NOT YOUR FATHER’S LNG PRODUCTION FACILITY

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ABSTRACT
The development of shale gas and the associated widening of the cost spread between natural gas distillate fuels has caused a gold rush of enthusiasm to develop small-scale LNG production facilities. Not since the mid-1970s has there been so much activity in this area, but back then it was for natural gas winter peakshaving support. Now the excitement is founded on over-the-road distribution of LNG to displace diesel in heavy duty trucks and stationary engines and distillate fuels used in off gas system industries. Developers are seeking 'standardized' designs, tolerance of feed gas compositional changes, operating simplicity and production turndown. Additional challenges to the developers are imposed by LNG storage optimization, regen gas and NGL use, boil off gas minimization, high ethane composition and simplification of the LNG truck loading process and custody transfer. This paper will review the potential over-the-road LNG market and the end-use equipment required but mostly the focus will be on the new thinking on the LNG production facility. This would include discussions on gas pretreatment, options and alternatives in small-scale liquefaction, modularization of the various systems, LNG storage advances and unattended LNG truck loading realities. The author will also relate how existing regulated LNG peakshavers can play a significant role in the evolving conventional fuel displacement model.

INTRODUCTION
The development of shale gas and the associated widening of the cost spread between natural gas and distillate fuels have caused a gold rush of enthusiasm to develop small-scale LNG production facilities. Not since the mid-1970s has there been so much activity in this area, but back then it was for natural gas winter peakshaving support. Now the excitement is founded on over-the-road distribution of LNG to displace diesel in heavy duty trucks and stationary engines and distillate fuels used in off gas system industries.

There were many LNG “peakshavers” built over the last 40 years. For various reasons, many now find that their original need has been greatly diminished and, in some cases, found unnecessary. How might these facilities help develop the new “vehicular LNG” market? What facility enhancements are needed to best utilize these assets?

To expand the vehicular LNG supply, developers of these new LNG production facilities are seeking “standardized” designs, high tolerance of feed gas compositional changes, operating simplicity and production turndown. Additional challenges to the developers might include LNG storage sizing optimization, boil off gas (“BOG”) minimization, high ethane composition and the simplification of the LNG truck loading process.

What this Paper is About
This paper will review the technological history of small liquefiers, particularly in the U.S. then review the drivers that are making many of these old facilities desirable as part of an overall strategy to “boot strap” the vehicular LNG market along with new, purpose-built LNG production facilities. The author will also relate how existing regulated LNG peakshavers can play a significant role in the evolving conventional fuel displacement model. Further, the combination of 30+ year-old LNG peakshavers and changing liquefaction feed gas composition have resulted in many of these facilities operating well away from optimum resulting in reduced production and/or increased operating costs. The author will discuss a straightforward approach to returning the facility to an optimized operation.
Lastly, the paper will look at the new thinking in the design and operation of state-of-the-art of small-scale LNG production facilities. If the reader expects to see discussion of liquefaction rates in terms of million tonnes per annum (MTPA), this is not the paper as most systems discussed herein are in the range of 0.07 to 0.17 MTPA.

**HISTORY OF U.S. LNG PEAKSHAVING**

**Brief History of Early U.S. LNG Peakshaving**

Beginning in the mid-1960s, gas utilities across the U.S. were studying the demand curves and finding that in the near future their historical gas supplies and gas pipeline networks capacities were going to be exceeded during the coldest periods of the winter. Where applicable these utilities utilized underground storage and/or propane-air facilities to “peak shave” these needle demands. In other areas of the U.S., for a variety of reasons these methods were not available or appropriate.

For many the answer was LNG peakshaving, that is, install a small natural gas pretreatment and liquefaction facility, slowly fill a large LNG storage tank over nominally 200 days such that on the coldest periods of the subsequent winter the LNG could pumped out of the tank, vaporized and injected into the gas distribution system to maintain pressure integrity. Figure 1 below provides a graphical representation of how many utilities chose to add LNG peakshaving in the period of 1965 through 1978. These facilities were built in 25 different states across the U.S. in areas lacking alternative peakshaving means.

![Figure 1: Number of U.S LNG Peakshavers Built per Year in the Period of 1965 to 1978](image)

**Design Variation of LNG Peakshavers**

With a few exceptions, one aspect of the historical LNG peakshavers was the relative lack of consistency in the design of the facilities. The author has previously described the approach to a given liquefaction system as a “chemical engineer’s dream and operations nightmare.” By that is meant that each facility was viewed as a “one of a kind,” each liquefier custom designed for its specific conditions. In order to deal with low feed gas pressure, for example, the technology provider might use multiple heat exchangers, control valves and phase separators on the mixed refrigerant side rather than install simple feed gas booster compressor and eliminate most of the additional equipment.
Of the 50 facilities represented in Figure 1, 56 different liquefiers were built with some facilities having multiple liquefiers. Table 1 provides a listing of the different liquefaction technologies applied. It should not be assumed that many of the mixed refrigerant or cascade systems were similar to others and each let down liquefier was certainly unique to its location.

Table 1: Liquefaction Technology Variation

<table>
<thead>
<tr>
<th>Basic Liquefaction Technology</th>
<th>Number Built</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed Refrigerant</td>
<td>26</td>
</tr>
<tr>
<td>Cascade</td>
<td>11</td>
</tr>
<tr>
<td>Let Down Expansion</td>
<td>9</td>
</tr>
<tr>
<td>Nitrogen Expansion</td>
<td>7</td>
</tr>
<tr>
<td>“Other”</td>
<td>3</td>
</tr>
</tbody>
</table>

Summary on Early U.S. LNG Peakshaving

The LNG facilities discussed above played a very important in meeting winter peakshaving needs when first constructed but today many of them represent obsolete or underutilized gas utility assets.

WHAT HAS HAPPENED SINCE 1978?

Interstate Gas Transmission System Growth

Over the years since 1978, although, some additional LNG peakshavers were built, the U.S. was also undergoing substantial growth in new interstate gas transmission infrastructure. This growth continues through today. Some of these pipelines greatly diminished the original need of nearby LNG peakshavers, reducing their operation to one of standby condition. Similarly, the availability of low cost imported LNG delivered by truck resulted in a number of LNG peakshaving liquefiers being “abandoned in place.” No matter what reason a given LNG peakshaver discontinued or minimized liquefaction, all of these facilities typically maintained a large underutilized LNG tank. With the exception of two of these tanks, typically in the range of 250 mmmscf (3 million gallons) to 2 bcf (24 million gallons), all remain today.

For those readers that have been promoting NGVs since the early 1990s, you may remember the *Natural Gas Fuels Magazine*. Jim Lewis and I had the privilege of alternatively authoring the Cold Corner column each month. In the August 1993 issue I stated: “According to a recent study by the Institute of Gas Technology, there are currently 53 LNG peakshaving facilities in the U.S. This represents a combined liquefaction capacity of 4.4 million gpd. It is often assumed that these are mostly in the Northeast US. While the Northeast does have its share, LNG facilities are found throughout most of the non gas-producing states, 25 states in all. However, there are some hurdles to the sale of LNG from these facilities, including the lack of truck loading capability, the lack of regulatory permission to sell LNG, and a corporate predisposition to not sell to the vehicle market.” My point was that there was a substantial and geographically diverse potential supply of LNG that could be used to jump start the use of LNG as vehicle fuel. But it wasn’t to be; the economics and, to some extent, engine technology held back adoption at that time.

Impact of Shale Gas

No doubt other papers and presentations at LNG 17 will delve deeply into the impact of the development of huge reserves of shale gas in the U.S. It is certainly the single biggest game changer in the history of the U.S. natural gas industry. Many of the presenters will discuss how shale gas in the U.S. is moving the country toward massive LNG export projects due to the low price of domestic gas. At the time this paper was
prepared, the Henry Hub price for natural gas was US$3.18/mmBtu. According to the U.A. Energy
Information Administration (EIA) the retail price of over-the-road diesel fuel was US$3.89/gallon. The Henry
Hub price converts to about US$0.43 per diesel gallon equivalent. This price gap provides adequate
incentive for developers to investigate the life cycle costs to liquefy, store, transport LNG for vehicle fuel. It
similarly provides the incentive for the end-users to build LNG vehicle fuel station(s) and purchase heavy-
duty LNG-fueled equipment.

DEVELOPMENT OF A TRANSITIONAL VEHICULAR LNG SUPPLY

First, despite numerous press releases indicating significant growth in the LNG vehicle activity, the U.S.
vehicular LNG industry is still very much in its infancy. The total available production capacity of LNG in the
U.S. today is less than 3 million diesel gallon equivalent. If that were a single refinery it would be one of
the smallest built since the 1950s. The point is not to disparage in any way the current growth of the industry, but
more to move toward thinking how does the industry grow out of this infancy. This paper will leave
discussions on the development of better and lower cost LNG vehicles to others. The focus going forward in
this paper is how to best utilize existing LNG assets and setting a course for newer and bigger and bigger
purpose-built LNG production facilities.

Use of Existing LNG Peakshaver Liquefiers

Independent of the physical condition of the liquefaction system installed at any given LNG peakshaving
facility is the reality that the facility has a substantial LNG storage tank when its volume is compared against
volumes of recent purpose-built facilities. Take, for example, the 1.8 million gallon LNG storage tank at the
Clean Energy California LNG Plant in Boron, CA. The smallest LNG tank of the historical LNG peakshavers
is about 10% bigger, but the average size tank is eight times bigger.

Realistically, there are very few of these "peakers" that would support long-term growth; they would,
however, in many cases provide some transitional support for a growing vehicular LNG market.

What does this mean? While many of these peakers could begin production of “transitional” LNG in the near
future,4 using their existing LNG production system, more importantly, the large LNG storage tank will allow
the installation of a substantially larger liquefaction system than those facilities with a “10-day” storage
capacity. Economics of scale will benefit the facility, granted capital is expended based on future growth.
Consider a simple, but surprisingly representative rule of factoring; the cost of building a given system versus
a larger unit follows the following equation:

\[ \text{Cost}_2 = \text{Cost}_1 \times \left( \frac{\text{Size}_2}{\text{Size}_1} \right)^{0.60} \]

If the cost of and capacity of a given sized system is known, the cost of a system of a different size is a
function of the original size times the ratio of the sizes raised to the 0.6 power. For example, assume a
pretreatment and liquefaction system that produces 100,000 gallon/day of LNG costs 100 monetary units; a
pretreatment and liquefaction system that produces 200,000 gallon/day of LNG would cost about 150% more, i.e., 150 units. Whereas, to built 2 x 100,000 gallon/day would cost 200 units.

What does this mean for an existing LNG peakshaving facility? Pre-investment of capital for a new
considerably larger liquefaction system is justified by the ability to liquefy at a very high rate, store in existing
large LNG storage and shut down liquefaction until the inventory needs to be replenished. As demand
grows, the large liquefaction system is run more often, while taking advantage of a lower unit capital cost for
production capacity. Conversely, a purpose-built facility must continue to expand both liquefaction and
storage capacity as the market grows, leaving the existing peakshaver with a substantial competitive
advantage.
If owner/operators of an existing peakshaving facility choose to follow the path described above, there would be other modifications to consider to better suit the vehicular LNG market, such as:

- Design the new liquefaction system for year-round operation. Liquefaction plants actually have better performance during the cold months with better cooling temperatures, but steps must be taken to assure that anything, such as amine acid gas removal systems, that can be detrimentally affected by cold temperatures are properly protected.

- Upgrade LNG trailer loading stations to minimize the impact of loading on the day-to-day operation of the LNG facility by placing the trailer loading station outside the main secured area of the LNG facility and allowing LNG truck drivers to perform all of the trailer loading operation at a nominal 350 gpm such that the LNG transfer requires about 30 minutes. This requires additional automation of the loading procedure, integration of drive-on scales and a separate, secured ingress and egress for LNG trucks. Consider the example below at left where an existing LNG peakshaver has a highly manual LNG loading operation (requiring facility operators to control loading process) within its secured plant proper area. The same facility, shown at right, is modified conceptually to place the same loading area outside the primary plant security system with an automated system that allows the truck driver to perform the loading operation with custody transfer integrated into drive-on scales simplifying the invoicing process.

![Figure 2-1: Conventional LNG Loading](image1)
![Figure 2-2: Upgraded LNG Loading](image2)

Most LNG peakshavers will remain to some extent LNG peakshavers, meaning that there may still be times when LNG must be pumped out of the LNG tank, vaporized and injected into the gas distribution system. As such, when moving into vehicular LNG sales LNG sendout capability must be maintained. These LNG peakshavers typically require LNG pumps that provide significantly higher pressures than those needed only for LNG trailer loading. Having said that, LNG peakshaving facilities almost exclusively utilize centrifugal pumps which benefit from the hydraulic “Affinity Laws.” Simply put, the flow from a pump varies directly with the speed of the pump, while the pressure is proportional to the ratio of pump speed squared. For example, if the pump design was to deliver 500 gpm at a head of 300 psi, then by slowing down the pump to 350 gpm (70%), the pump would deliver a much more appropriate 150 psi. Of course, this may not work for all facilities, but the retrofitting of a variable frequency driver (VFD) and possible upgrade of the pump motor may be a very simple solution to providing a single pump that serves double duty.

- Lastly, consideration must be given to the access to the LNG facility in terms of quality of access roads and routing of the LNG trucks. Increased LNG trucking can be seen by the public as an increased safety hazard or a variety of other issues. Public reaction to the El Paso Energy and Southern LNG proposal for LNG trucks to travel through the city of Savannah in late 2011 is one such example.

In closing on this topic, it should be noted that many existing LNG peakshavers are also near large metropolitan areas minimizing LNG transport costs and favoring sales to large, centralized LNG vehicle fueling stations.
Impact of Regulated LNG Peakshavers

During the 1990s it seemed that most regulated LNG operators believed that trying to assign some of their assets (LNG production or storage) to an off-system sale of LNG for vehicular use would jeopardize the current rate base protection. They may or may not have been correct in their positions, but today it matters less. As previously mentioned, the advent of supply from new gas transmission systems has dramatically reduced the need for the original LNG peakshaver storage and sendout requirements. Some LNG peakshavers are even finding issues with the lack of winter peakshaving demand causing “aging” issues with their LNG in storage. Some are required to take extraordinary actions in sending out current LNG inventories in order to keep the quality of the LNG composition within gas pipeline tariffs.

The primary purpose of a state public utilities regulatory body is to protect the rate base payer, i.e., to assure that the utility is not taking advantage of a monopoly position. If a given utility is keeping the physical assets of an LNG peakshaving facility “on the books” for the increasingly rare need (although real) of winter peakshaving; then any venture that generates outside revenues for the utility can thus be removed from the rate base payers obligations thereby reducing the cost to the rate base. The author has found in discussions with various state regulatory bodies, that reducing the cost to the rate base is usually considered a “good thing.”

Gas utilities have historically been very change-adverse organizations – “If it ain’t broke, don’t fix it.” This attitude can sometimes stand in the way of the better good. If the existing LNG production and storage assets not truly required for winter peakshaving were immediately made available to produce vehicular LNG, the market could grow much faster than is currently being experienced in the U.S.

Optimization of Older Liquefaction Systems

Two major factors contribute to the decline in the production rate of LNG peakshaving facilities as they age. The first is the decrease in the equipment efficiencies over time. As mentioned, most peakshavers are at least 30 years old, some over almost 50, and the consequent drop in the efficiencies of the key equipment such as the refrigerant compressors is inevitable and will result in production losses. The second is that almost every plant has a different feed gas composition or battery limit condition today than it did when it was originally designed and started up. Since the design of the refrigeration loop is directly based on the feed gas composition, temperature and pressure, any variation in the feed gas condition can negatively affect the production rate.

There are liquefaction optimization programs that can perform independent diagnostics of the entire liquefaction system. Once the diagnostic phase has been completed, the owner/operator can implement the improvements that allow moving to a monitoring phase where regular rigorous model-based performance monitoring and off-line optimization can be performed to assure that the liquefaction plant continues to operate at peak efficiencies and production rates.

If an LNG peakshaver is considering returning to a high level of operation, these optimization techniques can reduce operating costs while operating at the optimum set points and mixed refrigerant compositions to thereby further prolong the life of equipment.

The “Other” LNG Vehicle

Although it may have been missed by some, the North American Emission Control Area (ECA), under the International Convention for the Prevention of Pollution from Ships, came into effect in August 2012, bringing in stricter controls on emissions of sulfur oxide (SOx), nitrogen oxide (NOx) and particulate matter (PM) for ships trading within 200 nautical miles of the coasts of most of the U. S. and Canada by January 2015 (see Figure 3 below).
These newly imposed regulations will dramatically impact how marine vessels are fueled. A number of operating companies have already announced plans to convert to natural gas fuels, meaning LNG. Given the 2015 timetable, existing LNG peakshavers with marine access, and there are a number of them, would seem to have a distinct benefit over trucking these volumes to a new marine LNG fueling terminal.

**Small-Scale Purpose Built LNG Production Facilities**

It is certainly not the purpose of this paper to diminish the role developers of purpose built LNG production facilities have had on the growth to-date of the vehicular LNG industry. These developers are to be commended for their efforts in the incremental development of a transitional vehicular LNG supply. Many of these facilities have pre-invested for future growth, as well. Back when the author provided the “Cold Corner” mentioned earlier in this paper, the common refrain was “Is it chicken or the egg?” The developers of these purpose-built facilities obviously chose to ignore that question and chose to move in favor of a developing vehicular LNG market deserving tremendous credit of their convictions.

**WHAT MIGHT THE FUTURE LOOK LIKE?**

The future involves clear incentive to investigate how to best utilize the existing LNG peakshaving assets as well as develop strategically located purpose-built LNG production terminals. The topic of expanding the use of existing LNG peakshavers has been covered in the previous sections, what remains is improved concepts for new, larger-scale LNG production facilities built specifically for addressing the vehicular LNG market.

The author does not believe that the future of vehicular LNG lies in building numerous 100,000 gallon per day natural gas liquefaction plants. The future lies in thinking like the early crude oil refiners when it could be seen that gasoline was to become the new transportation fuel. To be clear, the author does not believe that LNG will ever take the market share of diesel in any foreseeable future which now stands at about 150 million gallons per day, however a small percentage of the diesel market is still a very large market. One challenge facing LNG production facility developers is to on one hand match capital expenditures on constructing new LNG facilities with near-term markets and yet not under-build for what clearly could become a substantial long-term market as there are real economics of scale in the construction costs of these facilities.
The “long-term” as intended herein, addresses growth of vehicular LNG production facilities moving from the “small-scale 100,000 gpd” (~8 mmscfd) facilities to substantial production facilities approaching “mid-scale,” i.e., 150 mmscfd, approaching 2 million gallons per day.

New LNG Production Facilities

Table 1 listed the generic liquefaction technologies used in the early years. Which ones fit looking forward?

- **Mixed Refrigerant** (MR) offers very good efficiencies due to using a boiling liquid as part of its heat exchange and is scalable to much larger facilities than historically built; it provides reasonably simple operation and has a proven track record.

- **Cascade** for small-scale liquefiers “has proven to be too complex and costly” to quote Brian Price in his Summer 2012 *LNG Industry* article. When vehicular LNG production facilities begin approaching mid-scale the author believes that cascade may offer some benefits.

- **Let Down Expansion** is very site-specific, typically located within “city gates” minimizing the possibility of siting adequate LNG storage and requiring future expansion to be a different liquefaction technology.

- **Nitrogen Expansion**, unlike MR, provides refrigeration only through sensible heat exchange and, thus, lower efficiencies and a substantially larger compressor than MR. To-date the largest Nitrogen Expansion liquefaction unit built appears to be on the order of 15 mmscfd or 180,000 gpd. Nitrogen Expansion is a relatively simple technology, easy to start-up and shut down and does not have flammable refrigerant making it a desirable technology for LNG peakshavers and small-scale vehicular LNG production, however.

- **Other**, for the purpose of liquefaction projects approaching mid-scale, would include using propane or other viable “pre-cooling” media for both the feed gas as well as the refrigerant.

Based on the above, the author believes the next generation of small-scale to mid-scale LNG production facilities will be predominantly be of a mixed refrigerant design and as the sizes approach 1.0 MTPA (143 mmscfd) pre-cooling systems will be incorporated into the design.

Not Your Father’s MR Liquefaction Technology

Beginning in the early 1970s, many of the MR systems in the original peak shavers were Black & Veatch’s (B&V) PRICO® mixed refrigerant process technology. B&V has no doubt continued to optimize the original PRICO® design since the 1970s, as their “World-Class LNG Capabilities” brochure indicates the PRICO technology can be applied to facilities well beyond any liquefaction plant size for production of vehicular LNG being considered. It should be noted that the original PRICO MR design has also been adopted by other technology providers incorporating their own “tweaks” to the process design. In terms of the design of larger and larger vehicular LNG production units a couple of points to consider are:

- Using single cryogenic heat exchanger, greatly simplifying the construction as well as the training of operation technicians.

- Variation of the design of the single cryogenic heat exchanger whether a brazed aluminum heat exchanger found typically in a “cold box” (See Figure 4) or as a stand-alone spiral wound configuration (See Figure 5).
• The incorporation of a variable frequency driver (VFD) on large compressor motors providing minimization of the initial motor starting inrush as well as provide tighter control of the start-up process minimizing recycle and venting/flaring.

• Simplification of the operation through state-of-the-art control systems thereby minimizing the size and need of operating staff through a 24 hour day.

It is fair to assume as LNG production facilities get larger and large LNG production facilities will begin to look more and more like the liquefaction systems being designed for Cheniere Sabine Pass (ConocoPhillips Optimize Cascade) and Freeport LNG (APCI Propane Pre-Cooled Mixed Refrigerant) or other “World-Class Liquefaction facilities.

As a final comment on this topic, developers need to consider the trade-off between “engineering efficiency” and operator simplicity. Many times the author has found the need to point out that that the Engineer will spend 3 years designing/building the facility but the operating technicians will be spending at least 20 years operating it. Thus, where should the focus in the design be? Complying with the Engineer’s “standard practices” or the implementing a logical, systematic numbering system for equipment, line and instrument numbers? If left to the Engineer it will undoubtedly be the former.

Not Your Father’s LNG Storage Philosophy

As mentioned earlier, LNG peakshavers assumed that LNG storage would handle 200 days of liquefier output. So if the LNG production was 10 mmscfd, the facility would require 200 x 10 mmscf or 2 bcf of storage (24 million gallons). Now developers have to consider only how much storage is needed to cover expected and unexpected outages. The author would suggest that that volume should consider the eventual build-out of all liquefaction capacity. This comment reverts back to belief of the eventual market and the economics of scale.

Take for example an LNG production facility size for 120,000 gallons per day, but with an eventual build-out capacity of 480,000 gallons per day. Assume that 10 days of storage is set as the design basis, i.e., 10 x 120,000 = 1.2 million gallons of storage. For the sake of discussion it is assumed that a full containment, field-erected LNG tank will be used to meet this requirement. Further it is assumed that the installed cost of this tank will be on the order of US$11 million. The choice for the developer is to build storage coincident with the existing liquefaction rate or build initially a tank that will handle the eventual production rate from a fully built out facility. If for every 120,000 gallon per day LNG train built an $11 million tank is added such that at full build out US$44 million is spent on LNG tank construction or, if with the construction of the initial train,
a single tank capable of holding 10 days of 480,000 gallons per day production is built at a cost of US$27 million, an eventual savings of about 40% on LNG storage.

As a side discussion, there is a school of thought that “LNG bullet” tanks (See Figure 6) have a role to play in the development of a viable vehicular LNG supply. The author would suggest this in not the case if LNG is to make a dent in the use of diesel fuel. The tank in Figure 6 reflects the tank needed for one days production from a 120,000 gpd plant, thus it would take ten such tanks to meet a 10 day storage contingency. Now, consider the operation of ten different tanks requiring make-up and at the same time be available to supply LNG trailers fed by separate LNG pumps. The point of this paper is not to drill down into the issues faced other than stating a single tank with internal pumps provides a much more reliable and operable system.

![Figure 6: A 120,000 Gallon “LNG Bullet” Being Moved to LNG Facility](http://www.at-v.com/)

Other analysis suggests that once the required storage of LNG exceeds about 1 million gallons, an FCT field-erected tank will typically be more cost effective. For a single containment design the capacity is more on the order of 500,000 gallons. It may be contrary to conventional thought, but many of the existing air liquefaction plants have cryogenic storage tanks that are virtually of the same design (API 620, Appendix Q) as LNG tanks shown in Figure 7 below. These tanks are not typically constructed by the same companies that build LNG tanks, but they could be.

![Figure 7: Typical Air Liquefaction Liquid Nitrogen/Oxygen Storage Tanks](http://www.at-v.com/)

From AT&V, Inc web site [http://www.at-v.com/](http://www.at-v.com/)
Not Your Father’s LNG Trailer Loading Practice

A key to new LNG production facilities is to separate the main pretreatment, liquefaction and LNG storage activities from the LNG truck loading activities from both physical layouts as well as process control. A state-of-the-art LNG truck loading station will integrate a drive-on scale, electronic card swipe and the control system to determine and control the LNG volume to be transferred as well as provide details of the commercial transaction. The entire loading process will be handled by the driver of the truck, however once the loading hose (and in a small number of cases, the vapor hose) has been connected the process control system will direct the driver when to open or close valves on the trailer. The only valves the driver will control alone are the position of the top and bottom fill valves to control the pressure within the trailer.

The actual loading process should require only about 30 minutes with initial purge and final draining and purging adding a few minutes. Other enhancements in a state-of-the-art LNG truck loading station would include:

- Automatic and complete hose draining and purging
- Recirculation system to provide fully subcooled LNG with no extra vapor generation
- Installation of vacuum-jacketed piping to minimize insulation maintenance, enhance LNG circulation system and minimize BOG generation
- Extended hose life with hose drag protection provided
- Truck drive-away protection
- Weather protection
- Bill of lading generation which includes LNG composition and total volume and heating value of product transferred
- Icing prevention of hose coupling between transfers
- Trailer "Cooldown Mode” for warm trailers
- In some cases, the use of articulated arms instead of hoses

Many of the enhancements above would also be applicable to rail car loading or ship bunkering, which are beyond the abstract of this paper.

Not Your Father’s LNG Siting Regulations

Unless your father was designing LNG facilities in 2012, there are major siting regulations that are affecting all new LNG production facilities in the U.S. with the exception of owner’s of LNG production facilities that are also the end-user of the LNG produced.

Consider the following for U.S.-based projects:

In early 2009, in an effort to develop LNG dispersion model evaluation tools for the NFPA 59A Committee, the Fire Protection Research Foundation (FPRF) funded research on LNG spill source term modeling. In March 2009 its findings were included in a report entitled “LNG Source Term Models for Hazard Analysis: A review of the State-of-the-Art and an Approach to Model Assessment.” The report concluded that the source term model generally used within the industry to provide input to the DEGADIS8 dispersion model, SOURCE 5,9 could result in under-prediction of hazard distances. Further, SOURCE 5 did not always accurately represent vapor accumulation within impoundments, vapor flashing and pool spreading.

Subsequently, in July, 2010, the U.S. Department of Transportation (USDOT) Pipeline and Hazardous Materials Safety Administration (PHMSA) issued written interpretations acknowledging the FPRF findings.
PHMSA also added new requirements in addition to LNG vapor flowing from LNG impoundments that vapor dispersion exclusion zone analysis also include vapor dispersion from:

- Jetting and flashing of a pressurized liquid
- Conveyance of LNG to impoundments

Although the DEGADIS dispersion model was capable of addressing vapor dispersion arising from pooling of LNG spills, it is not capable of solving the requirements to analyze the effects of jetting and flashing and the conveyance of LNG spills to impoundments.

In late 2010, Model Evaluation Protocols and Model Evaluation Reports for two new models were submitted to PHMSA for review and approval. On October 2011 PHMSA issued final approvals allowing the models to be used to perform vapor dispersion analysis to demonstrate compliance with exclusion zones. The approved models now being used to permit the construction of LNG facilities in the U.S. are:

- FLACS\(^{10}\) developed by Gexcon AS of Bergen, Norway.
- PHAST\(^{11}\) developed by Det Norske Veritas of Oslo, Norway.

Thus if you’re a developer looking to build an LNG production facility to supply the vehicular market, your design engineering company must take into account these new siting regulations when preparing any permitting application.

**SUMMARY/CONCLUSIONS**

**We’re Still in Our Infancy**

The author does not want to declare the obvious; however in a recent LNG conference in Houston, Texas it was stated that current vehicular LNG production in the U.S. is approximately 50 LNG trailer loadings per day or about 550,000 LNG gallons per day. This represents about 0.2% of the 150 million gallon per day diesel fuel market. As someone promoting LNG as a vehicle fuel since the mid-1990s, this is a great improvement, but we’re still looking for the proverbial “hockey stick” in our industry. There is now clear economic incentive; the question is simply how quickly will large diesel fleet operators, existing LNG peakshavers with underutilized assets and the entire shale gas production infrastructure realize that the “times they are a-changing”?

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1. Published by RP Publishing, Denver, Colorado.
2. At the time, President of Project Technical Liaison Associates, Inc.
3. About 2.6 million diesel gallons equivalent.
4. Assuming regulatory hurdles have been settled, as discussed later.
5. See “Product Supplied Table” [http://www.eia.gov/](http://www.eia.gov/)
8. Previously accepted vapor dispersion model for siting LNG facilities in the U.S.
9. Previously accepted vapor evolution model supplying DEGADIS for siting LNG facilities in the U.S.
10. Version 9.1
11. Version 6.6 or 6.7