Author's note: The following article is a guide to diagnosing refrigerant system issues with any system using vapor compression/direct expansion (DX) technology. The goal is to give service technicians a generic guide to troubleshoot different refrigeration and air conditioning systems.

This guide offers systematic methods based on the assumption of properly designed, applied, matched and installed equipment. It assumes that the system is functioning within the manufacturer's specifications relevant to air flow, fluid flow, product load and heat exchanger cleanliness.

Often fellow technicians, co-workers and field personnel ask: “Now that I have my test instruments hooked up to the system for a refrigerant system diagnosis, what readings should I expect?”

The answer is always the same: It depends on numerous factors. A refrigerant system diagnosis is perhaps one of the toughest jobs a tech will face, especially when determining if the system is charged correctly. First they must consider system type. Although the guidelines are similar, system type dictates which steps to take to reach a conclusion.

**Points to remember before testing**

- The equipment manufacturer's literature should always be adhered to.
- The system must run under stabilized operation before attempting to analyze refrigerant charge. Too often techs try to fine-tune a system's charge when their system is not stable. This can lead to disastrous results. This is a critical point. Stabilized operation means the system is properly applied, with matched components, and operating within its manufacturer's design envelope.
- The movement of the heat transfer medium through the heat exchangers must be within design parameters. The system's condensing and capacity controls, as applicable, must be working correctly.
- The system must operate under substantial heat loading conditions prior to analysis of the system's readings to accurately determine if system is charged correctly.

When any of the above steps is skipped the readings from the diagnostic process are unreliable. It would be wrong to ignore that fact and continue trying to fine-tune the system's charge.
The servicing technician must understand that it is their duty to ensure the system has a correct refrigerant charge and will continue to produce the required net refrigeration affect under all variables of operation. If the system is operating outside of its intended design parameters, determining the correct charge becomes even more difficult.

**Determining refrigerant charge by type**

Determining a system’s charge is not an exact science (other than fractional horsepower/self-contained equipment), but these guidelines can help the technician dial-in the charge to a very close target point to ensure proper operation, efficiency and equipment longevity.

→ **Fractional horsepower/self-contained equipment**—If the system involves fractional horsepower, which falls into the critical charge category, it is best to take the guesswork out and simply recover the charge, evacuate the system using standard good refrigeration practices, and weigh in the factory-stamped nameplate charge. This is one of the best methods for dealing with these systems.

Even connecting manifold gauges to these types of systems should only be done as a last ditch effort to determine proper charge. The operational temperatures, exchanger deltas, and actual amp draw should be checked first before gauges are applied. Additionally, you should consider gauge type prior to hooking up.

For this type of unit, stub gauges are preferred to avoid interference with what may be a sufficient refrigerant charge. Fractional horsepower/self-contained critically charged equipment requires utmost care when evaluating charge level. The old adage, a shot for the road, can mean the difference between a proper nameplate charge and a grossly overcharged system.

The technician who spends a lot of time adding and subtracting refrigerant from the system would be better served not to. It is always best to weigh in the virgin charge from a deep vacuum. This assumes the system’s OEM components have not been altered.
→ Split systems/packaged units—For systems other than the above we must consider the variables. Most situations dictate a baseline charge as a starting point. Typical split systems have a nameplate charge stamped on the condensing unit. All rooftop package equipment have a nameplate charge stamped. This makes our job easier when starting from an empty system.

Figure 1 represents a typical refrigerant nameplate charge for a rooftop package unit. The baseline charge is weighed in from a point of deep vacuum and we verify, then, if needed, fine-tune the charge from there. The fine-tuning and verification process is described later in this article.

→ Typical walk-in/reach-in/display cases—All remote medium- and low-temp condensing units connected to walk-in/reach-in/display case systems located outdoors or in an ambient area with temperatures less than the typical refrigerated space, typically employ a liquid receiver and a flooded condenser apparatus, or some other form of condensing temperature control.

These systems usually contain a thermostatic expansion valve (TXV) or an electronic expansion valve (EEV) as a metering device. The documentation accompanying the equipment lists the baseline liquid receiver charge as a starting point. This data follows the 90% liquid capacity of a given receiver.

Figure 2 lists the 90% liquid receiver baseline charge for a typical walk-in. If the data is not available one could research the 90% receiver charge by measuring the physical size of the receiver and referring to liquid receiver capacity charts available from several different refrigeration component manufacturers.

In this case, starting from a deep vacuum, the servicing technician weighs in via the receiver's king valve, the baseline liquid 90% charge. The key point to remember is that for the system to function correctly we must maintain a positive liquid seal at the metering device under all heat loading conditions; thus the need to maintain some form of condensing temperature control.

For systems that employ a remote condensing unit located indoors within sight of the refrigerated case or in a reasonably stable indoor remote location, determining the correct charge is similar to the outdoor equipment. There is no need to consider the flooded condenser approach, however, because these systems usually maintain reasonably stable condensing temperatures, or employ simple condenser fan cycling controls or condenser water regulating devices, as in the case of water cooled equipment.

On either of these applications maintaining a positive liquid seal at the entrance to the metering device is essential.

The best method to determine the correct charge with the typical walk-in/reach-in/display case system, regardless of the unit's location (indoor or outdoor), is to use the liquid line sight glass as a baseline. If the technician looks at the glass and sees no bubbles while the unit is running under a substantial heat load across the evaporator, and the system has had a chance to stabilize, it is safe to assume the charge is within its parameters.

However, do not use the sight glass method as a final conclusion. Too often we erroneously observe a system is grossly over or undercharged when relying on the sight glass. Make sure the system is operating under stabilized conditions and then use temperature and pressure measurements as the deciding factor.

Stabilized operation means the system has a substantial heat load on the evaporation coil, the system's pressures and operational temperatures, including exchanger deltas and pressure/ temp conversions (compared to the pressure-temperature conversion chart for the particular refrigerant) are within reason. That means the boiling point is somewhere within what is expected and the condensing temp is at minimum 95°F. Then the technician can conclude the system has a sufficient charge.

**Sufficient, but not fine-tuned**

Very often we will find the system was grossly overcharged. In this case the suggested steps should be taken:

1. Using a clean, dehydrated recovery tank and a good
quality digital scale, apply manifold gauges to the system. Connect the center charging hose to the recovery tank's liquid valve and the high side hose of the manifold to the liquid line service port only.

2. With the system running and the drum on the scale, purge the hoses from the system back thru the manifold to the closed liquid valve on the recovery tank. Then slowly open the valve and slowly open the high side gauge manifold handle. Slowly remove liquid refrigerant from the operating system into the recovery cylinder until some bubbling begins to form in the liquid line sight glass. Allow the system to run a few minutes and repeat the process if the sight glass clears.

3. Do this until the bubbling is maintained in the glass. Then slowly add the liquid charge back into the suction side of the system using the metering method until the glass clears. This will ensure the system is not grossly overcharged. Often this is done only to find that the bleed off charge in the recovery cylinder never needed to be re-added back into the unit, meaning the system was indeed overcharged.

When the system contains a zotrope (refrigerant blend), minor bubbling in the liquid line sight glass, even under stabilized conditions, may be normal. In this situation the technician should use the fine-tuning method described later in this article.

Conversely, if the operational temperatures, deltas and...
pressures are not within the expected range, chances are the system is undercharged. In this situation, although the sight glass appears clear, it is actually empty.

At that point the system needs to be leak-checked and repaired, with the appropriate filter drier added or changed. Once complete, the system should be evacuated and a baseline charge weighed in to the system’s condenser or receiver as a liquid if the system was completely recovered to facilitate the repair. If the system was pumped down for repair, then the charge should be introduced into the system while it is running, using the proper method of introduction applicable to the particular type of refrigerant.

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Other than critically charged systems
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These steps pertain to the system types discussed above and work for systems that use a thermostatic expansion valve (TXV), electronic expansion valve (EXV), or fixed orifice metering device. It is assumed that a baseline charge has already been established according to equipment type.

First, assure that system operating conditions are stable. This means there is a sufficient heat load available for the direct expansion heat exchanger, the system’s evaporator coil and the system has had time to absorb some of the heat load.

Next, the system’s operating condensing temperature must be at a minimum equivalent of 95°F–110°F. This is found by simply converting the operating discharge pressure into the given temperature for the refrigerant type.

If the operating condensing temp is lower than the minimum, the tech must use one of several methods to falsely inflate the condensing temp. This can be accomplished by simply blocking some of the airflow into an air-cooled condenser coil or restricting the water flow thru a water-cooled condenser.

In either case, the operating condensing temp needs to be at or around minimum before proceeding with the fine-tuning process.

Achieving proper measurement levels
After these steps have been taken, the key to the rest of the process lies in achieving proper levels of the following measurements:

→ **Superheat**—The system charge should be added until the correct level of operating evaporator superheat has been reached. Then the compressor’s entering suction line superheat should be measured.

→ **Sub-cooling**—The correct level of liquid sub-cooling should be verified either at the condenser outlet on the liquid line or at the receiver outlet on the liquid line, depending on system type.

   *Important note*: sub-cooling measurements only pertain to systems that are non-critically charged and are more relevant where the metering device is not a cap tube or fixed orifice.

→ **Delta T**—The system’s exchanger deltas should be measured and verified that they are within the proper range or temperature differences across the exchanger, in terms of air or water temp differences.

   The system manufacturer’s charging instructions should be followed in all cases. Most manufacturers provide charging charts and other materials, which are extremely important and should always be referred to. However, in some cases—for many reasons—the tech needs to fine-tune equipment without that material.

   In those situations there are some rules of thumb to conclude that the system’s charge is fine-tuned. They are as follows (when the above-mentioned conditions have been established): Across air-cooled heat exchangers, 15°F–25°F. Across water-cooled heat exchangers, 10°F–12°F.

   → **Evaporator superheat**—This is measured at the outlet of the evaporator as close to the outlet as possible on the suction line.

   → **High-temperature applications**, 9°F–13°F.

   → **Medium-temperature applications**, 5°F–9°F.

   → **Low-temperature applications**, 4°F–6°F (±2°F to allow for instrument accuracy).

   → **Liquid sub-cooling**—A minimum of 10°F–15°F as applicable. Note: High-efficiency condensing units will operate with a much higher liquid sub-cooling when properly charged. The above measurement reference is an established minimum.

   → **Total system superheat**—Note: This is also referred to as a compressor superheat and the differences will vary greatly, depending on system type, and suction line length between the outlet of the evaporator and inlet to the compressor, excluding non-refrigerant cooled compressors in low-temp applications. As measured approximately 6 in. from inlet to compressor on suction line.
Most compressor manufacturers require a 20°F compressor superheat at stable operating conditions entering the compressor.

**→ Suction gas temp**—Most systems running at stabilized operation will realize a 60°F–65°F suction line vapor temperature entering the compressor when the charge is correct.

**→ Pressure drop**—Manufacturers of thermostatic expansion devices, as well as supporting literature, base the full capacity of the metering device around a 100 lb pressure drop across the valve.

To achieve proper metering of refrigerant into the direct expansion evaporator the system’s discharge pressure must be maintained under all heat loading conditions. This is why a positive liquid seal at the correct pressure, at the entrance of the metering device, under all heat loading conditions and regardless of the heat load or surrounding condenser conditions, needs to be maintained. A properly charged system will help ensure these conditions are adhered to.

**→ Discharge line temperature**—All systems should not exceed a 225°F discharge line temperature, measured as close to the outlet of the compressor as possible. A system in which the discharge line temperature exceeds this reading could be the result of an incorrect refrigerant charge.

Conversely, a system with the discharge line temperature falling way below this temperature may also indicate a refrigerant charge issue. The culprit may be an overcharge if the operation is deemed stable. Additionally, an air-to-air heat pump discharge line will measure a minimum of 100°F–110°F when properly charged and operating in heat mode.

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