MODULE 139
HVAC&R SKILLS WORKSHOP

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INVERTER DIAGNOSTICS AND TESTING – PART 1

Skills summary

What?

A guide to inverters in modern air conditioning units and some common problems you may encounter in the field.

Who?

Relevant for HVAC&R technicians and anyone involved in installing, commissioning, and maintaining air conditioning equipment.

One of the most common ways to modulate the cooling capacity in air conditioning systems is via inverter technology.

An inverter controls the speed of the compressor to change the refrigerant flow rate. The turndown ratio depends on the system configuration and manufacturer.

Inverter technology is commonplace in today's air conditioning systems, from commercial units through to residential split systems. Often, issues with the inverter will cause the system to stop working.

This Skills Workshop looks at common causes for these issues and describes how to fix them.

PULLOUT

Background

The world has changed very quickly in a short period of time with air conditioning. There have been several factors governing this rapid change:

- A doubling of air conditioning sales from 2000 and continuing steady growth
- Increasing energy demand and the subsequent increase in carbon emissions
- A mandate for energy efficiency in household appliances with the original minimum energy performance standards (MEPS), and greenhouse and energy minimum standards GEMS, which came into effect in 2012
- Refrigerant phase-out, phase-down and replacement as per the Montreal Protocol, which has had various amendments since 1989, bringing some phase-out dates forward
- Customer needs and keeping up with technology, such as home wi-fi and internet-based control, plus indoor air quality enhancements made with unit design.

The average technician now has more demand placed on them to manage and work effectively with these new technologies that are commonplace in domestic and commercial systems. The evolution of air conditioning design has seen some very good old and tested designs disappear forever. Just like those old Kelvinator round shoulder refrigerators, some older design air conditioners are still in service today. Although the manufacturer got it right with those types, they could not evolve using those older designs.

Original design split system air conditioners (high-wall types) presented technicians with rudimentary simple logic and control interface. Inverters were not in use then.

There were three very common types:

1. Simple direct-switched (240V AC control) with five-wire interconnect and contactor-started permanent split capacitor (PSC) motor. The five wires comprised active, neutral (earth), compressor start, reversing valve signal, and outdoor fan control for heating mode governed by the indoor unit.
2. Direct-switched (240V AC control) cooling only with three-wire interconnect. Yes, you guessed it – only need on signal wire for the compressor. These also used contactor-started PSC motors and a current transformer (CT) in line with the contactor coil. This would create a fault call if it did not detect coil current. They were very simple but easy to work on and diagnose.
3. The model everyone liked.

This generation saw the introduction of the three-wire interconnect in which direct AC switching was replaced by communication and each indoor and outdoor has a PCB. The contactor and reversing valve power, fan motors came from the interface connections off the PCBs with very simple protections such as a motor overload, thermistor control and, in some models, a dedicated high- and/or low-pressure switch. The indoor fan was a phase control AC motor type, which was the first real variable speed used and not requiring speed tap windings.

Unfortunately, these designs ran constant speed compressors and used a simple on/off logic for temperature control. The result of this design saw efficiency at only one peak condition. Constant stop/start of the compressor added mechanical and electrical wear, and temperature control was an unwanted oscillation, giving rise to deviations far from the set-point.

These design types would not survive in the marketplace today, given the energy-efficiency needs and demands placed on refrigerated appliances.

The answer to efficiency with air conditioning came from aligning a system to part-load conditions while removing the temperature swing oscillation effect. In order to do that, mass refrigerant flow had to be controlled at changing conditions while preventing the temperature swing from causing erratic on/off. Changing mass flow rates to match load keeps the suction pressure at design, and maintains the volumetric efficiency while reducing power input through lesser demand at a more friendly low-compression ratio scenario.

The temperature swings are smaller because capacity is controlled. In the perfect world, the compressor does not turn off; rather it gently oscillates to load change like a fine-tuned PID.

Enter the variable speed compressor.

The diagnostic needs for former air conditioning design systems were relatively straightforward and required a technician really to be equipped with minimal electrical tools such as ammeters and multi meters. The logic of these systems seemed simple, so it was not questioned too much. It did, however, require a new understanding for working with printed circuit boards, and gave many an insight into communication needs between indoor and outdoor systems.

Common scenarios

It is useful to discuss inverters and some of the components, plus common scenarios. This is not a specific reading of a service manual or exact descriptive nature for fault finding. For that you can use the manufacturer-provided service manuals and technical support services.

The aim is to provide guidance on the things to look out for and consider onsite.

Remember:

- Contact your service agent/manufacturer for specific service and repair requirements for your unit. This is best practice.
- Electrical work is for licensed and competent tradespeople relative to the field of work and licence requirements inclusive of restricted licenses.
- Where a test or diagnosis involves resistance measurements, these are first option over any live-testing alternative. Regulations for this vary from state to state.

So, let us have a look at some of the key areas with split systems and how these designs affect the way you approach servicing issues onsite. Just note the figures and information provided are not deemed completely accurate, but are likely in range.

Thermistors vs pressure switches

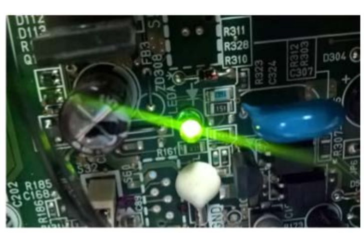
Our world is a binary system, and we use YES/NO in decision-making processes. This process is a pure digital response and everything that happens on modern air conditioning systems follows these rules.

An analog response sees changes over time, but regardless of how much time or how much variation it can deviate to and from, the end result is a digital outcome. If you consider a voltage between 0 and 10V where 0 = off and 10 = on , the analogue deviation between these points can be seen and measured but the digital outcome is fixed at only two points. These points can be shifted; however, the outcome is the same.

An analogue to digital converter ADC is used to convert analogue signals to a digital response or outcome. The value is converted into a simple digital on/off action. For the humble thermistor, which is analogue in operation, it is simply taking its time to get there.

Let's compare a very simple and familiar ADC with another.

Analog to digital converter. Uses incremental pressure changes to enact an open or closed switch.



Micro-processor controlled, uses both analog and digital decisions from multiple sources to enact outcomes.

The pressure control on the left is the simplest form of ADC, but it has a finite range of operation and it cannot be modified. The micro-processer can work with both analogue and digital signals with many variant rules applied to produce the required outcome.

This makes the split system very powerful. It is easy to incorporate multiple decisions all at once based on processing speed and the number of controlling points. We will look at the logic behind the decisions further on, but for now, appreciate that even the simplest sensors and inputs can have a huge impact on operation and control.

Pressure switches are basically unused in many domestic systems with the thermistors replacing their duty. When a pressure switch is added in a design, it is typically the last line of safety with the analogue systems in control of the main decisions.

Here's how this was done …

Indoor coil heat exchanger thermistor

In cooling mode acts as a low-pressure control by stopping operation below freeze conditions (0°C). In heating mode acts as a high-pressure control by keeping coil temperatures below 55°C by regulating outdoor fan operation first and then stopping the compressor as temperatures exceed 60°C (approximate).

Discharge pipe thermistor

The enthalpy of the refrigerant being used is already known to the system at pressure through mathematical operations associated with that refrigerant. Target superheats are set with the discharge thermistor from other operating thermistors depending on operation mode. Maximising performance is not to just run things flat out, but rather keeping a watch on the operating limits and superheats.

The discharge pipe thermistor is one of the most important sensors in the system and responsible for many of the protective modes being activated with the compressor. Discharge pipe protection modes are the ones that surface during high load, high ambient in summer, and overload conditions over time.

Protective modes are not just to stop operation – that is usually the most extreme of conditions – but rather to reduce the condition that is being caused to prevent further overload.

This is why compressor frequency speeds vary during these modes and performance drops off. Unless there is more sensor data input to prove a genuine fault condition, logic systems act on absolutes and parameters of operation because the current problem experienced may be temporary. Rather than shut off all operation, the system gives time for conditions to improve, gradually stepping down operation if it does not and stepping up when things improve until it fully releases back to normal operation.

Next time you are surfing the service manual, look at what thermistors do and what operations they are responsible for. The rules of operation logic for any such protective mode is usually well documented and as those conditions are absolutes. You can compare that with your communication interface tools that give real-time readouts.

Thermistor inputs create certain problems when they are faulty. Usually, these problems seem to be almost identical across brands. For a thermistor to be faulty, the logic must see that it is out of its design operating range.

Things have improved a lot here. Other thermistors can judge each other faulty if one is reactive (changing) while the other is not, depending on operating mode. Heat exchanger thermistors tend to be problematic if they experience excessive heat or if they breach their outer seal.

Operation in any mode can stop, units do not start, compressor speed is being limited constantly creating low performance, indoor fans do not operate at full speeds, or they are going very slow. It's the logic conundrum where the rules of operation are being applied and not contested, nor creating any fault code or fault response.

In some cases, things don't work but are quite normal. The outdoor air thermistor on heating mode will lock out the system if the ambient is above a set temperature. Even on a cold morning, direct sunlight or reflecting radiant heat and the perfect install facing the right way for sunrise can create a situation because of radiant energy on the sensor. This is fixed by waving a book to stir up air around the thermistor, but it does show that faults are not always accurate, and yet they are obeying their programmed logic rules.

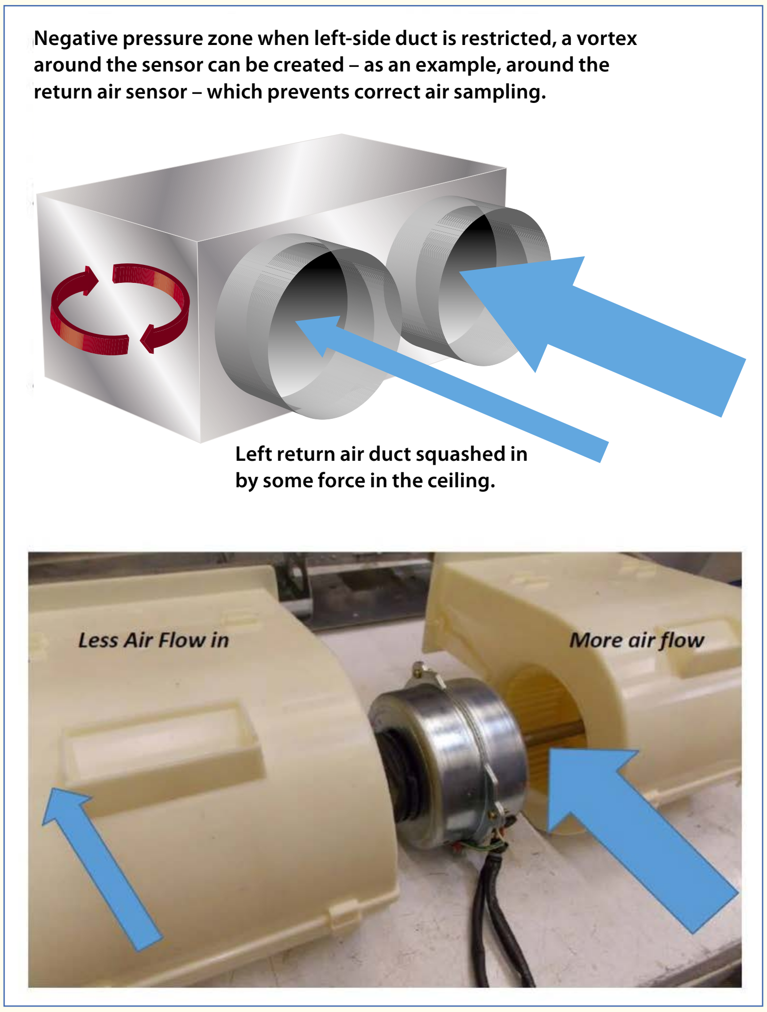
Indoor air sensors are the next most important sensor.

Inverters operate in many ways, but the simplest rules require a compressor frequency to be set by a differential from set-point and current room air on condition.

It is very important to check the unit's design operating ranges in all modes. Continuous operation is shown by manufacturers for both indoor and outdoor conditions. Working outside these ranges for too long can create overload or cause protective modes to activate.

The indoor air sensor location may be fixed on some models. The location and installation are important, especially if there is radiant energy from direct sunlight or the unit is recirculating air from obstruction. In the case of ducted units, wall remote sensors can be a real issue if they are not in a good monitoring area since in heating mode there is more reliance on the wall controller due to heating stratification effect. There are settings to switch the controller sensor out if it is not in a good monitoring area or enclosed. Fresh air intakes can also create problems in extreme weather on very hot days with return air in ducted systems.

Squashed ducting can create vortex or eddy current patterns in return air boxes through air favouring one side (as shown in picture). These can create poor movement around the sensor.



Example of impinged airflow.

All these situations create conditions that the system must adjust for and that may affect operation. Technicians in many cases need to look outside the square rather than just look at the split system as being faulty due to some ongoing fault or performance issue.

Temperature resistance checks can be done to prove functionality. The live readout tools are probably the best since some can fail mid-operation at certain temperatures over time with cases of erratic or intermittent faults suddenly occurring for no apparent reason.

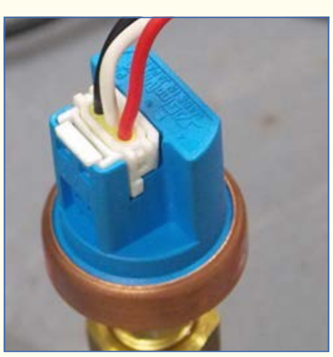
The simplest heat pump usually only contains indoor air temperature and heat exchanger sensors; outdoor units are the same and a discharge pipe thermistor. Domestic multi systems can have an extra indoor sensor for subcooling control and outdoor suction line thermistors.

Electronic expansion valve opening/closing control can operate from more than one sensor during operation. Once you go up to variable refrigerant commercial systems, they can be everywhere, including branch control. Without knowing the functionality of these thermistors, it can be overwhelming trying to pinpoint an issue. It is a good idea to read up on the control of thermistor grouping per unit or device.

Pressure transducers

Pressure transducers are simple, and easy to test and diagnose.

A 5V DC supply voltage is provided across the two wires (red/black) and the reference or feedback voltage is sent through the third wire to a ground reference (white/black).



Pressure transducer with common wiring colours

On heat pumps and commercial variable systems, you might see two types:

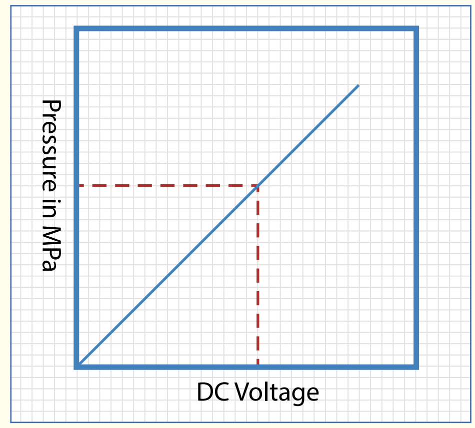
1. Dedicated high- and low-pressure transducers (independent)

2. Universal transducers that work with high- and low-pressure (suction line located).

There is usually a given formula to work out the exact pressure it is reading from a given reference voltage; however, a more user-friendly chart is supplied to determine what the pressure transducer is reading currently.

The advantage of transducers is the ability to use their analogue range and apply it to differing needs with refrigerants. Digital gauges are quite easy to transpose to other refrigerant types.

These are critical devices responsible for many operations and fault determinations.



Pressure/Voltage graph – example

The transducers by default take the place of first-stage pressure detection and monitoring for both high and low pressure. Unlike a conventional pressure switch, these will perform a pressure limit function through logic control and prevent unwanted pressure rise by controlling compressor speed. In the case that pressure does overload, they will halt operation and allow for retries over a period of attempts rather than just call it time for a sudden problem. If the pressure is overloading constantly, the system typically will call an error.

The transducer's best role is the ongoing control of both heating and cooling pressure/temperature design operations. For example, 6°C cooling and 46°C heating saturation temperatures. The compressor will be regulated to control and allow for other staging in a larger system for example. These do their best work in variable refrigerant systems in complement with other systems connected as one multi-unit.

In single heat pump systems, the universal transducer does much the same. In general it is quite a reliable device.

These also call changeover of reversing valves with needed pressure displacement differential and in some cases control EEV opening control from first start.

Typical problems with these are quite easy to find, but they can cause unusual faults to occur. Use a service gauge, a DC voltmeter, and a reference chart to investigate, unless you have a live service diagnostic tool.

The following faults with pressure transducers do occur, but may not show up in service manuals:

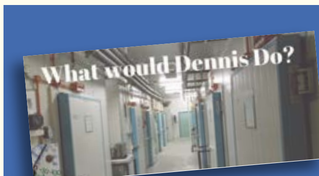
- Non-start of unit – failure to run or load up compressor speed (low and high)
- Non-start of unit due to false high pressure but transducer not out of range for an error code generation
- Failure of reversing valve to changeover on heating or back to cooling operation
- EEV on indoor unit does not open
- An error code for low refrigerant is generated, but no refrigerant has been lost. In this example the fault priority is beyond our control.

Once the transducer reads less than 1 Volt DC, its time to have a good look at the system charge. If it reads 0.5V DC, it will be in real trouble.

Manufacturers have really improved on these in the commercial side with multi-type units having sub-error codes to identify which condensing unit and which sensor is failing.

These units must be out of their operating range to be faulty. Because that range is quite generous, it is possible for them to operate in error from current pressure if they experience some malfunction.

Read the manual to check where the specific brand and model operates, and what needs to be tested. Nothing is impossible with erratic components. ■



This month's Skills Workshop was provided by **Dennis Kenworthy, Affil.AIRAH,** lecturer at South Metropolitan TAFE, WA and administrator of the website *What Would Dennis Do?* ***www.whatwoulddennisdo.com***

Next issue: Inverter testing and diagnostics – Part 2