Discover why pressure tests are poor leak indicators and why deep-vacuum tests are better for these systems.

BY JONATHAN PERRY, CM

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Variable-refrigerant volume air-conditioning systems, also known as variable-refrigerant flow and commonly referred to as commercial ductless mini-splits, are field-piped refrigeration systems. Like large commercial-refrigeration plants (think supermarkets), VRV/VRF systems have large lengths of field-installed pipe compared to typical HVAC systems. Just as the larger systems, VRV/VRF systems need to be installed using meticulous steps required for large-quantity piping projects. Particularly important is a deep-vacuum test.

Installation guidelines for many of these VRV/VRF systems emphasize significant pressure tests of 550 psig to 600 psig for up to 24 hours. Achieving these long, high-pressure tests often causes installers to assume there cannot possibly be a leak in a system. However, all installers of VRV/VRF systems need to understand that the key to a leak-tight refrigeration system is holding a deep vacuum. Even though a pressure test appears to indicate there are no leaks, it is the vacuum test that has to be trusted. It is important to understand that pressure testing only indicates gross leaks. Further, pressure testing would take tremendous time, weeks or months, for detecting small leaks. To indicate the presence of smaller leaks, trust the vacuum gauge over the pressure gauge.

A good indication that many leaks are going undetected is the report from one VRV/VRF manufacturer that refrigerant leaks from flare fittings alone can be 17% of the total service calls for these systems. Flare-fitting leaks are the second-largest service problem behind wiring communication issues, but they are the most costly to repair. Since leaks require reclaiming the remaining refrigerant, repairing the leaks, pressure-testing, pulling vacuums and recharging the system, repairs become very expensive. Adherence to the old HVACR adage “clean, dry and tight” during installation is not only paramount to a well-running system for the customer, but essential for a profitable installation for the contractor.

The cost of one leak repair will more than pay for the additional time required to pull a deep vacuum at startup. Leaks and leak repairs are costly enough, but leaks often re-
Issues from contamination to under- or overcharging often occur when maintenance is performed under emergency conditions. Faults such as clogged screens and TXVs or damaged compressors are more likely to occur as the frequency that a system is accessed increases. This ruins the performance of these systems while damaging the reputation of the installer and the equipment manufacturer for years.

**Pressure vs. vacuum**

Taking a look at the approximate amount of molecules involved in a VRV/VRF system pressure test compared to a vacuum test will emphasize pressure-gauge sensitivity vs. micron-gauge sensitivity. The system for this discussion will be a 20-ton VRV heat-recovery system with approximately 1,200 ft of assorted pipe sizes. The field piping and indoor units will have 1.3 cu ft of volume. Assume the system piping is at an average temperature of 70°F with very little variation. Further assume that mainly nitrogen and some small amounts of moisture are present in the system; therefore, the ideal gas law (PV=nRT) is applicable. The ideal gas law requires the use of absolute temperature for “T” and absolute pressure for “P” in the calculation. So, by converting pressure and temperature measurements into absolute values and solving for “n,” it is possible to calculate the amount of moles in the system. Each mole can then be converted into molecules by multiplying by a constant called “Avogadro’s Number,” which is 6.02214199 x 10²³ molecules per mole (molecules = moles x Avogadro’s Number).

The table above shows the calculated values from the formula for the example system.

<table>
<thead>
<tr>
<th>Row</th>
<th>micron</th>
<th>psig</th>
<th>psia</th>
<th>moles</th>
<th>molecules</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NA</td>
<td>550.00000</td>
<td>564.69600</td>
<td>58.57886316</td>
<td>35,277,021,986,635,200,000,000,000,000,000,000</td>
</tr>
<tr>
<td>2</td>
<td>NA</td>
<td>549.90000</td>
<td>564.59600</td>
<td>58.56848964</td>
<td>35,270,774,904,668,100,000,000,000,000,000,000</td>
</tr>
<tr>
<td>3</td>
<td>760,000</td>
<td>0.00000</td>
<td>14.69600</td>
<td>1.524492777</td>
<td>918,071,165,929,285,000,000,000,000,000,000,000</td>
</tr>
<tr>
<td>4</td>
<td>5,171</td>
<td>-14.59600</td>
<td>0.10000</td>
<td>0.010373522</td>
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</tr>
<tr>
<td>5</td>
<td>750</td>
<td>-14.68150</td>
<td>0.01450</td>
<td>0.001504161</td>
<td>905,826,885,273,175,000,000,000,000,000,000,000</td>
</tr>
<tr>
<td>6</td>
<td>500</td>
<td>-14.68635</td>
<td>0.00965</td>
<td>0.001001045</td>
<td>602,843,409,854,223,000,000,000,000,000,000,000</td>
</tr>
<tr>
<td>7</td>
<td>100</td>
<td>-14.69407</td>
<td>0.00193</td>
<td>0.000200209</td>
<td>120,568,681,970,845,000,000,000,000,000,000,000</td>
</tr>
</tbody>
</table>
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Rows 1 and 2 help to determine how many molecules are lost from the system when the pressure gauge indicates a start pressure of 550.0 psig to 549.9 psig during the time of the pressure test. (Please note, it is very difficult to tell if a pressure gauge drops 0.1 psi.) However, it is possible to calculate how many molecules have theoretically leaked out by subtracting the molecules left at 549.9 psig from the starting 550.0 psig. This result is approximately how many molecules escaped the system through the combined leaks of the system.

Row 3 is at standard sea-level pressure or one atmosphere. Row 6 is how many molecules are in the system at a typical 500-micron vacuum test. Notice that the quantity of molecules that must leak out of this system to drop the gauge reading 0.1 psi or 1/10 of a psi, from 550.0 psig to 549.9 psig, is more than 10 times larger than the entire number of molecules left in the system at 500 microns. To be clear, it is an amount of molecules that is 58,549 times smaller than the amount in the pressurized system.

Row 4 is the exact quantity of molecules in the system that leaked out of the system as a micron reading when only those molecules are in the system. A reading of 5,171 microns is very noticeable on a micron gauge.

<table>
<thead>
<tr>
<th>Row</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row 1</td>
<td>35,277,021,986,635,200,000,000,000</td>
</tr>
<tr>
<td>Row 2</td>
<td>-35,270,774,904,668,100,000,000,000</td>
</tr>
</tbody>
</table>

\[
\frac{(Row\ 1 - Row\ 2)}{Row\ 6} = \frac{6,247,081,967,119,860,000,000}{602,843,409,854,223,000,000} = 10.3 \text{ Times}
\]

Too much faith can be placed on pressure tests. Too often, systems hold pressure and do not hold vacuum because there are leaks in the system.
Surely, a vacuum test is more reliable for determining if a refrigeration system has leaks than a pressure test. Stepping away from the discussed system, it should be apparent that these relationships are true for all systems. Like the pressure gauge, the micron gauge is nothing more than a highly sensitive pressure gauge designed for measurement when the pressures are between 0 psig (sea level) and 0 psia (absolute zero pressure). In fact, referring to the table, 500 microns is equal to 0.00965 psia and 550 psig is equal to 564.696 psia. Therefore, the reason this system has 58,549 times the amount of molecules at 550 psig is that the pressure is 58,549 times greater than the pressure of 500 microns. The ideal gas law shows that when temperature and volume are held constant, pressure is directly proportional to the number of molecules in a system (P₁/P₂ = n₁/n₂). Most vacuum gauges can display differences in increments of 10 microns around the 500-micron range or 1/50 of the amount of molecules at 500 microns. This equates to 2,925,886 times more sensitivity than the pressure test when the reading can be done plus or minus 0.1 psi at 550 psig.

Conclusion

It should now be apparent that the high-pressure test with a gauge can allow for a lot more molecules to escape the system undetected than a vacuum test allows entering the system undetected. It shows that vacuum tests are the best method to determine a leak-tight system.

In summary, too much faith can be placed on pressure tests. Too often, systems hold pressure and do not hold vacuum because there are leaks. Failing to achieve a deep vacuum can mean that moisture is in the system. However, a rising micron reading indicates more time will be required to determine whether it is moisture or an actual leak.

Jonathan Perry, CM, is the Refrigeration Systems Manager for Hoffman & Hoffman Inc., a manufacturers’ sales representative serving VA, NC, SC, and TN in the selection and application of commercial and industrial HVACR and DDC systems. Perry specializes in Daikin VRV with aluminum refrigeration pipe and Reflok fittings. He has 18 years of experience designing, building, and maintaining refrigeration and HVAC systems for Farm Fresh Supermarkets. He can be reached at 757-548-1700 x207 or jon. perry@hoffman-hoffman.com. For more information, visit www.hoffman-hoffman.com.

One industry famous for dealing with refrigerant leaks is the supermarket industry. According to EPA/GreenChill, the yearly refrigerant leak rate average is 25% of the total charge of refrigerant per store. The average store has approximately 3,500 lb. of refrigerant running through 5 miles of pipe per store. Over the last few years, GreenChill partners have learned to improve their installation and service techniques. With an average leak rate of only 13% compared to the rest of the supermarket industry, these chains have found true benefit in holding deep vacuums. For new installations, they have instituted a policy of holding 300 microns or below for 24 hours as a best practice. The stores that have achieved these certifications have an average leak rate of only 1.3%. For more information, go to www.epa.gov/greenchill for a copy of “Best Practice Guide for Leak Tight Installations” or other information about leak reduction.

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