

LIFECYCLE REFRIGERANT MANAGEMENT (LRM) TRAINING MANUAL: NON-INVASIVE TEMPERATURE DIAGNOSTICS (NTD)

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1. Overview

- ✓ The Lifecycle Refrigerant Management (LRM) training manual is designed to help HVAC technicians achieve seven goals: (1) Enhance refrigerant responsibility and stewardship, (2) Increase refrigerant recovery, reclamation, and reuse, (3) Detect, repair, prevent, and reduce refrigerant leaks, (4) Improve reporting and enforcement with LRM database, (5) Training and Workforce Development, (6) Improved installation and service procedures including verification of refrigerant recovery, low/high pressure leak testing, and triple evacuations, and (7) Non-invasive temperature diagnostics to detect faults without connecting pressure gauges and locking Schrader caps to reduce refrigerant venting by 50% or more.¹
- ✓ The LRM training manual describes Non-invasive Temperature Diagnostic (NTD) and Refrigerant System Diagnostic (RSD) software methods for advanced fault detection diagnostics to meet or exceed the California Energy Commission (CEC) Refrigerant Charge Verification method required in climate zones 2 and 8-15.² The CEC method requires verification of subcooling (SC) for units equipped with thermostatic expansion valves (TXV) or superheat (SH) for units with fixed-orifice or piston metering devices (non-TXV) in climate zones 2, and 8-15.³ The NTD method provides accurate results without connecting refrigerant pressure gauges.
- ✓ The NTD method accurately determines low airflow, low cooling capacity, evaporator Heat Exchanger (HX) faults, condenser HX faults, restrictions, non-condensables, refrigerant Over Charge (OC), and determines the amount of refrigerant Under Charge (UC) without connecting refrigerant pressure gauges to reduce refrigerant venting.
- ✓ NTD software provides accurate information about airflow, refrigerant charge, and other faults based on four air temperatures and two refrigerant temperatures compared to 154 Intertek® laboratory tests.
- ✓ . The NTD software accurately detects faults which other methods based only on superheat or subcooling might not detect or might misdiagnose or provide false alarms.
- ✓ Please refer to the manufacturer's installation or service literature prior to servicing specific residential split-system, heat pump, or packaged air conditioning systems to ensure that the methods provided in this manual are applicable. If any minor issues are encountered with an Air Conditioning (AC) or Heat Pump (HP) system, then please refer to **Section 6** for "General Troubleshooting" information to check fan operation or minor HVAC issues.
- ✓ No pressure gauges are required to check whether an AC or HP system is properly charged.
- ✓ Measurements are recorded using NTD software and uploaded to the www.verified.co server.

¹ <https://www.nrdc.org/sites/default/files/lrm-90-billion-ton-opportunity-report-20221020.pdf>

² California Energy Commission (CEC). 2022. Single-Family Residential Compliance Manual for the 2022 Building Energy Efficiency Standards. CEC-400-2022-006-CMF. Refrigerant Charge Verification. pp. 4-152 to 4-159. <https://www.energy.ca.gov/publications/2022/2022-single-family-residential-compliance-manual-2022-building-energy-efficiency>

³ California Energy Commission (CEC). 2008. Reference Appendices for the 2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings. Appendix RA3 - Residential Field Verification and Diagnostic Test Protocols. Effective January 1 2010.

1.1 Safety

1. Always wear safety glasses and gloves when connecting or disconnecting refrigerant hoses to Schrader valves, handling refrigerant, troubleshooting electrical issues or when brazing.
2. Never vent refrigerant to atmosphere per EPA 608 (use recovery device).
3. Disconnect and turn OFF power before troubleshooting or working on electrical equipment and remove watch, rings, and jewelry to prevent shocks.
4. Read manufacturer's installation or service literature prior to installation or service.

1.2 Methods

The following methods encourage Lifecycle Refrigerant Maintenance (LRM) for split-system or packaged air conditioners or heat pumps (in cooling mode).

1. **Enhance refrigerant responsibility and stewardship** with LRM best practices – refrigerant leak detection, repair, prevention, recovery and recycling – by service professionals, equipment manufacturers, and chemical producers, through voluntary and mandatory programs established by government agencies such as the California Air Resources Board (CARB) and California Energy Commission (CEC), US EPA, utilities, and third parties to increase responsibility and technical feasibility.
2. **Increase refrigerant recovery, reclamation, and reuse** at End of Life (EOL) through economical and enforceable recycling and reclamation methods to provide a steady supply of refrigerant to reclamation companies and increase demand for reclaimed refrigerant.
3. **Detect, repair, prevent, and reduce refrigerant leaks** to achieve large climate benefits at low cost with voluntary targets and regulatory requirements to ensure AC and Heat Pump systems meet minimum standards with incentives from electric utilities to encourage building operators and technicians adopt best practice leak monitoring and repair practices.
4. **Improve reporting and enforcement with LRM database** to encourage best practices using mobile and online NTD software, electronic data collection, and an easy-to-use online LRM database to ensure proper reporting for CEC compliance, warranties, and incentives.
5. **Training and Workforce Development** to recruit, train, and retain technicians that handle refrigerants with EPA certification based on the latest standards of practice, with ongoing learning and development opportunities to reduce emissions from buildings.
6. **Improved installation and service procedures** including verification of EOL refrigerant recovery, low/high pressure leak testing, and triple evacuations to encourage widespread adoption of best installation and service practices to reduce topping up leaky systems without repairing underlying leaks and improve energy efficiency.
7. **Non-invasive Temperature Diagnostics (NTD)** to detect faults without connecting refrigerant pressure gauges and locking Schrader caps to reduce refrigerant venting by 50% or more. The NTD method uses four air temperatures and two refrigerant temperatures to determine refrigerant Under Charge (UC) amount, Over Charge (OC), low airflow, evaporator or condenser Heat Exchanger (HX) faults, restrictions, and non-condensables.

1.4 Equipment Calibration

Calibrated equipment must be used to perform LRM services. Measurement equipment must be calibrated at least every 30 days or whenever equipment is dropped or transported to an altitude change of 3,000 feet or more above sea level. Calibration procedures are provided in **Section 5**.

1.5 Rationale for NTD Method and AC Tune-up

- ✓ The NTD method determines whether an AC or HP system has proper refrigerant charge and airflow without connecting refrigerant pressure gauges which reduces refrigerant venting by at least 50%. If refrigerant charge is low, then leak detection and repair are required, and the NTD method determines a minimum refrigerant charge to add to the AC or HP system and best practices to connect a refrigerant hose to the suction line Schrader valve to weigh-in refrigerant and disconnect to avoid venting refrigerant.
- ✓ Refrigerant venting damages the ozone layer and produces 1810 lbs or equivalent carbon dioxide (CO₂e) emissions per pound of R22 and 2088 lbs of CO₂e per pound of R-410a.
- ✓ Locking Schrader caps are installed to prevent refrigerant leaks and prevent “huffing” refrigerant which can kill people.
- ✓ The International Mechanical Code (section 1101.10) and the International Residential Code (section M1411. 8) require locking Schrader caps to reduce refrigerant venting and equivalent carbon dioxide emissions.
- ✓ Proper refrigerant charge and proper airflow increase energy efficiency, comfort and equipment life and reduce noise.
- ✓ Low airflow can cause icing of the evaporator coil and compressor failure.

1.6 General Installation Requirements

Qualified Contractors/Technicians performing HVAC services must have EPA Section 608 certification and CSLB license and insurance required by State and Federal laws and regulations. AC or HP systems must be $\geq 18,000$ Btu per hour or 1.5 tons and $\leq 60,000$ Btu per hour or five (5) tons of cooling capacity.

1.7 Leak Detection

1. Detection and repair of refrigerant leaks is essential to prevent refrigerant loss to the atmosphere and maintain system reliability. Leak detection should be performed with electronic leak detector at Schrader valves on low-side and high-side service access ports.
2. Electronic leak detection equipment shown in **Figure 1.1** can detect leak rates of ½ ounce per year. Place leak detector sensing device next to component in system and slowly move (one inch per second) above and below areas suspected of leaking. Leak detector emits an audible alarm and a bright flashing light or both if refrigerant leak is detected.
3. Repair refrigerant tube or HX leaks with brazing torch, flux, and brazing alloys (SIL FOS).
4. Tighten or replace Schrader valves if leaking (see **Section 4.8**). Install locking Schrader valve caps with “O” ring seals shown in **Figure 1.2** with thread-lock blue on high- and low-pressure ports to prevent refrigerant leaks.



Figure 1.1 Electronic Leak Detection



Figure 1.2 Locking Schrader Caps

1.8 All Installations

1. Prior to performing RCA diagnostic work, condensing coils must be chemically cleaned and rinsed per specifications defined in **Section 2**, as coil cleaning may affect heat transfer and air flow which may also affect charge measurements.
2. Prior to taking measurements install new air filter and make sure supply airflow registers are open and unrestricted. If the air filter is not new or clean, then install a new air filter. If the filter is washable, then wash and dry the existing filter and replace it. Cleanable filters must be fully clean and dry before performing and RCA diagnostic tests. All panels on split system or packaged unit must be in place and attached properly. Replace any stripped fasteners.
3. Technicians must record equipment information (i.e., make, model, serial number, capacity, factory charge, orifice type, refrigerant type) and AC Tune-up measurement data using the NTD software. Recorded data for completed jobs must be uploaded to VERIFIED® www.verified.co server. VERIFIED® is not responsible for lost data or data not entered or uploaded properly. After cleaning the condenser coil and air filter, and after entering job data, select green checkmark to save job data.
4. For quality control, “technician” name is unique to each software application and is entered during setup. **NTD software can only be used by one assigned technician, and assignment must be verified.** Equipment information must be entered for each job: 1) AC or HP make, model, and serial number, 2) refrigerant R22 or 410A, 3) factory charge in pounds (lb) or ounces (oz), non-TXV or TXV, 4) required subcooling for TXV, 5) rated SEER/EER, 6) rated airflow (cfm), 7) AC or HP cooling capacity (kBtuh, 9) furnace capacity (kBtuh, 10) unit type (split or pkg), 11) AC or HP, 15) install Year.
5. Digital clamp thermometers must be installed with the sensor located at the 10 o’clock or 2 o’clock best positions on the tube to accurately measure refrigerant suction and liquid line

temperatures as shown in **Figure 1.3**. Place pipe clamps on a smooth linear section of suction line at least 12 inches from a compressor. Do not place pipe clamps where refrigerant lines are curved or where fittings of different sizes are brazed together. **Sandpaper or emery cloth must be used to sand suction and liquid lines to achieve proper thermal contact.**

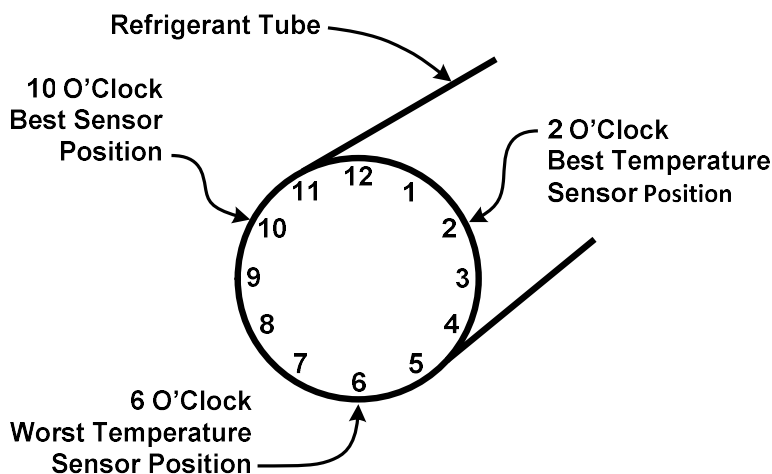


Figure 1.3 Refrigerant Tube 10 O'clock or 2 O'clock Temperature Sensor Positions

6. For proper control and operation of AC and HP units with a TXV, the TXV sensing bulb must be tightly clamped (with copper straps) to suction vapor line for good thermal contact at 10 or 2 o'clock position of suction line with TXV sensing bulb at its 4 or 6 o'clock position so vapor in sensing bulb can achieve suction line vapor temperature for proper control as shown in **Figure 1.4**. **Make sure sensing bulb strap is tight and completely wrap TXV sensing bulb, strap, and suction line pipe with R1 insulation tape for proper operation.**

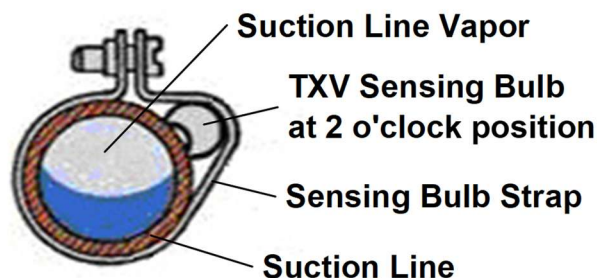


Figure 1.4 TXV Sensing Bulb with Copper Strap at Correct Position on Suction Line

Improperly strapped and uninsulated TXV sensing bulbs inside evaporator coil boxes are influenced by mixed supply-air temperature 10 to 30F greater than refrigerant temperatures. TXV sensing bulbs outside the evaporator coil box in hot attics or garages can be influenced by temperatures 50 to 80F greater than refrigerant temperatures. Hot attic or garage temperatures can range from 100 to 130F compared to 35 to 50F refrigerant temperatures.

7. **Refrigerant System Diagnostics (RSD) methods** with refrigerant pressure gauges connected using best practices to avoid venting provide accurate evaluations of Superheat (SH) and Subcooling (SC) to cost effectively evaluate and repair over charge faults, refrigerant restrictions, or non-condensables on newer systems.

2. Condenser Coil Cleaning (All Systems)

Perform a visual inspection of the condenser coil to make sure it is in good enough condition to be cleaned. The condenser coil must be chemically cleaned, rinsed, and dry before performing refrigerant charge and airflow diagnostic tune-up services.

IMPORTANT NOTE: Any unit that will have RCA performed the coil must be cleaned first, as coil cleaning may affect heat transfer and air flow which may also affect charge measurements. Air conditioner must be turned off before cleaning coil.



Figure 2.1 Dirty Condenser Coil



Figure 2.2 Cleaning Tube & Fin Condenser

Laboratory test measurements for a split-system air conditioner with condenser coil blockage are provided in **Table 2.1** (data from Intertek Testing Services). The air conditioner power impact is significant ranging from 3.2 to 26.6 percent and airside EER impact ranging from 3.7 to 32.1 percent. Dirty condenser coils cause incorrect refrigerant diagnosis as shown in **Table 2.1** where blocked or dirty coil causes an incorrect diagnosis to remove refrigerant charge. Reducing condenser airflow with a hood on outlet produces the same impacts.

Table 2.1 Condenser Coil Blockage, Airside EER Impact, and kW (Intertek® Data)

Description	Airside EER Impact	Total Air-Side Cooling Capacity Btu/hr	Airside EER	Total Air Conditioner Power kW	Impact on Air Conditioner Power kW	Impact on Air Conditioner Power kW	Refrigerant Diagnosis
Baseline	NA	32,335	9.82	3.292	NA	NA	Okay
30% Coil Block	-3.69%	32,136	9.46	3.397	3.19%	3.19%	Remove 4 oz.
50% Coil Block	-9.07%	31,439	8.93	3.52	6.93%	6.93%	Remove 10 oz.
80% Coil Block	-32.08%	27,806	6.67	4.168	26.61%	26.61%	Remove 12 oz.

2.1 Proper Condenser Coil Cleaning Tools (All Systems)

1. NTD software for collecting job data.
2. See **Appendix B** for the AC Tune-up Equipment List.
3. Poly sprayer low-pressure sprayer constructed of high-density polyethylene with pump, extension tube with adjustable nozzle and five feet of hose, funnel-top for pouring chemical into the container, and 3 gallon working capacity.
4. Non-toxic pH neutral condenser coil cleaner (Nu-Calgon “Cal Green” or equivalent) mixed to proper dilution with foaming detergents to penetrate and dissolve baked on greasy dirt.

5. Goggles, gloves, and other protective garments should be worn when cleaning coils.

2.2 Proper Condenser Coil Cleaning Verification

1. Check if the condenser coil is micro-channel (**Figure 2.3**) or tube and fin (**Figure 2.4**). Micro-channel coils can take 1 hour or longer to dry after cleaning. Compressed air will remove water quickly. Micro-channel condenser coil must be dry to perform AC tune-up.
2. With air conditioner off, rinse entire condenser coil with water to remove debris from inside to outside of coil prior to chemical cleaning. Be careful cleaning tube and fin condenser coils with aluminum fins which are delicate and can be damaged with high pressure.
2. Perform chemical coil cleaning according to the equipment manufacturer and cleaning product's recommended procedure. Spray chemical cleaning solution onto dirty coils or surfaces and leave on dirty surfaces for at least 5 minutes for proper coil cleaning. Entire coil surface must be cleaned including condensers with multiple coil rows. Make sure chemicals used for cleaning and water used to rinse coil pass through entire coil. Make sure refrigerant gauges and temperature sensors do not contact chemicals and that temperature sensors are not wet when recording condenser entering air temperature. Products used to clean coil must conform to all federal, state, and local laws and regulations.
3. After 5-10 minutes of dwell time, rinse the entire coil with water to remove chemical cleaner. Thoroughly rinse all chemicals from equipment including interior and exterior surfaces of condensers and packaged units. Make sure to thoroughly rinse coil cleaning chemicals from all exterior areas including equipment, roofing, asphalt, concrete, landscapes, vegetation, and building surfaces. Return system to service. Use water to rinse out sprayer, wand, and nozzle.
4. Allow the system to run (at least fifteen minutes) until the condenser coil is completely dry.
5. Perform temperature split and refrigerant charge measurements after coil is clean and dry and equipment has reached steady-state conditions.

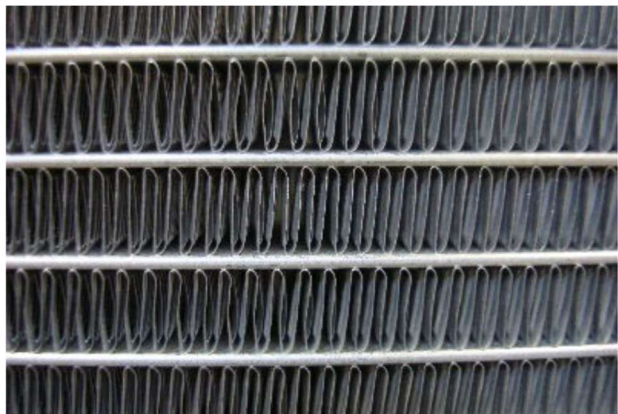


Figure 2.3 Microchannel Condenser Coil



Figure 2.4 Tube and Fin Condenser Coil

6. Microchannel coils are constructed of parallel flow aluminum tubes brazed to enhanced aluminum fins providing better heat transfer with smaller, lighter, corrosion resistant coil.
7. Tube and fin coils are copper tubes and aluminum fins tightly wrapped around tubes requiring a larger coil that is easier to damage and requires twice as much refrigerant.

3. Non-invasive Temperature Diagnostics (All Systems)

The Non-invasive Temperature Diagnostic (NTD) method evaluates refrigerant Under Charge (UC) and determines a UC amount based on measuring six (6) temperatures: 1) Return-air Drybulb Temperature (RDT), 2) Return-air Wetbulb Temperature (RWT), 3) Supply-air Drybulb Temperature (SDT), 4) Outdoor Air Temperature (OAT), 5) Suction Temperature (ST), and 6) Liquid Temperature (LT). **Figure 3.1** shows the NTD method uses Delta Temperature Split (DTS), OAT, ST, and LT to diagnose AC system faults including UC, Over Charge (OC), low airflow, evaporator or condenser Heat Exchanger (HX) faults, low cooling capacity, expansion valve faults, heat pump reversing valve faults, non-condensables, and refrigerant restrictions. DTS equals Actual Temperature Split (ATS) minus Required Temperature Split (RTS). ATS equals RDT minus SDT and RTS is based on RDT and RWT. **Figure 3.2** shows the NTD method indicating Verified RCA using two pipe-clamp probes to measure ST and LT, and air temperature flex psychrometer probes to measure RDT, RWT, SDT, and OAT. The NTD method reduces refrigerant venting by 50% or more.

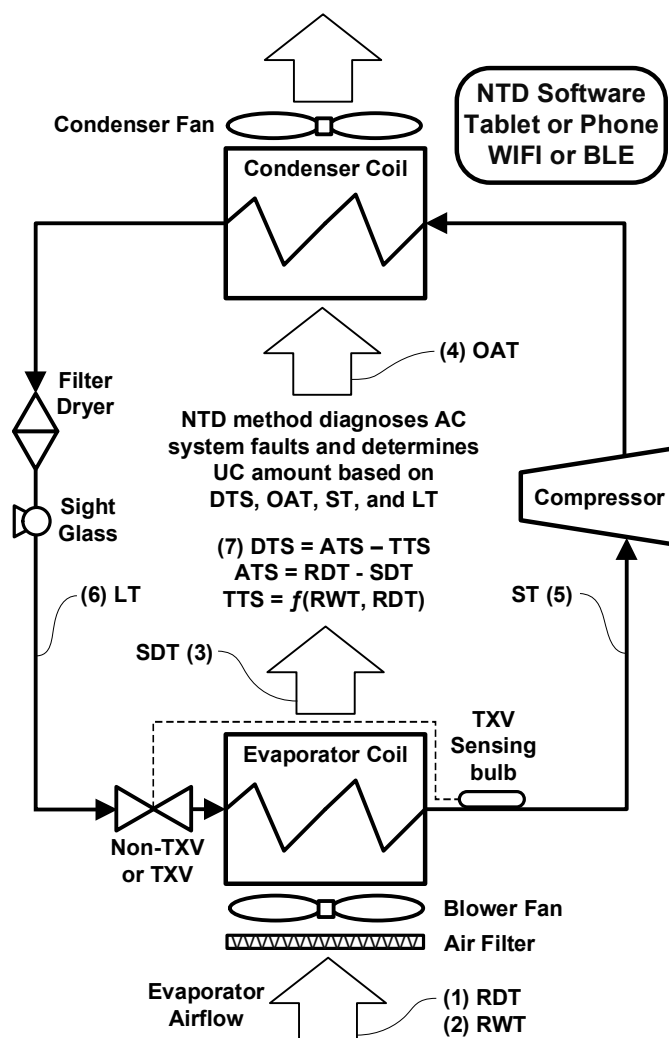


Figure 3.1 HVAC Schematic for NTD Method



Figure 3.2 NTD Verified RCA

3.1 NTD Tools (All Systems)

1. NTD software for collecting customer, AC or HP data, and measurement data and online LRM database to archive data for CEC compliance, incentives or manufacturer warranties.
2. See **Appendix B** for the AC Tune-up Equipment List.
3. **Two digital pipe clamp thermometers** to measure suction and liquid line temperatures and sandpaper or emery cloth to sand suction and liquid lines to achieve proper thermal contact.
4. **Two accurate digital psychrometers to measure RDT, RWT, and SDT.**
5. New air filter(s) must be installed for every AC system before making any measurements. If using cut-to-fit filters place aluminum rods within filter material at appropriate locations to provide rigidity needed for type of return and filter support. Filters may be located at return grill, in ductwork, or within equipment where return air enters. Some AC systems will have more than one return that may each contain air filters. Some buildings will have more than one AC unit and each unit will require a new air filter.
6. Accurate digital scale for weighing in refrigerant.
7. Refrigerant electronic leak detection equipment.
8. New refrigerant R-22 or R-410a.
9. Two Schrader core tools 18975, core removal tool 18979, threading tool 18978, and cores.
10. Locking Schrader caps with "O" ring seals (each valve port).
11. Digital Recovery Machine (Fieldpiece MR45 or equivalent).
12. Digital Vacuum Pump (Fieldpiece VPX7 or equiv.) and ½" or ¾" dia. Hoses.

3.2 NTD Verification (All Systems)

1. New or clean air filter(s) must be installed. If washable, air filter must be fully clean and dry before performing AC Tune-up diagnostic tests on all units.
2. All fresh air or make-up air dampers must be closed and all panels on packaged units must be installed during NTD testing to provide 100% return air only. Loose or improperly installed blower compartment doors or panels can keep equipment from operating. For split systems make sure panels are squarely installed to engage safety switch inside cabinet.
3. Make sure condenser coil is cleaned and fully dry and AC system has been operating for 15 minutes. If building is cool, then open windows and doors to increase indoor temperature if lower than outdoor air temperature.
4. **Use accurate digital psychrometers to measure RDT, RWT, and SDT.** Insert digital sensors into return and supply plenums at locations in figure below for split systems or within return and supply of packaged unit. This is important because hot attic temperatures and return duct leakage can influence return wetbulb temperature which is used to diagnose required superheat. The observed wetbulb temperature will vary until it reaches steady-state temperature. Wait at least 15 minutes until steady-state conditions are reached before entering return wetbulb temperature into NTD software.
5. For split systems two temperature measurement sensor access holes are required, one in supply and one in return plenum. Each location shall have a 5/16" (8 mm) diameter hole. Temperature measurements shall be taken at locations shown in **Figure 3.3**.

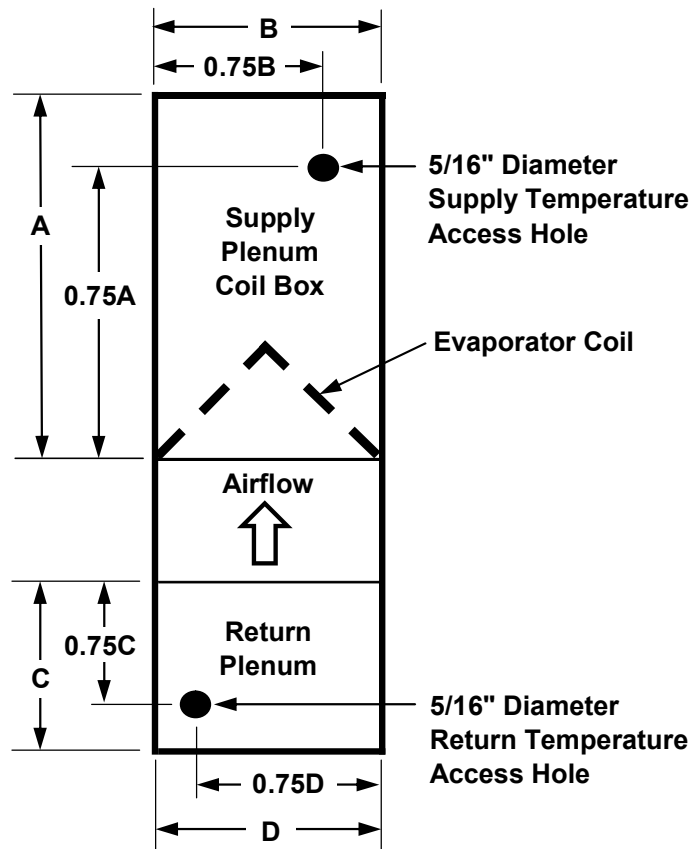


Figure 3.3 Supply and Return Plenum Temperature Sensor Access Hole Locations

6. **Measure and enter data** (after unit has been operating for 15 minutes):
 - Return-air Drybulb Temperature (RDT)
 - Return-air Wetbulb Temperature (RWT)
 - Supply-air Drybulb Temperature (SDT)
 - Outdoor Air Temperature (OAT)
 - Suction Temperature (ST)
 - Liquid Temperature (LT)
7. **NTD software calculates and records Actual Temperature Split (ATS)** = return air drybulb temperature – supply air drybulb temperature.
8. **NTD software calculates RTS** based on RDT and RWT.
9. **NTD software calculates and records DTS** = ATS - RTS.
10. **NTD software uses DTS, OAT, ST, and LT to determine Verified RCA** or determines UC amount or other AC system faults such as OC, low airflow, evaporator or condenser HX faults, low cooling capacity, expansion valve faults, heat pump reversing valve faults, non-condensables, and refrigerant restrictions.
11. The LRM NTD workflow is shown in **Figure 3.4**. Offering #1 is an AC Tune-up with $\geq 7.5\%$ charge addition with LRM and Verified RCA. Offering #2 is a HP Tune-up with $\geq 7.5\%$ charge addition with LRM and Verified RCA. Offering #3 is no charge adjustment with

LRM and Verified RCA. Offering #4 is normal replacement, refrigerant recovery, low/high pressure leak test, triple evacuation, NTD, and Verified RCA.

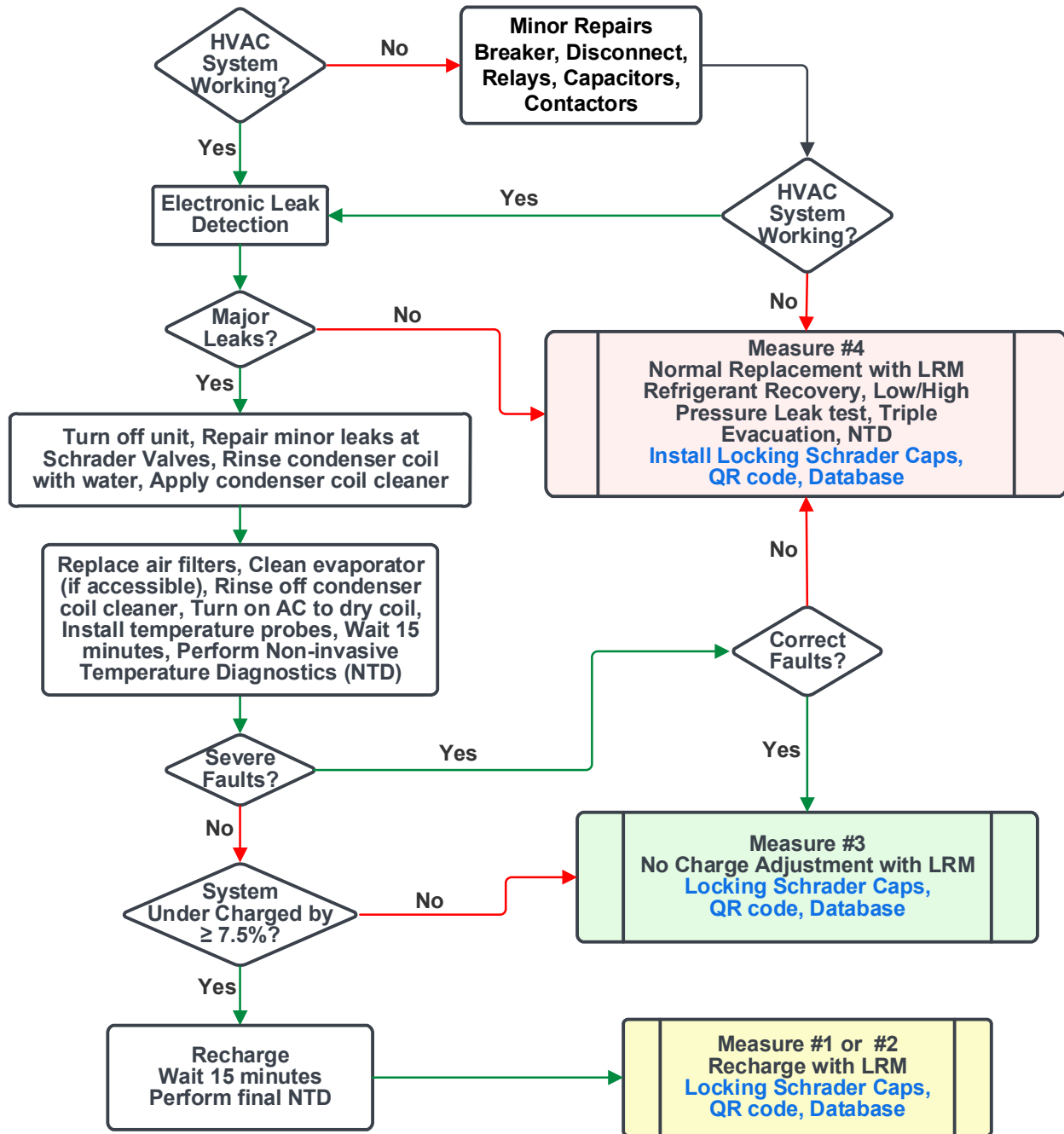


Figure 3.4 LRM NTD Workflow

3.3 NTD Fault Detection (All Systems)

1. Low Airflow

Figure 3.5 shows the NTD method detecting low airflow and Figure 3.6 shows the NTD and Refrigerant System Diagnostics (RSD) methods detecting low airflow. The RSD method requires two (2) separate compound digital pressure gauge manifolds (one for R22 and one

for R410a to avoid contamination) and two sets of refrigerant hoses requiring EPA low-loss fittings on each hose per EPA Section 608. Before connecting or disconnecting refrigerant hoses to system, please refer to **Section 4.4** “Connecting Refrigerant Hoses to Air Conditioning System” and **Section 4.5** “Disconnecting Refrigerant Hoses from Air Conditioning System.” The RSD method is shown to support the accuracy and advantages of the NTD method. The RSD method shows -6.5F delta superheat indicating a potential false alarm overcharge from the superheat method which might motivate technicians to remove charge instead of cleaning or installing new air filters. The NTD method reduces false alarms that can reduce efficiency.

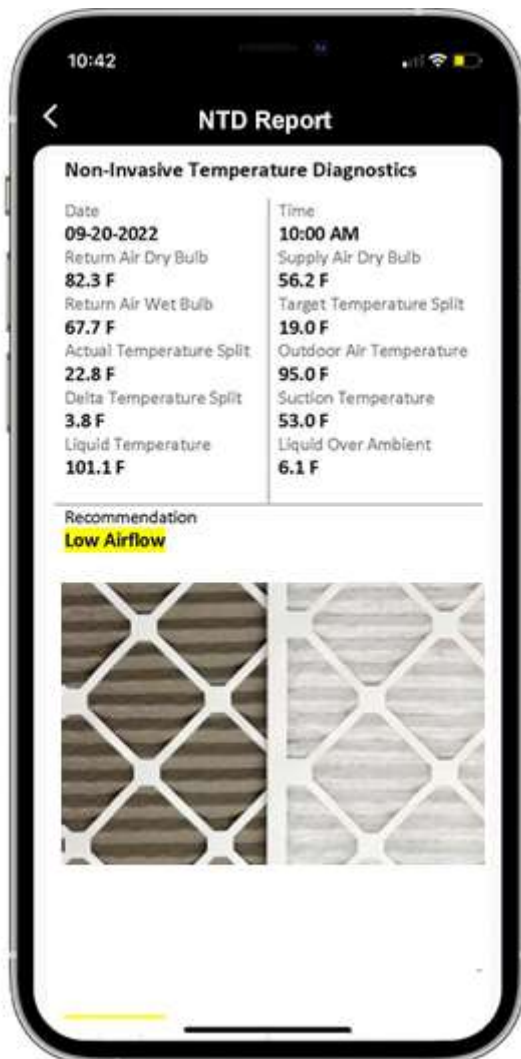


Figure 3.5 NTD Low Airflow

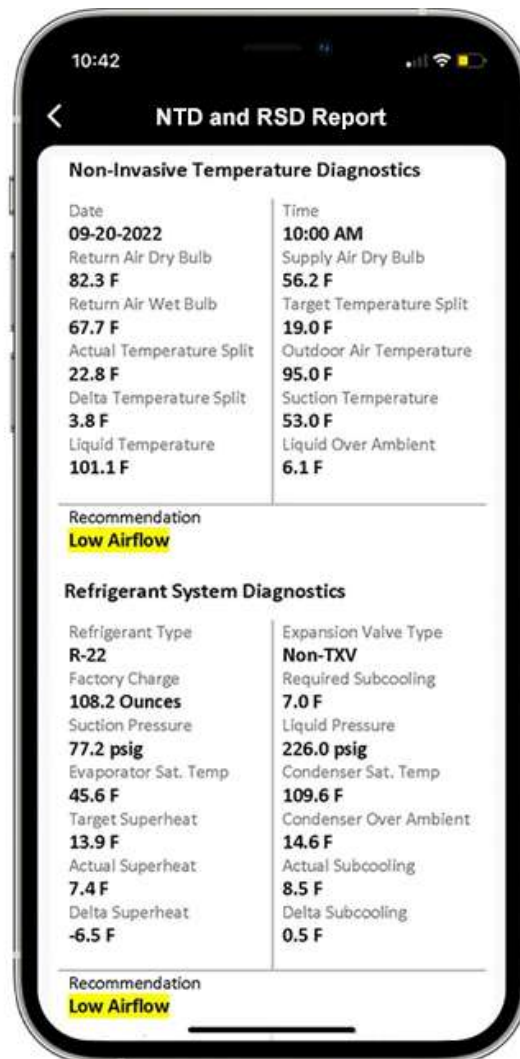


Figure 3.6 NTD and RSD Low Airflow

Follow instructions in **Section 4, Refrigerant Procedures**, when adding or removing refrigerant. Adjust refrigerant charge and wait 15 minutes to make “test-out” measurements. R410a refrigerant tank must be oriented properly to deliver liquid when adding refrigerant to the system since R410a is a zeotropic mixture of two refrigerants, and the orientation is clearly marked on R410a tank. R22 can be charged with the refrigerant tank in either orientation since R22 is a pure refrigerant. **Enter refrigerant charge added based on NTD**

recommendation, wait **15 minutes to enter final data**, and click “save.” Check appropriate boxes and enter ounces of refrigerant charge added. After clicking on the green checkmark button software will save measurement.

2. Clean Condenser

Figure 3.7 shows the NTD method detecting clean condenser and **Figure 3.8** shows the NTD and RSD methods detecting clean condenser. The RSD method shows delta superheat is -5.6F indicating a potential false alarm overcharge from the superheat method which might motivate technicians to remove charge instead of cleaning the condenser coil.

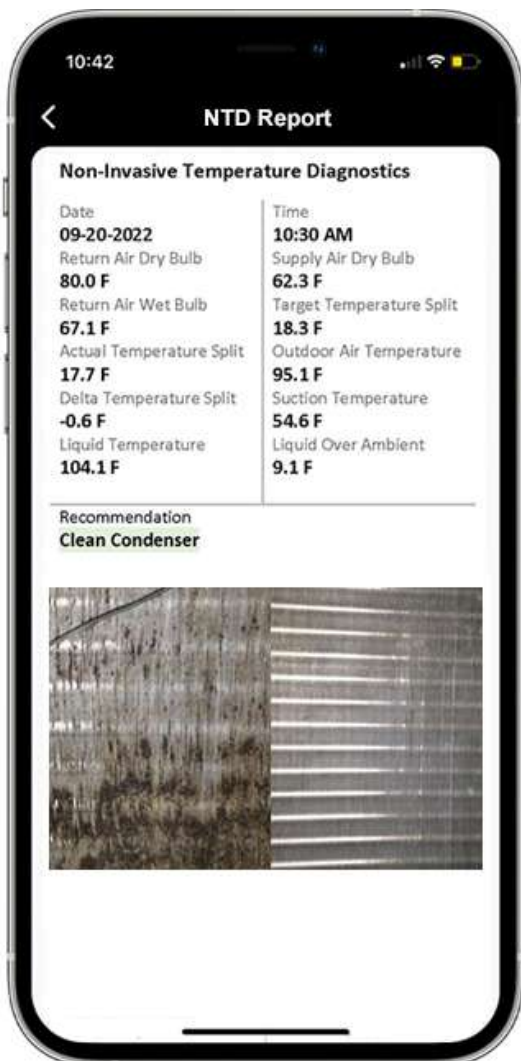


Figure 3.7 NTD Clean Condenser

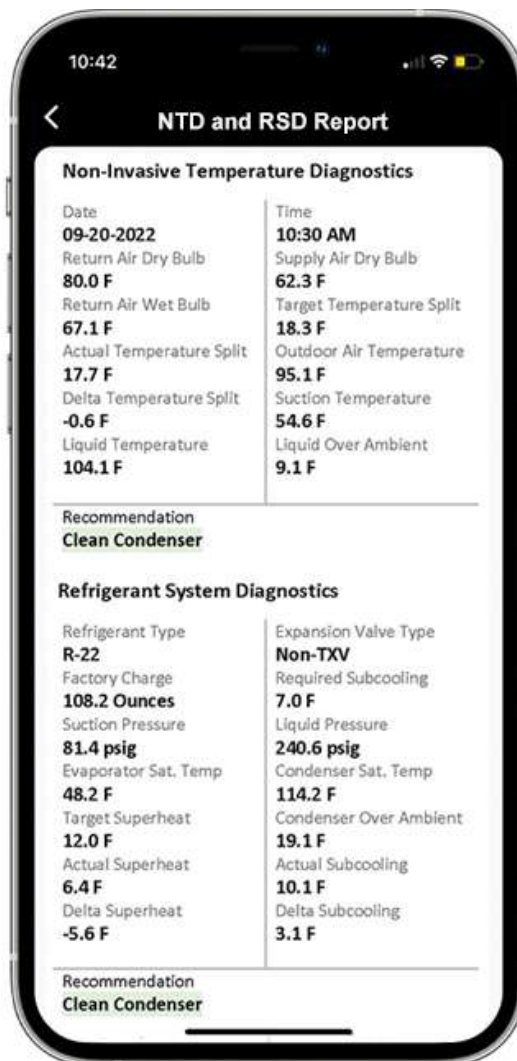


Figure 3.8 NTD and RSD Clean Condenser

3. Under Charge

Figure 3.9 shows the NTD method detecting an Under Charge of 12% and **Figure 3.10** shows the NTD and RSD methods detecting the same 12% Under Charge. Standard superheat methods do not determine the Under Charge amount causing technicians to make small charge adjustments which do not save energy. The NTD method avoids small charge adjustments by only recommending adding charge when the Under Charge is $\geq 7.5\%$. When adding charge, avoid mixing refrigerants which will cause abnormally high pressure, compressor damage, and injury. R22 uses mineral oil and R410a uses polyolester oils and these oils and refrigerants cannot be mixed.

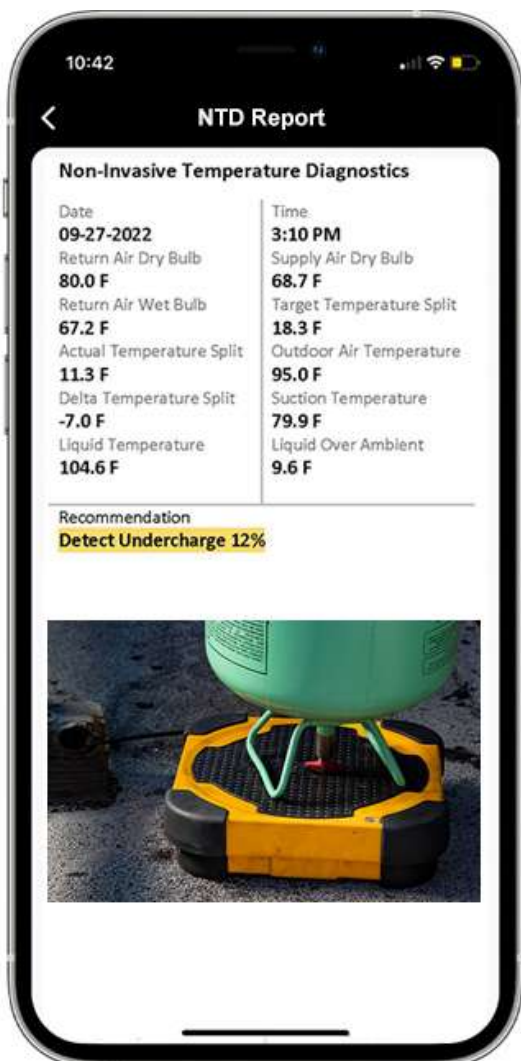


Figure 3.9 NTD Under Charge 12%

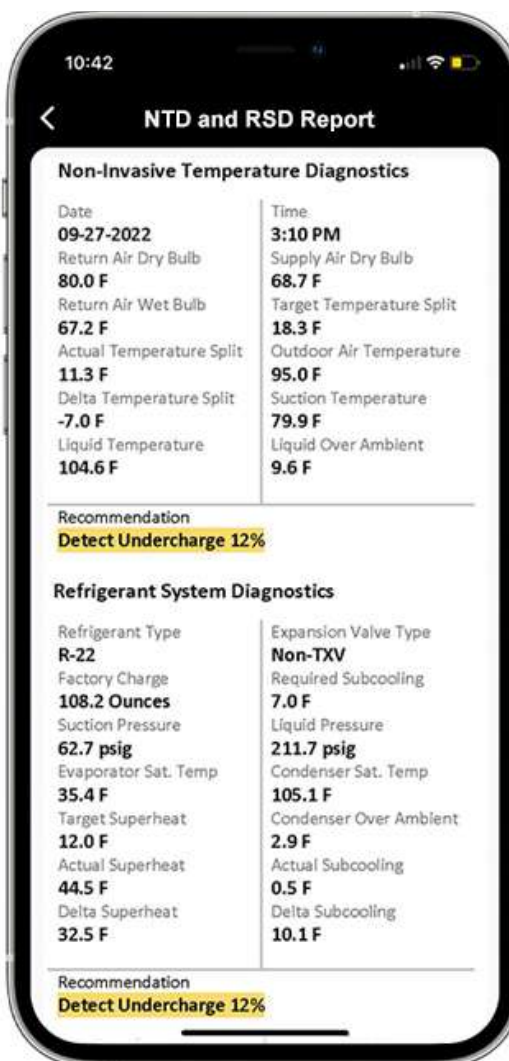


Figure 3.10 NTD and RSD UC 12%

5. Over Charge

Figure 3.11 shows the NTD method detecting an Over Charge (OC). **Figure 3.12** shows the RSD method detecting the same OC of 10%. The NTD cannot determine the OC amount. Standard superheat methods do not determine the OC amount, but the RSD method can detect the OC amount using delta Subcooling. The NTD method avoids removing refrigerant charge which generally provides negligible energy savings. The RSD with refrigerant pressure gauges connected using best practices to avoid venting will provide accurate evaluations of SH and SC to cost effectively determine how much refrigerant charge to remove and repair serious faults such as restrictions or non-condensables on newer systems

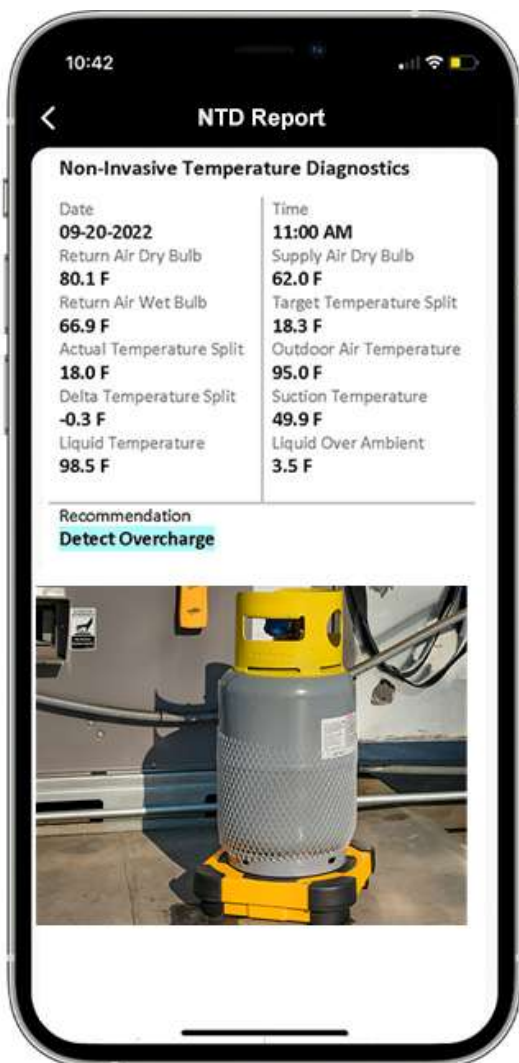


Figure 3.11 NTD Over Charge

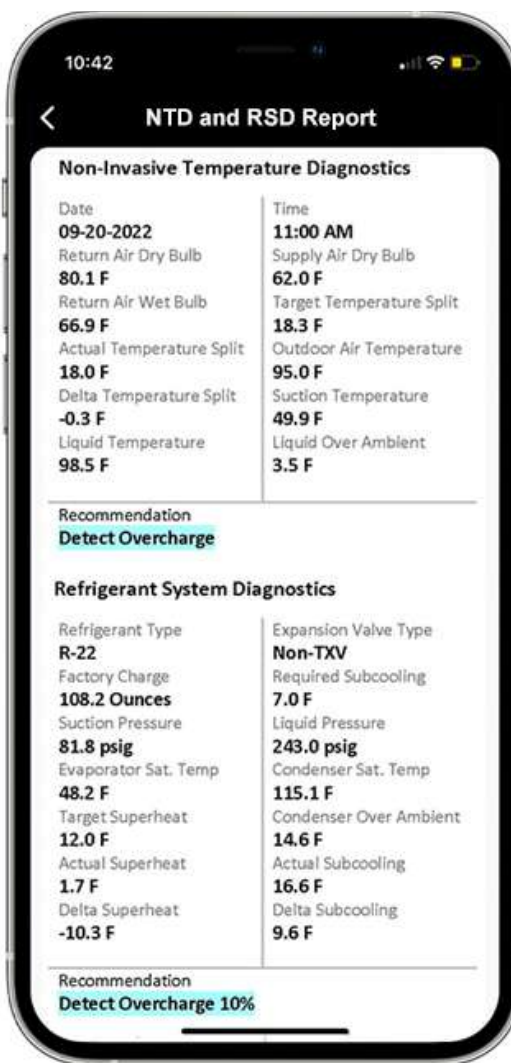


Figure 3.12 NTD and RSD Over Charge 10%

6. Restriction

Figure 3.13 shows the NTD method detecting a Restriction, evaporator HX or UC fault. **Figure 3.14** shows the NTD and RSD method detecting the same Restriction with Evaporator Saturation Temperature (EST) < 35F (shows 25.6F on an Infrared image). Standard TXV subcooling methods do not detect refrigerant restrictions, but the RSD method can detect the Restriction and avoid a false alarm Under Charge due to 36.6F Delta Superheat and 9.4F Delta Subcooling. The NTD method avoids adding charge with a restriction which can be located with the Infrared image or temperature sensors requiring refrigerant recovery and installing a new filter drier, low/high pressure testing, triple evacuation, and weighing in the factory charge plus any extra charge for longer line sets. Restrictions are generally caused by water vapor in the refrigerant system causing sludge blocking the filter drier restricting refrigerant flow and lowering cooling capacity and efficiency.



Figure 3.13 NTD Restriction

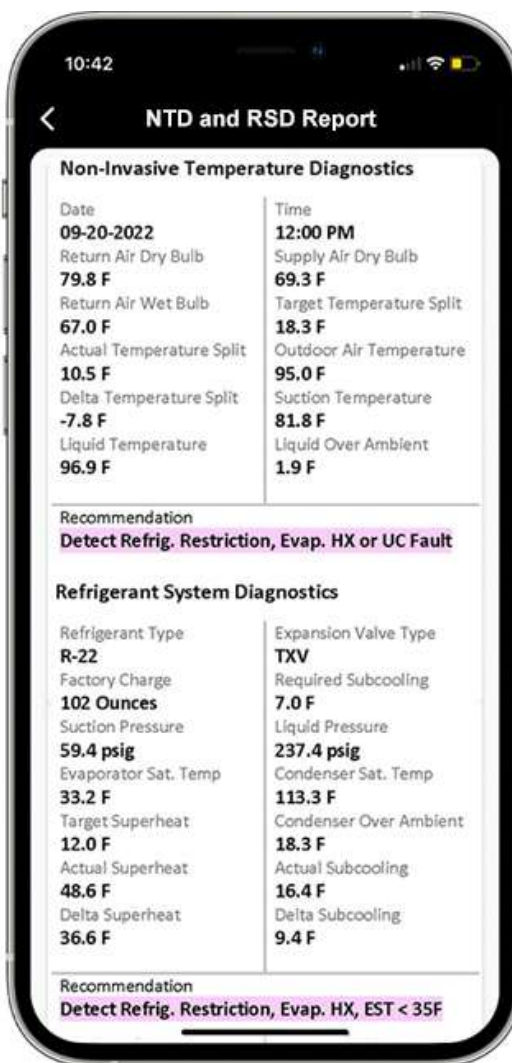


Figure 3.14 NTD and RSD Restriction

7. Non Condensables

Figure 3.15 shows the NTD method detecting Non-Condensables. **Figure 3.16** shows the NTD and RSD method detecting the same Non-Condensables with Condenser Over Ambient (COA) > 25F. Figure 3.14 shows 121F Condenser Saturation Temperature on an Infrared image. Standard TXV subcooling methods do not detect Non Condensables, but the RSD method can detect the Non Condensables and avoid a false alarm Over Charge due to 15F Delta Subcooling. The NTD method avoids removing charge with Non Condensables which can be located with the Infrared image temperature sensors requiring refrigerant recovery, triple evacuation, and weighing in the factory charge plus any extra charge for longer line sets. Non Condensables are generally caused by air, Nitrogen, or water vapor in the refrigerant system causing high condenser pressure and compressor power and low cooling capacity and efficiency.

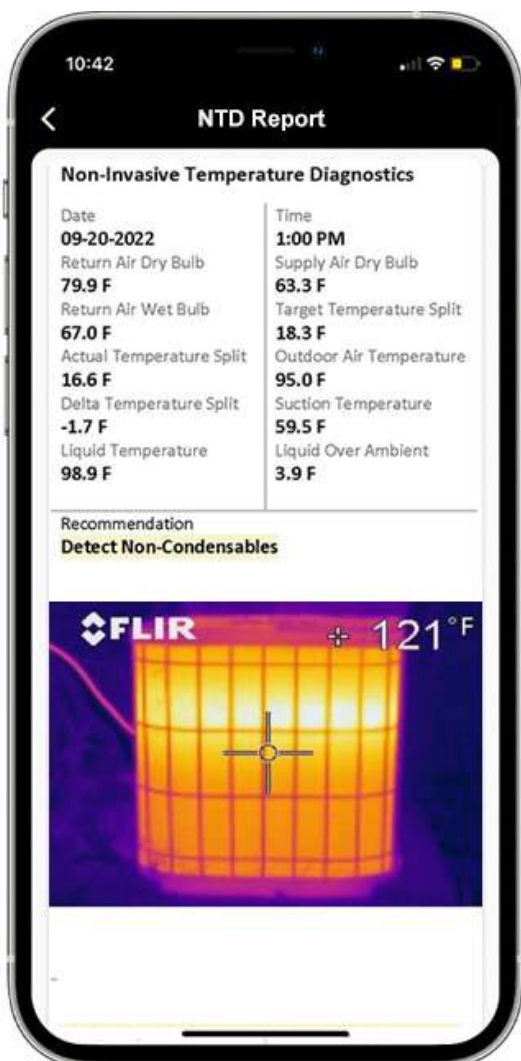


Figure 3.15 NTD Non Condensables

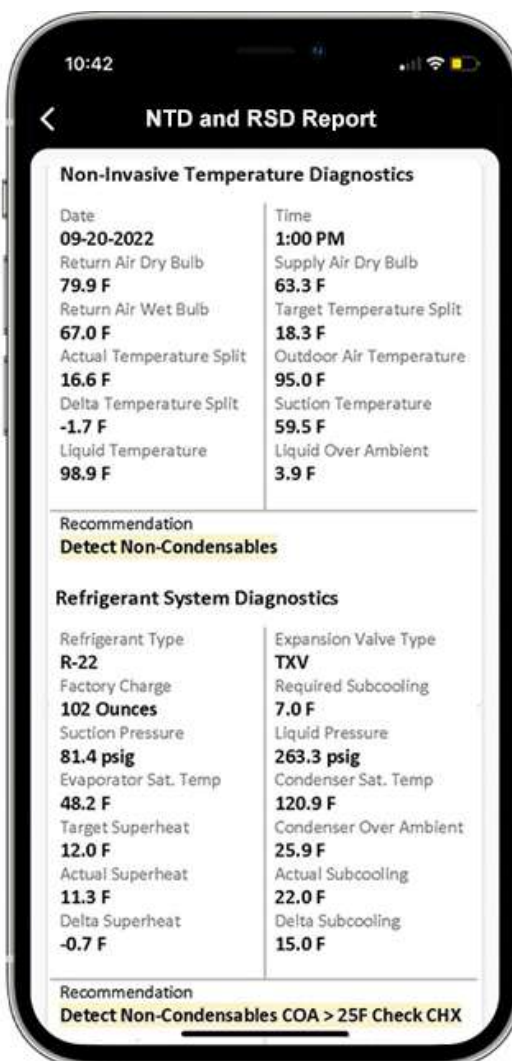


Figure 3.16 NTD and RSD Non Condensables

8. Refrigerant Recovery, Pressure Test, Evacuation, and NTD Verification

Figure 3.17 shows the Recovery, Low/High Pressure leak test, and Triple Evacuation methods recommended by manufacturers. **Figure 3.18** shows the same LRM information with NTD verification. The recovery, leak test, and evacuation methods ensure End of Life (EOL) recycling of refrigerant for pre-existing systems and low/high pressure leak testing, and triple evacuation of new systems to register with the online database for End of Life (EOL) refrigerant recovery for new units. The LRM measure (1) Enhances responsibility and stewardship, (2) Increases recovery, reclamation, and reuse, (3) Detects, repairs, prevents, and reduces leaks with locking Schrader caps, (4) Improves reporting and enforcement with online database, (5) Trains workforce, (6) Improves installation and service procedures, and (7) NTD software detects faults and verifies performance without connecting refrigerant pressure gauges to reduce venting by 50%.



Figure 3.17 Recovery, Leak Tests, and Triple Evacuation

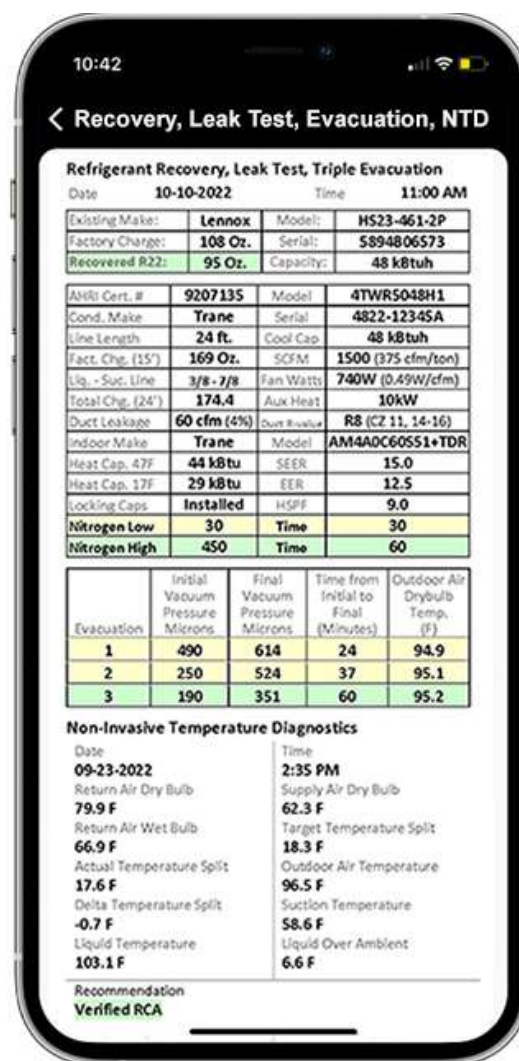


Figure 3.18 LRM Recovery, Leak Tests, Triple Evacuation, and NTD Verification

4. Refrigerant System Diagnostics and Leak Prevention

To comply with **Section 608 of the Clean Air Act (CAA) of 1990**, EPA has established regulations (**40 CFR Part 82, Subpart F**) that require service practices that maximize recovery and recycling of ozone-depleting substances (both chlorofluorocarbons [CFCs] and hydrochlorofluorocarbons [HCFCs] and their blends) during the servicing and disposal of air-conditioning and refrigeration equipment. **The Prohibition on Venting Effective July 1, 1992, Section 608 of the Act** (page 2) prohibits individuals from intentionally venting ozone-depleting substances (ODS) or their substitutes while maintaining, servicing, repairing, or disposing of air-conditioning or refrigeration equipment. Only three types of releases are permitted: **(1)** “De minimis” quantities of refrigerant released while making good faith attempts to recapture and recycle or safely dispose of refrigerant including releases that occur when connecting or disconnecting hoses to charge or service appliances. **(2)** Refrigerant emitted during the normal operation of air-conditioning and refrigeration equipment (as opposed to during the maintenance, servicing, repair, or disposal of this equipment), such as from mechanical purging and leaks. However, EPA requires that leaks above a certain size be repaired in equipment that contains 50 pounds of refrigerant or more. **(3)** Releases of substitute refrigerants that EPA has determined do not pose a threat to the environment. See the Recent Regulatory Developments box for more information. <https://www.epa.gov/section608/stationary-refrigeration-prohibition-venting-refrigerants>. **Recovery and recycling equipment manufactured after November 15, 1993, must be equipped with low-loss fittings on all hoses. Locking Schrader caps are required.**

The NTD software evaluates low airflow, low cooling capacity, evaporator and condenser Heat Exchanger (HX) faults, restrictions, non-condensables, refrigerant Over Charge (OC), and determines the amount of refrigerant Under Charge (UC) without connecting refrigerant pressure gauges to reduce refrigerant venting by 50% (patent pending). The NTD software also provides Refrigerant System Diagnostics (RSD) to determine the OC amount, the UC amount and detailed information about condenser HX faults, restrictions, and non-condensables for optimal cooling performance (US7500368, US8583384, US9207007, US10001289, and pending). The impacts of non condensables and refrigerant restrictions on energy efficiency are described in **Sections 4.1** and **4.2**. The tools and procedures required to recover, evacuate, and purge non condensables and contaminated refrigerant from hoses and manifolds are described in **Section 4.3** and **4.4**. The procedures for properly connecting and disconnecting refrigerant hoses to and from AC and Heat Pump (HP) systems are described in **Sections 4.5** and **4.6**. Procedures for refrigerant recovery and leak testing are described in **Section 4.7**. Procedures for Schrader core repair are described in **Section 4.8**. Procedures for Mini-Split AC and HP leak prevention, recovery, and evacuation are described in **Section 4.9**. Procedures for refrigerant pressure test and evacuation are described in **Section 4.10**. Procedures for refrigerant charging are described in **Section 4.11**.

4.1 Non-Condensable Fault Detection Diagnostics

The NTD and RSD software uses a patented or patent pending fault detection diagnostic method (US9207007) to distinguish non condensables from refrigerant over-charge or under-charge faults. Non condensable air, nitrogen, or water vapor in the refrigerant system are caused by improper evacuation during installation or repair. Non condensables occupy space in the condenser coil which reduces heat transfer, cooling capacity, energy efficiency, and compressor

life and increases condenser pressure and saturation temperature.⁴ Non condensables are introduced into the system during installation or repair, if technicians do not properly evacuate the refrigerant system to below a 250-micron vacuum held below 500 microns for 60 minutes (see **Section 4.7**). Improper evacuation will leave air and water vapor in the AC or HP system which will cause non-condensables and restrictions that reduce efficiency, cooling capacity, thermal comfort, and compressor life. Refrigerant systems can also be contaminated during routine service if technicians incorrectly attach refrigerant hoses to the suction line with air and water vapor inside the hoses (see **Sections 4.4 to 4.6**). Water vapor combines with oil and refrigerant to form corrosive acid and sludge which can cause refrigerant restrictions in the expansion device (see **Section 4.2**). Small amounts of air, water vapor or nitrogen (i.e., 0.3% of system charge by weight) can have a significant negative impact. **Table 4.1** provides Intertek® laboratory test results for 0.3 oz (~0.3% of system charge by weight) of non-condensable nitrogen in a TXV-equipped air conditioner.⁵ Tests are performed with standard airflow of 385 cfm/ton and refrigerant charge of 102 ounces. The 0.3% NC test (505) reduces efficiency by 13% and increases power (kW_A) by 6%. The CEC and manufacturer Refrigerant Charge (RC) protocols misdiagnose NC as an overcharge. Removing charge would make the system less efficient. The NTD software detects non-condensables. The patented RSD software recommends “Clean condenser or remove non condensables COA > 25F” based on high COA, SH, and SC.

Table 4.1 Non-condensable Impacts on EER* and Power (kW) for TXV System

Description	EER* _A Capacity (kBtuh)	EER* A	EER* _A Impact %	kW* _A	kW _A Impact %	Delta SC (°F)	COA (°F)	CEC or Manufacturer RC Protocol	VERIFIED® Advanced FDD Software	Test
Baseline	31,054	9.48	NA	3.28	NA	-2.7	13.7	Correct	Correct	303
0.3% NC	27,373	8.27	-13%	3.48	6%	15.0	25.9	Misdiagnose	Remove NC	505

Table 4.2 provides results for 0.3 oz (~0.3% system charge) of non-condensable nitrogen in a non-TXV unit. Tests are performed with 385 cfm/ton and refrigerant charge of 108 ounces. The 0.3% NC test (501) efficiency is reduced by 18% and power (kW) is increased by 8%. The ~1% NC test (501X) reduces efficiency by 38% and kW increases by 28%. For both tests, the CEC RCA protocol misdiagnoses non condensables as a false undercharge. Removing charge would make the system less efficient. The RSD software recommends “Clean condenser or remove non condensables COA > 26F” based on high COA, SH, and SC.

⁴ Unlike refrigerants, non condensables (as the name implies) are unable to condense into a liquid inside an air conditioning condenser. This has a serious impact on operating pressures, efficiency and compressor life.

⁵ 0.3 ounces or 0.3% non-condensable is based on nitrogen in an improperly evacuated 15-foot line set (262 in³) plus evaporator coil volume (200 in³) times the density of nitrogen at 6.535 x 10⁻⁴ oz./in³.

Table 4.2 Non-condensable Impacts on EER* for non-TXV System

Description	EER* _A Capacity (kBtuh)	EER* _A	EER* _A Impact %	kW* _A	kW _A Impact %	Delta SH (°F)	COA (°F)	CEC RCA Protocol	VERIFIED® Advanced FDD Software	Test
Baseline	31,050	9.42	NA	3.30	NA	2.1	16.1	Correct chg	Correct	189-4
0.3% NC	27,373	7.71	-18%	3.55	8%	10.5	28.9	Misdiagnosis	Remove NC	501
~1% NC	20,486	5.87	-38%	4.21	28%	4.0	46.8	Misdiagnosis	Remove NC	501X

Figure 4.1 shows the laboratory test of time required to check for 1% of non-condensable nitrogen by weight for non-TXV unit with R22 refrigerant. The total time required to check for NC is 45 minutes for the condenser pressure to reach 190.6 psig and saturation temperature to reach 98.2°F or 3.2°F above the 95°F condenser entering outdoor air temperature. It took 10 to 25 minutes for discharge and liquid temperatures to reach equilibrium with the 95°F condenser entering outdoor air temperature plus 20 more minutes for non-condensable nitrogen to coalesce in the condenser after the compressor and fans were turned off. Many technicians incorrectly assume it only takes 5 to 15 minutes to perform a standing-test of non-condensables. This is one reason non-condensable faults are not identified. The NTD and RSD software provides a patented method to diagnose non condensables and restrictions while technicians are performing an AC Tune-up and the system is operating (U.S. Pat. 9,207,007, pending).

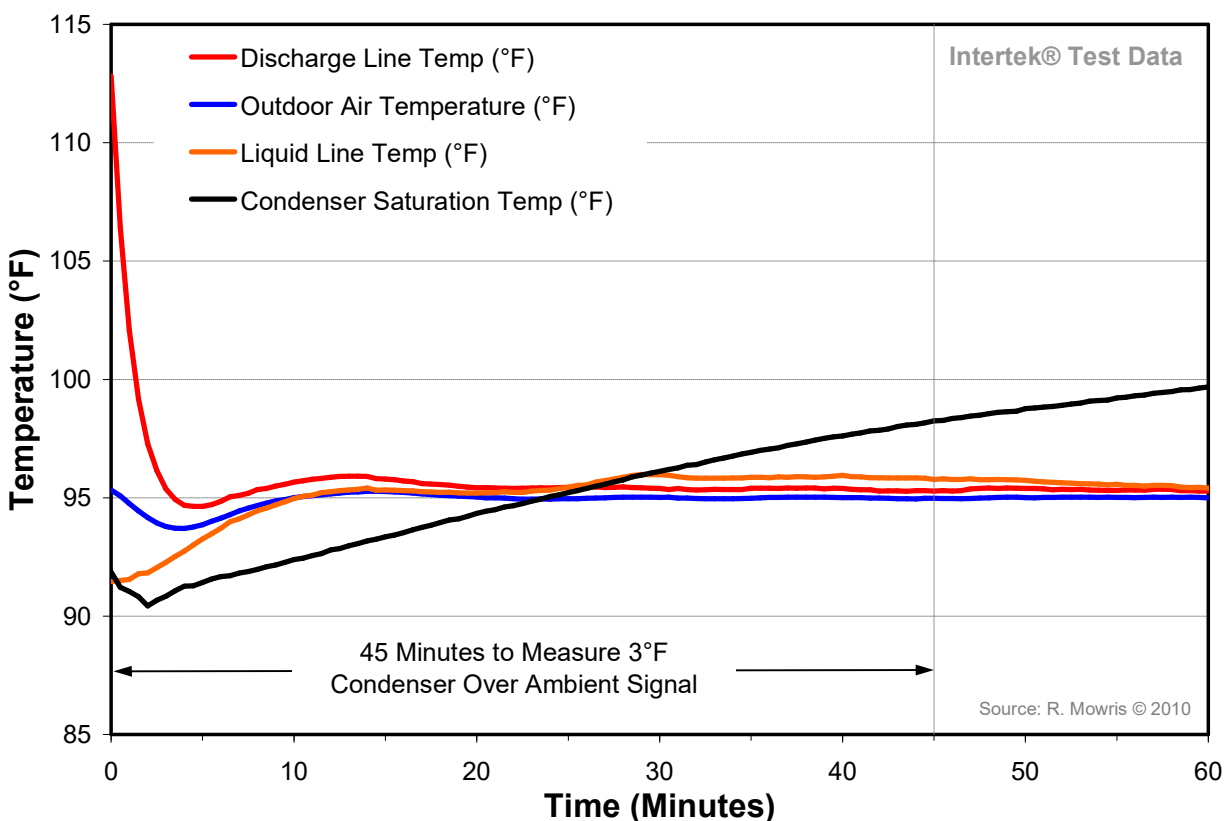


Figure 4.1: Time to check for 1% Nitrogen in a 3-ton non-TXV R22 Split-System with Condenser Fan Operating and Without Compressor or Evaporator Fan Operating

4.2 Refrigerant Restriction Fault Detection Diagnostics

The NTD or RSD software uses a patented or patent pending fault detection diagnostic method (US9207007) to distinguish restrictions from refrigerant over-charge or under-charge faults. Refrigerant restrictions are caused by moisture, flux/brazing residue, and particulates in the refrigerant system which damage compressors, clog metering devices, or make metering devices function improperly. Restrictions reduce refrigerant flow, evaporator pressure, evaporator saturation temperature, cooling capacity, and energy efficiency. Moisture in the refrigerant system combines with oil and refrigerant to form corrosive acid and sludge which can cause refrigerant restrictions in the expansion device. Liquid line filter driers are recommended to remove moisture, acid, and particulates and prevent restrictions.⁶ **Table 4.3** provides Intertek® laboratory test results for refrigerant restrictions on a non-TXV unit with refrigerant charge of 108 ounces. To emulate a restriction, an adjustable valve on the liquid line is used to cause a 22% increase in discharge pressure (DP) to suction pressure (SP) ratio. The restriction test (701) reduces EER*_A and EER*_B efficiency by 30% to 45%. Power decreased by 100 W or 3% similar to an under-charge. The CEC RCA protocol misdiagnoses the test 701 liquid line restriction as an undercharge. Adding refrigerant charge would decrease efficiency and damage the compressor. The NTD software detects restrictions. The RSD software recommends “Refrigerant line restriction detected. Check for plugged/iced evaporator coil, dirty evaporator fan, or collapsed duct. If okay, then check refrigerant line restriction EST < 33F.”

Table 4.3. Refrigerant Restriction Impacts on EER* and SEER* for non-TXV System

Description	EER* _A Capacity (kBtuh)	EER* _A	EER* _A Impact %	EST (°F)	Delta SH (°F)	EER* _B	CEC RCA Protocol	VERIFIED® Advanced FDD Software	Test
Base no restriction	32,759	9.42	NA	48.1	2.1	10.64	Correct RCA	Correct	189-4
Restriction non-TXV	22,385	6.62	-30%	33.51	33.3	5.81	Misdiagnosis	Restriction	701

Table 4.4 provides test results for restrictions on the TXV unit with refrigerant charge of 102 ounces. The restriction test (801) reduces EER*_A and EER*_B efficiency by 36 to 55%. The CEC and manufacturer RC protocol for test 801 misdiagnose the restriction as an overcharge. Removing refrigerant charge can cause ice formation on the evaporator coil and decrease efficiency. The RSD software recommends “Refrigerant line restriction detected. Check for plugged/iced evaporator coil, dirty evaporator fan, or collapsed duct. If okay, then check refrigerant line restriction EST < 32F.”

⁶ Carrier Corporation. 2010. Commercial Packaged Engineering Standard Work Procedure: System Evacuation and Dehydration. Lennox Industries Inc. 2008. Application and Design Guidelines: Lennox Refrigerant Piping Design and Fabrication Guidelines. Page 2. 9351–L9. www.lennox.com.

Table 4.4. Refrigerant Restriction Impacts on EER* and SEER* for TXV System

Description	EER* _A Capacity (kBtuh)	EER* _A	EER* _A Impact %	EST (°F)	Delta SC (°F)	EER* _B	CEC and Manufacturer RC Protocol	VERIFIED® Advanced FDD Software	Test
Base no restriction	32,764	9.48	NA	48.5	-2.7	11.14	Correct chg	Correct	303
Restriction TXV	19,812	6.06	-36%	30.5	4.8	5.02	Misdiagnosis	Restriction	801

If refrigerant restrictions are present in the system and the acid test indicates sludge, then standard cleanup procedures must be followed using filter driers to remove sludge. Vacuum pumps are not designed to remove sludge. If a split system older than 10 years contains sludge, it might be more cost effective to recover the charge and install a new system with new filter drier and clean or replace the line set. Manufacturers require properly sized liquid-line filter driers on new systems or whenever opened. This is especially important for R410A systems.⁷

4.3 Refrigerant Recovery and Evacuation Tools

The following equipment is required to purge non condensables and contaminated refrigerant from refrigerant hoses and manifolds prior to hooking up to refrigerant systems.

1. Compound digital pressure gauge manifold (3-hose with EPA low-loss fittings).
2. Digital micron pressure gauge for performing recovery and deep vacuum evacuation.
3. Fast Recovery unit for Class II, III, IV, V refrigerants rated at 1.98 to 4 lb/min liquid rating per UL ARI 740-98, with CPR valve, filter-drier, and automatic shut-off at 15 inches of Hg vacuum.
4. Two-stage vacuum pump (6 to 8 cfm) rated to 25 microns with inline isolation valve, gas ballast, vacuum gauge, and vacuum pump oil and ½” or ¾” diameter evacuation hoses
5. 3-way ¼ inch male Schrader-valve manifold fitting to connect 3 refrigerant hoses with EPA low-loss fittings to tank, recovery unit, or vacuum pump for purging refrigerant.
6. Accurate digital scale for weighing in or removing refrigerant.
7. Refrigerant leak detection equipment.
8. New refrigerant tanks of R-22 and R-410a and recovery tanks for R-22 and R-410a.
9. Two (2) Schrader valve core repair tools with accessories.
10. Locking Schrader caps with “O” ring seals and thread sealant.

⁷ Filter driers must be installed on R410A systems to remove moisture from polyolester (POE) oils. R410A POE oil is very hygroscopic and quickly absorbs moisture from air which will cause acid formation. Moisture cannot be removed by 500-micron vacuum developed by evacuation pumps.



Figure 4.1 Purging Refrigerant from Manifold Using Recovery Tank and Vacuum Pump

4.4 Purging Non Condensables and Contaminated Refrigerant from Hoses and Manifold

1. **Wear gloves, eye protection and foot protection when working on refrigeration systems.**
2. The **EPA prohibition on venting** requires precautions that must be followed when connecting or disconnecting refrigerant hoses per EPA 608.
3. **All hoses must be equipped with EPA low-loss fittings.**
4. Using a 3-way ¼-inch “T” with two male and one female fittings, attach one female fitting to the valve on top of R-22 or R-410a virgin refrigerant tank. Connect suction and liquid line hoses from manifold to two male fittings. Attached ¼” shut-off valve with at least one male fitting (e.g., Schrader core removal tool with shut off) to yellow charging hose attached to manifold. Make sure shut-off valve is closed. Once all connections are tight open valve on refrigerant tank, then open both sides of manifold to allow refrigerant to fill suction, liquid and charging hoses. Briefly open and close shut-off valve on end of yellow hose to purge manifold and hoses of air, old refrigerant, and contaminants. Manifold and hoses are now filled with virgin refrigerant vapor from R22 or R410a tank. Shut off valve on refrigerant tank and close both sides of manifold. Remove suction and liquid hoses from 3-way fitting and charging hose from shut off valve. Turn on digital manifold to check pressure and ensure that non-zero pressure is indicated in the low-side (blue) and high-side (red) refrigerant hoses. If no vapor remains in hoses, then fitting(s) or hoses are leaking and must be replaced.
5. **Optional purging method:** Attach 3-way ¼ inch male Schrader-valve manifold fitting to the recovery unit and connect all 3 hoses to 3-way fitting. Connect another hose from recovery unit to recovery tank. Open both valves on manifold and the valve on the recovery tank with the connected hose. Turn on the recovery unit and move valves on the recovery unit to recover refrigerant. Wait until low-side gauge on manifold reads 0 psig, close all valves on manifold and recovery unit, and turn off recovery unit. Connect 3-way ¼ inch male Schrader-valve manifold fitting to vacuum pump with 3 hoses attached. Open valves on manifold and turn on vacuum pump to achieve a vacuum of 0 psig as indicated on low-side pressure gauge and hold for 1 minute. Close manifold valves, disconnect hoses, and turn vacuum pump off.
6. Contaminated or used refrigerant is purged from hoses. Attach 3-way ¼ inch Schrader-valve manifold fitting to tank of new refrigerant and open valve to fill hoses with new refrigerant.

4.5 Connecting Refrigerant Hoses to AC and HP Systems

1. **Wear gloves, eye protection and foot protection when working on refrigeration systems.**
2. EPA low-loss fittings are required on all hoses.
3. Complete **Section 4.4**, Purging Non Condensables and Contaminated Refrigerant from Hoses and Manifold.
4. Attach low-side manifold hose to the suction line Schrader valve of the air conditioner.
5. Attach the high-side manifold hose to the liquid line Schrader valve of the air conditioner.

4.6 Disconnecting Refrigerant Hoses from AC and HP Systems

1. **Wear gloves, eye protection and foot protection when working on refrigeration systems.**
2. EPA low-loss fittings are required on all hoses per EPA 608.
3. Make sure both valves on manifold are closed and valve is closed on recovery tank or refrigerant tank.
4. With AC system running, remove high-side manifold hose from liquid line Schrader valve.
5. Open high-side valve and low-side valves on manifold. This will cause any refrigerant trapped in high-side and charging hose to be drawn into low-side of AC system.
6. When both manifold gauge pressures are equalized, so the high-side is the same pressure as the low-side, close off both high-side and low-side valves on the manifold.
7. Remove low-side manifold hose from suction line Schrader valve of AC system.

4.7 Refrigerant Recovery and Leak Testing Procedure

1. **Wear gloves, eye protection and foot protection when working on refrigeration systems.**
2. The **EPA prohibition on venting** requires precautions that must be followed when connecting or disconnecting refrigerant hoses. **Hoses must be equipped with EPA low-loss fittings.** Larger diameter evacuation hoses save time compared to 1/4" diameter hoses. Yellow Jacket makes 1/2" diameter hoses (<https://yellowjacket.com/product/maxflow-evacuation-hose-kit/>) and Accutools makes 3/4" diameter hoses (<https://accutools.com/evacuation-kits>).
3. **Recovery Preparation:** Attach two (2) Schrader valve core repair tools to liquid and suction line pressure ports and attach refrigerant hoses from manifold to the Schrader repair tools on the liquid and suction lines. Remove Schrader cores from AC or HP unit pressure ports to reduce recovery time. Attach center hose from manifold to recovery unit inlet. Optionally install a filter-drier on the vapor line inlet of recovery unit to protect compressor and CRO valve. Connect another hose from recovery unit outlet to the recovery tank. Open both valves on manifold and the valve on the recovery tank with the hose on it.
4. **Recovery:** Turn on the recovery unit and move valves on the recovery unit to recover refrigerant and wait until the low-side gauge on the manifold reads 0 psig. Most recovery machines automatically turn off at 0 psig. If MANIFOLD gauge indicates pressure has risen above 0 psig (0 bar), then refrigerant is still in system. Open the INLET valve and turn on machine and run until required 0 psig vacuum is reached again. Wait five minutes. Repeat process until refrigerant is removed and pressure is 0 psig or less. Close all valves on manifold and recovery unit and turn off recovery machine.
5. **Perform Repairs:** Remove restriction or replace filter drier, expansion device, reversing valve, or other failed, restricted, or damaged parts.
6. **Leak Pressure Test:** Install new Schrader core valves, sweep system with dry nitrogen by purging from suction to liquid side of system to carry out any moisture or particulates, and

perform leak pressure test. Pressurize system with nitrogen and allow to stand at manufacture's recommend test pressure for at least the minimum recommend time to assure a leak free system (e.g., 30 psig for 30 minutes). If system doesn't hold pressure, locate and repair leaks and repeat until 30 psig pressure test holds for 30 minutes. Perform high pressure test at 400 psig for 60 minutes. If pressure holds at 400 psig for 60 minutes, then perform triple evacuation.

4.8 Schrader Core Repair Procedure

Loose or damaged Schrader cores will cause refrigerant venting and need to be tightened, removed, or replaced. The Schrader core repair tool shown in **Figure 4.2** is required to tighten, remove, repair, or replace Schrader cores without losing charge. The extra 1/4" side port is used to attach an electronic micron gauge at the system for greater accuracy or to add refrigerant charge. **Figure 4.2** shows how the core removal tool allows refrigerant recovery at maximum efficiency to save time (3x faster) with core and retaining rod (on right) removed.

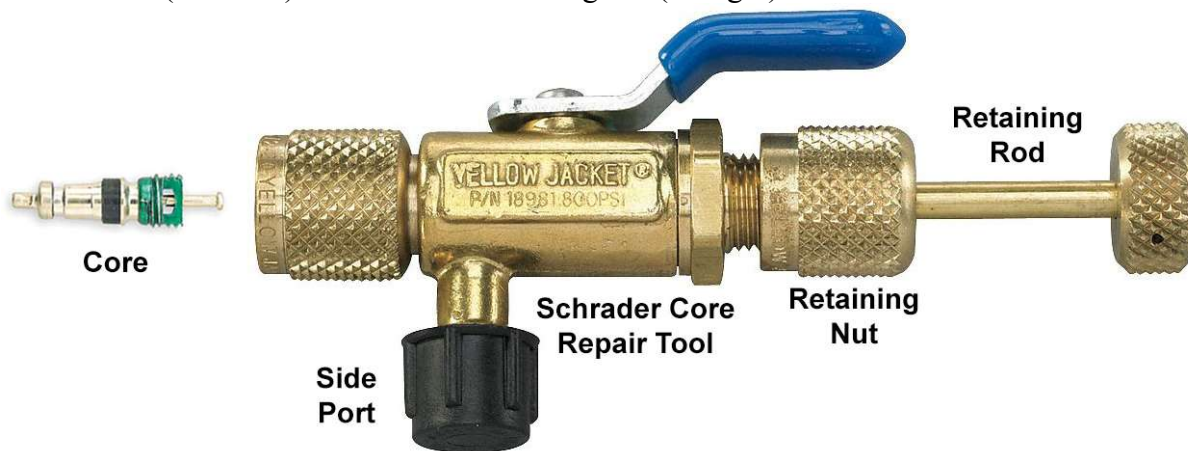


Figure 4.2 Schrader Core Repair Tool 18975 with Side port for Recovery or Micron Gauge

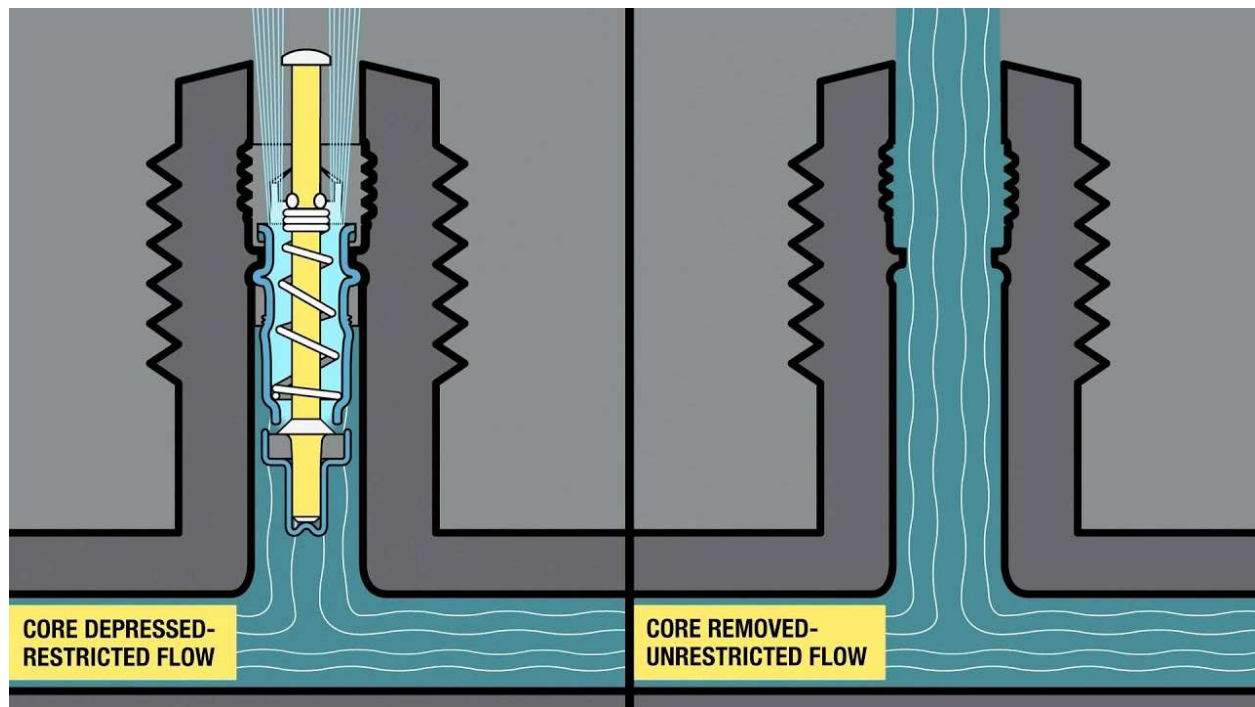


Figure 4.3 Schrader Core Removal Tool with Side Port Reduces Recovery Time by 3x

If a Schrader core is damaged or stuck, the Schrader core removal tool 18979 is used to remove a damaged core and threading tool 18978 is used to tap new threads for a new core per **Figure 4.4**.



Figure 4.4 Broken Schrader Core Removal 18979 and Threading Tool 18978

Schrader Core Removal

1. Attach female quick coupler to 1/4" or 5/16" male port on the system. Make sure shut off valve is open.
2. Push retaining rod forward and engage head and shoulder of Schrader stem. Turn counterclockwise until Schrader core is disengaged.
3. Pull retaining rod back all the way. Pressure in system will help push Schrader core back.
4. Turn ball valve handle 90° to close off passageway.
5. Unscrew retaining nut and remove rod/nut assembly and Schrader core.

Schrader Core Replacement

1. Put new core on end of retaining rod and insert both back and valve body and tighten retaining nut.
2. Turn ball valve handle 90° and push retaining rod forward.
3. With clockwise motion, tighten Schrader back into 1/4" male fitting.
4. Disconnect from system.

For Vacuum or Charge

1. Attach charging or vacuum hose.
2. Open ball valve and charge or pull vacuum without restrictions. On model 18975 and 18985, there is an extra 1/4" Schrader port. Attach a micron vacuum gauge here for system's internal vacuum reading. When charging a system or checking system pressure, a manifold set can be attached to this port.
3. After servicing, close ball valve. Remove hose and reinstall Schrader core into system.
4. Disconnect from system.

Rethreading Schrader Threads

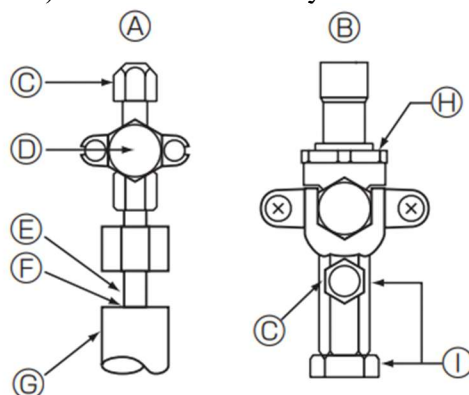
6. Insert 18978 or 18988 tool into valve tool and tighten
7. retaining nut.
8. Open shut-off valve.
9. Push 18978 or 18988 rod forward and use clockwise
10. motion to chase internal threads.
11. Unscrew rod and pull it back.
12. Close shut-off valve and remove 18978.

Removing Broken Schrader

1. Remove retaining rod assembly and insert 18979 (**Figure 4.4**) with shut-off valve open.
2. Attach to 1/4" male fitting.
3. Turn counterclockwise, engage Schrader.
4. Continue to push on broken/frozen core and turn until the core releases. Pull rod back.
5. Turn shut-off handle 90° to close.
6. Unscrew retaining nut, remove 18979 tool and damaged core.
7. Replace with new core per Schrader Core Replacement (discussed above).

4.9 Mini-Split AC and Heat Pump Installation Procedure

1. **Mini-split AC and heat pumps use flare fittings** require installation procedures to prevent refrigerant leaks and ensure proper evacuation.
2. **Mini-split refrigerant leaks occur at flare fittings caused by following problems.** 1) improper size or cracked flare, 2) over or under tightening flare (ft-lbs torque too high), 3) cone tool scarring flare (improper oil), 4) no refrigerant oil or Nylog Blue on flare face, 5) incorrect flare nut (requires mini-split nut not plumbing nut), 6) scratched flare face, 7) not deburring hole at end of copper tubing before flaring, 8) improper flaring tool, and 9) not performing low, medium, and high pressure leak tests with Nitrogen for sufficient time.
3. **Mini-split refrigerant pipe airtight testing method.**⁸ (1) Connect testing tools, (2) Make sure stop valves A and B are closed and do not open them (see **Figure 4.5**). (3) Gradually pressurize refrigerant lines with Nitrogen through the service port C of the liquid stop valve A and gas stop valve B. (4) **First** pressurize to 75 psig (0.52 MPa) and wait 5 minutes making sure pressure does not decrease. If pressure decreases, then look for leaks. Use leak detector or soapy water to check for leaks at pipe connections of outdoor unit (5) **Second** pressurize to 220 psig (1.51 MPa) and wait five minutes making sure pressure does not decrease. If pressure decreases, then look for leaks. (6) **Third** pressurize to 600 psig (4.14 MPa) and measure surrounding air temperature pressure. (7) If the specified pressure holds for 24 hours and does not decrease, then refrigerant tubes have passed the test and there are no leaks. If surrounding temperature changes by 1.8F (1C), the pressure will change by about 0.2 psig (0.0014 MPa). Make the necessary corrections.



(A) Stop valve <Liquid side>

(B) Stop valve <Gas side>

(C) Service port

(D) Open/Close section

(E) Local pipe

(F) Sealed, same way for gas side

(G) Pipe cover

(H) Do not use a wrench here.

Refrigerant leakage may result.

(I) Use two wrenches here.

4.5 Figure 4.5 Mini-split Liquid and Suction Line Valves

4. **Two Schrader core valve repair tools installed on low and high-side pressure ports** are required to remove Schrader core valves and reduce time for evacuation.

⁸https://www.mylinkdrive.com/viewPdf?srcUrl=http://s3.amazonaws.com/enter.mehvac.com/DAMRoot/Original/10006/M_MXZ-SM-NAM-NAMHZ_INSTALL_RG79F368H05.pdf. Mitsubishi Hyper-Heat Mini-split heat pumps.

5. **Mini-split Manufacturer Triple Evacuation.**
6. **Evacuation #1:** Evacuate mini-split system to 4,000 microns from both service valves. Micron gauge must be used at all times and system manifold gauges must not be used to measure vacuum. Break vacuum with Nitrogen into discharge service valve to 0 psig.
7. **Evacuation #2:** Evacuate mini-split system to 1,500 microns from suction service valve. Break vacuum with Nitrogen into the discharge service valve to 0 psig.
8. **Evacuation #3:** Evacuate to below 500 microns and hold vacuum at or below 500 microns for a minimum of 1 hour. Conduct a rise test for a minimum of 30 minutes. Total 90 minutes.
9. **Purpose of evacuation is to remove non-condensable water vapor.** Pressure increase after evacuation is due to water vapor in system. Many technicians only wait 15 minutes, but it can take 60 minutes or longer for ice inside system to melt and evaporate which causes vacuum pressure to rise above 500 microns. Fully evacuated system is required for R410a refrigerants which use Polyester (POE) oil which are hydrophilic. Small amounts of non-condensable water vapor in system which will increase condensing pressure and compressor power and reduce efficiency and capacity. Water vapor will create acid and sludge in refrigerant system causing low cooling capacity, increased compressor power and failure.
10. **Calculate additional line set required and add recommended refrigerant per OEM** typically 0.6 ounces/ft of line-set depending on liquid line diameter per manufacturer.
11. **There are no shortcuts to quality.** Refrigerant leak detection, repair, triple evacuation, leak prevention, and NTD methods help verify proper installation.

4.10 Refrigerant Pressure Test and Evacuation Procedure

1. **Evacuation Preparation: Vacuum pump oil must be clean.** In order for the vacuum pump to pull a near perfect vacuum, oil must be clean and moisture-free throughout evacuation. Take a few minutes during and after each job to drain, flush, and refill vacuum pump oil. Doing so will help the pump run at peak performance and maintenance-free for years. Attach center hose from the manifold to the vacuum pump. Sweep system with dry nitrogen by purging from suction to liquid side of system to carry out any moisture or particulates.
2. **Leak Pressure Test:** After nitrogen sweep, pressurize system with nitrogen and allow it to stand at manufacture's recommend test pressure for at least the minimum recommend time to assure a leak free system (e.g., 30 psig for 30 minutes). If system doesn't hold pressure, locate and repair leaks and repeat until 30 psig pressure test holds for 30 minutes. Perform high pressure test at 400 psig for 60 minutes. If pressure holds at 400 psig for 60 minutes, then perform triple evacuation.
3. **Remove Schrader Core Valves:** Vent nitrogen and remove Schrader cores from system using Schrader core repair tools.
4. **Evacuate from both sides of system:** Use two ½" or ¾" diameter evacuation hoses 1-meter long connected directly to system and vacuum pump. Evacuate from both sides to reduce time and improve dehydration.
5. **Evacuation #1:** Open valves on manifold and turn on vacuum pump with gas ballast open. Vacuum pumps cannot achieve full vacuum with ballast open. Shut ballast at 10000 to 12000 microns. System pressure may drop quickly. Pay close attention to vacuum readings. Close gas ballast and evacuate to target pressure typically 200 to 300 microns below maximum decay pressure for system dehydration. Leave vacuum pump running below target for 1 to 60 minutes. Turn off vacuum pump and isolate system from vacuum pump by slowly closing core tools to remove gas trapped in ball valve and watch rate of pressure increase (e.g., decay

test). Monitor pressure for 5 to 20 minutes. A slight rise followed by slow leak rate assures system is dry and tight. If vacuum rise rate does not slow system, is leaking. If system pressure increases above 1500 microns and levels off at 2000 to 3000 microns, then system is tight with moisture and needs more evacuation time. A rapid rise above 1500 to atmospheric pressure indicates a leak in the AC system or connecting hoses. Locate and repair any leaks.

6. **Evacuation #2:** If pressure isn't rising above 1500 microns, then break vacuum with Nitrogen, turn on vacuum pump, and perform another deep vacuum to 250 microns to remove moisture and hold for 60 minutes. If pressure stays below 500 microns for 60 minutes, then system is properly evacuated and ready for charging with new refrigerant.
7. **Evacuation #3:** If pressure increases above 500 microns, then break vacuum with Nitrogen, turn on vacuum pump, and perform another deep vacuum to 250 microns and hold for 60 minutes. If pressure stays below 500 microns for 60 minutes, then system is properly evacuated and ready for charging with new refrigerant.
8. **New Systems Install New Schrader Cores and Release Charge into System:** Release refrigerant into AC system from condenser per manufacturer's instructions. Install new valve cores with Schrader valve core repair tool. Remove Place new core in slotted tool.
9. **Existing Systems Install New Schrader Cores and Weigh-in Charge:** Weigh-in charge as described below. Install new Schrader valve cores using Schrader core tool.

4.11 Refrigerant Charging Procedure

1. **Wear gloves, eye protection and foot protection when working on refrigeration systems.**
2. Complete above procedures to recover refrigerant from old AC or HP system, leak test, and triple evacuation procedures.
3. Determine factory charge from manufacturer's specifications on name plate or manufacturer website. Enter factory charge into NTD software Job screen. If manufacturer factory charge is unavailable (i.e., name plate is illegible or information is unavailable online), then determine cooling capacity from compressor model number or other information. For packaged systems, factory refrigerant charge per ton can vary from 1.5 to 2.5 lbs of refrigerant per ton of cooling capacity. For split-systems, factory refrigerant charge can vary from 1.75 to 2.5 lbs of refrigerant per ton of cooling capacity. Split-systems with micro-channel condenser-coils use less refrigerant than standard condenser coils. For split systems, include line-set length beyond or shorter than standard length per manufacturer's specifications. Manufacturers generally recommend adding 0.6 oz. of R22 or R410a refrigerant per foot of 3/8" OD liquid line length beyond 15 feet.
4. See https://www.shareddocs.com/hvac/docs/1011/Public/02/42106500001_ICP_10370.pdf.
5. See: <https://www.shareddocs.com/hvac/docs/1009/Public/05/LLGDFS-5XA.pdf>.
6. York provides "refrigerant line charge adders" for R22 and R410a at the following URL: <https://yorkcentraltechtalk.wordpress.com/2013/07/26/refrigerant-line-charge-adders/>
7. Place new refrigerant tank on digital scale, attach center hose of manifold to new refrigerant tank, locate manifold so as not to affect refrigerant scale readings, and place low-side hose to the suction line Schrader valve of the air conditioner. R410a refrigerant tank must be oriented properly to deliver liquid when adding refrigerant to the system since R410a is a zeotropic mixture of two refrigerants, and the orientation is clearly marked on R410a tank. R22 can be charged with the refrigerant tank in either orientation since R22 is a pure refrigerant.
8. Tare scale to indicate zero reading.

9. Open new refrigerant tank valve slowly to add new refrigerant per NTD recommendation or add factory charge for recovered system. Do not feed refrigerant too quickly to avoid allowing liquid refrigerant to enter compressor (“slugging”) which can damage compressor.
10. If charging an evacuated system, then AC system will gradually fill with new refrigerant close to factory charge. As AC system gets within 10 to 40 percent of factory charge, turn ON AC system and allow compressor to draw in correct factory refrigerant charge.
11. Check final charge with NTD software to achieve proper superheat for non-TXV-equipped systems or proper subcooling for TXV-equipped systems (per manufacturer).

5. Equipment and Calibration

5.1 Equipment

Calibrated digital equipment must be used to perform NTD or RSD verification services. Analog pressure gauges are not allowed. Refrigerant hoses must have EPA fittings. Required field measurements, measurement equipment, and tolerances are provided in the following table.

Table 5.1 Field Measurements, Measurement Equipment, and Tolerances

Field Measurement	Measurement Tolerances
Digital Psychrometer Air Temperature in degrees Fahrenheit (°F) of return and supply wetbulb and drybulb and outdoor condenser entering air	Psychrometer Drybulb Accuracy: $\pm 1^\circ\text{F}$, Resolution 0.1°F Psychrometer Wetbulb Accuracy: $\pm 0.75^\circ\text{F}$, Resolution 0.1°F Humidity Accuracy: $\pm 2.5\%\text{RH}$, Resolution: $0.1\%\text{RH}$
Pipe-clamp temperature (°F) of vapor and suction lines Bead probe condenser entering air temperature	Pipe-clamp Temperature Accuracy: $\pm 1^\circ\text{F}$, Resolution 0.1°F Air Temperature Accuracy: $\pm 1^\circ\text{F}$, Resolution 0.1°
Refrigerant pressure in psi of vapor and suction line	Refrigerant pressure: $\pm 1\%$ at full scale for R22 and R410a
Ounces (oz.) of refrigerant charge added or removed	Electronic scale: ± 0.5 ounces or $\pm 0.1\%$ whichever is greater
Refrigerant Leak Detection	Single sensor, single level refrigerant detection system senses to 100 PPM or 0.06 oz/yr, Highly resistant to false alarms
Amperage (amps) of evaporator fan or compressor	AC Amps true-RMS Accuracy: 1.5% Resolution: $10\text{ A} / 0.001\text{ A}$ A, DC Amps Accuracy: 1.0% . Resolution: $10\text{ A} / 0.001\text{ A}$

1. **Temperature:** Digital thermometer must have at least two-channel capability with Fahrenheit display. Meter accuracy must be plus or minus 0.1% of reading or plus or minus 1.0°F and resolution must be 0.1°F .
2. **Temperature sensors:** Measurements four (4) temperature sensors and two (2) digital psychrometers are required. Acceptable sensor technologies include type thermistors with minimum $\pm 1.0\text{F}$ accuracy or Type-K thermocouples and RTDs with minimum $\pm 1.0\text{F}$ accuracy. Pipe-clamp temperature sensors to measure refrigerant line temperatures must be installed to not be affected by surrounding air and provide thermal contact with refrigerant pipe and insulation behind sensor to insulate from ambient conditions.
3. **Wetbulb or Relative Humidity:** Digital psychrometer to measure return and supply wetbulb and drybulb temperatures. Accuracy of wetbulb or relative humidity sensors must be within $\pm 2.5\%\text{RH}$, $\pm 0.75\text{F}$ wetbulb, and $\pm 1\text{F}$ drybulb with $0.1\%\text{RH}$ and 0.1F resolution.
4. **Refrigerant Pressure:** Digital pressure measurement with $\pm 1\%$ accuracy and 2 second response. Standard multi-port refrigerant manifold with digital electronic pressure gauges and accuracy of $\pm 1\%$. Hose lengths should be as short as reasonable to minimize refrigerant loss from air conditioning systems. All fittings must be EPA certified to reduce leakage when

removing hoses from the Schrader valve refrigerant ports. EPA fittings should be installed on both ends of separate low- and high-side hoses dedicated to R22 and R410A to allow use of one multi-port refrigerant manifold with electronic pressure gauges. Analog refrigerant pressure gauges are not allowed.

5. **Refrigerant Weight:** Electronic scales used to weigh refrigerant that is added or removed from the air conditioner to achieve proper refrigerant charge must be accurate to $\pm 0.03\%$ of reading with resolution of ± 0.25 ounces, ± 0.1 lbs, or ± 10 g.
6. **Amperage:** Electronic clamp-on or multi-meters used to measure evaporator fan amperage before and after cleaning evaporator coils plus or minus 1.5% AC or plus or minus 1% DC.

5.2 Calibration

Calibrated equipment must be used to perform NTD or RSD verification services. Measurement equipment must be calibrated at least once per week or whenever equipment is dropped or transported to an altitude change of 3,000 feet or more above sea level.

5.2.1 Temperature Sensor Field Calibration Procedure

Temperature sensors used for measuring refrigerant temperatures must be calibrated monthly to ensure that they are reading accurate temperatures. The following procedure must be used to check bead or pipe-clamp temperature sensor calibration:

1. Fill an insulated cup (foam) with crushed ice. The ice shall completely fill the cup. Add water to fill the cup.
2. Insert two temperature probe sensors (or two wet wick or pipe-clamp sensors) into the center of the ice bath and attach them to the digital thermometer.
3. Let the temperatures stabilize. The temperatures shall be 32°F ($\pm 1^{\circ}\text{F}$). If the temperature is off by more than 1°F make corrections according to the manufacturer's instructions. Any temperature sensors that are off by more than 2°F shall be replaced.
4. Switch sensors and ensure temperatures on T1 and T2 are still within $\pm 1^{\circ}\text{F}$ of 32°F .
5. Repeat the process for all temperature sensors.

5.2.2 Wetbulb or Relative Humidity Sensor Maintenance

Solid-state digital sensors used to measure relative humidity (RH) and wetbulb (WB) temperature must be checked weekly for accuracy (compared to wetted cotton wick using type K bead probe) or calibrated using 33% or 75% Relative Humidity (RH) salt solution. Temperature sensors not suitable for immersion (solid-state digital sensors used to measure relative humidity) must be factory calibrated on an annual basis. Wetbulb or RH sensor accuracy must be calibrated using either the sling psychrometer method or the reference sensor method.

1. Place cotton wick on end of calibrated temperature probe. Wet wick with distilled water.
2. Wait until temperature goes down and stabilizes for at least two minutes.
3. Enter wet wick wetbulb (WB) temperatures into software calibration screen (shown below). Digital wetbulb temperature sensors shall be within $\pm 1.0^{\circ}\text{F}$. If digital temperature sensors are off by more than 1.0°F , make corrections according to manufacturer's instructions. Any sensors off by more than 1.5°F shall be replaced.

Digital psychrometers are calibrated using an RH salt solution or calibration software using an offset algorithm and known calibrated sensor located in the same environmental conditions.

1. An RH300-CAL Humidity Calibration Kit (33% and 75% Humidity Calibration Reference) can be used to verify calibration of digital humidity sensors. Bottles have small openings to snugly fit a remote sensor probe.⁹ Thermosense offers RH calibration tools.¹⁰
2. To check the 33% or 75% RH Calibration insert RH sensor into the 33% or 75% salt reference bottle. Check reading after 10 minutes and verify reading is within specification.
3. For RH calibration (33% and 75%) check the “DP” and “WB” appear in the bottom displays before turning the meter OFF.
4. 33% Calibration. Insert sensor into 33% salt reference bottle. Allow one hour to stabilize. While holding down °C/°F button, press and hold the ON/OFF button for 2 seconds to enter calibration mode and “32.8%” will flash on the LCD screen and “DP” and “WB” will display “_ _ _ _”. After 30 minutes, flashing will stop indicating 33% calibration is complete. Exit calibration before completion by pressing ON/OFF button to turn OFF meter.
5. 75% Calibration. Insert sensor into 75% salt reference bottle. Allow one hour to stabilize. Press and hold button for 2 seconds to enter the 75% calibration. “75.3%” will flash on LCD. After 30 minutes, the flashing will stop to indicate 75% calibration is complete. Turn OFF power to complete calibration. If salt at bottom of calibration bottles is dry, replace bottle.
6. Another option is to create a 75% RH environment by moistening one teaspoon of table salt, in an open container such as a clean plastic bottle cap. Place the bottle cap with salt solution and digital RH probe in a large sealable plastic bag and leave the bag in a conditioned space maintained at 68F to 86F where the bag will not be disturbed for 24 hours. Do not allow salt solution to directly contact the digital psychrometer sensor which can damage the sensor.¹¹

5.2.3 Refrigerant Gauge Field Check Procedure

Refrigerant gauges should be checked weekly or daily. Remove EPA fittings and zero readings on both gauges to atmospheric pressure.

5.2.4 Checking Recovery Tank Pressure for Removing Refrigerant

In order to remove refrigerant from overcharged units to the recovery tank, the pressure in the recovery tank must be lower than the liquid line pressure. The recovery tank pressure can be determined from the outdoor air temperature and refrigerant temperature/pressure charts. The NTD software contains the temperature/pressure charts for R22 and R410a. To check the pressure, go to the subcooling screen and adjust the liquid pressure until the condenser saturation temperature (CST) matches the outdoor air temperature. The liquid line pressure that corresponds to the CST match to outdoor temperature will be close to the recovery tank pressure (if the recovery tank is in the shade).

⁹ <https://www.extech.com/products/RH300-CAL>. Relative Humidity Calibration Reference Standards.
https://www.extech.com/products/resources/RH300-CAL_UM-en.pdf.

¹⁰ https://www.thermosensedirect.com/acatalog/hh-rca-33-75_rh_humidity_calibration_bottles.html.
https://www.thermosense.co.uk/pdfs/usermanuals/hh-rhcal-33-75_operation_manual.pdf

¹¹ <https://resources.fieldpiece.com/wp-content/uploads/2020/11/Opman-SRH3-v05.pdf>

6. General Troubleshooting

Section 6 provides general troubleshooting information to check fan operation and minor cooling or heating issues. For split-systems always make sure the cabinet door is squarely installed properly to engage the safety switch inside the cabinet. For packaged units make sure the “disconnect” is in the ON position or check for blown fuses. For all systems make sure all wire connections at thermostat are tight, thermostat has new batteries and terminals on thermostat are properly connected.

6.1 Check Minor Cooling or Heating Issues

- ☐ If insufficient cooling, then replace air filter, clean condenser, check compressor contactor, and/or check and correct refrigerant charge or install new thermostat batteries or check for common “C” wire at the thermostat.
- ☐ If insufficient heating, then replace air filter, check igniter, inducer fan, gas valve, or install new thermostat batteries or check for common “C” wire at the thermostat.
- ☐ If heat pump is not providing sufficient heating replace air filter and clean condenser, check compressor contactor, reversing valve, and/or check and correct refrigerant charge.
- ☐ If hydronic system is not providing sufficient heating, then check pump, air filter, and check water heater or hot water supply temperature to make sure setpoint is at least 130°F.

6.2 Check Contactors

- ☐ When a contactor is damaged and needs replacement, it won't pull closed and connect power. If thermostat is ON, but AC unit isn't starting, the contactor might have failed.
- ☐ Visually check for black marks and pitting on contactor connections. Excessive pitting can cause contactors to fail.
- ☐ Replace pitted or failed contactors.

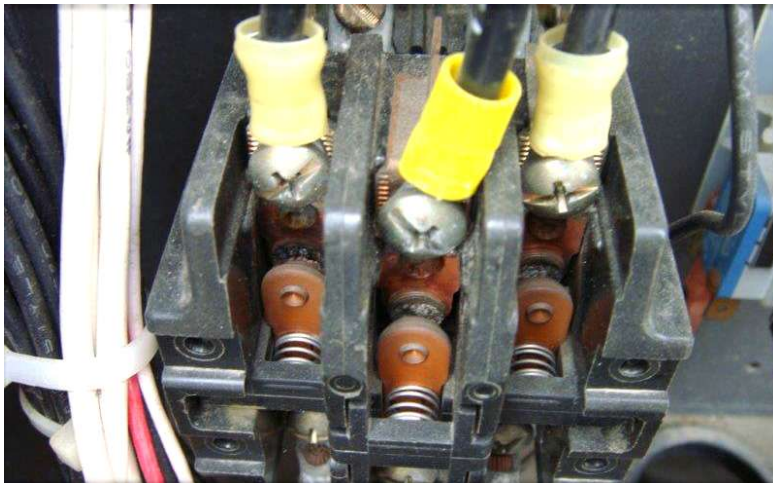


Figure 6.4 Example of pitted contactors indicating pending failure

8.3 Check Capacitors

- ☐ Start capacitors have a relief plug or disc on top that bulges or leaks if capacitor has overheated. Visually inspect and replace any bulged or leaking capacitors.

- ☐ Wearing insulated gloves and safety glasses, remove disconnect, turn thermostat to OFF, remove panel covering electrical components.
- ☐ Use capacitor discharge tool and screwdriver with insulated handle to touch both common “C” and compressor “HERM” connection tabs on top of capacitor to discharge capacitor.
- ☐ Use capacitor discharge tool and screwdriver to touch both fan “G” and common C tabs on top of capacitor to discharge fan side of capacitor.
- ☐ With digital Multimeter set to micro-farads, touch one lead to common “C” and other lead to either fan “G” or compressor “HERM” tab. If micro-farad reading is within 0% to +/-20% of operating range on side of capacitor, then capacitor is good. If not, then replace capacitor.
- ☐ Replace electrical cover on unit, replace electrical disconnect, and turn thermostat to ON.



Figure 6.5 Checking 50 μF capacitor but only measuring 0.012 μF indicating failure

6.4 Check Transformer

- ☐ Wearing insulated gloves and safety glasses, turn OFF power to AC unit. Set up digital Multimeter to measure control voltage across secondary winding. Turn ON power and measure voltage across secondary winding. If within 10% of voltage indicated by schematic or manufacturer service manual (e.g., 24 +/- 2.4 VAC), then control transformer is good. If secondary voltage is low (< 21.6 VAC) it can affect operation of relays and other control circuits. If there is no voltage or low voltage, then perform next check.
- ☐ Wearing insulated gloves and safety glasses, turn OFF power to AC unit. Set up digital Multimeter to measure high voltage across primary winding. Turn ON power and measure voltage across secondary winding. If no voltage or low voltage, measure single-phase equipment input voltage or three-phase equipment voltage. If input voltage is good, then trouble-shoot circuit between power supply and control transformer primary winding.
- ☐ If high voltage across primary winding is good and there is no voltage or low voltage across secondary winding, then replace control transformer.

6.5 Check Fuses

- ☐ Wearing insulated gloves and safety glasses, remove disconnect to turn OFF power and remove panel covering fuses.
- ☐ Using an insulated fuse puller remove fuse(s) from disconnect switch.
- ☐ Set up digital Multimeter to measure continuity. If fuse is good, digital Multimeter will measure ZERO Ohms and beep. Fuse has failed if digital Multimeter reads open or measures a resistance. Fuses can fail due to poor contact. Check disconnect switch for loose connections, discolored or hot clips or blades. Replace failed fuse(s).

Appendix A: Air Conditioner Model Numbers

Carrier – The first two Carrier numbers are a code for the basic type of unit. The “38” in **38TDA036** is the code for a split-system condensing unit. The “48” in **48HJD036** is the code for a gas/electric rooftop packaged unit. Newer Carrier model numbers start with “24” and **24ANA736** is the code for a split-system condensing unit. Newer Bryant models start with “187” **187ANA036** is the code for a split-system condensing unit. The “50” in **50HX024** is the code for a packaged heat pump unit. The next two or three letters refer to the design series **38TDA036**. The last three numbers provide the cooling capacity in thousands of British Thermal Units per hour (kBtuh). One ton of capacity times 12 equals kBtuh of capacity. The cooling capacity for Carrier split-system **38TDA036** is 36 kBtuh or 3-tons. The capacity for Carrier packaged unit **48HJD005** is 4-tons. Here are some model numbers and capacities.

Carrier Split-Systems	Carrier Gas/Electric Packaged	Carrier Packaged Heat Pump
Split-System Air Conditioners	48HJD004 = 36 = 3 tons	50HX024 = 24 = 2 tons
38TDA018 = 18 = 1.5 tons	48HJD005 = 48 = 4 tons	50HX030 = 30 = 2.5 tons
38TDA024 = 24 = 2 tons	48HJD006 = 60 = 5 tons	50HX036 = 36 = 3 tons
38TDA030 = 30 = 2.5 tons	48HJD007 = 72 = 6 tons	50HX042 = 42 = 3.5 tons
38TDA036 = 36 = 3 tons	48HJD008 = 90 = 7.5 tons	50HX048 = 48 = 4 tons
38TDA042 = 42 = 3.5 tons	48HJD009 = 102 = 8.5 tons	50HX060 = 60 = 5 tons
38TDA048 = 48 = 4 tons	48HJD012 = 120 = 10 tons	
38TDA060 = 60 = 5 tons	48HJD014 = 126 = 12.5 tons	50TJQ004 = 36 = 3 tons
Newer Carrier Models	48HJD016 = 180 = 15 tons	50TJQ005 = 48 = 4 tons
24ANA736 = 36 = 3 tons	48HJD024 = 240 = 20 tons	50TJQ006 = 60 = 5 tons
Newer Bryant Models	48HJD028 = 300 = 25 tons	50TJQ007 = 72 = 6 tons
187ANA036 = 36 = 3 tons	48HJD034 = 360 = 30 tons	50TJQ008 = 80 = 7.5 tons
	48HJD044 = 480 = 40 tons	50TJQ009 = 102 = 8.5 tons
	48HJD054 = 600 = 50 tons	50TJQ012 = 120 = 10 tons
	48HJD064 = 720 = 60 tons	
Split-System Heat Pumps		
38YKC018 = 18 = 1.5 tons		
38YKC024 = 24 = 2 tons		
38YKC030 = 30 = 2.5 tons		
38YKC036 = 36 = 3 tons		
38YKC042 = 42 = 3.5 tons		
38YKC048 = 48 = 4 tons		
38YKC060 = 60 = 5 tons		
Newer Carrier Heat Pump		
25ANA636 = 36 = 3 tons		

Coleman – For first two to four alpha-numeric characters indicate the type of unit and its efficiency. The next two or three numbers provide the cooling capacity as shown below. Sometimes Coleman uses a “-” before the capacity and provide capacity in tons. Sometimes

Coleman uses a “0” before the capacity and provide capacity in kBtuh such as 36 (kBtuh) for a three ton unit. There are many different alpha numeric characters used for different models.

Coleman Split-System AC	Coleman Pkg Heat Pump	Coleman Pkg Gas/Elec AC
BRHS0181BD = 18 = 1.5 tons	BA-03E05ATA = 36 = <u>3</u> tons	DCHB-T036N050 = 36 = <u>3</u> tons
BRHS0241BD = 24 = 2 tons	BA-04E07ATA = 48 = <u>4</u> tons	DCHB-T048N075 = 48 = <u>4</u> tons
BRHS0301BD = 30 = 2.5 tons	BA-05E10ATA = 60 = <u>5</u> tons	DCHB-T060N100 = 60 = <u>5</u> tons
BRHS0361BD = 36 = 3 tons	BA-06E20ATA = 72 = <u>6</u> tons	DCHB-T072N125 = 72 = <u>6</u> tons
BRHS0421CD = 42 = 3.5 tons		
BRHS0481BE = 48 = 4 tons		
BRHS0601CD = 60 = 5 tons		

RUUD or RHEEM – The first 3 to 5 alpha-numeric characters are used to designate the basic product type. The first letter in the product model number is used to designate RHEEM (“R”) or RUUD (“U”) except for packaged units or 13/14 SEER models (13AJA or 14AJA) that are branded with RHEEM, RUUD, or Weatherking. Model numbers are as follows.

R22 Split Cooling – 13AJA, AND, UAND, 14AJA, APC, UAPC, ARA, UARA.

R410A Split Cooling – 13AJL, ANL, UANL, 14AJA, APL, UAPL, ARL, UARL, ASL, UASL.

Commercial Split – AKB, UAKB, AWD, UAWD, AWE, UAWE.

R22 Split Heat Pump – 13PJA, PNE, UPNE, PPC, UPPC.

R410A Split Heat Pump – 13PJA, PNL, UPNL, PPL, UPPL, PRL, UPRL.

Commercial Split Heat Pump – PWC, PWE.

Commercial Packaged – RKKA (standard efficiency), RKMA (high-efficiency).

The next three numbers provide the cooling capacity as shown below in the first two columns.

Rheem/Ruud Split-Systems	Rheem/Ruud Gas/Elec Pkg.	Rheem/Ruud Heat Pump Pkg.
Split-System Air Conditioners	RKKA-A036 = 36 = 3 tons	RQKA-A036 = 36 = 3 tons
UAND-018 = 18 = 1.5 tons	RKKA-A042 = 42 = 3.5 tons	RQKA-A042 = 42 = 3.5 tons
UAND-024 = 24 = 2 tons	RKKA-A048 = 48 = 4 tons	RQKA-A048 = 48 = 4 tons
UAND-030 = 30 = 2.5 tons	RKKA-A060 = 60 = 5 tons	RQKA-A060 = 60 = 5 tons
UAND-036 = 36 = 3 tons	RKKA-A072 = 72 = 6 tons	
UAND-042 = 42 = 3.5 tons	RKKA-A073 = 72 = 6 tons	RJKA-A036 = 36 = 3 tons
UAND-048 = 48 = 4 tons	RKKA-A085 = 84 = 7 tons	RJKA-A042 = 42 = 3.5 tons
UAND-060 = 60 = 5 tons	RKKA-A090 = 90 = 7.5 tons	RJKA-A048 = 48 = 4 tons
	RKKA-A102 = 102 = 8.5 tons	RJKA-A060 = 60 = 5 tons
Split-System Heat Pumps	RKKA-A140 = 140 = 10 tons	R410A Heat Pumps Pkg.
UPNE-018 = 18 = 1.5 tons	RKKA-A150 = 150 = 12.5 tons	RJNL-A036 = 36 = 3 tons
UPNE-024 = 24 = 2 tons		RJNL-A042 = 42 = 3.5 tons
UPNE-030 = 30 = 2.5 tons	RKKA-A180 = 180 = 15 tons	RJNL-A048 = 48 = 4 tons
UPNE-036 = 36 = 3 tons	RKKA-A240 = 240 = 20 tons	RJNL-A060 = 60 = 5 tons
UPNE-042 = 42 = 3.5 tons	RKKA-A300 = 300 = 25 tons	
UPNE-048 = 48 = 4 tons		
UPNE-060 = 60 = 5 tons		

Trane – The first three Trane numbers are a code for the basic product type.

Split Cooling – TTA, TTN, TTR, TTS, TTX.

Split Heat Pump – TWA, TWN, TWR, TWS, TWX.

Package Cooling – TCC, TCH, TCD, TCX, TCM.

Package Heat Pump – WCC, WCD, WCH, WCM, WCX, DCX.

Gas/Electric Package – YCC, YCD, YCH, YCX.

The next three numbers provide the cooling capacity as shown below in the first two columns.

Trane uses the first four numbers for Self Contained Package. For example, SFHF refers to self-contained DX cooling with gas heat(SF), single-zone (H), development sequence 6 (F). The next three numbers provide the cooling capacity as shown below in third column.

Trane Split-Systems	Trane Gas/Electric Package	Trane Self-Contained Package
Split-System Air Conditioners	YCD036 = 36 = 3 tons	SFHFC20 = 240 = 20 tons
TTR018 = 18 = 1.5 tons	YCD037 = 36 = 3 tons	SFHFC25 = 300 = 25 tons
TTR024 = 24 = 2 tons	YCD048 = 48 = 4 tons	SFHFC30 = 300 = 25 tons
TTR030 = 30 = 2.5 tons	YCD049 = 48 = 4 tons	SFHFC40 = 480 = 40 tons
TTR036 = 36 = 3 tons	YCD060 = 60 = 5 tons	SFHFC50 = 600 = 50 tons
TTR042 = 42 = 3.5 tons	YCD061 = 60 = 5 tons	SFHFC55 = 660 = 55 tons
TTR048 = 48 = 4 tons	YCD074 = 72 = 6 tons	SFHFC60 = 720 = 60 tons
TTR060 = 60 = 5 tons	YCD075 = 72 = 6 tons	
	YCD0864 = 84 = 7 tons	
	YCD090 = 90 = 7.5 tons	
Split-System Heat Pumps	YCD091 = 90 7.5 tons	
TWA018 = 18 = 1.5 tons	YCD106 = 240 = 8.5 tons	
TWA024 = 24 = 2 tons	YCD103 = 240 = 8.5 tons	
TWA030 = 30 = 2.5 tons	YCD120 = 120 = 10 tons	
TWA036 = 36 = 3 tons	YCD121 = 120 = 10 tons	
TWA042 = 42 = 3.5 tons	YCD150 = 120 = 12.5 tons	
TWA048 = 48 = 4 tons	YCD151 = 120 = 12 tons	
TWA060 = 60 = 5 tons	YCD180 = 180 = 15 tons	
	YCD181 = 180 = 15 tons	
	YCD210 = 210 = 17.5 tons	
	YCD211 = 210 = 17.5 tons	
	YCD240 = 240 = 20 tons	
	YCD241 = 240 = 24 tons	
	YCD300 = 300 = 25 tons	

Lennox – The first three to five Lennox numbers are a code for the basic product type.

The first letter designates the class or series of products. Packaged rooftop units are designated with S-Class, L-Series, and T-Class. Split systems are designated with S-Class and T-Class.

The next letter designates cooling with gas heat G, cooling only C, or heat pump H. The third letter designates the design series. Lennox sometimes uses another letter plus a number to designate the Series. Lennox often uses a dash (“-”), zero “0” or a “1” to start the three digit

cooling capacity as shown below. The old Lennox capacity nomenclature is shown in the left column, new nomenclature is shown in the middle column, and package unit model numbers in the right column.

Old Lennox Nomenclature	New Lennox Nomenclature	Lennox Package
-14 = 12 = 1 ton	-12 = 12 = 1 ton	Gas/Electric R22
-21 = 20 = 1.5 tons	-18 = 18 = 1.5 tons	LGA024H2 = 24 = 2 tons
-26 = 24 = 2 tons	-24 = 24 = 2 tons	LGA030H2 = 30 = 2.5 tons
-31 = 30 = 2.5 tons	-30 = 30 = 2.5 tons	LGA036H2 = 36 = 3 tons
-41 = 36 = 3 tons	-36 = 36 = 3 tons	LGA042H2 = 42 = 3.5 tons
-46 = 42 = 3.5 tons	-42 = 42 = 3.5 tons	LGA048H2 = 48 = 4 tons
-51 = 48 = 4 tons	-48 = 48 = 4 tons	LGA060H2 = 60 = 5 tons
-65 = 60 = 5 tons	-60 = 60 = 5 tons	LGA120H2 = 120 = 10 tons
-81 = 72 = 6 tons	-72 = 72 = 6 tons	LGA300H2 = 300 = 25 tons
-95 = 90 = 7.5 tons	-90 = 90 = 7.5 tons	
-135 = 120 = 10 tons	-120 = 120 = 10 tons	Gas/Electric R410A
-185 = 180 = 15 tons	-150 = 150 = 12.5 tons	LGA120H4 = 120 = 10 tons
-275 = 240 = 20 tons	-180 = 180 = 15 tons	LGA300H4 = 300 = 25 tons
-300 = 300 = 25 tons	-240 = 240 = 20 tons	
-360 = 360 = 30 tons	-300 = 300 = 25 tons	Heat Pump
-415 = 396 = 33 tons	-360 = 360 = 30 tons	LHA036 = 36 = 3 tons
-450 = 450 = 37.5 tons	-450 = 450 = 37.5 tons	LHA048 = 48 = 4 tons
-600 = 600 = 50 tons	-504 = 504 = 42 tons	LHA060 = 60 = 5 tons
		LH060 = 60 = 5 tons
		LHA120 = 120 = 10 tons

Heil – For older Heil units the first four numbers are a code for the basic product type. The fourth number is the efficiency (3=13SEER, 4=14SEER, 5=15SEER, 6=16SEER, 7=17SEER, 8=18SEER). The fifth and sixth numbers are capacity with 18=1.5 tons, 24=2 tons, 30=2.5 tons, 36=3 tons, 42=3.5 tons, 48=4 tons, and 60=5 tons. For newer Heil units the seventh through ninth numbers are the capacity (i.e., 018=1.5 tons through 060=5 tons).

York – For York the first four numbers are a code for the basic product type. The fifth through seventh numbers are capacity with 018=1.5 tons, 024=2 tons, 030=2.5 tons, 036=3 tons, 042=3.5 tons, 048=4 tons, 060=5 tons, 072=6 tons, etc.

Bard – The first two Bard numbers are a code for the basic product type.

Wall-Mount Air Conditioners – WA and Wall-Mount Heat Pumps – WH.

Packaged Air Conditioners – PA10 (10 SEER), PA12, (12 SEER), PA13 (13 SEER).

Q-Tec Series Air Conditioners with Electric Heat – QA and Q-Tec Series Heat Pumps – QH.

Horizontal Discharge Split-System Air Conditioners – HA.

The next three numbers provide the cooling capacity as shown below in the first two columns.

Bard Wall-Mount AC	Bard Wall-Mount Heat Pump	Bard Packaged Units
WA182 = 18 = 1.5 tons	WH18 = 18 = 1.5 tons	PA13241 = 24 = 2 tons
WA242 = 24 = 2 tons	WH24 = 24 = 2 tons	PA13301 = 30 = 2.5 tons
WA302 = 30 = 2.5 tons	WH30 = 30 = 2.5 tons	PA13361 = 36 = 3 tons
WA372 = 36 = 3 tons	WH36 = 36 = 3 tons	PA13421 = 42 = 3.5 tons
WA423 = 42 = 3.5 tons	WH43 = 42 = 3.5 tons	PA13481 = 48 = 4 tons
WA484 = 48 = 4 tons	WH48 = 48 = 4 tons	PA13601 = 60 = 5 tons
WA602 = 60 = 5 tons	WH60 = 60 = 5 tons	

Bard Q-Tec AC/Electric Heat	Bard Q-Tec Heat Pumps	Bard Horizontal Split-Systems
QA241 = 24 = 2 tons	QH241 = 24 = 2 tons	HAC241 = 24 = 2 tons
QA301 = 30 = 2.5 tons	QH301 = 30 = 2.5 tons	HAC301 = 42 = 2.5 tons
QA361 = 36 = 3 tons	QH361 = 36 = 3 tons	HAC361 = 36 = 3 tons
QA421 = 42 = 3.5 tons	QH421 = 42 = 3.5 tons	HAC431 = 42 = 3.5 tons
QA481 = 48 = 4 tons	QH481 = 48 = 4 tons	HAC481 = 48 = 4 tons
QA601 = 60 = 5 tons	QH601 = 60 = 5 tons	HAC601 = 60 = 5 tons

Appendix B: LRM Equipment List

Each technician must have the following equipment to perform NTD method.

- ☐ 1. (Qty. 2) Dual in-duct psychrometer with accurate digital drybulb ($\pm 1^\circ\text{F}$)/wetbulb ($\pm 0.75^\circ\text{F}$) sensors to measure return/supply air temperatures (Fieldpiece SDP2 or equivalent).
- ☐ 2. (Qty. 2) Accurate digital clamp-on temperature sensors ($\pm 1^\circ\text{F}$ accuracy) to measure refrigerant suction/liquid line temperatures (Fieldpiece JL3PC or equivalent).
- ☐ 3. Digital thermometer with four ($\pm 1^\circ\text{F}$) accurate sensors to measure condenser entering air temperature (Fieldpiece SPK2 or equivalent).
- ☐ 4. (Qty. 2) Digital pressure manifold gauges (R22 and R410a) with EPA low-loss fittings required on all hoses per EPA Section 608 (Fieldpiece SMAN380V, SMAN480V wireless).
- ☐ 5. Digital infrared refrigerant leak detection tool and leak detector fluid.
- ☐ 6. Digital refrigerant charging scale (Fieldpiece SRS1 or SR47).
- ☐ 7. R22 tank to add refrigerant (30 lbs), and R22 recovery tank for recycling.
- ☐ 8. R410A tank to add refrigerant (25 lbs), and R410A recovery tank for recycling.
- ☐ 9. Digital Recovery Machine (Fieldpiece MR45 or equiv.) and $\frac{1}{2}$ " or $\frac{3}{4}$ " diameter hoses.
- ☐ 10. Digital Vacuum Pump (Fieldpiece VPX7 or equiv.) and $\frac{1}{2}$ " or $\frac{3}{4}$ " diameter hoses.
- ☐ 11. (Qty. 2) Schrader core tool 18975, core removal tool 18979, threading tool 18978, cores.
- ☐ 12. (Qty. 2) 3-way connector "T" with $\frac{1}{4}$ " female flare x $\frac{1}{4}$ " male flare x $\frac{1}{4}$ " male flare to connect two refrigerant hoses (liquid and suction) with EPA low-loss fittings to refrigerant tank to purge air and contamination from hoses and manifold (C&D 9621).
- ☐ 13. Ball valve on charging hose to control refrigerant flow to purge air from hoses.
- ☐ 14. Air filters to be replaced on every HVAC unit (including pleated air filters or air filter material 25" wide x 1" thick x 36 feet roll filter media Permatron Mfg #: PFLO1-ROLL25 and 36" aluminum rods to provide support ('lightning rods') Schaefer Brush Mfg #: 13003.
- ☐ 15. Flexible rubber hose $\frac{5}{8}$ " x 75 feet for pre- and post-rinse of condenser coil.
- ☐ 16. Flare-fitting tools and torque wrenches, goggles, gloves, and protective garments.
- ☐ 17. Condenser coil cleaning low-pressure poly sprayer with pump and adjustable nozzle <http://www.nucalgon.com/products/coil-cleaners/sprayers/coil-gun>.
- ☐ 18. pH neutral condenser coil cleaner (Nu-Calgon "Cal Green" or equivalent) mixed to proper dilution and formulated with foaming detergents to penetrate and dissolve baked on dirt, <http://www.nucalgon.com/products/coil-cleaners/condensers/cal-green>.
- ☐ 19. Brazing torch, flux, and brazing alloy to repair leaks, slotted and Phillips screw/nut drivers, self-tapping screws, electrical tape, wire cutters/strippers, connectors, wire nuts.
- ☐ 20. Clamp-on Digital Multimeter to check electrical continuity, voltage, and amperage readings (Fieldpiece SC460 Clamp Meter).
- ☐ 21. Fieldpiece wireless 100' job link transmitter for wireless manifold (SMAN440 or 460) and SDP2 dual in duct psychrometer for ease of use and time savings on split systems.
- ☐ 22. R1 elastomeric thermal closed-cell foam insulation UL181 tape (AP Armaflex or equivalent) for insulating Thermostatic Expansion Valve (TXV) sensing bulb to ensure proper metering of refrigerant to the evaporator coil.
- ☐ 23. Optional electrical parts as needed to make non-working AC units operable including: fuses, fan relays, contactors, capacitors, transformers, and igniters.

Appendix C: LRM Checklist

- ☐ 1. Make sure HVAC system works in at least cooling mode.
- ☐ 2. Turn off unit and replace air filter (if roll filters cut to fit and use metal rods for support).
- ☐ 3. Wash outdoor condenser coil with AC off (per pages 5-6 of manual). Condenser coil must be chemically cleaned, rinsed, and dry before performing AC Tune-up services.
- ☐ 4. Drill one 5/16" access hole into return plenum and one 5/16" access hole in supply plenum to install probes to measure return and supply air drybulb and wetbulb temperatures. **Please be careful to avoid drilling into evaporator coil or refrigerant tubes.**
- ☐ 5. Check refrigerant Schrader valves for leaks and if leaks are present tighten or replace core valves using Schrader valve core repair tools to eliminate leaks per training manual. Care must be taken to avoid over tightening or damaging Schrader core valves. If no refrigerant leaks are present, then install locking Schrader caps on pressure ports.
- ☐ 6. Insert digital psychrometers into 5/16" access holes on return and supply plenum, attach digital pipe clamp thermometers to suction and liquid line, and attach temperature probe to condenser coil entering air.
- ☐ 7. Connect digital psychrometers, condenser entering air temperature sensors, and pipe clamp sensors on liquid and suction lines per manual.
- ☐ 8. Turn on AC system and wait 15 minutes for AC system to reach equilibrium.
- ☐ 9. Launch NTD software, go to "jobs" pull-down, select "program" and "today" for list of jobs. Double click appropriate job, click "JOB" button and enter condenser or packaged unit make, model, serial number, refrigerant type. If TXV is installed, click TXV button and enter required subcooling, refrigerant charge, cooling capacity, furnace capacity, unit type (packaged or split system, and AC or heat pump). Click on green checkmark to save.
- ☐ 10. Click anywhere under "Initial Measurement" on NTD software to enter measurements. Enter initial return and supply air drybulb and wetbulb temperatures, condenser entering air temperature and suction and liquid line temperatures into NTD software.
- ☐ 11. NTD software performs Fault Detection Diagnostics and if Under Charged provides accurate recommendations about how much refrigerant to add (See Section 3.3).
- ☐ 12. If NTD software recommends adding refrigerant, then weigh-in refrigerant and enter into NTD software per **Section 4.11**. If adding refrigerant, attach refrigerant pressure gauge to suction line per **Section 4.5**. Purge refrigerant pressure hoses of non-condensable air and water vapor or contaminated refrigerant before attaching to Schrader valves (**Section 4.4**).
- ☐ 13. NTD software provides 15-minute timer after refrigerant charge entry.
- ☐ 14. When NTD timer ends, click on "New Measurement" button to enter final return and supply drybulb and wetbulb temperatures, condenser entering air temperature and suction and liquid temperatures to determine whether or not AC system is properly charged per NTD software and select green checkmark to save final measurement.
- ☐ 15. After NTD method is complete at top of screen select 'Click Here to Make It Ready to Submit for Review!' to prepare job for uploading.
- ☐ 16. As frequently as possible (i.e., weekly or more often) connect computer tablet to WIFI, click on 'Tools' pull-down and select 'Upload data' to send job data to NTD server.
- ☐ 17. Remove refrigerant suction hose (**Section 4.6**) and install locking caps as required.