Ballancing Liquid and Gas Sales at Helium Facilities with Liquefiers

By James Evans West of RMW Solutions, LLC

Industrial gas companies and distributors routinely vent vaporized oxygen and nitrogen when filling dewars or transferring liquid. However, the value of helium makes it too expensive to vent. So when the amount of liquid helium vaporizing at a facility is greater than helium gas sales or use as a gas, steps must be taken to prevent venting or reliquefy the helium.

Helium is transported as a liquid in 11,000 gallon ISO containers or 15,000 gallon trailers, from the mostly remote production plants to large liquid helium users, industrial gas companies and distributors cylinder and dewar filling facilities all over the world. The transported helium is used in manufacturing processes or decanted into liquid dewars and/or compressed into cylinders and tube trailers at transfill facilities. If the proportion of helium sold as liquid in dewars exceeds approximately 30 percent of total helium usage, excessive helium gas will be accumulated by the facility.

Figure 1

Liquid helium vaporizes as a result of time in transportation, storage and re-handling. Some vaporization of liquid helium occurs when an arriving container is depressurized, when transferring liquid to dewars and due to storage equipment heat leak. Vaporized helium is collected and compressed into cylinders or tube trailers. If that volume is insufficient to meet gas sales, then additional liquid helium is purposely vaporized and compressed into cylinders and tube trailers. In the event the proportion of helium sold as liquid increases, the amount vaporized may exceed the local gas market. Also as helium has become more expensive, some larger consumers recover portions of helium used in their own processes, and sell it back to the supplier or to a third party. All of this may present a facility operator with a dilemma. If the liquid sales are to be satisfied, helium will have to be vented or techniques employed to reduce vaporization that may include the installation of a helium liquefier.

Vaporization As a Result of Transportation & Depressurization

Liquid helium is filled into the transports at current production plants located in the Western U.S., Algeria, Poland and Russia. Additional plants will come onstream in the next few years in Algeria and Qatar. Within the U.S. some liquid helium is transported in 15,000 gallon trailers, but any overseas shipments are in ISO containers which hold 11,000 gallons (1,100,000 scf or 41,300 liters). Half size containers are available but infrequently used. Most containers are bottled up after filling, and remain that way while in transit. The inner liquid helium vessel under a high vacuum and wrapped with super insulation is surrounded by a thin metal enclosure (shield) that is cooled with liquid nitrogen. The liquid nitrogen shield absorbs much of the heat transferring through the vacuum before it reaches the liquid helium. The helium pressure rises during the time the container is bottled up in transit due to the heat leak into the contained liquid helium. The container pressure rises more rapidly if the percent ullage decreases. Most shipments are made with a five percent ullage. (The percent of the vessel not filled with liquid.)

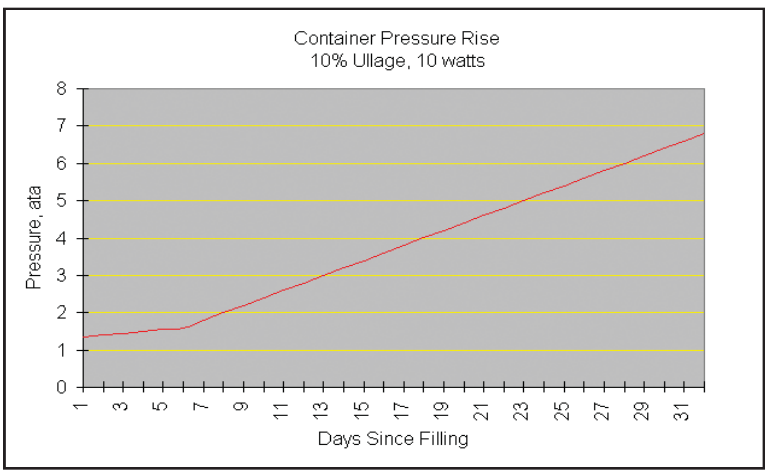

Figure 2

Typical pressure rises

for a shipped container is shown in Figure 2. The container pressure rises slowly below the critical pressure, and then more rapidly.

Container route time can range from two days to 15 days, but shipments to remote locations, such as the Pacific Rim, Australia, South America and Africa will encompass 30 days or more.

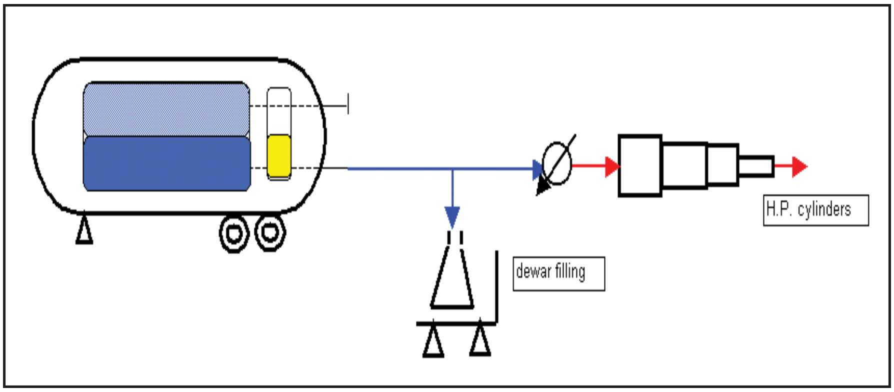

Figure 3

Once the container arrives at a facility, it must be depressured below its critical pressure (two bara) and preferably to less than 1.4 bara if efficient dewar filling is required. As helium is removed from the container, the removed fluid expands isenthalpically, and the fluid remaining in the container, isentropically. The quantity that must be removed to reach 1.4 bara depends upon the time (which results in pressure rise) the container was in transit.

For a 10-day transit, only about five percent of the container volume will have to be removed before dewar filling can begin. However, for a 30 day trip the quantity to be removed reaches 18 percent or more of the total amount of shipped helium. Helium transfill facilities are normally equipped with cylinder filling compressors having capacities ranging from 5,000 scfh (132 nm3/hr) to 20,000 scfh (526 nm3/hr). Therefore the time to de-pressure can be as long as 40 hours after a 30 day container trip. Enough empty cylinders, tube trailers and/or onsite gas storage must be available to received the removed helium gas. Unlike the air gases, high-pressure liquid pumps for helium are rarely used. Only one manufacturer has a proven pump, but a compressor is still needed to recover helium during dewar filling and similar tasks. Therefore at remote facilities, sizeable quantities of gas must be removed and stored before dewar filling can begin.

At a transfill facility, the container is used as a storage vessel while onsite. Normally when a full container is delivered, an empty one is away. Dewars are filled by decanting liquid from container into a dewar, once the container pressure is reduced. If permanent liquid storage is installed at a transfill, filling helium storage adds another vaporization step. The major industrial gas firms will invest in more containers rather than add a permanent liquid storage.

While the container is onsite, its heat leak will continue to vaporize liquid at the rate of about 1/4 percent/day of the container volume, which for 30 days is about seven percent of the helium delivered. This quantity is not as significant as the vaporization that occurs from the other steps. On-site container heat leak is less important in large liquid consuming facilities since transport is onsite a short amount of time. Offsetting that to some degree is the container pressure decay, as product is withdrawn.

Vaporization of Helium During Dewar Filling

As shown in figure 3, when filling of liquid helium into dewars from the container, approximately 30 to 50 percent of the helium transferred will vaporize and is too expensive to vent. Therefore, the vaporized helium is warmed and recovered either into a “gas bag” or directly into an onsite recovery compressor. The quantity of helium vaporized will be determined by 1) the pressure of the container, 2) the dewar back pressure, 3) the quality of the transfer system and 4) the temperature of the dewar to be filled. A well-designed system with pre-cooled dewars will not only lower vaporization but also minimize helium losses to the atmosphere.

Once an on-site container is empty of liquid helium, a considerable amount of cold dense helium gas remains. The density of saturated helium vapor is such that 15 percent of the container capacity remains after all liquid is withdrawn. It does not make sense to send all that remaining helium back to the production plant. In fact, the production plant will charge an extra fee, since re-liquefying the helium will be an additional liquefaction load on the production plant liquefier. The residual helium can be removed by adding a small quantity of ambient temperature gaseous helium into the inner vessel, just enough to warm the residual helium to about 20K. The container pressure rises and the residual helium can be de-pressured to the recovery system. If too much gas is added and the container returns to the production plant too warm, an extra fee will be charged to cool down the container. Figure 4 shows the remaining residual helium at different temperatures and why warming above 20K is unnecessary

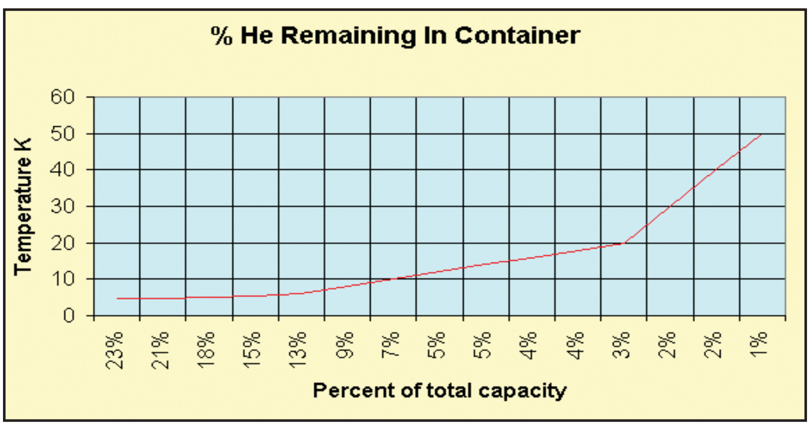

Figure 4

In summary then, if all of the discussed factors are taken into consideration, the net quantity of liquid helium that can be filled into dewars from a single container distant from a remote production plant, will be approximately 35 percent of the helium received in a full container and about 43 percent for those within seven days shipment time.

TECHNIQUES TO REDUCE VAPORIZATION

Using Helium Container Shields

Many but not all of the liquid helium ISO containers are equipped with helium gas shields.The inner vessel holding the liquid helium is surrounded by the normal liquid nitrogen shield plus the helium gas shield, both are intercepting heat leak to the inner vessel. If the container is shipped with the helium shield vent open, helium boils off and cools the shield before escaping, intercepting some of the heat transferring from the liquid nitrogen shield to the inner vessel. That lowers the expected heat leak from 1/4percent/day to 1/8percent day. Therefore, during a 30 day trip 3.75 percent of the helium or 42,000 scf or 1100 nm3 of helium is vented and lost - an expensive disadvantage. The advantage is that the container does not have to be de-pressured when it arrives and dewar filling can commence immediately.

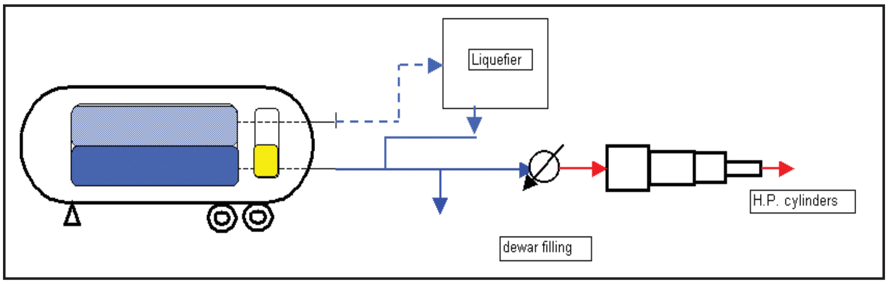

Figure 5

Reducing Dewar Filling Losses

Vaporization of liquid helium during dewar filling can be divided into four categories: 1) the cooling of the dewar itself, 2) the quality of the transfer piping, 3) liquid/vapor separation in dewars, and 4) the actual technique of dewar filling.

At the transfills, most of the dewars are empty and at varying temperatures up to ambient. Vaporization of helium due to dewar cooling can be reduced sometimes by partially cooling the dewar with liquid nitrogen. That is, adding liquid nitrogen until the inner vessel is cooled and then blowing it out with helium gas. Another technique is to connect dewars to be cooled using the cold outlet gas from a filling dewar connected in tandem.

The most important factor is the quality and design of the dewar system. The heat leak of the transfer lines are important, but also important is the inner line size. The less residence time in the lines, the less helium vaporized. The pressure drop in the VJ-lines is important because it lowers the container pressure needed to drive the transfer and resultant flash, and keeps the residence time low. Good dewar filling occurs at a rate of about eight liters/minute in large dewars and at a transfer pressure of less than six psi.

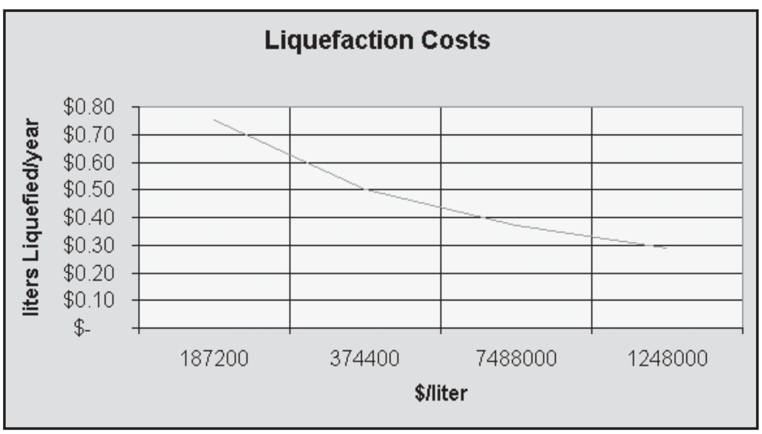

Figure 6

Helium Liquefiers

A liquefier is the ultimate solution if the ratio liquid/gas sales are too high. Helium liquefiers can be a valuable asset for a transfill not only in the obvious manner, but also as a mechanism to leverage liquid storage. For example, for a small reseller a single container may be able to transport all the volume needed but while the container is being refilled at the distant production facility, there is no stored liquid helium to meet customer demands. An onsite liquid storage tank exacerbates the conservation of liquid because 15 to 20 percent of its capacity will be vaporized every time it is re-filled. The storage tank also generates a continuous vaporization resulting from heat leak. On the other hand, a liquefier can provide product while the container is away being refilled, and delay the need to buy a second container. Stored helium gas is re-liquefied as needed until the re- filled container returns.

Technology today has made new liquefiers reliable and easy to operate when compared to those available in the past for helium transfills or large liquid helium users because those older liquefiers were actually small process plants needing to run 24 hours a day and requiring skilled attention. Today, liquefiers are completely automatic, and will stop, start and readjust to different operating modes without human intervention. The moving parts are all rotating (oil flooded screw compressors and gas bearing turbines) and rarely require maintenance.

Liquefiers can to speed the emptying of the container. The cold gas from the container can be drawn into the liquefier. Using the refrigeration of the cold gas, the liquefier gas liquefaction capacity will boosted by magnitudes. If the container has arrived and no dewars need to be filled, the liquefier outlet can be directed back into the container continuously lowering its pressure without removing any product and without having to store any gas.

Another very important plus, is that most liquefiers contain built in purifiers. Some impure gas will be recovered in the operation of the facility that is contaminated usually by air. The contamination can occur during dewar filling, purging vessels and piping and distribution cylinders. This recovered and contaminated helium can be re-used as balloon grade helium or it can be re-purified. A stand-alone purifier could also be purchased, but the purification capability of a liquefier will easily purify any stored helium at the same time it liquefies the helium or it can simply purify available gaseous helium.

Liquefiers are capital intensive, and although they consume electricity and liquid nitrogen, the major cost is capital. Of course as with all cryogenic equipment, liquefiers have economies of scale, unit costs decreasing as size increases. Standard size liquefiers range from 10 liters/hour to 200 l/hr. The unit cost added to recovered helium that is re-liquefied, based on a 10 percent internal rate of return after taxes, electricity and liquid nitrogen costs, and a five day/week operating frequency, will range from $0.92/liter for the smallest to $0.30/liter for the largest liquefier. These costs assume a 15-year life, five-year rapid depreciation, 36 percent taxes, $.06/kwh electricity $.075/liter liquid nitrogen and five percent of capitalization for maintenance costs.

However, with a liquefier there are additional savings. The purification aspect of the liquefier can be applied so impure helium can be re-used or sold at a higher margin, and also opens the possibility of buying back recovered helium from customers. For smaller distributors, a liquefier can defer the need to buy an additional container.

Current market pricing for helium is escalating and likely will continue to do so as older helium sources deplete and new sources become available, but at much higher prices. Because of such market changes, more helium gas recovered at users facilities is being repurchased by sellers for purification and resale. This action only worsens the liquid to gas balance and has awakened interest in liquefiers. ■

James E. West is a partner in the consulting firm RMW Solutions, LLC, Bethlehem, Pa.(www.rmwsolutions.net); RMW Solutions offers consulting services to users and producers of industrial gases including new system designs, upgrades, sourcing, economic evaluations, & project management. He can be reached via e-mail at jim@rmwsolutions.net.