
Stephen W. Duda

Explaining to a Layperson How Air Conditioners Work

BY STEPHEN W. DUDA, P.E., BEAP, HBDP, HFDP, FELLOW ASHRAE

One challenge I like to pose to younger consulting engineers is to explain to me how a simple air-conditioning unit works, at its most basic, fundamental level. Usually, the responses I get include a lot of college textbook jargon such as "well, there is an isentropic process in the compressor which . . ." or some version of the perfect gas law with regard to the refrigerant, or a discussion of the Reverse Carnot Cycle. I stop them. And, I ask them to tell me in simple layperson's terms what is the process in an air conditioner that makes air cold. That skill is important because it confirms whether they truly understand how it works, and it enables them to explain the process to non-technical clients in the future.

Even the least mechanically inclined layperson usually has a basic understanding of how a residential gas furnace works. The furnace ignites natural gas (or propane) inside a heat exchanger chamber. Fire is hot. Therefore, the heat exchanger becomes hot, and the furnace fan blows air across that chamber to make air hot. Very simple—essentially intuitive. Cave dwellers figured out fire a long time ago.

But many people don't have this basic understanding of what happens inside an air conditioner. When explaining a project design or concept to a client without a technical background, I've had them ask how it works. So the ability to explain basic engineering concepts in a non-technical manner, without pandering or insulting their intelligence, is a useful tool for your toolbox.

Some Basic Concepts

I usually preface my explanations to non-technical clients with some basic concepts:

- There is no such thing as "cold" in science or engineering. There is only heat*—maybe more of it or maybe less of it, but there is always some heat. Even when the weather is bitterly cold outside, it is not because the air is filled with "cold"; the air has heat and actually quite a lot of it—just not as much as we wish it had.
- Engineers try to make things cold by moving heat away from a place we don't want it (inside our buildings) and relocating it somewhere else (outside our buildings). We really don't get rid of it; we just move it somewhere else. And the energy we use in moving the heat around actually makes more heat overall than we started with!
- And I use a water tower-pump analogy. If you have water in a tall tower at the top of a hill, a pipe leading from that tower to an empty pool at the bottom of the hill, and you want to fill the empty pool, what should you do? Effectively nothing. Just open the valve in the pipe, and the water will drain from the tower into the pool. That is commonly understood.

* In physics, heat is a form of energy that is in transit from higher to lower temperature.

Stephen W. Duda, P.E., is senior mechanical engineer at Ross & Baruzzini, Inc. in St. Louis.

Conversely, if I want water to flow from the pool at the bottom up to the tall tower at the top of the hill, I just open the valve again, right? Wrong. Water won't flow uphill. So is that it? There is nothing I can do to make the water go uphill? Well, there is. You can add a pump and an energy source (ranging from your own hand to an electric motor) to pump the water uphill. Again, most everybody understands that. In technical terms, it is Newton's Law of Gravity, and anybody who has graduated from high school has heard of it. Not as many are familiar with the thermodynamic equivalent.

- Similar to the water tower-pump example, heat wants to flow from a place there is a lot of it ("top of the hill") to a place there is less of it ("bottom of the hill"). (I have to emphasize with the client that it is *not* gravity that moves heat from one place to another, but it is a thermodynamic force analogous to gravity.)

If your house interior is 85°F (29°C), you wish it were 75°F (24°C), and it happens to be 50°F (10°C) outside, you really don't need a mechanical device to make that happen. With some patience and perhaps some open windows, your house will cool down (absent of significant internal loads).

But if your house interior is 85°F (29°C), you wish it were 75°F (24°C), and it happens to be 95°F (35°C) outside, you can't just wait and hope heat will leave your house and travel outside voluntarily. It won't. Instead, you need a "heat pump" to pump the heat "uphill," so to speak. (Your audience may be surprised that they now know the Second Law of Thermodynamics!)

With that introduction and background, you can now explain how a vapor-compression refrigeration cycle, or (avoiding jargon) how an air conditioner, works.

Step One: The Compressor

In an air-conditioning unit, we start with a refrigerant in its gas form, at approximately room temperature. We compress the refrigerant gas in the compressor, essentially taking a large but fixed number of refrigerant molecules in one container and forcing them into a smaller container. This requires some form of energy, usually electrical energy, to drive the compressor.

What happens when you compress a gas? Well, the pressure increases, certainly. Some people understand that the gas becomes warmer, too, but others don't—and it is not necessarily intuitive for the layperson. So why does a compressed gas increase in temperature? Well, that's where the perfect gas law comes in, but we agreed not to use technical terminology.

So I attempt to explain it like this: Molecules are not stagnant; they are always moving. When one forces the same number of molecules of a gas into a smaller volume, it results in more close and vigorous interaction between those molecules. One can imagine those molecules brushing up against each other much more frequently, not unlike people dancing aggressively to a fast song on a continuously shrinking dance floor. The result is many collisions and, perhaps, flaring tempers.

While it is not technically correct to say the gas becomes hot due to friction between molecules, it is not altogether incorrect to think of it that way. And, it adequately models the situation in a manner that gets the point across. This is because friction is intuitive; one only needs to rub their hands together vigorously for a few seconds to feel the temperature increase.

Therefore, when the refrigerant leaves the compressor, its temperature has increased. Also not to be overlooked, the pressure of that refrigerant has gone up, increasing the boiling point of that refrigerant. (For example, water has a higher boiling point at sea level than at the top of a mountain.) This becomes important in the next two steps.

Step Two: The Condenser

The hot, compressed gas now enters the condenser. The condenser's job is to cool off the refrigerant gas. It can be air-cooled, like a typical residential unit, or water-cooled, as in a large chiller. Cooling off the refrigerant takes heat energy away from the refrigerant, causing the molecules to slow down.

For a residence with central air, the layperson will be familiar with the "box" on the back of their house in which a fan blows (or, usually, draws) air across a coil containing the hot refrigerant, bringing its temperature down. In our dance floor analogy, the dance floor is still reduced to a small size, but now the band plays a slow song, The resultant slower dancing reduces the number of dancers who collide, decreasing friction (and perhaps tempers) among the dancers.

Because the boiling point of the refrigerant was raised (due to high pressure) in Step One, and we have now cooled off the refrigerant in Step Two, what happens?

The refrigerant crosses down through its boiling temperature and condenses. Now the refrigerant is a liquid.

At this point it is helpful to explain that air-conditioning refrigerants are chemicals specifically chosen because they cross back and forth from a liquid to a gas at temperatures and pressures convenient for comfort air-conditioning purposes. (Otherwise, we could just use water.) The transition from a gas to a liquid releases a large amount of heat energy to the surroundings (making the condenser a heat-rejection device). The transition from a liquid to a gas requires a large amount of energy taken from the surroundings.

Step Three: The Expansion Device

Basically, this step removes the pressure put into the system in Step One. At this point, the layperson thinks, "Wow, what a waste." You release the pressure you paid for (via electricity, usually) at the compressor a few short steps ago. But we have to do this to "trick" the refrigerant into behaving in a manner convenient for air conditioning.

What happens when you remove pressure from the refrigerant? Remember, you started with a refrigerant near ambient temperature (more or less). But, you made the refrigerant hot by compressing it. Then you cooled it off in the condenser. Now you are removing the pressure the compressor had given you. So now how would you find the refrigerant? Cold! If the refrigerant became hot due to pressure, then you cooled it off, and then you took away the pressure, you end up with refrigerant that is cold. Make sense? At this point, hopefully you see people's eyes light up or heads nod as they comprehend basic air conditioning or refrigeration.

In our dance floor analogy, people are still dancing to a slow song, but now the dance floor expands back to its original larger size. The increase in dance floor size during a slow song decreases the number of dancers who collide, and everybody cools down.

Step Four: The Evaporator

The cold liquid refrigerant now enters the evaporator. The evaporator warms up the refrigerant, while at the same time cooling off the surrounding air or water. In a residence, this is often an "A-coil" in the furnace or fan coil unit. The unit's fan blows air across the cold refrigerant to take heat energy away from the air (making it cooler) and adds that same heat energy to the refrigerant, causing the refrigerant molecules to speed up (so those molecules are zooming around fast again).

Because the boiling point of the refrigerant was lowered in Step Three due to lower pressure, and we have added heat to the refrigerant in Step Four, what happens? The refrigerant crosses upward through the boiling temperature and evaporates, removing heat energy from the air (or liquid) passing across the evaporator.

Now the refrigerant is a gas at the same temperature you started with, and it goes back to the compressor for Step One all over again. On our dance floor, the floor is back to its original size, and the band goes back to playing a fast song, so we are back to the original starting condition and ready for the next trip through the cycle.

Conclusions

When speaking to non-technical persons, it is of no use to apply technical, textbook engineering jargon. On the other hand, one must avoid insulting someone's intelligence by using childish or oversimplified language. Consulting engineers need to be prepared to explain basic concepts to laypersons in non-technical language, accented with analogies to everyday familiar experiences. For practice, try explaining it to a non-technical spouse or relative. ■