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Using Vapor Return Lines on Liquefied Petroleum Gas (LPG) Meters

By Dick Suiter

At the July 2004 NCWM Annual Meeting Item 332-1 UR.2.3. Vapor Return Line was withdrawn from the S&T Committee agenda. Handbook 44 Section 3.32. LPG And Anhydrous Ammonia Liquid-Measuring Devices, paragraph UR.2.3. currently has a provision for allowing the use of a vapor return line if it is not possible to make a normal delivery without its use or when filling a new tank for the first time if the ambient temperature is above 90 °F. The item proposed amending paragraph UR.2.3. to allow the use of a vapor return during custody transfer at wholesale terminals. During the S&T Committee discussion, the question was raised as to why it is acceptable to use a vapor return line during meter testing and calibration, but not during custody transfer. To appropriately answer that question a field official or service person must have a basic understanding of the properties of LPG and their effect on the measurement of the product.

The normal boiling point of a liquid is the point where the liquid changes to a vapor state. For instance, at 212 °F water changes to steam. Commercial LPG is a mixture of propane, butane, and other gases that can be liquefied through refrigeration or compression. Commercial LPG is maintained in a liquid state by keeping the liquid under pressure. The amount of pressure required to maintain the liquid state is related to the ambient temperature.

Typical commercial LPG has a normal boiling point of approximately -44 °F. In an *open* container LPG will remain in a liquid state at or below that temperature under normal atmospheric pressure. Above that temperature the liquid will begin to “boil” and change to a gaseous state or “LPG vapor.” In a *closed* vessel as the liquid begins to “boil,” the pressure within the vessel will rise. There is a direct relationship between the temperature of the liquid and the pressure created within the vessel. As the temperature increases, more liquid will change into gas and the pressure will increase. For instance, at a temperature of 40 °F the pressure is approximately 72 pounds per square inch gauge (PSIG). At 70 °F the pressure is approximately 132 PSIG, and at 100 °F the approximate pressure is 205 PSIG. If the temperature remains constant for a period of time, the liquid will cease to “boil” once the normal pressure for that temperature is achieved. This condition can be referred to as a "state of equilibrium."

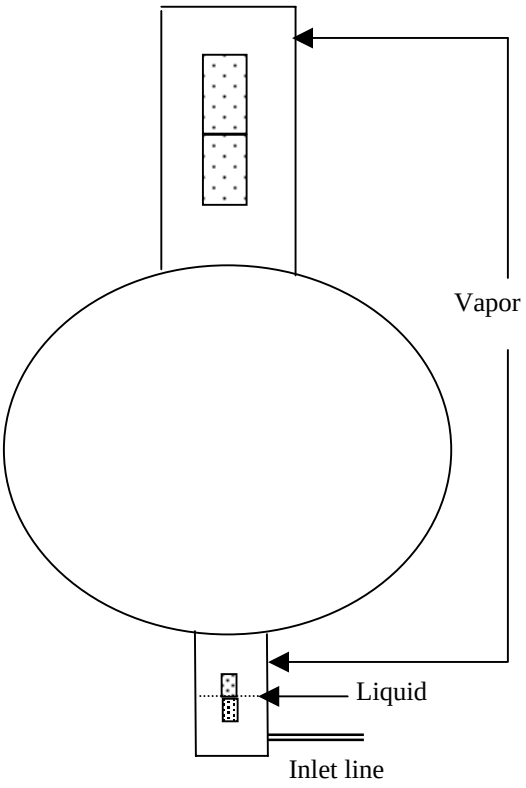
From a state of equilibrium vapor in a closed vessel can return to a liquid state by either lowering the temperature of the vessel and its contents or by increasing the pressure within the vessel. The amount of LPG vapor created by one gallon or 231 cubic inches of LPG liquid with a specific gravity of 0.508 is 36.39 cubic feet (cu ft). Conversely, converting 3639 cu ft (100 gallons) of LPG vapor to liquid will yield approximately 2.7 gallons of liquid.

Without a vapor return line the vapor in an LPG prover, when product delivery starts, is compressed by the liquid pumped into the prover. Some of that vapor will return to a liquid state and some will occupy the remaining space above the level of the liquid in the prover when product delivery stops.

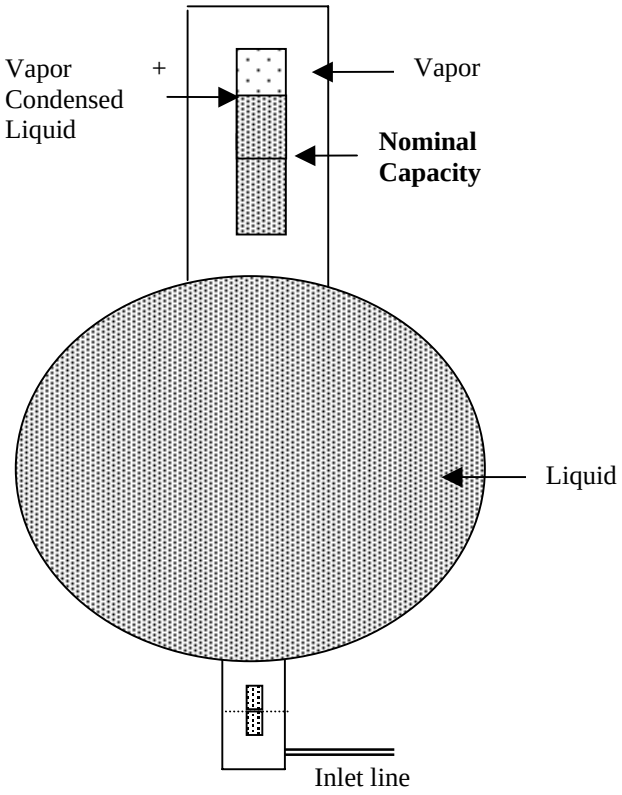
The example below illustrates what happens when a vapor return line is not used during a meter test or calibration. For the purposes of illustration, assume that the meter being tested in the example has no error and that product is dispensed until the meter indicates the nominal capacity of the prover.

The diagram on the left shows the condition of the prover at the start of the test; the entire volume of the prover above the zero mark is filled with LPG vapor. As product is pumped into the prover, pressure increases as the vapor is compressed into a much smaller space. If the ambient temperature remains constant, the increased pressure will cause some of the vapor to return to a liquid state; as the product is liquefied, the pressure will drop and the contents of the vessel will again be at equilibrium.

The diagram on the right illustrates the prover at the end of the test. Because the liquid level is above the nominal capacity line of the prover, it would appear that there is error in the meter; however, that is not the case. The amount of liquid above the nominal capacity line represents vapor that has been liquefied.



The entire volume of the prover above the zero mark is filled with LPG vapor.



The volume of LPG vapor from the drawing on the left has been compressed. Some vapor became liquid. The remaining vapor occupies the space above the liquid level.

Thus, without the use of a vapor return line during the testing or calibration of an LPG meter, irrespective of safety issues involved, the amount of vapor that would change to liquid might incorrectly be interpreted as meter error. On a 100-gallon delivery, the condensed vapor can represent as much as 2.7 gallons, depending on temperature and pressure conditions. For larger deliveries and tank sizes, the quantities are even greater.

During custody transfer at the retail level the same phenomenon occurs within the receiving vessel (the customer's tank) as that described above. The tank will always have a certain percentage of its total volume occupied by LPG vapor. That vapor will also be in a constant state of transition depending on ambient temperature and the accompanying vapor pressure. As the ambient temperature increases, more vapor is created and the tank pressure increases. As the temperature decreases, the pressure will decrease as some of the vapor returns to a liquid state. The percentage of total tank volume occupied by vapor will also change as the product is used and the remaining liquid boils to return the tank to a state of equilibrium.

When a vapor return line is used during normal meter proving or calibration, most of the vapor in the prover will be pushed through the vapor return line into the meter supply tank. This is desirable for meter proving or calibration to avoid the problems outlined in the examples above and to ensure accurate interpretation of the test results. However, it is not desirable for custody transfer at either the retail or wholesale level since the vapor that would be pushed from the customer's tank into the meter supply tank represents product that belongs to the customer.

If a vapor return line were to be used during the routine filling of a tank at either the retail or wholesale level, the actual amount transferred would be determined by such things as the ambient conditions at each tank at the beginning and end of the filling process, the amount of heat generated by the filling process, and the size and length of the vapor return line. When item 332-1 was being considered, information provided to the S&T Committee from various sources placed the amount of product transfer between 2.5 and 2.8 % of the delivered volume. The S&T Committee agreed that the potential amount is significant and agreed to withdraw the proposed change to permit a vapor return line at the wholesale level.