CRYOGENIC INDUSTRIES

FrostByte

Volume 13 No. 2 | A Newsletter from Cryogenic Industries | Summer 2002

The $P2K_{30}$ offers low cost, high reliability pumping

ACD and ACD CRYO release a new cylinder and storage filling pump for the European industrial gas market

ACD and ACD CRYO's P2K pump has quickly gained strong credibility as the industry's leading cylinder-filling pump. After two years of validating improved design features and operation of the pump, the P2K has been modified to cover European cylinder filling needs.

The $P2K_{30}$ is Europe's answer to low cost operation, high reliability, and integrated after-sales support for cylinder filling pump applications. The $P2K_{30}$ pump meets European needs and is designed for operations up to 420 bar and 19 lpm.

The pump's design allows for higher flows yet runs at much slower speeds (RPM) than conventional-type pumps being used throughout Europe today. Because of this, maintenance costs are greatly reduced and reliability increased, which yields lower operational costs and higher profits.

The $P2K_{30}$ uses two IEC-34 motor sizes: 22Kw and 30Kw. There is a two-speed motor option available which would further enhance the flexibility of the pump to meet customer needs. Standard accessories such as cavitation detection, loss-of-prime detection, unloader valve, cooldown ready, and shaft leak detection are just a few of the features available on the $P2K_{30}$.

The $P2K_{30}$ is a vertical sump pump and designed for light and medium duty cylinder filling applications. It comes standard with a manual control panel and an hour meter. Also available are semi- and fully-automatic PLC control panels per European specifications and standards.

The $P2K_{30}$ comes with a 3,000 hour limited warranty and an integrated after-sales support program which includes prompt service turnaround times, exchange programs, and regional technical support should assistance be required.

FLOW RATES
for pressures up to 420 bar

cold end x 38mm stroke	*lpm*
32mm	up to 8.1
38mm	up to 11.5
44.5mm	up to 15.9
50.8mm	up to 19+

For more information, contact Bob Lilly at ACD, tel: +1 949.261.7533 or blilly@acdcom.com, or Dieter Ziegler at ACD CRYO, tel: +41.61.413.0230, dieter.ziegler@acdcryo.com.

Inside This Issue

ACD and Cryoquip equipment service public transit

Omnitrans, a public transit agency serving the San Bernardino Valley, California, recently began operation of two new, unique liquefied compressed natural gas (LCNG) fleet fueling station with the inclusion of several ACD pump and Cryoquip vaporization products.

The agency was founded in 1976 through a joint powers agreement. Its fleet carries over 15 million passengers each year throughout its 480 square miles (773 km^2) service area. The new East Valley facility is the largest LCNG fueling station in the United States, with the ability to fuel the 100 bus fleet at the rate of two buses at a time in less than four (4) minutes with odorless, compressed, methane gas. This is one of two stations constructed by General Physics of Escondido, CA, USA, for Omnitrans with design, equipment, and installation support by NorthStar Inc. of Evanston, WY, USA. By using LCNG, Omnitrans has made their new stations more "neighborhood friendly." Previously, the odorant added to natural gas was an irritant to near-by neighbors and air quality districts. Since the LCNG is odor-free, the new stations and buses use monitoring systems and sensors to detect possible methane leakage. These systems are state of the art and have been approved by both the state and local safety, fire and health departments as well as the California Highway Patrol (Commercial Vehicle Inspection Division).

At the heart of the East Valley station are two large 30,000 gallon (113,562 liters), double-walled, vacuum jacketed storage tanks that supply LNG to the pumping and forced air vaporizer system. The tanks store liquefied natural gas (LNG) at -250 °F (-157 °C), using vacuum pressure and insulation to keep the fuel cold. The LNG is pumped by ACD submerged, sealess centrifugal pumps to the three (3) ACD high pressure, 5000 psi (345 bar), 100 hp (75kw), forced oil lubricated model 3-SGV reciprocating pumps.

To produce CNG from LNG, the liquid is pumped through a pair of Cryoquip horizontal forced draft, fan assisted, ambient vaporizers, then sent to CNG storage or directly to the bus fuel tanks.

A smaller version of this station is installed at Omnitrans' West Valley facility in Montclair, California, to handle a fleet of 36 buses. (See Figure 1 for general construction and operational data on both stations.)

One of the unique features of these stations is their multiple-use design. While the station is primarily an LCNG fueling station, it can be expanded to fuel LNG vehicles if required. By incorporating the ACD sealess submersible pump in its system design, NorthStar was able to use the pump for four (4) possible functions:

1. TC-34 pumps are used as trailer unloading pumps to fill LNG supply tanks more quickly.
2. TC-34 pumps are used as boost pumps to provide liquid to reciprocating pumps at a positive pressure allowing each pump to operate without cavitation.
3. TC-34 pumps are used as supply tank saturation pumps when required for LNG vehicle fueling.
4. TC-34 pumps are used to fill LNG vehicle fuel tanks when required.

This flexibility allows Omnitrans to change and grow as future requirements dictate. Also, plant space is reduced and costs are kept to a minimum by not duplicating efforts with additional pumps.

FIGURE 1

Omnitrans liquefied compressed natural gas (LCNG) fueling stations

	East Valley	West Valley
Operational Date	April 2002	May 2002
LNG Tanks	2	1
Tank Capacity (each)	30,000 gallons (113,562 liters)	20,000 gallons (75,708 liters)
Tank Weight (each)	50 tons	35.5 tons
Tank dimensions	12 ft x 60 ft (3.6 m x 18.3 m)	10 ft x 54.2 ft (3.1 m x 16.5 m)
Construction	Inner tank surrounded by insulating material, then covered by outer tank of 1/2 in (1.3 cm) thick steel	
Pumps:		
ACD AC/TC-34 1.5x2.5x6.5"- 2 stage sealess submersible boost pumps*	3	3
ACD reciprocating pump 3-SGV	3 units @ 100 hp each 20 gpm @ 5,000 psi (76 lpm @ 345 bar)	2 units @ 60 hp each 16 gpm @ 5,000 psi (61 lpm @ 344 bar)
Vaporizers:		
Cryoquip Model KAF 899 SSL15 horizontal, forced draft, fan assisted, ambient vaporizers	2	
Vertical, forced draft, fan assisted, ambient vaporizers		1
Daily usage	11,000 gallons (41,640 liters)	1,200 gallons (4,543 liters)
Fuel delivery	6 days/week	2 days/week
Construction Cost	US $3.8 million	US $2.1 million

** Pumps are used to assist in unloading LNG fuel from trailers and can be used to fill LNG vehicles when required.*

ACD'S Model AC/TC-34

ACD'S AC/TC-34 submerged pump models are a sealess design with integral pump and motor vertically mounted in a sump or tank. The design meets or exceeds all EPA and OSHA standards. The TC-34 is extremely durable and can handle tough pumping requirements, including methane (LNG), ethylene, and other light end applications in addition to the more traditional fluids like nitrogen and argon.

authority's natural gas fueling stations

The TC-34 is designed to endure thousands of starts per year without requiring an overhaul. The submerged pump's design, unlike conventional pumps, does not include a mechanical seal. Instead, the pump and motor are completely immersed in fluid without a seal to wear out, allowing the unit to operate for longer periods between overhauls.

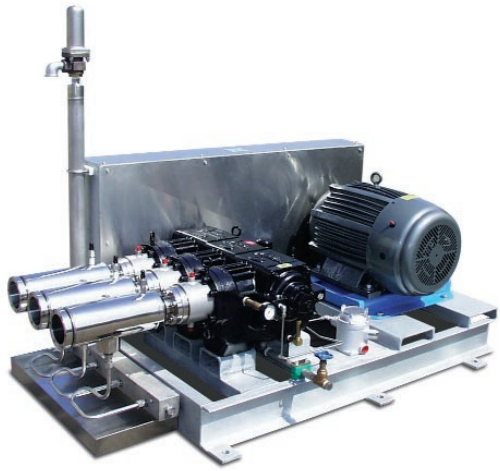
ACD has been supplying sealess pumps that have been operating in hydrocarbon (light ends) service, including LNG, with no indication of winding deterioration or contamination. The pumps' fully flooded motors comply with National Fire Protection Association 79 Electrical Standards and NEMA 70, section 501-8. The integrally connected pump and motor (on both the AC-32 and TC-34) are designed without the need for a conventional shaft seal. The TC-34 pump and motor are mounted vertically in a vacuum jacketed sump housing. Reliability of the sealess pump begins with advanced motor design and production techniques which allow the motor to be cooled by pumped cryogenic fluid. The sub-cooled liquid prolongs motor insulation life.

Available cooling from the cryogenic liquid is more than enough to remove excess heat and provide required torque to drive the pump in normal pump operation. Heat loss is negligible. The heat input to the LNG is equivalent to vaporizing less than 0.011 percent of the flow. All motors used for sealess or submerged pumps are variable speed inverter duty type, and in most cases require a variable frequency drive (VFD).

Among other key features of the TC-34 is the product-lubricated bearings and motor, which both benefit from immersion in the cryogen. Diverting and filtering a portion of the pumped product flow through the bearings provides longer bearing life and pump operation. With proper selection of the internal bearing geometry, coupled with adequate liquid flow (cooling), bearing life expectancy is equal to or greater than conventional grease lubricated bearings. At the same time, the cooling effect of the cryogen makes it possible to reduce the motor's physical size. The pump also is fitted with a state-of-the-art inducer to provide minimal NPSH required for the pump to operate without cavitation.

In addition to a reliable sealess motor, ACD has developed inducers to provide the lowest possible NPSHR by employing computer analysis in their designs, which uses hydraulic parameters to optimize the pumps' performance. The inducer generates adequate pressure to allow the main stage impeller to operate without cavitation. Cavitation not only limits flow (or prevents it altogether), but it is extremely destructive to the rotating elements of the pump. Cavitation rapidly deteriorates impellers and causes wear rings and bearing damage, compromising overall pump performance and efficiency. The TC-34 is normally driven by a variable frequency drive controller for greater flexibility as it relates to variable flows and differential pressures as well as reducing speed to obtain a positive flow in extremely low NPSH conditions.

The TC-34 has many uses in filling applications and the customer benefits from the pump's capability for multiple instantaneous quick starts. Because the pump is immersed in a vacuum-jacketed sump where it is continuously flooded in a liquid, the traditional waiting period for the pump to cooldown is eliminated. Hence, more deliveries per day with lower product losses are possible, resulting in maximized profits when used as a trailer pump. The TC-34 in argon service provides the most benefits to the customer by eliminating cool down time of the pump without product loss. Coupled with the proper tank system and money saved by not venting expensive argon, the pump will provide a valuable return on your investment dollar.



ACD Model 3-SGV

The other ACD LNG pump featured in the Omnitrans project is the three cylinder, high capacity, high pressure, Model 3-SGV reciprocating pump, operating at 20 gpm (76 lpm), 5,000 psi (345 bar) working pressure. As a result of recent design improvements, the SGV series has become the industry's leader for high pressure, high flow, liquid methane applications.

Key to the SGV design is the vacuum jacketed cold end and suction adapter. ACD has minimized heat leak losses, providing many benefits from reduced cooldown losses to overall economic operation of the pump. Refinements in the cold end assembly extend seal life and enhance pump volumetric

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efficiency. The new SGV large 50 mm bore (1.97 inch) cold end allows for flows to 25 gpm (95 lpm) at 6,000 psi (414 bar), meeting market need for faster fill ups as demand for environmentally clean burning LNG and LCNG vehicle fleets continues to grow.

Another key feature of the SGV is its oil pressure lubricated drive. The drive contains an integral oil pump that enables clean operation without the need for external oil reservoirs. The pump can be either belt driven from electric motors or foot mounted for use with hydraulic drives allowing for extended pump duty.

The SGV comes complete with a vacuum jacketed cold end with pressure oil lubricated drive end, a positive locking coupling, standard suction adapter with Monel strainer, distance piece with purge ports, hot dipped galvanized steel skid, TEFC motor, high pressure relief valve with discharge line and surge chamber, and suction/vapor return manifold for multiple cylinders. Models are available in complete skid assemblies with auxiliary piping components included to ensure safe, reliable, and efficient liquid methane pumping.

Optional accessories include vacuum jacketed suction adapter, foot mounted configuration with no motor, manual or semi-automatic control panel, loss of prime detector for cavitation protection, and cooldown lock-up control.

This modular, compact, heavy duty pump is available in single, double or triple cylinder configurations for a wide range of flow options. In addition to liquid methane, the pump can be used with nitrogen, oxygen, argon, and hydrogen.

Cryoquip's Model KAF 899 SSL15

Two of Cryoquip Model KAF 899 SSL15 horizontal, forced draft, fan assisted, ambient vaporizers are in place at the Omnitrans East Valley station. The units can produce

continuous vaporization of up to 102,000 scfh (2,681 Nm^3/hr) of LNG. The vaporizers are installed in a outdoor hazardous classified area requiring the vaporizers to meet Class 1, Division 2, Group D Explosion Proof requirements. Each vaporizer is equipped with an Explosion Proof fan motor and NEMA 7 Explosion Proof control enclosure that houses the fan motor starter and operating controls. The two vaporizers operate in parallel and are sized for eight hours of continuous operation.

Due to special requirements, the vaporizers were designed for a horizontal installation profile in order to satisfy customer criteria that imposed a low height restriction for the installation. Special mounting pads were installed to allow the vaporizers to operate in the horizontal orientation and other special features were also included to allow good defrosting characteristics in the horizontal position.

In order to satisfy NFPA 59A requirements the vaporizers were ASME Code inspected and certified to Section VIII, Division 1 with U-stamp for a maximum working pressure up to 5,700 psig (393 bar) using a high pressure wetted liner made of 304 stainless steel material.

For information on LNG pumps contact Denis DePierro at ACD, tel +1.949.262.7533 or ddepierro@acdcom.com. For information on natural gas vaporizers contact Raul Boza at Cryoquip, tel +1.909.677.2060 or rboza@cryoquip.com.

Cryoquip's vapo the electronics i

The semiconductor equipment industry is a multi billion dollar industry supplying gas delivery systems and manufacturing equipment to fabrication sites. Within one fab there can be between 350 to 600 process tools requiring a supply of industrial gas. Semiconductor chips are manufactured by a multi step process involving chemical vapor deposition, photolithography, chemical stripping and other processes, many of which involve both bulk and speciality exotic gases. These gases can be categorized as inert, corrosive, toxic, or flammable. For the latter categories of gases, special equipment is required with emphasis placed on seal integrity and contamination. (See Figure 1.)

Arsine and phosphine, widely used in ion implantation, are highly toxic. Silane, used in silica deposition, burns spontaneously on exposure to air. The halogen gases, such as hydrogen chloride or hydrogen bromide are very corrosive and gases like boron trichloride will corrode stainless steel when moisture levels exceed a few ppm. This kind of internal corrosion is a particular challenge for equipment manufacturers because it introduces the additional consequence of particle generation, which may lead to serious production problems. Particles as small as 0.025 micrometers, about half the size of a human hair, can lead to the possible compromise of a production line. These stringent manufacturing requirements necessitate that all equipment in contact with process gases must be engineered to minimize or eliminate potential sources of system contamination leakage or moisture ingress.

Cryoquip recently adapted one of its innovative VEB series of electrical vaporizers for use in vaporizing boron trichloride. Many of the unique features of these vaporizers

For more information contact Doug Denney at C

orization equipment enables ndustry to use gas safely

were ideally suited to meet the stringent specifications of the equipment needed for the application of this very corrosive gas. The modular vaporizers are manufactured as standard to meet UL, CSA, IEC, and CE requirements and are approved for use in global applications. In addition the electric control panel had to be manufactured as an explosion proof design (Class 1, Division 2, Group C/D) including a purged main enclosure and an explosion-proof (NEMA 7) main disconnect because of the environmental regulations in effect in the area in which the vaporizer needed to operate.

Figure 1: Gases used in the semi-conductor industry.

Category	Gases
corrosives	hydrogen chloride boron trichloride hydrogen fluoride
toxics	chlorine silane
flamables	hydrogen silane phosphine
bulk gases	argon helium nitrogen oxygen

Note: This is not an exhaustive list.

The design of the vaporizer gas piping minimized the gas piping joints, which are automatically fusion inert gas welded for integrity. All the gas piping joints in final installation were similarly welded to ensure zero leakage and the total integrity of the installation. During the manufacturing process the stainless steel grade 316L tubing, standard in the industry, was specially treated to eliminate all possibility of moisture ingress. After final assembly and testing, the vaporizer was purged with hot inert nitrogen gas to reduce the ppm moisture levels to values well below the specification. The unit was sealed and maintained under nitrogen pressure during delivery to the customer prior to installation. Special filters are used in conjunction with the vaporizers and other equipment in the complete system to ensure that microscopic particles are removed form the gas stream prior to its arrival at the point of use within the semiconductor fabrication facility.

The vaporizer's modular design enables the electric heater elements to be replaced quickly with minimal down time. The extruded wafer construction is comprised of individual elements connected to a common manifold that facilitates replacement. The units are lightweight, easy to handle, extremely portable, and re-locatable. The heating elements and gas carrying tubes are specially positioned in the highly conductive aluminum modules. Over 30 standard units are available in 4 different voltage configurations, flow rates from a few hundred to over 30,000 SCFH (800 Nm^3/hr) and operating pressures up to 10,000 psig (690 bar). Pressure drops are typically less than 15 psig (1 bar) with a 150 psig (10 bar). The vaporizers are protected by an independent, solid state over-temperature protection system with an automatic reset. NEMA 4 or IP 55 electrical are normally standard with fully automatic controls.

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Why is a recirculation line necessary on a cryogenic centrifugal pump?

Recirculation lines are necessary to eliminate gas phase circulation on pump cooldown and startup. The line should be installed on the discharge side of the pump with a globe valve in the recirculation line to throttle during pump startup. In addition a discharge control valve should be installed within 10-15 diameters downstream of pump suction to adjust pump pressure and flow as called out on the pump's duty condition. This will minimize overloading the pump motor, or pump cavitation, by not having the pump run in a fully open condition. In the case of motors above 30 hp, possible hydraulic hammer or shock wave that could damage equipment is minimized. In conjunction with the control valve, a pressure gauge is a must on all pumps to properly evaluate actual operating conditions when adjusting the control valve.

Why is installation of a vapor return line important for cryogenic pumps?

Most cryogenic pumps are installed in "closed loop" systems where the liquid is fed to the pump from the bottom of the tank and the vapor is returned to the gas phase of the tank. (If a siphon tank is used the vapor is returned to the liquid phase just above the liquid outlet.) Possibly the most common installation error is incorrect vapor return piping to the tank.

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New hire brings computational fluid dynamic expertise to the group

Dr. Ron Franz has been hired by Energent Corporation, a Cryogenics Industries company, to perform aerodynamic analysis in support of company projects and research and development of new energy technology.

Previously he worked at SECA, a computational fluid dynamics (CFD) company in Hunstville, AL, USA. As a research engineer, he developed a design tool to use CFD. A particular application was to optimize a volute with respect to the force acting on the impeller, which arises from the asymmetric flow in the volute. This entailed writing a grid generator to describe the pump components, particularly the volute using a minimal set of geometry variables. The design procedure is indicated in Figure 1.

Franz earned his doctorate in mechanical engineering from Caltech, Pasadena, CA, USA. While a student, he investigated the hydrodynamic forces on turbomachinery. These fluid-induced forces, acting on the impeller and therefore on the bearings of a turbomachine, can cause self-excited whirl, where the rotor moves away from and whirls along a trajectory eccentric to its undeflected position, Figure 2. The forces are indicated in Figure 3. By considering a linearization of these forces about the impeller centered in the volute, they can be described as an excitation force and an interaction force, which are, respectively, steady and unsteady in the stationary volute frame of reference. Whenever the tangential force is in the same direction as the whirl motion, it encourages the whirl motion and is thus destabilizing. A positive normal force tends to increase the radius of the whirl motion. Knowledge of this unsteady force which is related to the lateral vibration of the rotor is part of understanding the rotordynamics of the turbomachine.

Measurements have been conducted over a range of whirl/impeller angular speed ratios at different flow coefficients without cavitation for various turbomachines. A destabilizing force was observed over a region of positive whirl ratio. The effect of cavitation upon these forces was examined for an impeller in a centrifugal pump. Compared to the non-cavitating case, cavitation corresponding to a head loss of three percent did not have a significant effect upon the unsteady force. However, at the design point with a lesser degree of cavitation for a whirl ratio of .3 there was an effect. The tangential force exceeded its non-cavitating value, though the normal force was smaller.

Figure 1. Program layout for the volute optimization.

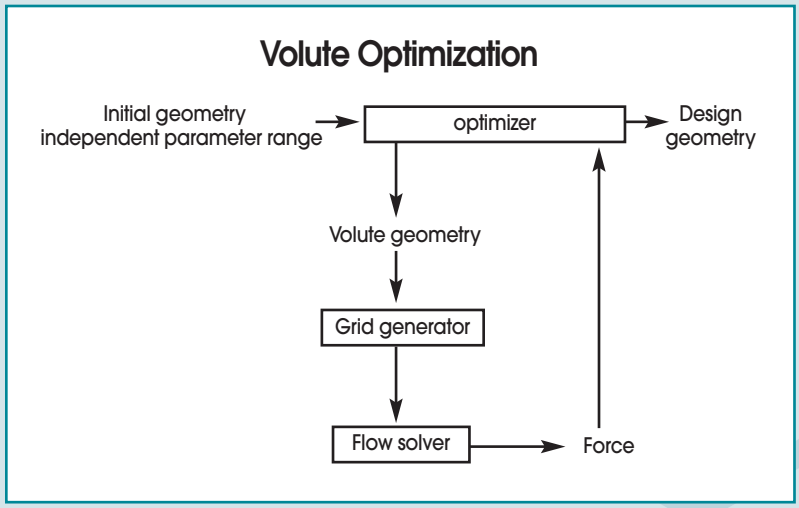
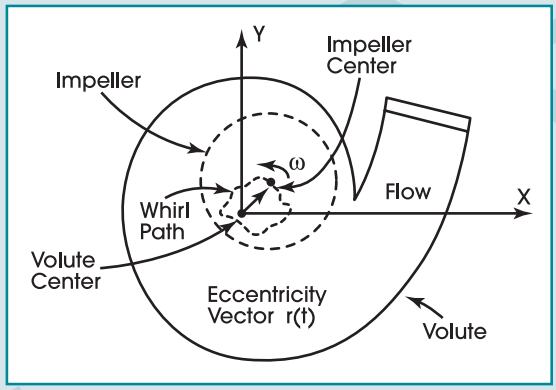


Figure 2. Sketch of a centrifugal pump with a whirling impeller.



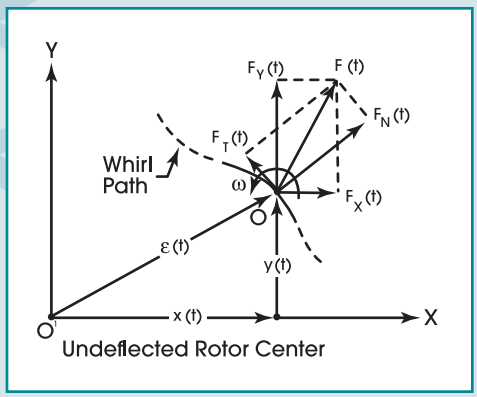


Figure 3. Diagram of the forces acting on a whirling impeller in the plane of vibration. FX and FY are in the stationary volute frame. FN and FT are in the local polar coordinate frame, normal to and tangential to the circular whirl orbit.

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During initial cooldown the liquid is vaporized and the gas is returned to the tank. As pump inlet temperature reaches equilibrium, liquid begins to fill the vapor return line until it reaches elevation close to the tank liquid level. During cooldown and pumping heat leak into the liquid produces gas and must be continuously removed to prevent pressure increase in the pump inlet. Without venting gas from the pump liquid will not enter the pump or the liquid will become saturated and the pump will cavitate and result in severe damage or injury.

Proper vapor return line installation is critical for efficient pump operation and long, trouble-free pump life. The vapor return line must slope upward from the pump to the tank with no liquid traps or low points will prevent gas from percolating back to the tank. Annealed tubing is preferred to allow as short and direct installation as possible. Insulating the line will result in lower heat leak and product losses.

Most newer tanks are designed to be used for cryogenic pumps and the design incorporates dedicated liquid supply and vapor return nozzles. If the tank does not have these dedicated nozzles, contact the tank or pump manufacturer for installation recommendations.

Why are atmospheric gases liquefied?

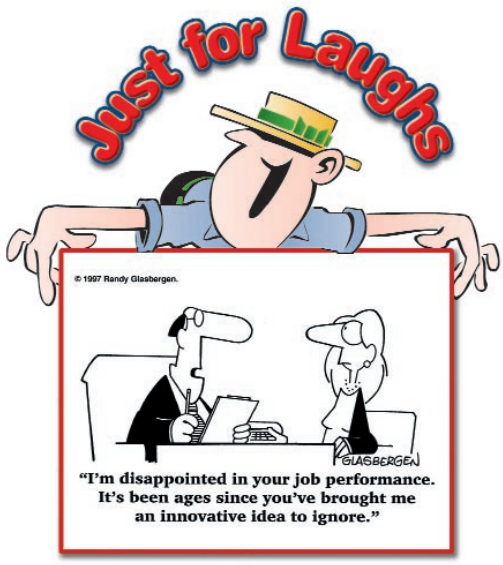
Gaseous oxygen requires 862 times as much volume as an equivalent amount of liquid oxygen. Similarly, the nitrogen ratio is nearly 700 times as great.

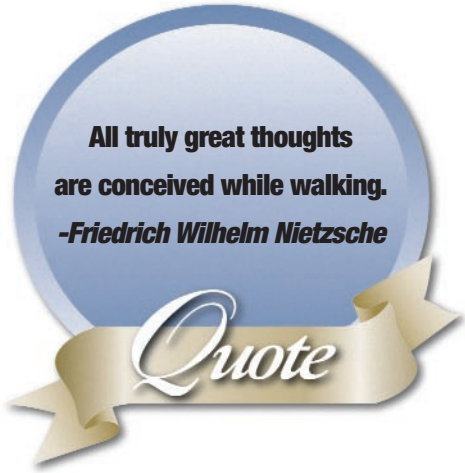
Even if these gases were compressed it would require trailers and storage tanks at least 5 times as large as the ones we commonly see today to transport and store the same amount of product.

Alternatives to liquefaction include increasing the number of trailers in the delivery fleet or making many more deliveries. Either solution leads to a significant increase in total gas cost. This is the primary reason the industrial gas industry and its customers benefit from using the liquefied gas state wherever possible.

Calendar of Events

JUL 22-26	ICEC19, 19th International Cryogenic Engineering Conference Grenoble, France – tel +33.476.88.1291 sec@icec19.org, www.icec19.org
JUL 27-31	CRYO 2002, 39th Annual Meeting of the Society for Cryobiology Breckenridge, Colorado, USA – tel +1.970.547.3032 www.cryo2002.com
AUG 4-9	APPLIED SUPERCONDUCTIVITY CONFERENCE Houston, Texas, USA – tel +1.303.499.2299 asc@centennialconferences.com, www.ascinc.org
SEP 4-5	OIL SANDS TRADE SHOW AND CONFERENCE Fort McMurray, Alberta, Canada – tel +403.209.3561 simonrose@ca.dmgworldmedia.com, www.petroleumshow.com
SEP 21-25	NWSA ANNUAL CONVENTION Orlando, Florida, USA – tel +1.215.564.3484 nwsa@nwsa.com, www.nwsa.com
OCT 13-16	GASTECH 2002, The 20th International Conference & Exhibition for the LNG, LPG and Natural Gas Industries Daha, Qatar – tel +44(0) 1895.454533 j.tyler@turret-rai.co.uk, www.gastech.co.uk
OCT 15-18	CRYOWORLD 2002, Reach for Process Solutions Basel, Switzerland – tel +41.58.206.2784 anje.quellmalz@messe.ch, www.reachfair.ch
OCT 29-Nov 1	OSEA 2002, 14th Offshore South East Asia Exhibition & Conference Suntec, Singapore – tel +44 (0)20 7862 2072 oil@montnet.com, www.montnet.com
APR 22-25	ICCR '03 , The 3rd International Conference on Cryogenics and Refrigeration Hangzhou, China – tel +0086.571.87951771 ICCR2003@cmee.zju.edu.cn, www.cmee.zju.edu.cn/ICCR2003.htm





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