

Indoor Coil Matching



The importance of a properly matched comfort system



Indoor Coil Matching: Why It's an Issue

The HVAC industry continues to change rapidly, including the adoption of new, regional energy efficiency standards for split system applications which took effect at the beginning of 2015. Now that the minimum required efficiency depends upon which region you operate in – North, Southeast or Southwest – it's more important than ever to make sure every system you install can measure up to the Department of Energy's requirements. At the same time, customers continue to expect high levels of quality and value with assurances that their HVAC system will perform to the level they have been promised.

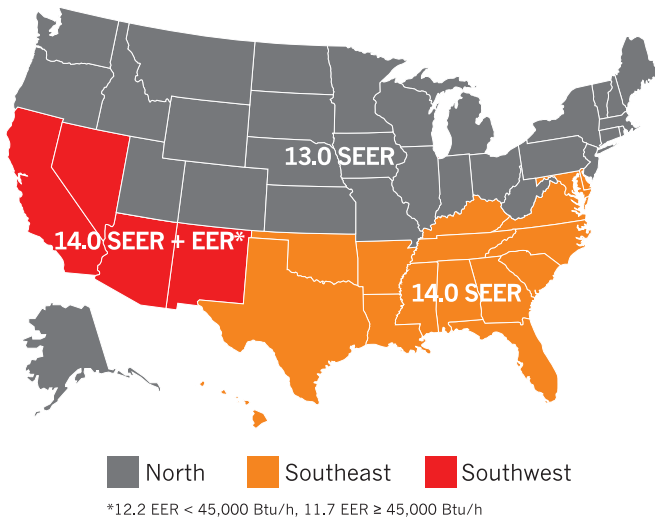


Figure 1 - Regional Efficiency Standards – The U.S. Department of Energy's Regional Efficiency Standards have changed the game for residential split-system HVAC contractors. In addition to higher SEER requirements in both of the southern regions, the Southwest also includes a minimum EER requirement.

Maximizing efficiency through evaporator coil matching can also affect your customers' ability to qualify for local utility company rebate incentives which may be available.

When you add it all up, properly matching a new outdoor condensing unit with a new indoor evaporator coil is the best way to ensure DOE minimum efficiency compliance and even better, to deliver optimized efficiency for the system. It helps prevent premature failures caused by stress on the system due to not being properly matched. The resulting high-efficiency, high-reliability system should go a long way to creating happy, comfortable and satisfied customers.

As the industry works to support the new regional standards, it is important for customers to understand that **achieving the required efficiencies is a function of the entire system, not just one component**. Specifically, for a residential split system application, proper matching of the outdoor condensing unit to the indoor components is necessary to ensure the complete system delivers the promised value and performance. This is especially critical in the high volume add-on and replacement markets where contractors might be tempted to simply replace only the outdoor unit while leaving the older indoor components intact (Figure 2).

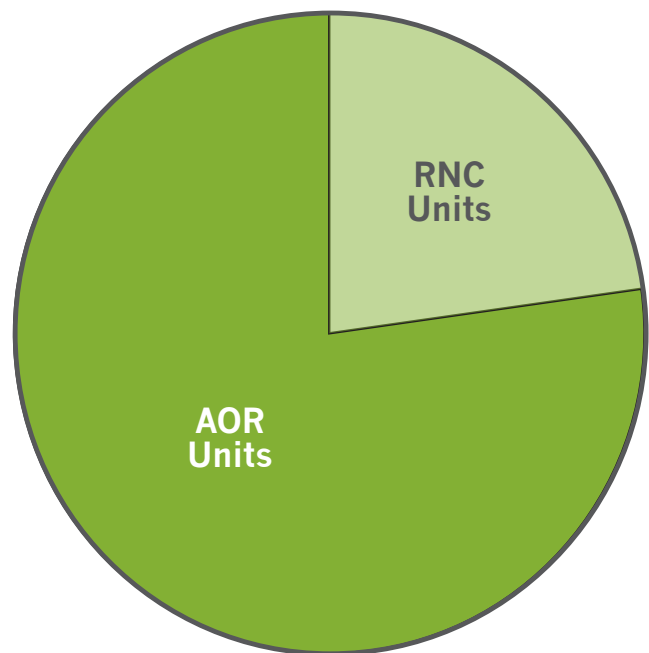


Figure 2 - Market Segmentation – Today's HVAC marketplace mix continues to offer higher volume in add-on/replacements (AOR) than residential new construction (RNC), by a better than 3-to-1 ratio. As current systems get older, the need to replace the indoor evaporator coil becomes more and more important to achieve current energy efficiency requirements as well as utility company rebates.

New Evaporator Coil Technology and Thermal Expansion Valves

Like condensing unit technology, evaporator coil designs are changing significantly (Figure 3). Compared to evaporator coils designed and manufactured about thirty years ago, the 2015 indoor evaporator coils are larger and more efficient. They incorporate internally enhanced tubes and externally enhanced fins. Many 2015 evaporator coils will utilize thermal expansion valves (TXV's). The TXV provides many system benefits including cyclic performance enhancement (SEER improvement) and improved refrigerant control in the higher charge 14.0 SEER/12.2 EER systems. The hard shut-off TXV limits off-cycle refrigerant migration to the compressor, which can be harmful to the compressor at start-up. Finally, the TXV is a variable refrigerant metering device that provides reliable compressor operation over the whole operating envelope of the air conditioner or heat pump system. It provides a more consistent flow of superheated refrigerant back to the compressor throughout all operating conditions. **New indoor coils for 2015 and beyond have been designed to meet the higher SEER and EER system performance standards while continuing to deliver the expected reliability.**

Coil Design Differences				
	1980's Coil	10.0 SEER Coil	13.0 SEER Coil	14.0 SEER Coil
Face Area, Ft ² /Ton	0.75 - 1.0	1.3 - 1.8	1.4 - 1.9	1.4 - 3.0
Fin Density, Fin/In	10 - 12	14 - 16	12 - 17	12 - 17
Number of Tube Rows	3	2	2 and 3	2 and 3
Inner Tube Surface	Smooth	Grooved	Grooved	Grooved
Fin Type	Corrugated or Flat	Lanced	Lanced	Lanced
Expansion Device	Capillary Tube	Piston	TXV	TXV

Figure 3 - Coil Design Differences - Differences in heat exchanger design greatly affect an evaporator coil's ability to deliver a system's rated performance and reliability. The bottom line: new indoor coils have been designed to function reliably and efficiently with new condensing units that meet the 2015 regulatory changes. Old evaporator coils may not be properly sized which could cause reliability problems and lower efficiency levels.

Efficiency, Capacity and Reliability: Old Coils VS. 2015 Regional Standards Evaporator Coils

To quantify the risks of retaining an old evaporator coil when installing a new condensing unit, a series of tests were conducted. The test facility used is a state-of-the-art psychrometric laboratory consisting of computer controlled indoor and outdoor test rooms and automatic data acquisition equipment which provides control of all operating parameters. All measurements were conducted according to appropriate DOE, ASHRAE and AHRI standards.

Tested Combinations

A new 14.0 SEER 30,000 Btu/hr air conditioning system was tested and compared to previous data. The system consisted of a condensing unit, an evaporator coil and a hard shut-off TXV for the expansion device. The evaporator coil was designed for higher performance than previous 13.0 SEER and earlier coils. It included an enhanced performance heat exchanger with significantly more fin heat transfer area, enhanced fin and tube technology and a hard shut-off TXV.

Three additional coils were tested: a 13.0 SEER, a 10.0 SEER and a pre-10.0 SEER coil. A new 13.0 SEER 30,000 Btu/hr air conditioner was also tested using a new 13.0 SEER coil with a hard shut-off TXV expansion device. The 10.0 SEER evaporator coil was a typical matched evaporator sized for 10.0 SEER 30,000 Btu/hr systems and was equipped with fixed orifice (piston) expansion device. The pre-10.0 SEER coil was of 1980's vintage with a significantly smaller heat exchanger and utilized capillary tubes as the expansion device.

All critical operating parameters of the system were recorded during each test. The compressor operating points were closely monitored to check for conditions outside the approved operating envelope. Compressor suction and discharge pressure, temperature and superheat were recorded and evaluated. Suction and discharge pressures indicate how hard the compressor is working. Increased compression ratios (pressure differential between the high- and low-side) cause increased power consumption and excessive wear on internal parts. The suction and discharge superheats (the difference between the actual refrigerant temperature and its saturated temperature at a given pressure) indicate the amount of liquid flooding the compressor is experiencing. As the suction superheat approaches 0°F, discharge superheat is used as an indicator of flooding severity.

It should be noted that all tested combinations were matched Carrier® indoor coil and outdoor condensing unit combinations. The best way to ensure compliance with DOE standards is to install Carrier evaporator coils properly matched with Carrier outdoor units. This also ensures that the entire system provides the same level of quality and reliability, inside and out.

Description of Tested Evaporators (2.5 Ton)

	1980's Coil	10.0 SEER Coil	13.0 SEER Coil	14.0 SEER Coil
Fin Heat Transfer Area, Ft ²	80	82	110	171
Face Area, Ft ²	3.56	4.0	4.58	5.5
Fin Density, Fin/In	12	14	16	16
Rows	3	2	2	2
Inner Tube Surface	Smooth	Grooved	Grooved	Grooved
Fin Type	Corrugated or Sine Wave	Sine Wave with Lances	11 Element Lanced Sine Wave	11 Element Lanced Sine Wave
Expansion Device	Cap Tube	Piston (0.070 in.)	TXV	TXV

Figure 4 - Description of Tested Evaporators – A typical 14.0 SEER, nominal 30,000 Btu/hr condensing unit with a properly matched 14.0 SEER indoor coil served as the baseline for the study. A standard 13.0 SEER coil, a 10.0 SEER coil and a 1980's vintage (pre-10.0 SEER) coil were tested for performance and reliability comparisons. All coils were tested with the baseline condensing unit.

Test Results

Efficiency (SEER)

System efficiency (SEER) has two important inputs – steady state efficiency (EER_B), as measured at the DOE “B” conditions (82°F outdoor) and the cyclic degradation factor (C_d) as calculated from the DOE “C and D” tests. SEER is calculated using the following formula:

$$SEER = EER_B * (1 - C_d/2)$$

The size of the heat exchanger has a direct impact on steady state efficiency. Smaller coils provide lower heat transfer capacity resulting in lower efficiency. The TXV improves both steady state efficiency and the cyclic degradation factor. The results of efficiency testing are dramatic – see Figure 5.

The 14.0 SEER system with a newly designed condensing unit, matched with a new 14.0 SEER evaporator and a hard shut-off TXV, resulted in a full 14.0 SEER. A similar setup matching a 13.0 SEER outdoor unit with a 13.0 SEER evaporator coil achieved a full 13.0 SEER. Replacing the TXV with a piston caused a reduction in efficiency to 12.6. When matched with a 10.0 SEER coil and a TXV, the efficiency was also 12.6. The 10.0 SEER coil with a piston resulted in a SEER of 12.2. Finally, the 1980’s coil equipped with cap tubes yielded a 12.0 SEER rating!

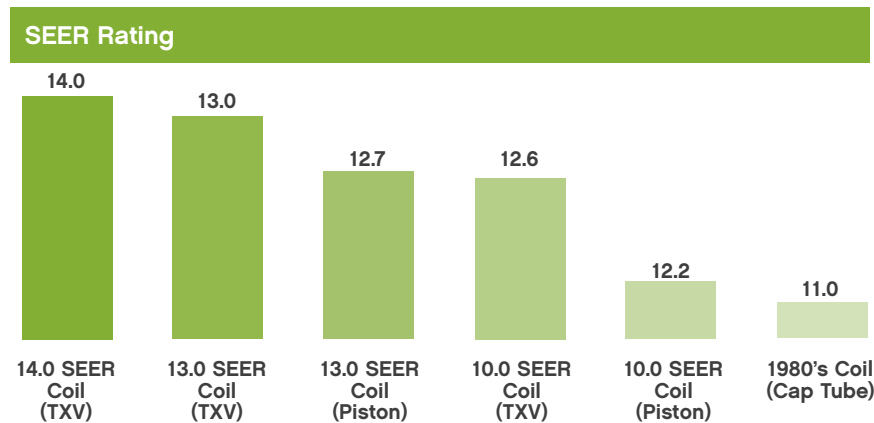


Figure 5 - Efficiency Impact – Coils with smaller heat exchangers reduce the efficiency rating. Smaller coils equipped with fixed expansion devices can reduce the efficiency rating by 1 full SEER point or more resulting in a system below the minimum requirements! The loss in performance can be even greater if the fins of the existing coil are dirty from years of use.

Capacity

Testing of the old evaporator coils with the new outdoor unit shows a significant loss of rated capacity. Cooling capacity is measured at the DOE “A” conditions (95°F outdoor). Figure 6 graphically shows the results.

The 10.0 SEER coil with TXV and with piston resulted in a loss of capacity (400 - 600 Btu/hr) at the rating point. However, the capacity loss with the 1980’s coil with cap tubes was 1400 Btu/hr; three times more loss! When you need cooling most, at higher outdoor ambients, the capacity loss will be even greater!

Carrier 14.0 SEER coils provide the best cooling capacity for the homeowner.

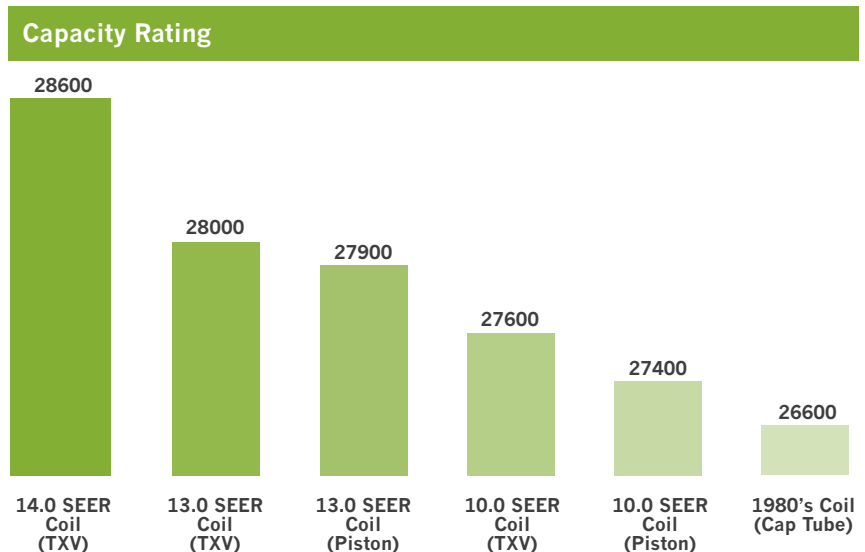


Figure 6 - Capacity Impact – Coils with smaller, indoor heat exchangers provide lower capacity. Old coils with improper expansion devices result in a great loss of capacity. At higher ambients, when cooling is needed most, the capacity loss is even greater.

The EER Effect

As of January 1, 2015, the Department of Energy now requires a minimum of 12.2 EER for ducted split-system applications 45,000 Btu/hr and below in the Southwest U.S. region. Energy Efficiency Ratio (EER) also has two main inputs – output cooling energy (in Btu/hr) and the input electrical energy (in Watts), as measured at 95°F outdoor (and 80°F dry-bulb, 67°F wet-bulb indoor temperatures). EER is calculated using the following formula:

$$\text{EER} = \frac{\text{output cooling energy (Btu/hr)}}{\text{input electrical energy (Watts)}}$$

EER is an important measure that can be used to compare approximate energy usage between systems.

Achieving the 12.2 EER minimum for Carrier® split systems required some design changes involving a larger overall coil surface. As a result, systems that meet the 2015 standards may have any combination of a larger indoor coil, larger outdoor coil, or both.

Installation and Performance

Matched systems that meet the 2015 criteria will provide some advantages with both installation and performance. Proper installation is the key to ensuring that any coil used achieves its intended performance. Previously, N coils tended to require a transition between the furnace and the coil to allow for proper distribution of air across the coil. This added to overall system length and made installations more difficult and time-consuming. Now, because of the A coil shape, airflow through the coil is more consistent, which results in fewer up-and-down temperature swings and even, steady comfort. Better airflow also prevents nuisance tripping issues on furnaces that can result from hot spots on the coil. Our A coil design is robust enough to provide consistent airflow and coil reliability without using lengthy transitions. Eliminating the transitions translates into simpler, easier installations as shown in scenario A versus scenarios B or C in Figure 7 below.

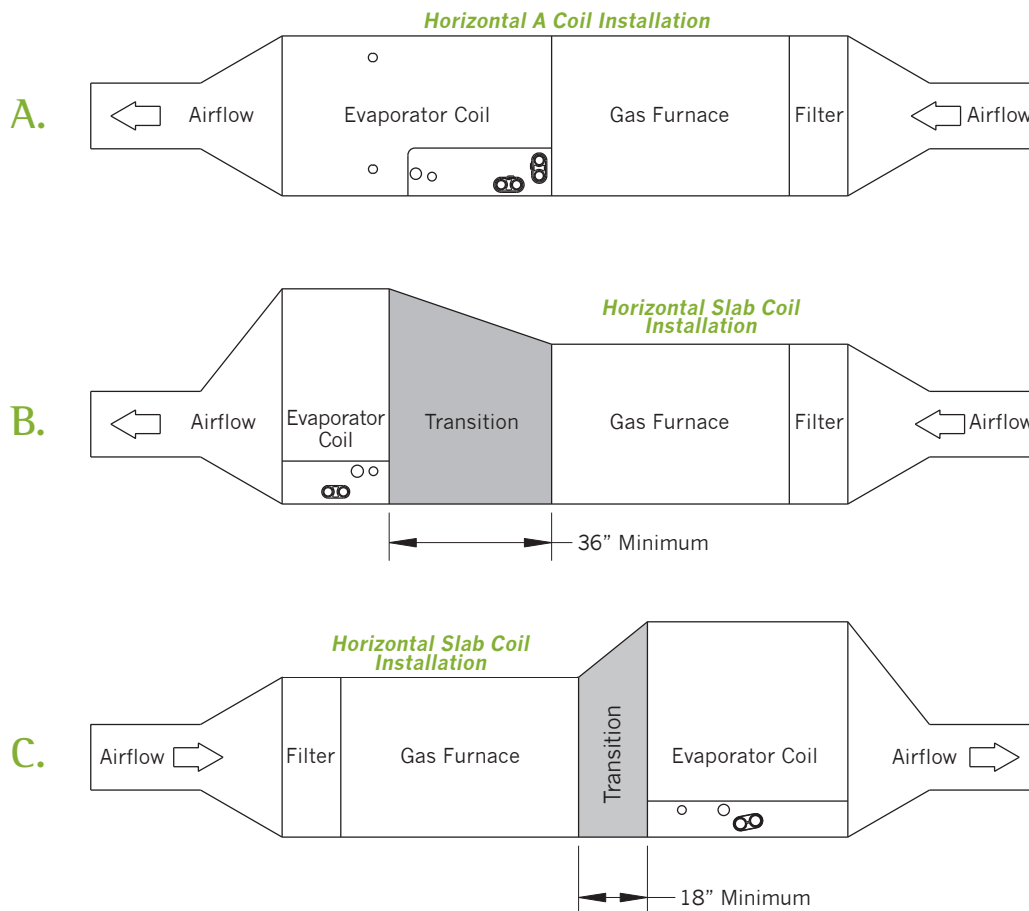


Figure 7 - Installation – The new evaporator coils designed to meet 2015 DOE requirements will be slightly larger than previous models. However, depending on the tonnage, they can provide a benefit of reduced static pressure due to fewer fins per inch, along with easier installation options.

Reliability and Testing

The evaporator coil plays a large role in the reliability of air conditioner and heat pump systems. The amount of heat exchange area and the type and design of the expansion device play important roles in providing reliable compressor operating conditions. To ensure the highest levels of reliability, Carrier® engineers complete rigorous, physical testing of coils under many scenarios.

Flooded Operation

The four evaporator coils were tested under “floodback” conditions. This test combines low-ambient temperatures and low indoor airflow, simulating a blocked filter or a dirty indoor coil to determine the system’s response to fairly common installed conditions. Under these tough conditions, test results show that the 2015 A coil with a TXV provided the best amount of refrigerant superheat coming back to the compressor. The 10.0 SEER coil, when equipped with a TXV, provided adequate superheat. However, both the 10.0 SEER coil equipped with a piston and the 1980’s coil with cap tubes resulted in liquid refrigerant coming back to the compressor. The discharge superheat, a further indication of flooding through the compressor, was significantly lower for both systems with fixed expansion devices. The condition known as “flooding” damages internal compressor parts and will ultimately cause premature failure. Scroll tip wear, worn thrust surfaces, worn bearings and unloader bushings, in addition to increased operating noise, are a few of the resulting damages.

Minimum Load Operation

This test is conducted at the minimum approved operating ambient temperature of the condensing unit. The pass criterion for this test is whether the evaporator coil will “freeze-up”. As expected, the coils equipped with the TXV provided no concern with coil freeze-up. The piston and cap tube coils resulted in coil temperatures significantly below freezing. As the coil freezes, liquid is sent back to the compressor, resulting in compressor damage.

Accelerated Corrosion Testing

Using a proprietary solution of corrosive elements, our engineers tested the ability of our coils to resist corrosion using methods that mimic a 15-year lifespan. Our 2015 evaporator coils all passed this corrosion testing before moving on to production.

Performance

Carrier® coils are tested with current production furnaces to ensure the highest likelihood that the homeowner experience in real-life installations will mirror our test results. Our individual products are tested as one complete system so we can provide the best home solution.

Blow Off Testing

Our coils are designed to prevent blow off in horizontal applications. When airflow on a coil is higher than recommended, it can result in water blowing off the coil. This does not occur with Carrier® coils, when used with allowed airflow ranges. **Our coils are tested across the whole range of rated airflow to give you confidence that, up to 500 CFM, there won’t be an issue.** We test at 70% higher CFM than our typical competitors, who offer limited data beyond 350 CFM. Those other manufacturers also must provide their contractors with warnings of potential blow off that could impact system performance without taking additional precautions (such as installing splash guards) during installation.

A note about testing – Some of the testing, as mentioned above, was conducted on a 30,000-Btu/hr air conditioning system. Bear in mind that Carrier® reliability testing follows a more rigorous set of parameters than required by AHRI, so you should feel confident that the products you install will offer the highest levels of reliability and customer satisfaction. And, our evaporator coil testing is completed with actual physical testing of products while most other manufacturers rely more on computer modeling for their results. As a further validation of the test results, computer simulations were conducted on a complete family of 14.0 SEER AC products. The results were consistent throughout the whole family of products ranging from 1.5 tons to 5 tons. Capacity and efficiency were reduced by comparable amounts when using improperly sized coils. Operating conditions also showed the same trend toward unreliability when old evaporator coils were used and improper expansion devices installed.

Compressor Reliability

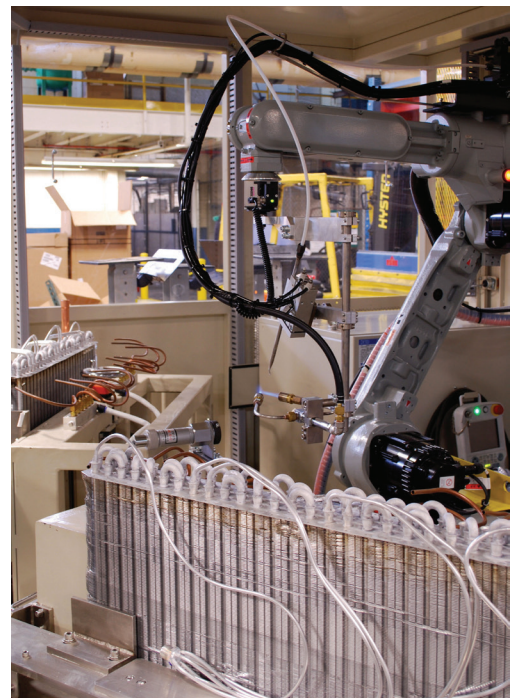
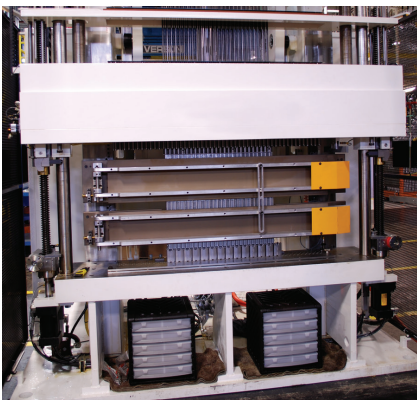
Because compressor reliability is highly dependent upon proper system design and installation, installing a new condensing unit without replacing the old evaporator coil can lead to serious problems. First, the old indoor coil will probably provide less heat transfer capability. Second, it will typically have an expansion device that is not sized or designed properly for use over the whole range of operation with the recommended refrigerant charge. In addition, any improperly designed indoor coil will increase the risk of compressor failure due to: 1) liquid entrainment in the suction line and compressor during start-up (slugging); 2) liquid entrainment in the suction line during steady-state operation (flooding); 3) operation at excessive compression ratios; and 4) overheating. Like all mechanical equipment, the indoor coil's performance will naturally degrade with time, due to dirt and corrosion.

It is estimated that the chances of a first year compressor failure increases 45% when an old undersized coil and fixed expansion device are used.



Built to Last

Carrier® aluminum evaporator coils are the result of millions of dollars in research and manufacturing technology to create a product that offers years of lasting durability. The aluminum used in these coils was specifically formulated to minimize the effects of common household airborne corrosives, and is particularly effective defending against formicary corrosion. And, these coils exceed the Department of Energy standards for pressure-based leaks. To minimize installation-based reliability issues, the critical connection between the aluminum coil and the copper refrigerant tubing is made at the factory. Finally, Carrier cased coils include fully insulated cabinets to reduce condensation-related issues such as leakage, corrosion and even potential indoor air quality degradation.



Old Indoor Coils Can Have a Negative Impact on Compressors

Condition	Description/Cause	Results In
Slugging	During the off-cycle, liquid refrigerant migrates from the high pressure side of the system to the low side and can accumulate in the compressor. "Slugging" occurs as the compressor starts up and tries to pump liquid refrigerant. Since liquid refrigerant is virtually incompressible, the compressor "hammers" away at the refrigerant causing excessive noise and internal compressor damage. Higher efficiency systems have more refrigerant charge that can migrate. Evaporator coils equipped with hard shut-off TXV's minimize off-cycle migration. Old coils with fixed expansion devices cannot accomplish this and will lead to increased levels of slugging.	• Oil pump out • Broken scrolls • Broken Oldham coupling • Stripped hold-down bolts • Thrust surface galling • Scroll tip galling • Excessive scroll noise
Flooding	Flooding occurs when liquid refrigerant reaches the compressor during operation. Flooding is caused by excessive refrigerant charge, an improper expansion device and/or low indoor airflow caused by dirty coils, clogged filters and excessive air pressure drop. As this excess liquid refrigerant enters the compressor, oil dilution occurs and results in lack of lubrication to critical compressor parts. New 14.0 SEER/12.2 EER systems with matched indoor coils are properly designed to handle this condition. TXV's supply almost constant superheat to the compressor during operation, virtually eliminating flooding. Old coils without properly designed expansion devices or coils that are dirty or are installed in high pressure drop duct systems, allow liquid refrigerant to flow back to the compressor.	• Oil dilution • Rapid scroll tip wear • Worn thrust surfaces • Increased oil carryover • Increased operating noise • Increased scroll chatter • Worn bearings • Motor failure • Worn crankshaft • Worn unloader bushing
Excessive Compression Ratios	Excessive compression ratios can occur in the cooling mode when metering devices are too small, as may be encountered in old evaporator coils. This will cause excess refrigerant to build up in the condenser and raise the discharge pressure and pressure ratio of the compressor. If an old evaporator coil is left in place and matched with a 14.0 SEER/12.2 EER heat pump, excessive compression ratios will be encountered in heating mode when the indoor coil, acting as a condenser, is greatly undersized for the system. Excessive compression ratios will reduce lubrication throughout the compressor resulting in excessive wear on scroll elements and bearings and can lead to motor winding burns and high temperatures. New 14.0 SEER/12.2 EER systems with matched indoor coils provide the correct refrigerant expansion for the cooling mode. The 14.0 SEER/12.2 EER heat pump system using a matched indoor coil will provide the expected heating performance under acceptable compressor operation.	• Reduces oil film on scrolls and bearings • Loss of oil lubricity • Overheating • Rapid scroll tip wear • Motor overheat • Motor overload failure • Motor spot burn in windings
Overheating	Overheating can be caused by excessive compression ratios. When the evaporator is undersized or the expansion device is not properly designed, the system result can be low refrigerant flow rates that correlate to low suction pressure. In heating mode, the older, smaller indoor coil, now acting as a condenser, will cause high discharge pressures and temperatures. Both conditions can cause temperatures so high that the oil will "coke" (turn to carbon). The result will be overheated and scored scroll tips. Damage to the critical scroll tips will result in performance degradation and ultimately failure. New 14.0 SEER/12.2 EER systems with matched indoor coils are designed to match with new outdoor units to provide proper heat transfer and refrigerant expansion which eliminates overheating conditions.	• Scroll tip wear • Burned cavity seals • Worn thrust surfaces • Scored unloader bushing • Scored drive bearings • Burned motor stator

Issues Beyond Compressor Failure

As if these reliability risks are not enough, evaporator coils that are not properly matched may also affect warranty coverage. If a manufacturer's warranty is conditional on installation of air conditioning and heat pump systems with properly matched coils, as dictated by Air Conditioning, Heating and Refrigeration Institute (AHRI) standards, then mismatched systems may not be eligible for coverage by the manufacturer's warranty.

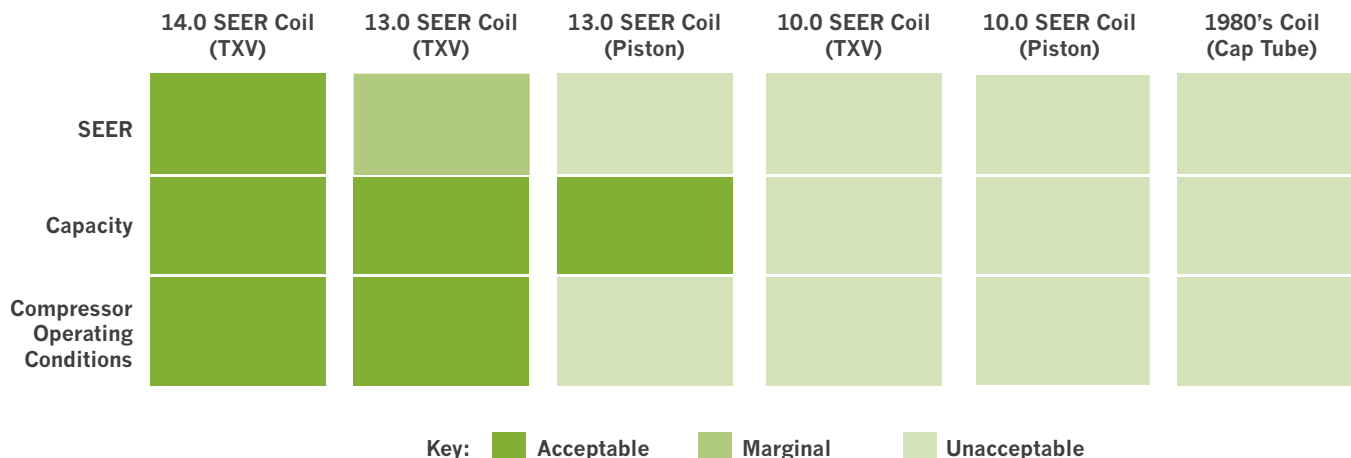
Even more important in the issue of matched evaporator coils is the effect it can have on your relationship with customers. Many utility companies now require that both components of an air conditioner or heat pump system be AHRI certified and properly matched before a customer can qualify for their rebate programs. Of course, it will be the dealer who gets blamed when the customer learns that their system doesn't qualify because the indoor coil was not replaced. In spite of all this, according to some surveys as few as half the contractors and dealers regularly replace the customer's indoor evaporator coil when a new condensing unit is installed (Figure 8). Many customers are not even aware of the issue, much less how important it is. But considering the mounting evidence, proper evaporator coil matching presents more opportunities than problems.



Figure 8 - As few as half of the contractors and dealers regularly replace the customer's indoor evaporator coil when a new condensing unit is installed.

Summary Results: New Evaporator Coils Provide Performance, Comfort and Reliability

The results speak for themselves. New coils designed for 14.0 SEER/12.2 EER systems using a TXV deliver the expected efficiency, capacity and reliability. Old evaporator coils with smaller heat exchangers and incorrect expansion devices cheat the consumer out of their expected performance. Low capacity and efficiency will result in higher power consumption that leads to higher utility bills. Even new 14.0 SEER/12.2 EER coils equipped with piston expansion devices have detrimental effects on compressor reliability when the outdoor unit is designed to match with a TXV indoor coil. Reduced reliability will cost the consumer the agony of ultimately replacing a compressor or a complete system. Figure 8 outlines the test results.



For proven performance, comfort and reliability, *change the indoor coil and expansion device!*

What Does It Mean to the Consumer

Most consumers won't be interested in the technical details, but it will be helpful for you to talk about coil matching in terms they can understand. If your customers insist on leaving the old indoor coil in place, be sure to remind them of the drawbacks of a mismatched system:

- Less comfort/poor performance on those hot and “sticky” days they want cooling the most
- Decreased reliability and possible premature failure of the compressor, the most important and costly component of the entire system
- Reduced energy efficiency and higher monthly utility bills
- Possible disqualification of utility company rebates that often require ARI certified, properly matched system components
- Possible loss of manufacturer warranty coverage on the compressor
- Possible non-compliant system based on the 2015 DOE regulations

Most consumers will opt to go with the matched system when reminded of these issues – and in the long run, they'll be happier, more satisfied customers.

Do It Right the First Time

In a rare case, taking a stance on indoor coil replacement may cost you a customer seeking the least expensive route. But rest assured, that customer will be back when he doesn't get the comfort and efficiency he'd hoped and paid for – or worse, when the system fails prematurely.

The best rule of thumb: always give the customer what you would want – a job done right the first time. HVAC contractors and dealers who don't pay attention to the evaporator coil matching issue risk a lot. They may end up paying for expensive repairs or replacement not covered by the warranty. Even worse, they risk creating unfavorable relationships with their customers. All of this is part of the mounting evidence that it truly does pay to do the job right the first time.





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