All A/C and refrigeration systems leak. Even the metals used in the lines, fittings and connections are porous, and when viewed with significant magnification, cracks and other faults are easily seen. One could argue that it is not the leak that matters as much as the system's leakage rate. Leaky systems can run 50-plus years without shutting down or greatly affecting the appliance's efficiency. Yet, beyond efficiency, technicians also are concerned with the risk of system contamination. And with the changes made regarding refrigerants and systems, what was once easy to correct in past practice no longer remains simple and provides a new set of challenges.

A new day

For a very large segment of the HVACR industry, the transition to HFC refrigerants—and in turn, POE oils—requires changes from past practice to best practice. What once was considered acceptable for mineral-oil systems (in terms of leaks) no longer holds true for the vast majority of new installations that technicians encounter today.

A standing pressure test and inspection prior to evacuation is required for all piping systems, and should be performed without exception at the time of installation (or after mechanical service where the sealed system has been breached) to assure a leak-free system. This helps minimize the chance of any liquid or environmental moisture (in the form of humidity) from entering the system through physical leaks during the evacuation process. Leak-free systems are imperative to assure proper moisture removal during evacuation—and in turn, a long, trouble-free service life.

While leak testing using a standing pressure test is a very common practice in the industry, pertinent variables are often not considered—resulting in leaks within the piping and other related components that ultimately compromise the system's efficiency and capacity. Without a thorough understanding of the physics of pressure, temperature and volume as it relates to gases, leaks can be easily overlooked. A correctly performed standing pressure test is quick and accurate, but it also is a test that can quickly tell a lie.

How is that possible? Too much information. Digital technology seems particularly useful with pressure testing—as the resolution is typically in tenths of 1 psi versus 5-psi increments—however, it reveals what technicians have never been able to see: the small pressure changes that occur normally on a standing system over time.

The science behind accurate testing

In 1800, French scientist Jacques Charles discovered the relationships between pressure and temperature in gases. Charles’ Law simply states that at a constant volume, the pressure of a
gas varies directly with its absolute temperature—when a gas is heated, it expands; and when cooled, it contracts.

This simple law (often overlooked by HVACR technicians) plays a vital role in ensuring the tightness of refrigeration systems and related components during installation and service. Without considering this relationship, a system with no apparent pressure drop when testing over time may not be as tight as one may think. Mathematically, Charles’ Law shows that the ratio of starting and final pressures and temperatures are proportional to each other in the final measurement: \( \frac{P_1}{T_1} = \frac{P_2}{T_2} \), where \( P_1 \) = original pressure (absolute); \( T_1 \) = original temperature (absolute); \( P_2 \) = final pressure (absolute); and \( T_2 \) = final temperature (absolute).

Technicians must first remember that the gas laws require conversion to absolute pressure and temperature. Everyday units of measure will not work. Absolute scales use zero as their starting points because zero is where all molecular motion actually stops. In the following examples, we will use psia (absolute pressure) and degrees Rankin (absolute temperature) to show how a typical piping system would respond to changes in temperature.

A real-world example
Say a technician is working with a small, 10-ton, R-410A, commercial split system, hard piped, with a 50-ft lineset. It is late afternoon and 95°F (remember the scale matters) when the system is filled with nitrogen, which the technician plans to let sit overnight under pressure to determine if the system-leakage rate is acceptable. Looking at the manufacturer’s label, they pressure test the system to 300 psig, which is the maximum allowable test pressure for the evaporator (the lowest pressure-rated component). Upon arrival the next morning, it is 75°F and the pressure has dropped more than 11 psi.

The question the tech must answer: is the drop due to a leak or a change in temperature?

This can be answered using Charles’ Law (\( \frac{P_1}{T_1} = \frac{P_2}{T_2} \)):
- \( P_1 = 300 \text{ psig} + 14.69 \text{ (atmospheric pressure)} = 314.69 \text{ psia} \);
- \( T_1 = 95°F + 460°F = 555°F \text{R} \) (absolute);
- \( P_2 \) = Unknown; and
- \( T_2 = 75°F + 460°F = 535°F \text{R} \) (absolute).

To solve \( P_2 \) in the formula above, the readings must be rearranged so the known stands alone:
- \( P_2 = \left( \frac{P_1 \times T_2}{T_1} \right) / T_2 \);
- \( P_2 = \left( 314.69 \times 535 \right) / 555; \) and
- \( P_2 = 303.35 \text{ psia} \).

Now that the absolute pressure has been figured, the change that should be on the gauge needs to be determined, so 303.35 psia - 14.69 (atmospheric pressure) = 288.65 psig; to determine the final psig, 300 - 288.65 = 11.35 psig. This means the system is tight.

An 11.3-psig drop occurred overnight, but this drop could have happened in a matter of hours or minutes due to a change in temperature from a cold front and a resulting thunderstorm. The reality is that a change in pressure does not mean a leak. Going the opposite direction, if the system was charged with nitrogen on a 75°F day and the temperature increased too, a system without a drop in pressure may be leaking, as the pressure should increase as a result of the changing temperature.

Pressure-testing basics
First, never use air to pressure test a system; always pressure test with dry nitrogen and a trace of refrigerant. Pressure testing may require multiple steps, including those needed to locate the leak. R-22 can be used as the trace gas for any refrigeration system, even in R-404A or R-410A systems, as it is easily detectable and any trace of the refrigerant will be removed during the evacuation process.

It is considered acceptable to start at 0 psig and add refrigerant into the system until the vapor pressure reaches 10 psig for trace-gas testing. This can be done without violating the EPA Section 608 ruling regarding the handling of HFC/
HCFC refrigerants. The technician should then add nitrogen to the system until it reaches a final test pressure. Remember, never use air or oxygen to test a piping system. Mixtures of oil and air in refrigerant piping can cause a violent explosion, leading to injury or death.

In addition, compressed air drops out moisture in the system—which, depending on the ambient conditions and system size, can take hours if not days to remove. If POE oil has circulated through the system, no amount of evacuation will remove the moisture (now bound into the POE); the moisture only can be removed with filter-driers. Always use a nitrogen pressure regulator when testing piping systems and never test at pressures above that of the system’s lowest pressure-rated component. The regulator should always be equipped with a pressure-relief valve for personal safety and to protect the system from over-pressurization dangers.

Techs also should use good low-gas-permeable hoses for testing. All hoses leak and tend to leak worse with age. Check the gaskets and/or O-rings for damage as well. There is nothing worse than looking for a system leak, only to find it is coming from leaky test components.

The tech should start at a lower test pressure and gradually work up to the final pressure. Start at about 50 psig, and let the system rest for several minutes to equalize before observing the pressure. Listen for leaks while pressurizing the system. If the pressure is not dropping, continue to pressurize the system at increments of about 50 psig until the desired test pressure is reached. Remember, the only components considered to be high pressure are the discharge line, condenser and liquid line. The compressor shell is low pressure and should never be over pressurized. Once the pressure is equalized, the technician should audibly check the system at each joint for leaks and, provided none are found, commence the testing procedure.

When using a high-side pressure gauge for a standing leak test, the gauge should be tapped lightly to set the needle and then marked. Aside from the effect of temperature on the gas in the sealed system, there are several factors that could influence the reading, including gauge position, temperature, hysteresis or parallax. Because of the resolution, a long-term pressure test is desired to tell if the system is actually leaking. The longer it sits without a drop in pressure, the more confidence the technician can be that the system is leak-free.

**Why digital does it better**

A low-cost digital gauge utilizes high-accuracy, temperature-compensated pressure transducers and a separate air-temperature sensor to perform a timed pressure-drop test with ambient-temperature compensation, making all the measurements and calculations for the technician. After the stabilization period, the technician starts the pressure test; the initial pressure, current pressure and pressure difference are displayed. The pressure difference is the calculated difference based upon ambient temperature and Charles’ Law.

The initial and final pressure may be different, with no change in differential pressure as the change in temperature is automatically compensated for. This, in conjunction with the higher accuracy, allows the technician to significantly reduce the time required to verify a leak-free system. The industry standard for systems ≤10 tons is currently 1 hour; and for ≥10-ton systems, a 24-hour period is recommended. Whether pressure-testing time is reduced may be a question for the high-pressure piping inspector, but a significant factor in pressure testing has been the resolution of the gauges used to do it. Because the test is a timed test, what can be an acceptable leak rate (if any) can be easily determined during testing. Also the minimum, maximum and mean temperatures and pressures can be displayed if desired.

**Wrapping it up**

When performing a standing pressure test, technicians need to consider all the variables. In a truly sealed system, the gas laws will hold true. A sealed refrigeration system charged with nitrogen (and trace gas) has a constant volume that will respond to temperature with a change in pressure. The extent of the change varies with the changes in ambient conditions.

Digital gauges offer greater accuracy. Resolution and temperature compensation, along with constant calculation of pressure change due to ambient temperature, will quickly let the technician determine if the system is leak-free and ready for evacuation.

It has been said that the definition of insanity is performing the same process repeatedly and expecting different results. Some technicians will do what they have always done and get the same results they always have—a system that leaks. And while using digital gauges certainly does not guarantee a leak-free system, the technology does allow the technician to identify a leaky system faster and have more confidence that a tight system is truly tight.

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