (OPEC+) announced a cut to crude oil production of 1.2 million barrels per day (b/d) through the end of 2023, which increased crude oil prices on expectations of tightening oil supplies. However, weakening global economic conditions, perceived

risk around the global banking sector, and persistent inflation outweighed the initial increase in oil prices and have led to lower prices. (Note: Organization of the Petroleum Exporting Countries, also known as OPEC, was formed in 1960 and has grown to 16 members. In 2016, largely in response to dramatically falling oil prices driven by significant increases in US shale oil output, OPEC signed an agreement with 10 other oil-producing countries to create what is now known as OPEC+. Among these ten countries was the world’s third-largest oil producer in 2022, Russia.)

The US produced 11.88 million barrels per day (bpd) of crude oil in 2022, compared with an average of 11.25 million bpd in 2021, according to data from the US EIA. The yearly record to date is 2019, when annual production reached 12.3 million bpd. If not for the Covid-19 pandemic, 2020 would probably have been higher as the monthly numbers reached 12.9 million bpd just before the pandemic impacted production. But by May 2020, oil production had plunged to 9.7 million bpd, and then began a slow recovery. That dragged the 2020 average down to 11.3 million bpd.

According to the Baker Hughes Rig Count data, at the end of 2022 there were 620 rigs drilling for oil. That was an increase of 140 rigs, or 29%, from the end of 2021, and nearly back to the 680-rig level in the months preceding the start of the 2020 Covid pandemic. However, that is still significantly lower than the levels of 2014, when the rig count briefly exceeded 1,600.

Hydrogen plants are located next to or near (piped) oil refineries to produce hydrogen for use in the production of cleaner burning fuels. According to the Oil and Gas Journal, between January 2022 and January 2023, US hydrogen capacity ▶

GAS INNOVATIONS®

Gas Innovations can meet your hydrogen needs with a large fleet of high pressure tube trailers and modules.

- Hydrogen up to 99.999%+
- Short and long term leases available
- Manifold and regulation equipment to provide turnkey solution
- Scalability to fit the size of your project



Contact: 281-471-2200 OR
Sales@gasinnovations.com



CRYOGENIC
INDUSTRIAL SOLUTIONS

ESTABLISHED ON RELIABILITY, DURABILITY & INNOVATION

TRAILER REPAIR (FORT COLLINS, CO)

- Cryogenic & CO2 Trailers
- Cryogenic & CO2 Bulk Trailers

CIS LEASING

- Cryogenic & CO2 Trailers
- Cryogenic & CO2 Bulk Trailers
- Cryogenic Portable Units
- Cryogenic Mobile Storage

FIELD SERVICE

- Field Services bring industry-leading product knowledge, ingenuity, and workmanship directly to you.
- Crews Based in Texas, Colorado, Virginia, Florida, and Arizona

INTEGRITY GAS SERVICES

- Nitrogen Services & Equipment
 - Transports Storage & Pumps
- Nitrogen Pumping
 - Low, Mid, and High Rate

NITROCRETE

- Automated Concrete Cooling
 - Delivers Liquid Nitrogen as a Service.

FORT COLLINS, COLORADO
CRYOINDSOLUTIONS.COM | 281-744-7374

OUR CONTRIBUTION TO THE ENERGY TRANSITION

processes' heartbeat
www.mehrer.de

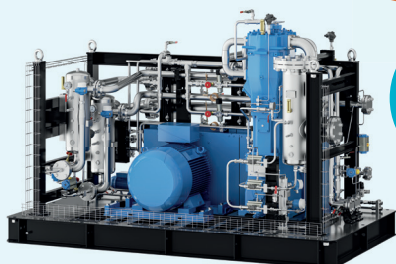


CO₂



Oil-free

H₂



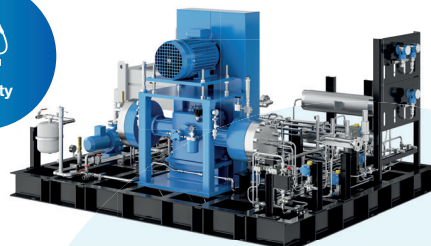
Recovery &
liquefaction



Power-to-
liquid



Mobility



OUR CARBON DIOXIDE COMPRESSORS:

- Discharge pressure up to 25 bar
- Mass flows up to 3000 kg/h
- Motor capacity up to 375 kW

OUR HYDROGEN COMPRESSORS:

- Discharge pressure up to 1000 bar
- Mass flows up to 45 kg/h
- Motor capacity up to 160 kW

► was flat at 3.7 Bcf/d compared to a peak production in 2015 of 4.3 Bcf/d, as shown in figure 1. In March, ExxonMobil announced the beginning of operations at the expansion of its Beaumont refinery, adding 250,000 b/d of capacity. The Beaumont expansion is the first major refinery capacity expansion to come online since the Covid-19 pandemic, which prompted several refinery capacity closures over the course of 2020 and 2021.

Beaumont's added capacity is the largest of a cluster of new capacity expected to come online in 2023 and 2024, much of it concentrated on the US Gulf Coast. The region has historically been the largest refining

hub in the US and accounts for eight of the ten largest refineries in the country. New refinery capacity in the region capitalizes on growing US crude oil production. The region also benefits from existing infrastructure for shipping refined products to the East Coast, to Mexico, and to other destinations using coastal tanker loading facilities.

Merchant hydrogen

Merchant hydrogen is defined as hydrogen that is generated on site or in a central production facility and sold to a consumer by pipeline, bulk tank, or cylinder truck delivery. The merchant hydrogen business supplies

a broad range of markets with small to medium hydrogen requirements via bulk liquid, tube trailer, and cylinders. These markets include electronics, float glass, hydrogenation of fat and oils for food, chemical and petrochemical, cosmetics, pharmaceuticals, metals and heat treating, alternative energy (fueling stations and fuel cells), and research markets. The chemicals industry uses hydrogen to make ammonia, fertilizer, and methanol. Metal processors and heat treaters use hydrogen to help create bright and shiny stainless steel, improving product quality while reducing waste. The electronics market uses hydrogen in manufacturing



integrated circuits. The power industry uses hydrogen fuel cell batteries for backup power for remote telecommunications or mission-critical applications. Fuel cells can be used in a wide range of applications, including transportation, material handling, stationary, portable, and emergency backup power applications.

The US Department of Energy Hydrogen Program, led by the Hydrogen and Fuel Cell Technologies Office (HFTO) within the Office of Energy Efficiency and Renewable Energy (EERE), conducts research and development in hydrogen production, delivery, infrastructure, storage, fuel cells, and multiple end-

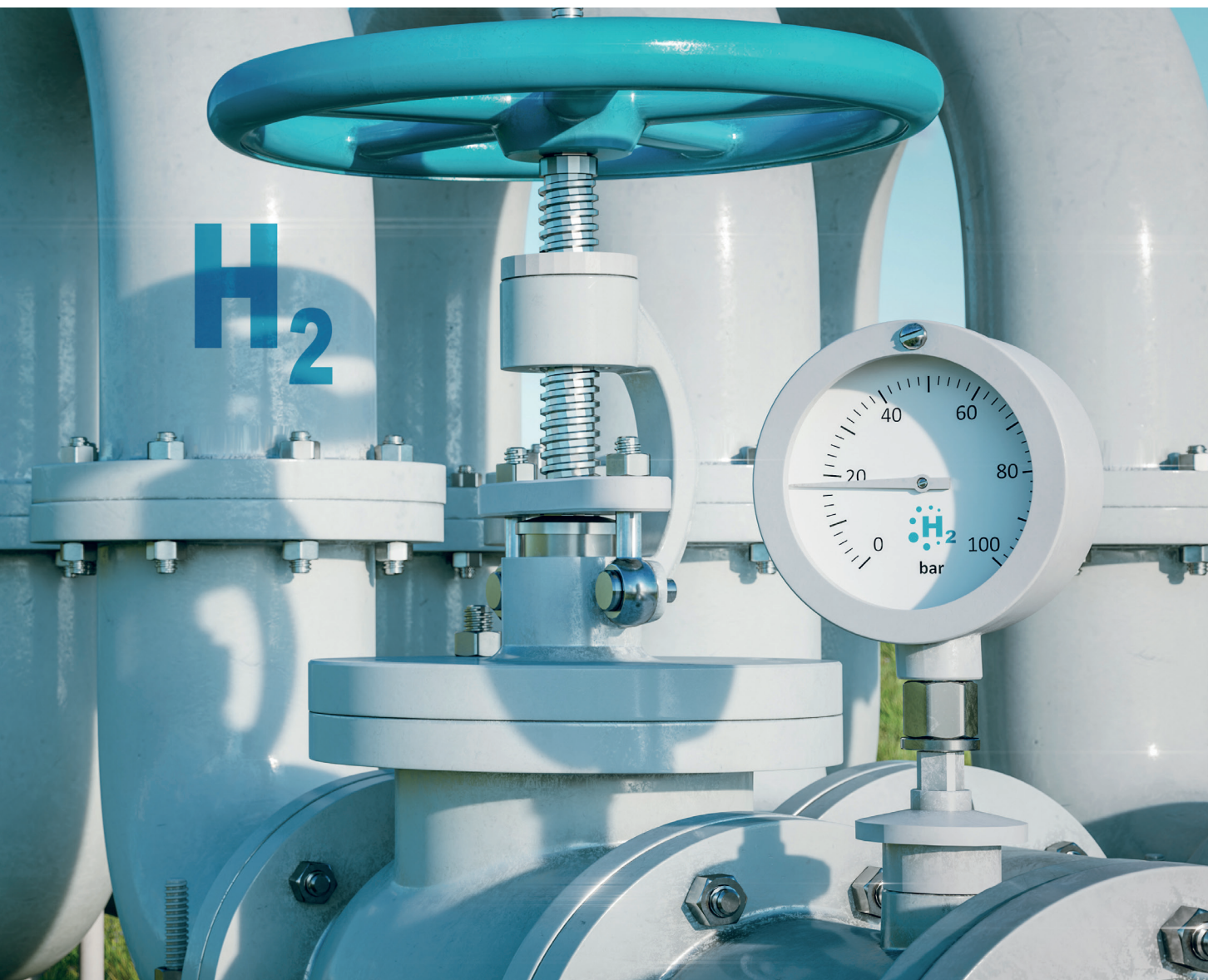
“In mid-2021, there were 48 open retail hydrogen stations in the US. Additionally, there were at least 60 stations in various stages of planning or construction”

uses across transportation, industrial, and stationary power applications.

Stationary and backup power, and material-handling equipment are some

of the potentially largest and fastest growing markets for liquid hydrogen. Transportation and energy storage are emerging sectors for hydrogen and fuel cells. Recent improvements in fuel cell cost and performance are giving the technology economic viability. The increased number of retail hydrogen fueling locations in select markets is supporting the initial rollout of hydrogen-fueled cars.

In mid-2021, there were 48 open retail hydrogen stations in the US. Additionally, there were at least 60 stations in various stages of planning or construction. Most of the existing and planned stations were in California, with one in Hawaii and 14 ▶



▶ planned for the Northeastern states. As the market expands, hydrogen fueling stations will be matched with vehicle rollout as both grow together in parallel. According to the DOE, the goal is 200 hydrogen stations in California by 2025. By 2030, a total of 1,000 stations in the state is the vision. Once refueling stations are added in other states, the number of fuel cell vehicles is projected to grow nationwide.

Approximately 80% of hydrogen refueling stations now have a capacity of 150 to 200 kilograms of hydrogen. A typical refueling requires about 3 kilograms or a little more. So a typical station can fill between 50 and 67 hydrogen fuel cell cars before running out. Many future stations will deliver liquid hydrogen, the supply of which is larger and more reliable, to service a greater number of cars.

Merchant liquid hydrogen capacity was flat until 2016 when Airgas opened the Calvert City, KY plant with a capacity of 11 tons per day (tpd), bringing total merchant capacity to about 283 tpd. Four more new merchant liquid hydrogen plant builds were announced, three of which started up in 2021 and 2022, increasing capacity by 92 tpd to over 400 tpd.

Air Products continued this trend when it announced in March 2022 plans to build a 10 tpd green liquid hydrogen production facility in Casa Grande, AZ. The zero-carbon liquid hydrogen facility is expected to be on-stream in 2023 and its product will be sold to the hydrogen mobility market in California and other locations requiring zero-carbon hydrogen.

This increase in capacity is being built because capacity utilization has continued to increase from high growth in the stationary and portable fuel cell market and in liquid hydrogen fueling stations. Overall,

“Approximately 80% of hydrogen refueling stations now have a capacity of 150 to 200 kilograms of hydrogen”

new capacity of 415 tpd (376 metric tpd) represents a 53% increase since 2015, according to estimates by Intelligas Consulting.

Relatively new to the merchant hydrogen production is Plug Power, a leading provider of turnkey hydrogen solutions for the global green hydrogen economy. The company has put six green hydrogen liquid facilities on the drawing board since 2019 in the US. This is all part of its plans for its North American green hydrogen production network. The company targets producing 70 metric tpd by the end of 2022 and 125 metric tpd by 2023. According to Plug Power, it is on track to deliver 500 metric tpd by 2025.

The company's national network of plants is in Tennessee, New York, Pennsylvania, Georgia, California, and Louisiana. The network will supply 500 metric tpd of liquid green hydrogen by 2025, replacing 4.3 million metric tons of CO₂ emissions, and 1,000 tpd globally by 2028.

Through the acquisition of Joule Processing LLC in 2022, Plug Power gained core competency in liquefaction systems known for their operational efficiency, flexibility, and reliability. Plug Power's hydrogen liquefaction system has one of the most energy-efficient designs on the market, utilizing hydrogen as the refrigerant in the main liquefaction cycle. This leads to the most efficient and cost-effective product on the market.

In January 2023, Plug Power was awarded an order to deliver two 30 tpd hydrogen liquefaction systems (also known as hydrogen liquefiers) to TC Energy Corporation. These 30 tpd hydrogen liquefaction systems utilize a hydrogen refrigeration cycle and bring to market one of the most energy-efficient designs to date. The two hydrogen liquefiers are scheduled for delivery in Q2 or Q3 2024 and will serve TC Energy facilities in North America that are not yet operational.

Liquid hydrogen has higher energy density than gaseous hydrogen, making it easier to transport and use in hard-to-decarbonize sectors. By liquifying hydrogen with Plug Power's highly efficient and reliable liquefaction systems, TC Energy will achieve significant cost savings, broader distribution coverage, and overall energy efficiency with minimal hardware.

Future outlook

The future growth in the hydrogen business over the next few years will depend on the US and global economies. The push to go green and associated government incentives will drive the future of the refinery and merchant hydrogen business.

Hydrogen fuel cells will continue to drive the transportation, stationary, and portable hydrogen fuel cells as industrial gas companies work with government to make the commercialization of this technology successful. [gw](#)

ABOUT THE AUTHOR

Maura D. Garvey is a Principal and Director of Market Research for Intelligas Consulting (a J. R. Campbell & Associates, Inc. company), an international consultancy specializing in strategic analysis and forecasting in the industrial gas industry. She can be reached at mdgarvey@intelligasconsulting.com.



Manual and actuated
VJ cryogenic valves

Vacuum seal-off valves
and operators

Cryogenic bayonets in
pipe and tube size

Vacuum relief valves

Cryogenic vapor vents
and vent heaters

For all cryogenic
applications—nitrogen,
argon, oxygen, hydrogen
and helium service.

Contact Us Today
+1 908.686.3643

cryocomp.com A division of Cryofab, Inc.



Leader in Hydrogen Storage and Transportation



FIBA Technologies, Inc.

53 Ayer Rd, Littleton, MA, USA 01460

☎ 508.887.7100

✉ info@fibatech.com

| www.FIBATECH.com

Turbines, Inc. Offers Liquid H2 Measurement Solutions

Liquid H2 Complete Delivery System Components:

- HMC Turbine Meter
 - Linde & Air Force bayonet options
- CDS1000-TPC-H2-EX Totalizer
 - Temperature & Pressure Compensated Delivery Total
 - Class 1 Div 1 Group B/C/D Enclosure
 - Intrinsically safe external Off/On/Reset switch
 - Wireless Keypad for programming ease



What Turbines, Inc. can offer you:

- Proven, technologically advanced, user-friendly liquid H2 Complete Delivery System
- Endless possibilities with a full complement of staff engineering, manufacturing, & IT
- Combined 150 years of cryogenic measurement experience
- Key industry-wide partnerships that continue to deploy, design and perfect TI's current cryogenic product-line
- On-site training, service and calibration available upon request



864 882-4544 www.turbinesincorporated.com