



The Right Connection®

Liquefied Natural Gas: **The Fuel of the Future for Shipping and Transport**

- ▶ As the fleet of LNG tank ships continues to grow, LNG's prospects are looking robust in other transportation sectors, too.

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November 2017



As the drive towards good environmental stewardship continues to intensify, Liquefied Natural Gas (LNG) has been making great strides as the cleaner burning “fuel of choice” for shipping and transport.

LNG is a cryogenic natural gas, cooled to its liquid state of minus 162 degrees Celsius (minus 260 degrees Fahrenheit). In converting natural gas to LNG, the volume is reduced by about 600 times, allowing it to be stored and transported effectively.

Once delivered to its destination, LNG is warmed back to its original gaseous state so that it can be used like any other natural gas resource for heating and cooling, cooking, generating electricity, and powering manufacturing/processing operations.

The transport of LNG has been around for decades, but its growth trajectory has never been higher than it is today. And the reason is quite simple: LNG fills a need driven by the stricter environmental requirements for the shipping industry, which dictates that traditional bunker fuel must be replaced by the use of cleaner fuels. LNG is a special fuel because it requires no after-treatment to meet emissions control and other environmental requirements.

Beginning in 2015, new international emissions regulations apply to sulfur in sensitive marine environments – particularly in “first world” regions such as Europe and North America. Additional regulations covering nitrogen oxides and particles, plus carbon dioxide and other greenhouse gases, will go into effect in 2020.

The International Maritime Organization (IMO), an agency of the United Nations, has also issued sanctions against the availability and use of “dirty fuels” after 2020, so ship owners and operators are actively seeking alternative fuels that can meet these more stringent emissions criteria.

As our society adapts to these stricter environmental and climate change realities, LNG is a star performer in a number of ways:

- LNG reduces nitrogen oxide emissions by approximately 90%
- LNG causes virtually no sulfur emissions or particulate emissions
- LNG reduces greenhouse gas emissions by approximately 15%

In short, converting to LNG fuel means more than meeting the new emissions control requirements – which is something no other fuel can accomplish.

Marine Leads the Way

LNG technology for ships is highly developed – and also highly beneficial:

- LNG engines, available as new or converted models from global manufacturers such as Caterpillar, MAN, Rolls-Royce and Wartsila, are energy-efficient and have low emissions
- The price of LNG is often lower than the price of petroleum

Moreover, the market for LNG is set to undergo dramatic expansion as more LNG terminals in North America and Europe are scheduled to come onstream by 2020.

According to industry estimates, by 2025 LNG is expected to account for nearly 15% of the entire fuel bunkering volume in Europe, and close to that percentage in North America.

LNG carriers

A half-century heritage with strong future growth prospects.

The first LNG carrier was the *Methane Pioneer*, a 5,034 DWT vessel which departed the Louisiana Gulf Coast in 1959 bound for London, carrying the world's first ocean cargo of liquid natural gas.

Today, much larger ships carry up to 9.5 million cu. ft. of LNG anywhere in the world. The global LNG shipping fleet makes up more than 450 vessels, of which nearly 200 are in use at any given time.

Cruise ships, ferries and cargo ships are additional vessels that can be bunkered with LNG.

The future bodes well for LNG shipping, too. According to *Tradewinds*, as of January 2017 there were more than 120 LNG ship builds on order. Nearly 20% of the cruise ships now on order will be LNG-powered as well, including ones for Carnival Corporation, MSC Cruises, Royal Caribbean and Disney Cruise Lines.

NOx and SOx

What's it all about?

With more ships venturing to different parts of the world, the pollution caused by them is rising, leading to global concerns. While land-based emissions have been gradually lessening, air pollution from ships has continued to rise.

According to some estimates, if current trends continue, by 2020 shipping will be the biggest single emitter of air pollution in Europe, surpassing emissions from all land-based sources including automobiles and other sources.

Even more startling, European scientific studies note that air pollution from international shipping accounts for significant numbers of premature deaths around the world – particularly in places like Europe, the Far East, and parts of North and South America.

The two main pollutants from ship emissions are **Nitrogen oxides (NOx)** and **Sulfur oxides (SOx)**. The reason? These combustible gases, emitted into the environment in the form of smoke, can have adverse effects on the ozone layer in the troposphere, which results in the “greenhouse effect” and may contribute to global warming.

Marine fuel in an internal combustion engine is burned inside the combustion chamber by the correct mixture of fuel and air in the presence of heat or an ignition source (the compression stroke of a piston). Nitrogen reacts with oxygen under certain engine operating conditions to form **Nitrogen oxide (NOx) emissions**. Contributing factors include:

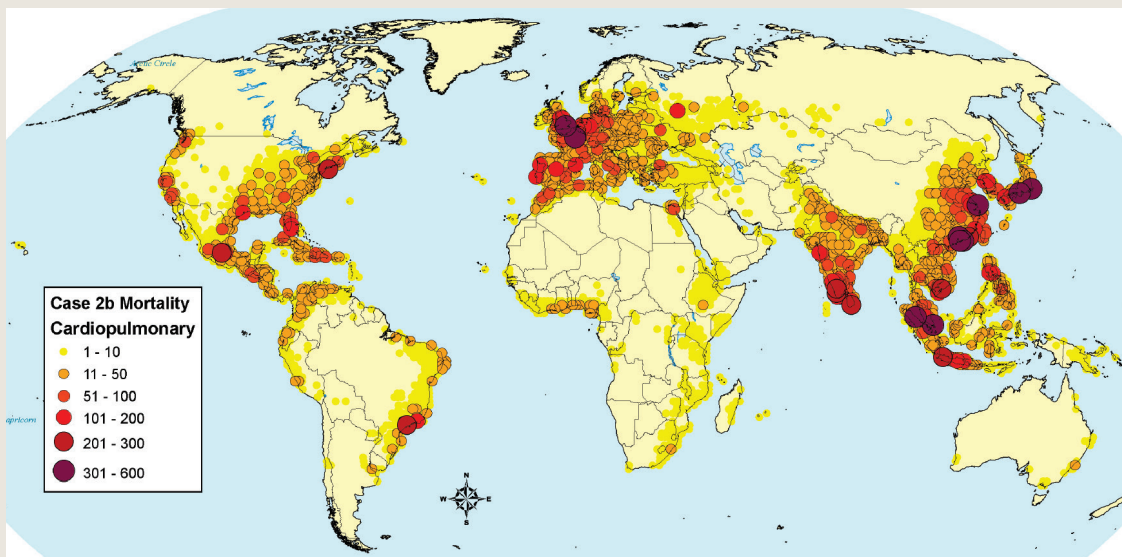
- High cylinder temperature and pressure during the combustion process
- Improper air and fuel ratio for combustion
- The high temperature of the intake or scavenger air inside the cylinder
- Lower quality of fuel used for the engine

Sulfur oxide (SOx) emissions are mainly due to the presence of sulfur compound in the fuel. Smoke containing sulfur oxides emitted by the combustion of marine fuel will often oxidize further, forming sulfuric acid which is a major contributor to acid rain. SOx emissions also contribute to the formation of secondary inorganic aerosol gases – fine particulates that are harmful to people.

When ships operate within an emission-controlled area such as the North Sea, the Baltic Sea and portions of the North Atlantic, the sulfur content of any fuel oil must not exceed 0.1% m/m. (Outside of an emission controlled area [ECA], the sulfur content must not exceed 3.5% m/m.) To achieve compliance, LNG fuel or expensive, highly refined diesel oil must be used; the alternative is employing an expensive exhaust gas cleaning system to reduce total sulfur emission levels.

The better the grade of fuel the lower the sulfur content will be, since it is removed through the refining process. LNG is the best choice in this regard because of its clean-burning characteristics. It is comprised of only carbon and hydrogen (CH₄). Not only are nearly all NOx and SOx emissions eliminated, but LNG will also reduce carbon dioxide (CO₂) emissions by between 20% and 40%, depending on how it's consumed.

Reducing air pollution from ships via the use of LNG is considered a very cost-effective solution to the health and environmental costs of “doing nothing.”



Cardiopulmonary mortality attributable to ship PM2.5 emissions worldwide.

Source: Environmental Science & Mortality.

LNG Transfer and Bunkering Methods

The transfer and bunkering of LNG involves ships, tanker trucks and onshore facilities:

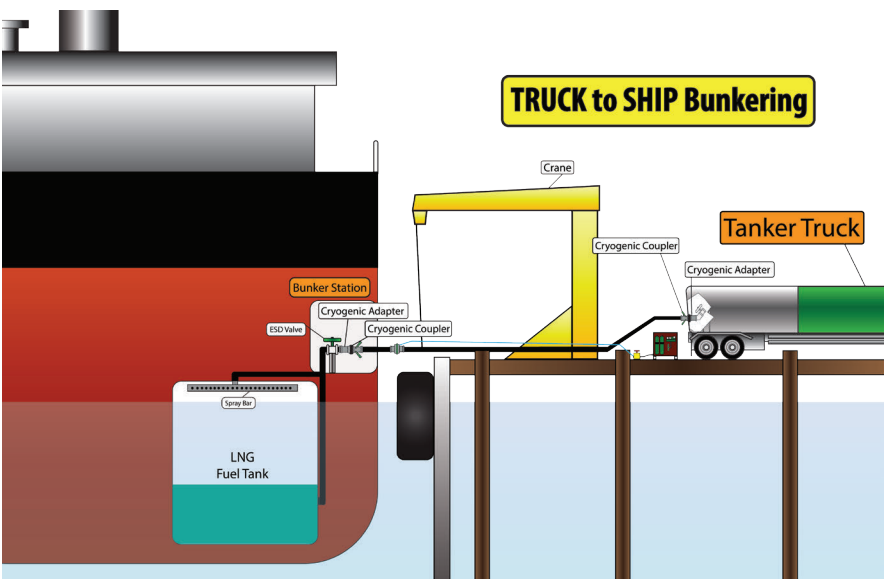
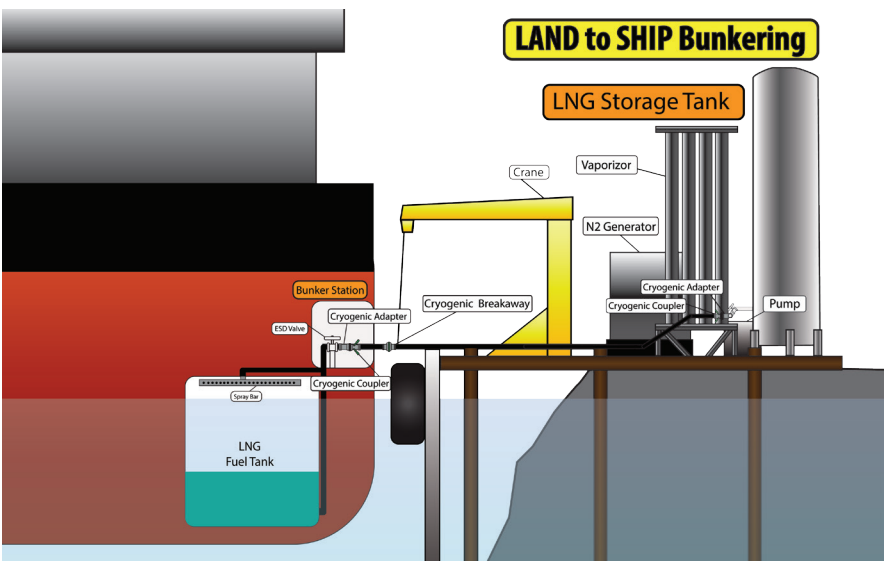
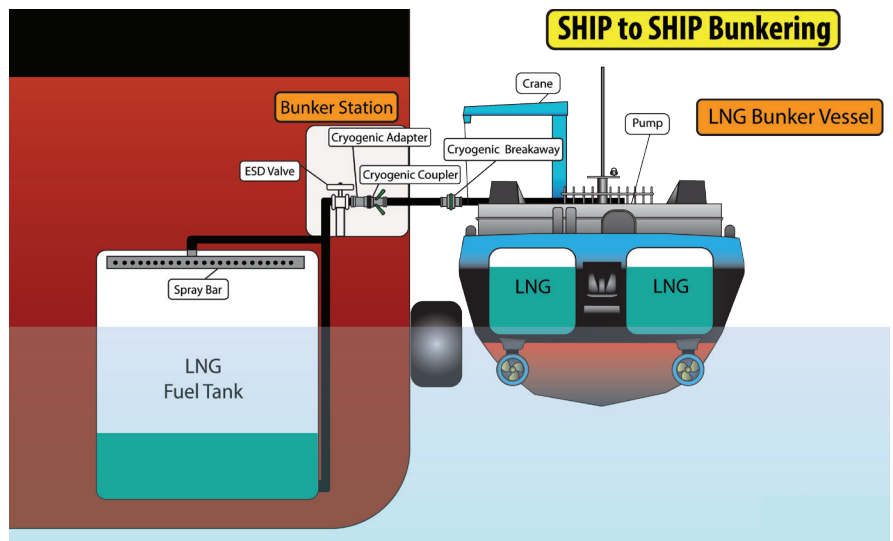
Ship-to-ship LNG transfer operations include oceangoing vessels underway or harbor operations where a moored ship is typically docked at a pier. It can involve either a cargo transfer or a fueling operation for an LNG-propelled ship. Either way, the transfer operations demand strict safety standards and flawless execution considering the factors involved with two ships at sea.

Shore-to-ship operations involve LNG being transferred to a ship from an onshore storage terminal or depot. Shore-to-ship operations are performed in sensitive environments where safety concerns are critical. Of paramount importance is the need to have simultaneous operations (SIMOPS) happening at the same time as the fuel transfer, as minimizing time in port helps keep operating costs in line. Operations such as crew changes, offloading/onloading of cargo, plus passenger departures and arrivals on cruise lines and ferries play a role in optimizing operational efficiencies and keeping their related costs under control.

Truck-to-ship transfer operations occur where ships and ferries are fueled from tank trucks. The fueling is either a direct transfer from a tank truck to the ship, or a system where several tank trucks connect to a fueling skid which then delivers the fuel to the ship. As these operations involve a number of tank trucks moving in and out of position to unload fuel for passenger ships and ferries, safety is of utmost concern.

Terminal or port waterway operations cover both loading and unloading of LNG tank trucks or LNG barges. They're typically well-defined methods and procedures, involving operators at the same transfer location working repetitively with the same equipment.

The key to proper LNG bunkering is not allowing any of the methane – a greenhouse gas 20 to 30 times more harmful to the environment than carbon dioxide – to escape during the transfer procedures.



The Dixon Innovation Center



The **Dixon Innovation Center** in Chestertown, MD is one of the few places in the world where research on cryogenic couplings and other components for LNG fuel transfer is happening. A specially designed cryogenic workstation at the Center allows for R&D testing and repair in environments similar to those encountered “real-life” in the field.

The Dixon Innovation Center offers cryogenic design workshops and classes for engineers and operators, led by leading technical specialists. Dixon customers are also welcomed to the Center to consult with Dixon engineers and specialists in evaluating and designing LNG transport and bunkering systems that meet their specific requirements.

Dixon’s technical expertise is also being tapped by the American Society of Testing and Measurement (ASTM) in its endeavors to establish specifications for LNG bunkering systems. Those specifications are currently under development by the F25 Committee on Ships and Marine Technology’s LNG working group. Dixon specialists serve on the U.S. Coast Guard’s Chemical Transportation Advisory Committee (CTAC) Sub-Committee on LNG, which is working in concert with the Coast Guard to identify gaps in existing policies and regulations that pertain to the design of LNG vessels – and to develop criteria to fill those gaps.



The best LNG transfer systems feature safe and reliable designs and operational ease-of-use, adhering to numerous international class society Type Approvals such as ABS (American Bureau of Shipping), BV (Bureau Veritas), CSS (China Shipping) and DNV GL, as well as bodies such as PHMSA (Pipeline & Hazardous Materials Safety Administration), SGMF (Society for Gas as a Marine Fuel), the U.S. Coast Guard and others.

Precision Manufacturing to Meet Safety Needs

Over the past decade, several companies have established themselves as international experts in the design and functionality of the various components that make up LNG transport systems:

- **Dry cryogenic couplings:**
Dixon and MannTek
- **Cryogenic breakaway couplings (standard and cable type):**
Dixon and MannTek
- **Powered emergency release couplings (PERCs):**
Dixon and MannTek
- **LNG transfer hose (composite material):** Gutteling
- **LNG transfer hose (stainless steel):**
Hose Master
- **LNG transfer hose assemblies:**
Dixon and MannTek

The superior quality and functionality of these components are based on years of experimentation and evaluation of temperature differentials and how they affect the expansion and contraction of different materials used in the components. These factors include Teflon® seals, the engineered stainless steel mating components and how they are energized. It’s a complex combination of engineering and scientific factors that includes careful evaluation of surface finishes as well as the geometry of how and where the seals make proper contact with the mating components in extreme-cold temperatures.

Adding assurance to the integrity of the product designs, tens of thousands of successful transfers involving millions of gallons of LNG material have been recorded.

Cryogenic Dry Disconnect Couplings

The self-sealing valve design of cryogenic dry disconnect couplings is based on a style that has been used with fuel oil and chemicals for a half-century. Cryogenic dry disconnect couplings consist of a tank unit or adapter with a spring-loaded poppet and hose unit or coupler with a valve driven by an internal cam.

The coupling procedure is simple: align the rollers on the coupler with the notches on the adapter, push the coupler onto the adapter and then rotate past 100 degrees. This procedure locks the coupling together, creates a self-seal, and opens the internal valves for full flow with low pressure drop. The dual poppet shutoff mechanism seals liquids and gases safely behind the valve, thereby eliminating fugitive emissions as well as the danger of a spill of LNG fluid.



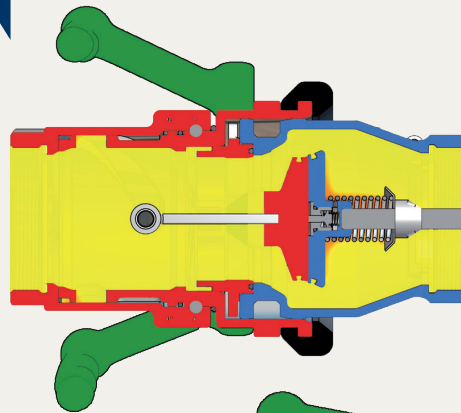
While the operation of dry disconnect couplings is quite intuitive, it is important that proper personal protective equipment (PPE) be worn during the bunkering process, conforming to standards set by ISO/DTS 18683:2015 standards established by bodies such as the International Code of Safety for Gas-Fueled Ships (IGF), plus organizations such as the Pipeline and Hazardous Materials Safety Administration (PHMSA), the Society for Gas as a Marine Fuel (SGMF), and the U.S. Coast Guard.

Cryogenic Breakaway Couplings

Cryogenic breakaway couplings use a closure mechanism similar to the dry cryogenic coupling, with an optimized poppet designed to close off and stop the liquid flow while containing the LNG in the hose and pipe.

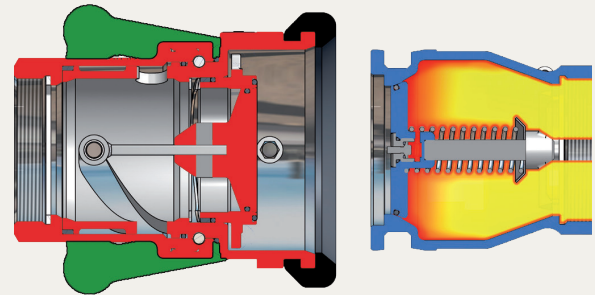
The breakaway couplings have three external break bolts. In the case of axial tension, all of the bolts will take up the force

Cryogenic Dry Disconnect Couplings

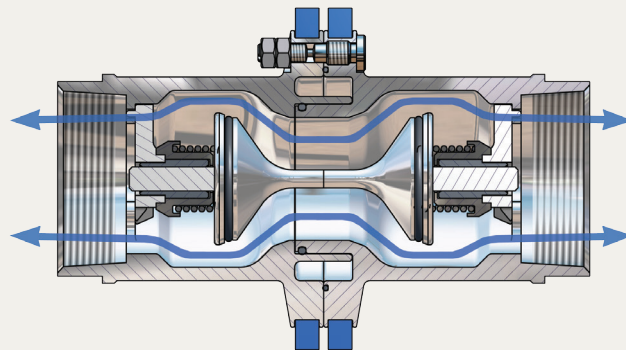


To connect: Push and turn – it's coupled at full flow.

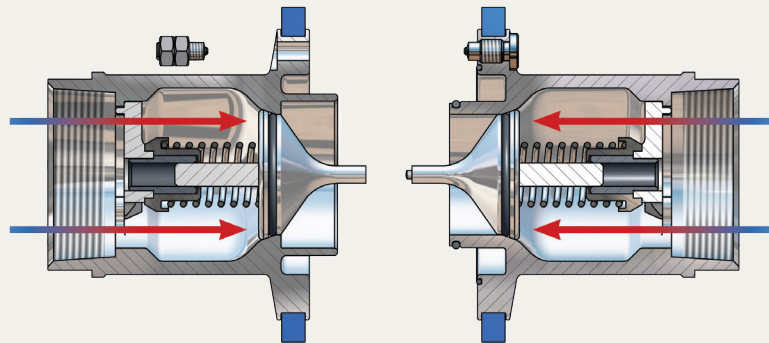
To disconnect: Turn and pull – it's released with no spillage or fugitive emissions.



Cryogenic Breakaway Couplings



Before emergency disconnect: The safety breakaway valve consists of two halves – each with a valve that has a cryogenic seal.



After emergency disconnect: When the cryogenic breakaway coupling separates, it allows the valves to close. The two valves close rapidly, minimizing LNG exposure to workers, equipment and the environment.



corresponding to the break force on the hose. Non-axial forces concentrate the tension forces more strongly on one bolt, so that the breakaway coupling reacts in a natural way to the reduction of the hose break forces.

Cryogenic breakaway couplings are available in two additional designs, depending on the layout of the bunkering system:

- **Cable release cryogenic breakaway couplings** are designed to minimize fuel spills or damage associated with inadvertent drive-away or pull-away incidents. They are activated by a cable that limits the stress that can be applied to the hose or to the loading equipment. A cable release guards against damage happening to loading arms or other piping and equipment, which might otherwise happen due to the force of the breaking bolts.



- **Powered emergency release couplings (PERCs)** incorporate the ability to actively and remotely release the coupling “on-demand” without causing any strain on the transfer system. The release of the coupling happens by injecting high-pressurized nitrogen into a dedicated chamber in the coupling body, resulting in instantaneous release of the PERC.

The PERC will also activate and respond to stress on the loading system, thereby giving it both “active” and “passive” security and safety characteristics.

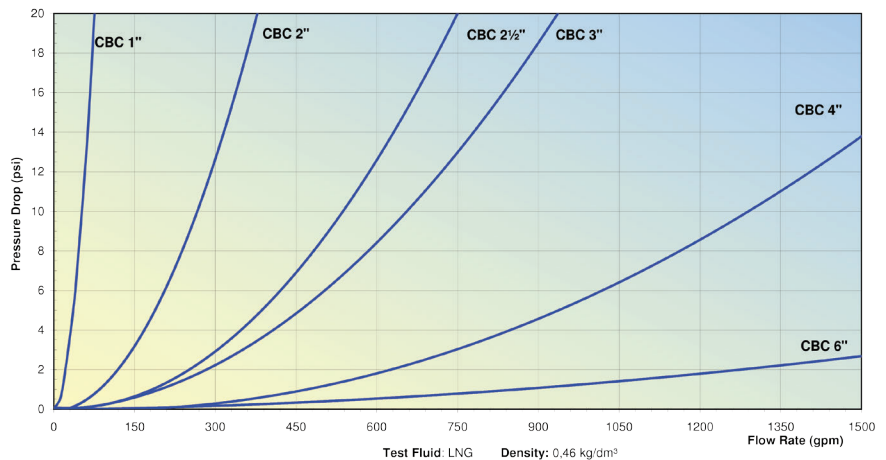


The PERC option is substantially more complex than other breakaway coupling options because of the power pack, activation equipment and other components that are necessary to accomplish PERC’s “on-demand” breakaway functionality. But for some operators, the added expense is worthwhile based on how their bunkering operations are set up, as well as the need for safety.

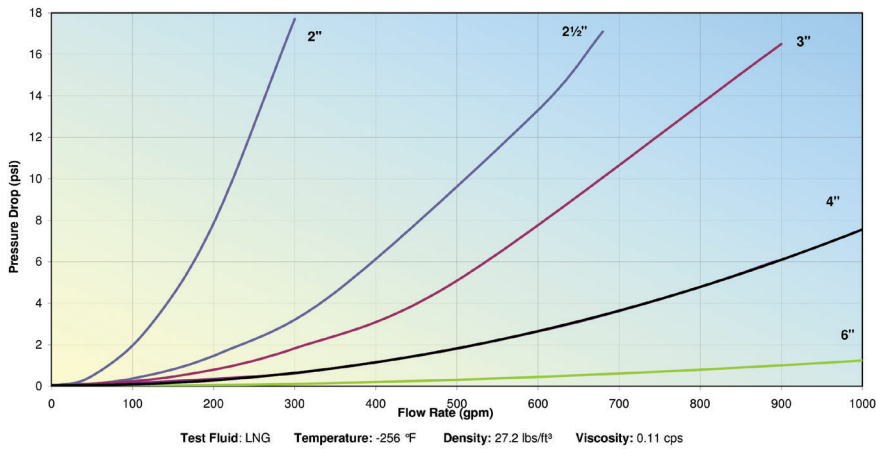
With all breakaway couplings, repair kits are available that enable the bunkering operation to be brought back online quickly – usually within an hour’s time. Commonly referred to as a “breaking bolt” and “seal kits,” they include new breaking bolts that are installed following draining of the line, replacing the seals, and then pushing the two hose assembly halves back together.

In fuel bunkering, the smaller the hose assembly, the easier it is to maneuver the

Cryogenic Breakaway Coupling Flow



Dry Disconnect Flow



systems due to their lighter weight and lower connection force requirements. In the chart on Page 7, a 6-inch coupler is matched to a 6-inch hose, which would pump approximately 72,000 gallons of LNG fuel per hose.

Also affecting the flow rate is the choice of hose size and the breakaway coupling, which is why engineers consider both in tandem when designing their system. The chart above shows the pressure drop associated with pumping LNG fuel using different hose sizes with a breakaway in line.

What About Safety?

To the casual observer, LNG is sometimes thought of as a dangerous substance and its transport fraught with danger. But that perception doesn't match at all with the reality.

It is true that as a cryogenic material, LNG is a liquid and its vapors are flammable. As such, there are some potential safety risks associated with LNG. That being stated, LNG can be produced, transported and re-vaporized as safely – and in most cases more safely – than other liquid energy fuels. It has the best safety record of all common fuel types – particularly when compared to refineries and other petrochemical segments.

In nearly 35,000 shiploads of LNG traveling well over 100 million miles, there is no record of any fire occurring on the deck or in the cargo tanks of any LNG ship. One reported fatality at an LNG terminal occurred in 1977, when a large-diameter valve ruptured and a worker was sprayed with LNG. The worker's death occurred not because the LNG ignited, but because of his contact with the very cold LNG liquid.

LNG's enviable safety record makes it

easy to understand why insurance rates average 25% lower for LNG container shipping than for crude oil shipping. Moreover, the liability within the insurance coverage is focused on fire and property damage rather than on environmental pollution. That's because if LNG spills on the ground, it vaporizes into non-toxic methane vapors that dissipate quickly, leaving behind no residue.

LNG spills on water do not damage waterways or harm aquatic life. The only danger is of a vapor cloud catching fire before dissipating, if there is a sufficient source of ignition.

As for any other environmental concerns, LNG can be readily produced from bio-methane, which means that it can be a renewable fuel – essentially the greenest as well as safest fuel available in the world.

Dixon couplings and retention devices are designed to work safely for their intended use. It is recommended that all hose assemblies be inspected regularly (before each use) to ensure that they are not damaged or have become loose. If any problem is detected, hose assemblies must be removed from service immediately.

Next Up: Trucks, Trains and More

While much of the historical and current focus is on LNG fuel usage in the maritime industry, interest in LNG extends to other forms of transportation as well. UPS has more than 2,500 natural gas-powered vehicles on the road today, nearly half of which use LNG and the remainder use CNG (compressed natural gas).

The heavy truck industry is also in the midst of switching to cleaner fuels as part of the wider societal trend to reduce emissions.

One example is Caterpillar, where certain mining activities are being handled by its LNG-powered big-haul trucks.

The railroad industry is also exploring LNG in a major way – actively considering the conversion of diesel locomotives to run on LNG. Such actions would require major retrofits and are therefore costly, but the economics are beginning to look promising. A major railroad in Florida has 24 LNG-powered locomotives in service currently.

Beyond the transportation and off-highway vehicles markets, the potential for LNG looks promising as well. Asphalt plants are recognizing the potential for LNG to displace less-clean fuels traditionally used in preparing the asphalt mixture. In Jamaica, Red Stripe's brewery operations are reportedly switching from heavy fuel oil to LNG in the boilers they use for sterilizing beer. And in three Canadian provinces, facilities mining diamonds, gold, copper, zinc and molybdenum are being developed that will use LNG to power their electric generators.

And just when it seems that the sky's the limit when it comes to the expansion of LNG into many new sectors, we discover that LNG is poised to go beyond even that. Space launch company United Launch Alliance is working with Blue Origin, a privately-funded aerospace firm owned by Amazon.com founder Jeff Bezos, to develop a new rocket engine fueled by LNG. According to Bezos, the goal of the project is to develop technologies that enable human access to space at significantly lower cost. Testing on the newly developed engine is in currently in process, with first flights anticipated before 2020. ◆

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Founded in 1916, Dixon is a premier U.S.-based worldwide manufacturer and supplier of hose couplings, valves, dry disconnects, swivels and other fluid transfer and control products. Dixon's products and services support a wide range of industries including chemical processing, petroleum exploration, refining and transportation, steelmaking, construction, mining, manufacturing and processing. dixonvalve.com • 877-963-4966