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In Pursuit of Energy Efficiency, Better Physics Can Trump Better Electronics

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Recently one of my air conditioning units in a three-zone system needed a recharge of refrigerant. This installation was at my home in the Phoenix, Arizona area where air conditioning is a necessity. Daytime temperatures here rise above 108°F on a regular basis and have gone as high as 120°F in the summer. Even with R30+ insulation, most homes require sizable air conditioners (ACs). In my case, there are three 3-ton AC units, each of which cools a different zone in the house (Fig. 1.)

This simple need to recharge my AC quickly got complicated, leading me to begin a home project to upgrade the performance of one of my AC units. Initially, I envisioned this project as an opportunity to not only recharge the unit but also add features, which might possibly include energy-saving electronics. A combination of economics and environmental law led me down this path. But ultimately, I learned a lesson about another type of law—the laws of physics—and how the inherent physics of the application can influence how, when and where we apply power electronics.

Fig. 1. Three 3-ton air conditioning units are required to cool my home in Phoenix where temperatures have been known to reach 120°F (or about 49°C) in the summer.

It's Just A Simple Recharge, Right?

Until recently, it seemed that having your air conditioner recharged was a minor event. It was the equivalent of changing the oil in your vehicle—just another form of routine maintenance. In fact, many people in this area historically get a check up on their AC unit every year and shoot in some refrigerant.

However, recharging your AC is not as simple as it used to be because of environmental regulations. When my housing development was built back in the 2004-2005 time period, the builders installed AC units containing a refrigerant known as R22. Later, this substance was deemed to be ozone depleting, and subsequently regulations were put in place to discourage its continued use.

Your AC unit's use of R22 only becomes an issue when you call to have your AC recharged or if there is a leak that needs fixing. In either case, if the service provider discovers that you have R22 refrigerant, your routine service call will become anything but routine. Soon you will have the equivalent of a hazmat team on your premises bearing special equipment and looking as though they were on a mission to decontaminate a house full of radioactive asbestos. That impression will be confirmed by the astronomical estimate they give you for removing the R22. (The skeptical among us may wonder whether the real impetus for removing R22 is simply revenue enhancement.)

As I went through this process of trying to have my AC recharged, it quickly became apparent that this simple "add some Freon" maintenance item has turned into a big event. My inclination might have been simply to obtain more R22 and do the recharge myself. Unfortunately, R22 has become as rare as unicorn blood and it's priced accordingly. So that was not really a good option.

But after doing a little research, I learned of a new refrigerant made by DuPont called Isceon MO99, also known as R-438A. This new substance is considered a safe and better performing alternative to R22 (Fig. 2.) So I decided to use this as an opportunity to upgrade my system. Not only could I recharge the refrigerant, I could add some features that should have been installed when the AC was first put in. Maybe I'll even want to add some electronics to improve the AC unit's performance? Maybe I could add a variable frequency drive or microprocessor controls to improve performance? This assumes of course that these features are not already installed.

Fig. 2. DuPont's Isceon MO99 refrigerant, which is also known as R-438A, is a both an environmentally friendlier and better performing replacement for R22, which has become hard-to-find and expensive.

Speaking of what's already installed, let's consider what "electronics" I actually encountered when I took apart my not quite 10-year old AC unit. The insides of this design looked much as they would have 50 years ago. Other than a scroll compressor design, the electrical system was the usual contactor, capacitor for start–run and the sealed motor compressor. So, the electronics engineer in me thinks that clearly, there is an opportunity here to add some electronics that will improve the AC performance. But before we get to that point, let's look at the other improvements that needed to be made.

If you spend any time around refrigeration systems, you'll discover that the professionals will always install sight glasses and a filter dryer in the high-side line of the compressor. Unfortunately, home builders want to obtain the lowest-cost, minimum-required equipment that still meets spec and install it with the lowest-price labor and materials to maximize profit. That explains why my AC system had neither sight glass nor filter-dryer installed.

The sight glass is valuable because it allows you to assess the health of the system visually. If you have moisture in the system, a dot in the glass turns from blue to pink. And if you see bubbles, your system is low on refrigerant. The best part is you can tell this without gauges and without potentially breaking the seal of the Schrader valves. Doing that type of physical test causes a leak and takes out some refrigerant. Of course, some of this refrigerant goes into the air too, which is not nice for the environment.

The filter dryer does just what the name says—it filters the refrigerant and oil combination. Refrigeration oil is miscible. In other words, it becomes atomized in the refrigerant vapor, which then distributes the oil in mist form throughout the system, keeping the compressor lubricated.

In taking on this AC unit upgrade, it was not my intention to go it alone. A buddy of mine does commercial refrigeration work so I contacted him for a hand on this project.

Since we have three units I decided to experiment with the unit less used than the others. So I disassembled the unit and cleaned and inspected everything. I also took some measurements. The AC unit was powered off of 220 V ac and drew about 12 A when running. The high- and low-side pressures were noted and the inlet temp on the evaporator was 80°F and the cold air outlet vent was at about 70°F.

Next, my buddy and I proceeded to recover the R22 with a vacuum pump and using the compressor itself to pump out the R22 refrigerant into a holding tank and then pull down a vacuum on the system. After equalizing the pressure, we shut off the power and cut the high-side line. Then we installed the filter dryer and sight glass (see Fig. 3), while also adding about 4 oz. of refrigeration oil.

At that time, we tested for leaks. To do this, we pulled a vacuum on the line to ensure there were no leaks and that it would hold a complete vacuum for several minutes. The next step was installing the Isceon MO99, filling it into the system and starting it up. The results were impressive.

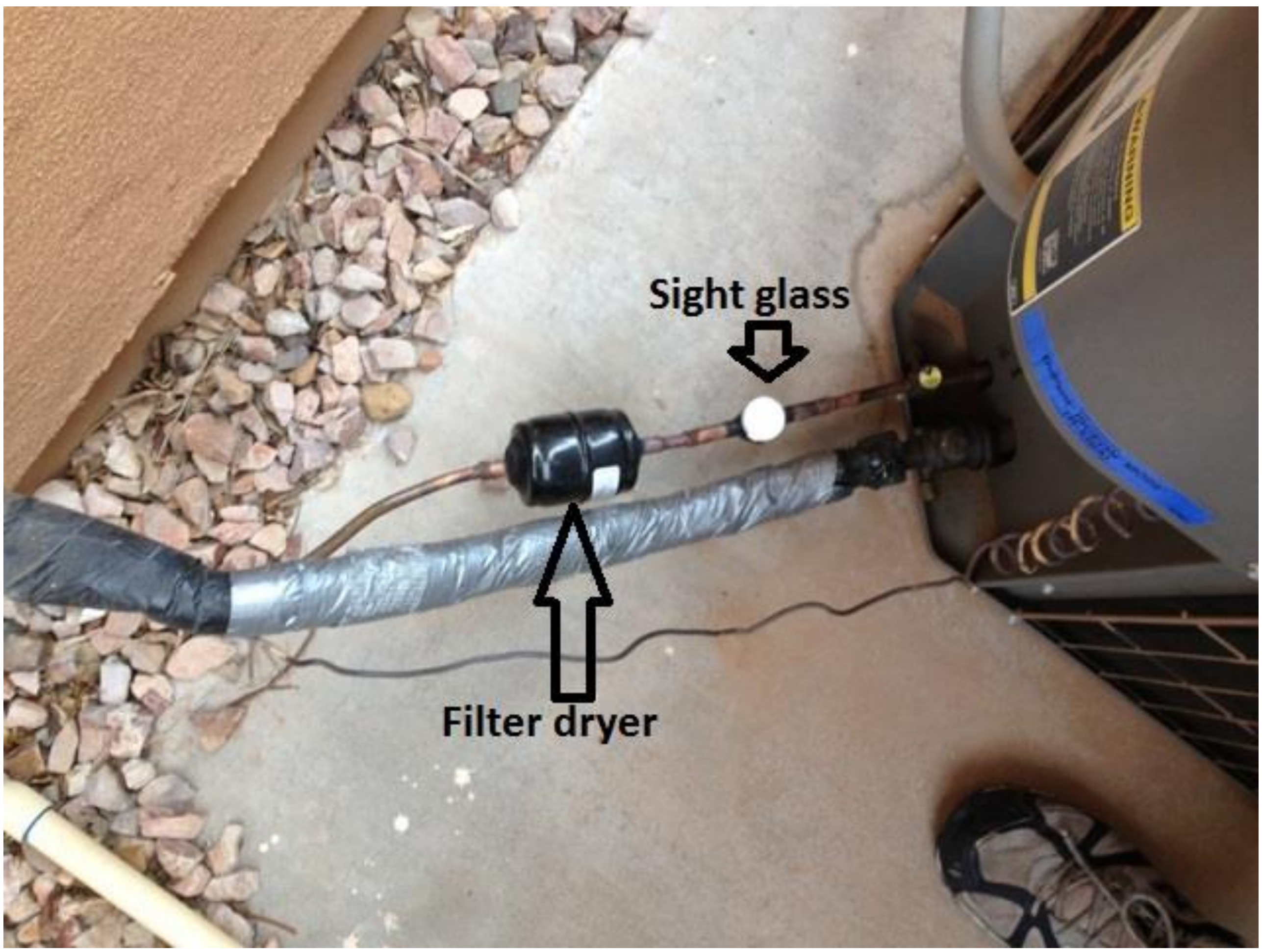

Fig. 3. Recharging the refrigerant in my AC unit provided me with an opportunity to make other improvements such as adding the filter dryer and sight glass shown here.

First, let's look at what happened electrically after installing the new refrigerant. The current draw dropped from the 12-A (2640 W) measured previously to just 6.5 A. (1430 W). At the same time, the evaporator was running much colder. Recall that before the changeover, the inlet temp on the evaporator was 80°F and the cold air outlet vent was at about 70°F. Now, after installing the Isceon MO99, the inlet temperature was about the same

(81°F this time), but the outlet temperature was reduced to 63°F! I can't think of any electronics I could add that would do this with R22 installed.

That result is amazing considering that the compressor is drawing much less current and the compressor is running much cooler, 35°C cooler on the outside case and much quieter. It is likely the compressor will last longer as it's not working as hard even as it is providing more cooling capacity. A side benefit of doing this upgrade on my own, so to speak, was that I can sell the R22 I've collected to a proper source, which buys the used refrigerant at a collection site. The money I get back from selling the R22 may actually pay for the entire upgrade!

As if that weren't enough, let's also note that the new refrigerant is free of CFCs so it's safe for the environment. Moreover, it's relatively inexpensive, when compared to R22 at the present market prices, which have skyrocketed. So hopefully when it's time to recharge the system in the future and add a bit more, the cost of the refrigerant will not really be an issue.

At this point, let's go back to my wish/question at the beginning of the project: Maybe I should add a VFD or microprocessor controls as part of the AC upgrade? In this case, I concluded that it wasn't really necessary. I was able to raise the cooling efficiency of the system dramatically, while also adding some maintenance-enhancing diagnostic tools (the sight glass and filter)—all at minimal expense. Since the results of the upgrade wildly exceeded my expectations, I didn't feel the need in this case to upgrade the system further by adding electronics to the system. In reality, the only thing I could really get to would be the condenser fans, which would require swapping as the compressor motors are sealed inside the compressor.

That's not to say, that I might not opt to add electronics in the future. However, my experience with this AC upgrade puts such technical decisions in better perspective.

With all the discussion in the industry about adding electronics and VFDs to appliances and HVAC systems, it's interesting to see how much improvement can be made in other areas such as improving the physics of the refrigerant.

Looked at another way, if you have an inefficient refrigerant you cannot compensate for it by throwing electronics at it. First, optimize the elements of the refrigeration system that the addition of electronics cannot fix—the thermal and mechanical portion.

What Did I Learn?

So, why am I discussing this type of home improvement project in a power electronics publication? I have a few reasons.

First, as electronics engineers we often believe we must throw electronics at every single problem reflexively, even when the application really cannot afford it. Engineering is the art of delivering something that works and lasts and can be sold at a profit. Clearly power savings and energy efficiency are important at a system level—but how do we get there? Let's start by optimizing the physical system first and then adding electronics to the system that enhance performance second. This might explain why for years everyone has been talking about adding electronics to home HVAC systems and yet, electrically, they still look much as they did 30 years or more ago.

I also want to commend DuPont. This company, which invented Freon in the first place, has created a replacement that not only performs better but also is less harmful to the environment. Through this innovation, DuPont made it possible to increase the efficiency of AC systems without adding any electronics, while eliminating CFCs and reducing any potential ozone-layer damage by its use. This is pretty amazing stuff.

Let me state here that I have no financial interest in DuPont or its technology. My motivation is just in increasing the efficiency of HVAC systems, and of course in saving money and getting a more-efficient system in my own installation. If you too are a candidate for an upgrade to your AC system, consider the approach taken here yourself. (I have already noticed the savings on my electric bill.) The improved efficiency, energy savings and possible increase in the longevity of the system that you experience should be impressive.

I encourage you to watch the video and read the DuPont manual on this amazing replacement refrigerant and try it for yourself. Keep in mind you need to have experience in working with high voltage and use proper PPE (personal protective equipment) and get a licensed professional to help or do it for you if you do not have the requisite background and experience. Moreover, it's important to consider you are working with a material that should not be vented to the atmosphere but reclaimed in a proper tank.

Given the energy savings that are possible with widespread adoption of the new refrigerant, it would make sense if the utilities offered rebates or other financial incentives for their customers to upgrade to the new refrigerant. However, I am unaware of any such incentives at this time.

In the future perhaps electronics could be added to HVAC systems to improve the condenser fan operation or the compressor performance even further after optimizing the physical system itself with this much-improved refrigerant. But for now, the conceptually simple act of replacing and upgrading the refrigerant can work wonders. In my case, the undertaking was well worth the effort.

References

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About The Author

Kevin Parmenter has over 20 years of experience in the electronics and semiconductor industry. Kevin is currently vice president of applications engineering in the USA for Excelsys Technologies. Previously, Kevin has served as director of Advanced Technical Marketing for Digital Power Products at Exar, and led global product applications engineering and new product definition for Freescale Semiconductors AMPD - Analog, Mixed Signal and Power Division based in Tempe, AZ.

Prior to that, he worked for Fairchild Semiconductor in the Americas as senior director of field applications engineering and held various technical and management positions with increasing responsibility at ON Semiconductor and in the Motorola Semiconductor Products Sector. Kevin also led an applications engineering team for the start-up Primarion where he worked on high-speed electro-optical communications and digital power supply semiconductors.

Kevin serves on the board of directors of the PSMA (Power Sources Manufacturers Association) and was the general chair of APEC 2009 (the IEEE Applied Power Electronics Conference.) Kevin has also had design engineering experience in the medical electronics and military electronics fields. He holds a BSEE and BS in Business Administration, is a member of the IEEE, and holds an Amateur Extra class FCC license (call sign KG5Q) as well as an FCC Commercial Radiotelephone License.