Managing Boil-Off at Intermodal LNG Delivery Points

WesMor Cryogenic Manufacturing, Ltd.

Keith Hall
Director of Engineering & Product Development

Keith.Hall@WesMor.com
WesMor Cryogenic Companies

Specialize in the design, manufacture, and repair of Cryogenic Industrial Gas, LNG, and CO2 equipment

- WesMor Cryogenic Manufacturing
  - La Porte, TX

- WesMor Cryogenic Services
  - La Porte, TX
  - Slidell, LA
  - Port Washington, OH
WesMor Cryogenic Companies

• Family business started as a cryogenic repair facility in 1998 by Judy West Morreale and Joe Morreale, Sr.
  • Hence the company name WesMor

• Joe Morreale, Sr. had been with Air Product for 33 years in their maintenance division.

• Began manufacturing new cryogenic equipment in 2007
  • With a solid maintenance and repair background, WesMor has a focused philosophy when it comes to new product designs and manufacturing:
    1. High quality
    2. Operator friendly
    3. Easy to maintain
WesMor Cryogenic Services

- Cryogenic Vacuum Work
- DOT Testing & Inspections
- Piping and Valve Modifications & Repairs
- Complete Rehabilitation of all Manufacturers’ Cryogenic Equipment
- Accident Repairs
WesMor Cryogenic Manufacturing

- Cryogenic Industrial Gas, LNG, & CO2 Transports & Queen Mobile Storage Trailers
WesMor Cryogenic Manufacturing

- Off-Shore & Truck Mount Tanks
- Queen Electric LNG Regasification Trailers
- 16K-173 psi LNG Queen Fueling Station, 6K-173 Portable LNG Fueling Stations, & ISO Container / Skid-Mounted LNG Fueling Stations
- LNG Heat Recovery Regasification Units with our partner Vita International
40-FOOT ISO CONTAINER

Used to ship LNG (liquefied methane), liquefied Ethylene, or liquefied Ethane around the world via truck, train or ship.

70 or 115 MAWP
End or Side Piping

4 Models Available
40-FOOT ISO CONTAINER

4 Models Available

Optional Pressure Building Regulator and By-Pass Valve

Option: Carbon or Stainless Steel Outer Vessel
40-Foot ISO Container

### 70 psi (4.83 bar) MAWP Container

<table>
<thead>
<tr>
<th>Description</th>
<th>11,186 US Gal (42,186 L)</th>
<th>11,602 USG (43,918 L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm Full Volume</td>
<td>22,600 lbs (10,252 kg)</td>
<td>22,800 lbs (10,342 kg)</td>
</tr>
<tr>
<td>Tare Weight</td>
<td>34,785 lbs (15,778 kg)</td>
<td>36,079 lbs (16,365 kg)</td>
</tr>
<tr>
<td>Max. LNG Mass</td>
<td>9,938 gallons (37,619 L)</td>
<td>10,308 USG (39,020 L)</td>
</tr>
<tr>
<td>Hold Times Per IMDG/USDOT</td>
<td></td>
<td>69 DAYS</td>
</tr>
<tr>
<td>5 PSIG to 70 PSIG (.35 Bar TO 4.83 Bar)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 115 psi (7.93 bar) MAWP Container

<table>
<thead>
<tr>
<th>Description</th>
<th>11,093 US Gal (41,992 L)</th>
<th>11,507 USG (43,559 L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm Full Volume</td>
<td>24,500 lbs (11,113 kg)</td>
<td>24,700 lbs (11,204 kg)</td>
</tr>
<tr>
<td>Tare Weight</td>
<td>33,067 lbs (14,999 kg)</td>
<td>34,301 lbs (15,559 kg)</td>
</tr>
<tr>
<td>Max. LNG Mass</td>
<td>9,446 gallons (35,765 L)</td>
<td>9,800 USG (37,097 L)</td>
</tr>
<tr>
<td>Hold Times Per IMDG/USDOT</td>
<td></td>
<td>93 DAYS</td>
</tr>
<tr>
<td>5 PSIG to 115 PSIG (.35 Bar TO 7.93 Bar)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Optimized for tractors weighing 16,600 lbs (7,530 kg) to 14,400 lbs (6,532 kg). Depending upon tractor weight, the fill density may be limited on some models when transporting over-the-road.

Gooseneck Tunnel Design – can be transported on any 40-foot ISO hauling trailer.
40-Foot ISO Container

Many piping options. Optional PB Regulator & By-Pass valve, bottom sparger, etc.
40-Foot ISO Container Piping Schematic
Terms and Practical Definitions

- **NPSH – Net Positive Suction Head**
  - The minimum pressure required, either from the weight of the column of liquid in the tank or from artificial pressure generated using the PBU, for a pump to catch and maintain prime.

- **Sub-Cool**
  - Building artificial pressure to press down on the surface of the liquid to suppress the boiling (the liquid is considered “sub-cooled” as it is actually at a colder temperature than it normally would be at that pressure).

- **Saturation**
  - The amount of heat in the liquid, measured as temperature or pressure. As pressure and temperature are directly related, and all tanks have a pressure gauge, saturation is generally expressed in terms of pressure.
Terms and Practical Definitions

• **Ullage Space & Pressure**
  • The tank pressure is the pressure measured in the head or vapor space above the liquid (also referred to as the ullage space)

• **Pressure Head**
  • The pressure exerted at the bottom of a column of liquid, i.e. the pressure measured at the bottom of the tank

• **Full Trycock**
  • A valved port from the inner vessel which is located at the maximum safe (code defined) fill level. The fill operation is stopped when liquid spews from this valve. On ISO Containers for example, the trycock level is located so that if the tank were filled with zero psi cold liquid and left unused, as heat leaks into the tank and the liquid warms and expands in volume (decreases in density), when the primary relief valve opens at the MAWP of the tank there still must be a 2% ullage space.
Terms and Practical Definitions

- **Sparger**
  - Looks like a Top Fill Spray Header but is located in the bottom of a tank. Is often used in LNG fuel stations in the saturation circuit. Can also be used to introduce vent gas into the bottom of the tank to bubble up through the liquid and recondense. Often simply introducing vent gas to the head space, especially when the tank is full, could cause the relief valve to open.

- **Pressure Building Unit**
  - Can be of many forms, but generally on portable LNG equipment it consists of aluminum star-fins lined with stainless steel tubing. Ambient heat is transferred through the aluminum star-fins, through the stainless steel tubing, and into liquid withdrawn from the bottom of the tank, causing it to vaporize. The vapor is then reintroduced into the top of the tank, to exert added or artificial pressure onto the surface of the liquid.
Why do we care about boil-off gas & venting?

1) We are venting money
2) Methane is said to be a 23 times worse greenhouse gas than CO₂!
Off-Loading an ISO Using a Ground-Mounted Pump

- Connect static grounding cable
- 2 hoses required
  - The liquid supply hose from bottom/drain connection on ISO (C-1) to pump needs to be at least same diameter as the pump’s suction connection (3” recommended)
  - Connect 2\textsuperscript{nd} hose from pump’s recirculation connection back to the Top Fill connection (C-2)
- **TIP:** PROP UP THIS RETURN HOSE SO THERE IS NO LOW POINT, CREATING A VAPOR TRAP
- Purge hoses - only to blow out any dust and humid air, and not to also cool them down
Off-Loading an ISO Using a Ground-Mounted Pump

- Support Return/Recirc hose so that it is always uphill or level (no vapor trap), to facilitate pump cool down.
Off-Loading an ISO Using a Ground-Mounted Pump – Con’t

- Extend the life of the pump seal:
  1. Cool down a 6-7” pump for seven minutes, or a 10” pump for 12 minutes before attempting to catch prime (cooling longer just adds unwanted heat to the liquid)
  2. Before attempting to catch prime make sure you have built 5 psi sub-cool pressure. If cooling down the pump did not provide the necessary 5 psi, open the Pressure Build Valve on the ISO container and build the 5 psi, and maintain it throughout the off-load process. Tip – if the pressure is high in the receiving vessel, before catching prime you can connect a hose between the head spaces of the two vessels to pressurize the ISO without adding heat by using the PBU
  3. After catching prime, while recirculating and while off-loading, maintain back pressure on the pump using the discharge valve as needed
Pressure-Transfer Off-Loading an ISO Container

- Connect static grounding cable
- Connect hose from the Bottom Fill/Drain connection (C-1) on the ISO Container to the Top Fill connection on the receiving vessel
- Purge hose (not to cool, rather to blow out any dust and humid air)
- If pressure in receiving vessel is higher than pressure in the ISO Container, before off-loading open the Top Fill valve on the receiving vessel and just crack open V-2 Bottom Fill valve on ISO Container (assumes V-1 Fire Block is open).
Pressure-Transfer Off-Loading an ISO Container

- Instead of venting receiving vessel, patiently permit higher pressure vapor from receiving vessel to slowly bubble up through the liquid in the ISO Container and recondense (saturating the liquid) until the pressure has equalized. Monitor the ISO pressure and if necessary stop the operation 25 psi below the MAWP of the ISO container
Pressure-Transfer Off-Loading an ISO Container – Con’t

- Open pressure building unit on ISO Container and build 10-20 psi pressure higher than the receiving vessel pressure (stay 5 psi below MAWP, max)
- Then open Bottom Fill / Drain valve V-2 and the Top Fill Valve on the receiving vessel and off-load the product.
  - As you “top fill” the liquid from the ISO container should be colder and rain down through the warmer vapor in the receiving vessel, causing the pressure in the receiving vessel to drop and the transfer flow rate to increase.
- If required, vent receiving vessel only enough to keep the liquid flowing
Tips for Designing, Managing, and Operating LNG Systems

• Design piping circuits so that after off-loading product, and before disconnecting the transfer hose, you can close the drain valve and open a valve from the top of the tank to use vapor pressure to “push” all the liquid from the hose into the receiving vessel (as is done for CO₂). This way you will only be venting one hose volume of pressurized vapor instead of venting 639 equivalent volumes if venting liquid to drain the hose.

• Keep dust plugs on hoses and pressure caps on fill connections to keep them clean. This will aid in minimizing subsequent purge (venting) operations.

• Additionally, the pressure caps are required as they serve as the 3rd required isolation device on ISO containers (along with the Fire Block and other valve on each circuit)
Tips for Designing, Managing, and Operating LNG Systems

- Consider adding a sacrificial liquid nitrogen “de-saturation” circuit inside your tank
  - Relatively inexpensive liquid nitrogen flows through tubing inside your LNG tank
  - Heat from the LNG and methane vapor is transferred into the colder nitrogen and the nitrogen vapor is vented back into the atmosphere from whence it came
To avoid the unnecessary venting of methane from trapped liquid thermal safety line relief valves, include a back pressure regulator on the circuit and pipe it back into the supply tank.

- The set pressure on the back pressure regulator must be greater than the operating pressure, but less than the line relief valve setting when the tank’s MAWP is added to it.
- Note, the tank’s pressure pushing backwards against the back pressure regulator is additive to spring setting.
Other Tips to Minimize Venting

- For intermittent flow applications, or where you may experience brief interruptions in the vaporization process, include an accumulator tank in your vaporization system with a safe but higher than operating pressure relief valve.

- Use as high rated line relief valves as is safe for every component in the piping circuit, and ensure it flow capacity is sufficient.

- Where venting is expected, include a flare stack in your system design.
Tips for ISO Containers

- Purchase a Pressure Building Regulator & PB By-Pass Valve on your ISO Container
  - Gives you the unattended versatility to supply liquid to an end-use application, i.e. a vaporizer. Without a regulator someone has to stand beside the container and manually regulate the tank pressure
  - The PB By-Pass valve permits you to manually build pressure in excess of the regulator’s setting whenever needed.
Tips for ISO Containers

- Pre-cool warm containers using cold nitrogen vapor to avoid or limit the venting of methane when filling
  - Blow down to just a couple of psi (maintain a positive pressure)
  - Depending upon your purity requirements you may not need to vent methane to purge away the nitrogen vapor
  - One volume of nitrogen at a given pressure will only be 1/639th of the filled volume of liquid at the same pressure
  - 1/639th nitrogen vapor = 99.998436% purity of the LNG/methane vapor
Other Tips to Minimize Venting

- Use the Vapor Recovery connection when filling at a fill plant to recover the vapor; or to equalize pressure before filling, to minimize venting.

- Use insulated piping or hoses where possible
  - Vacuum jacketed for permanent or semi-permanent installations
  - Insulated for permanent or semi-permanent installations
    - i.e. Cryogel-Z (based on NASA’s aerogel insulation).
Other Tips to Minimize Venting

- Re-Fill a tank at high pressure with cold liquid to knock down the pressure before the primary relief valve opens
  - Ideally, if you can size the tank and schedule deliveries to be able to dump a full load of product each time, it is more economical for you and you will vent less product to the atmosphere
  - When filling at the proper refill level there is a smaller quantity of saturated liquid to mix with the large quantity of cold liquid being introduced, leaving the tank at a lower saturation (pressure) condition
  - And you can fit more cold molecules into the tank than warm molecules
Other Tips to Minimize Venting

- Re-Fill with cold liquid to knock down tank pressure before the primary relief valve opens
  - Optimally if you can size the tank, and schedule the delivery to be able to dump a full load of product at a time it is more economical for you
  - And there is a smaller quantity of saturated liquid to mix with the large quantity of cold liquid, leaving the tank at a lower saturation (pressure) condition
  - And you can fit more cold molecules into the tank than warm molecules
Tips for ISO Containers

- Drain as much product from the container as possible; but know the maximum heel weight you could leave.
  - If all residual product warms on the return trip, and turns to vapor, you must ensure that it is not enough to lift the container’s relief valve.
Natural Gas - $aving you and the environment (when combusted, not vented)