EXPANSION ENERGY

The Patented "VX™ Cycle"

Ultra-Small-Scale, "Mobile LNG™" Production Technology

System Overview & Vehicle Fueling Applications

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Background

Expansion Energy LLC develops and licenses proprietary energy-related technologies, many of which utilize the disciplines of gas processing and cryogenics. The "common threads" that run through Expansion Energy's technology portfolio include the following:

- Optimally balanced compression plus refrigeration, achieving density increases in gases with less energy input than compression or refrigeration alone.
- The recovery of waste heat and cold to substantially improve the efficiency of any compression and refrigeration cycle and to enhance the front-end clean-up system.
- Cost-effectively increasing the density of gases, yielding greater storage and transport capacities, with less energy input and lower emissions per unit of density achieved.

VX™ Cycle Overview & Applications

Expansion Energy's "VX™ Cycle" technology provides cost-effective, ultra-small-scale (1,500 to 100,000+ gallons per day) production of liquefied natural gas (LNG) or cold compressed natural gas ("CCNG™"). This ultra-small scale allows the VX Cycle to be the world's only "Mobile LNG™" technology—able to be skid- or trailer-mounted.

The VX Cycle achieves several goals that are unattainable by other LNG production systems:

- Economic viability at production scales as small as 1,500 gallons per day.
- Cost-effectiveness is achieved by a combination of modest capital costs and exceptionally high production efficiencies.
- Low capital costs are achieved, in part, by the use of proven "off-the-shelf" equipment.
- Multiple heat (and cold) recovery steps achieve the high efficiency.

VX Cycle plants are suitable for a wide range of applications, including the following:

- To produce vehicle-grade LNG (and/or CNG) using feed gas from standard low-pressure (or high-pressure) pipelines or local gas distribution lines. Currently all vehicle-grade LNG in the US is produced at several large plants that are located far from their main customers, requiring the LNG to be trucked to distant fueling stations, which increases transportation costs, emissions and logistical complexity. VX plants allow LNG production right at the fueling station—avoiding the need for transporting the LNG by truck. LNG-fueled vehicles include: trucks, delivery vans, buses, construction & mining equipment, railroad locomotives, and ships/barges/ferries.
- At "stranded" gas wells located far from gas pipelines. VX plants can produce LNG at the well site. That LNG can then be transported by truck to pipelines (where it can be re-gasified and sent to market), or it can be used to fuel nearby drilling rigs, "frac spreads" and field trucks.
- Capturing and monetizing associated gas from oil wells, which would otherwise be flared off.

- Offshore oil & gas platforms—to avoid flaring or the need for expensive subsea pipelines.
- Natural gas storage and "peak shaving."
- Providing LNG for shipping to remote communities or industrial/mining sites.
- On pipelines, to increase the density of the outflow stream from compressor stations.
- Producing LNG from landfill gas (LFG).

Limitations of Current LNG Fuel Production & Distribution Practices

Existing LNG-fueled vehicle fleets depend on tanker deliveries from large-scale, "centralized" plants or import terminals, increasing the cost of the LNG product, adding logistical complexity, and diminishing its environmental advantages. Moreover, the customer must maintain a large storage tank so that frequent deliveries can be avoided.

One alternative is on-site compressed natural gas (CNG) production. However, CNG is not dense, and cannot be stored in large quantities, so it must be made at a high rate during the peak demand period, which raises both capital costs and operating costs. Furthermore, onboard CNG storage tanks are heavy, relative to the amount of fuel they store.

The VX™ Cycle Solution—"Distributed" LNG Production

The relatively low capital cost and small (mobile) footprint of VX Cycle plants and their high operating efficiency provide a cost-effective way to produce LNG right at the fueling station—i.e., "distributed" LNG production. Fueling depots that deploy VX Cycle plants can produce, store, and dispense LNG without depending on tanker deliveries (which large, "centralized" LNG plants require). The on-site LNG storage tank can also dispense CNG or CCNG™ (after cold recovery and re-vaporization of the LNG) to existing CNG fleets that wish to transition to LNG in the future.

Additional Application: Upgrade CNG Fueling Stations to L/CNG Stations Using the VX Cycle

The VX Cycle can be deployed for new LNG/CNG fueling stations, or as an upgrade to existing CNG stations, producing LNG, CNG and CCNG™ (cold compressed natural gas). CCNG is a highly dense, vapor state of natural gas that can be pumped to pressure (which uses less energy), rather than requiring compression alone (as CNG is currently produced). Shortcomings of existing CNG stations include:

- CNG stations cannot "store" any significant amount of product produced during off-peak periods. CNG stations need to be over-designed and over-built (resulting in higher capital costs) so that they can keep up with the peak period dispensing demand.
- If the CNG station is driven by electric power, its peak production output corresponds to the peak demand for electricity—during which power is priced significantly higher.
- If a natural gas engine drives a CNG station, it will be less than 30% efficient. Much of the energy input is lost in the hot exhaust and the hot water jacket of the engine.

- Compressing natural gas from low pressure to more than 3,000 psia results in a significant amount of heat that is thrown away in the inter- and after-coolers.
- During hot months and in hot climates, the heat of compression is difficult to dissipate, causing the compressors to perform poorly and causing further loss of efficiency.
- If warm CNG (i.e., "standard" CNG) is delivered to the vehicle's fuel tank, the tank will seem to be "full" sooner than if cold CNG (which VX Cycle plants can produce) is delivered. Using warm CNG means the onboard vehicle tanks hold fewer BTUs, which limits the vehicle's range and requires it to re-fuel more frequently.
- The density of warm CNG is not especially high. Centrally fueled, heavy-duty trucks and buses require many tanks of CNG if they travel significant distances. Long-haul, heavy-duty trucks are not good candidates for CNG because they will not give up cargo carrying capacity in exchange for carrying many heavy CNG tanks. LNG is the better choice for long-haul trucks and buses.

What Are the Benefits of This L/CNG Fueling Station Model?

The VX Cycle solves all of the problems listed above. Small-scale LNG, CNG and/or CCNG production at existing and future CNG stations will allow LNG to be pumped to pressure, vaporized (and recovering the cold), and dispensed as cool CNG to all existing CNG vehicles. (Note that pumping a cryogenic liquid to any pressure, prior to its vaporization, requires very little energy input because liquids are virtually incompressible.)

The cold content of the pumped-to-pressure LNG is recovered prior to dispensing it as cool CNG. Similarly, low-pressure CCNG can be pumped to CNG pressures, and with cold recovery, dispensed as cool CNG. The VX Cycle offers several "tiers" of dense-phase NG production, yielding many benefits, including the following:

- CNG stations could increase their dispensing capacity by producing LNG 24-hours per day, storing the LNG for dispensing as either LNG or CNG during the peak demand periods, and allowing for a faster dispensing rate to each vehicle.
- Cold CNG will allow more fuel (BTUs) to be stored in each vehicle's CNG tanks.
- The total efficiency of the VX Cycle is better than the efficiency of standard CNG plants because the waste heat produced by the prime mover is recovered, as is the heat of compression. Also, during dispensing of LNG as CNG, its cold content is recovered to help produce the next batch of LNG. Given those heat-recovery and cold-recovery steps, and the fact that the VX Cycle produces LNG at much lower pressures than a standard CNG compressor, the total energy demand of the VX Cycle is competitive with the fuel used by existing CNG systems, making the end product more competitive with gasoline or diesel fuel.
- Because the compressors operate at lower pressures, their maintenance schedules are improved, as are their total life expectancy.
- Upgrading CNG stations with the VX Cycle to allow for L/CNG dispensing yields significant benefits to vehicle owners, to the CNG industry, and to the natural gas vehicle industry on the whole.