Problem of Excess Gas

By Andy Pearson, Ph.D., C.Eng., Member ASHRAE

This article is the eleventh in a series exploring refrigeration and heat pump concepts without using jargon.

Last month's jargon buster included a definition for non-condensable gas, sometimes abbreviated to NCG (fridge guys love three-letter acronyms, or TLAs as we like to call them).

The definition mentioned that other gases can sometimes get mixed in with the refrigerant. The most common of these is air, which can leak into systems where the evaporator operates at a pressure lower than atmospheric pressure, or might be left in the system after service or maintenance. Nitrogen leaking into part of the system during a pressure test will also act as a non-condensable gas.

So why is this a bad thing? A system that has non-condensable gas trapped in the condenser will need to run harder to achieve the same cooling effect and therefore will be less efficient than it should be. In this case "run harder" means the compressor has to pump the gas up to a higher pressure than ought to be necessary in order to reliquefy it.

There's only so much gas that you can tolerate. Photo credit: English Wikipedia user Froggydarb.

There are several analogies used to describe the effect; some of them are better than others, and some are downright wrong so we need to go a bit carefully here. The effect has nothing to do with the air "covering part of the heat exchange surface" or "insulating the inside of the condenser."

To get to the real reason we need to look to the work of a self-taught scientist from the northwest of England called John Dalton. He is perhaps most famous for his pioneering work on atomic theory at the very beginning of the nineteenth century or his analysis of color blindness, which is still known as Daltonism in some places. However, we need to think about his "law of partial pressures" that describes how mixtures of gases behave.

Simply put, Dalton realized that gases are fundamentally antisocial; each one in a mixture behaves as if it is the only one there. So if there were three gases mixed in equal quantities with a total pressure of 150 psi, each one would behave as if the pressure was only 50 psi and it was filling the space. Doesn't this strike you as a bit odd?

Imagine an ice skating rink with a bunch of hockey players knocking seven bells out of each other. Mixed among them are a group of skaters, some holding hands, some doing the conga and some just gliding round in circles. Also on the same rink there are a couple of figure skaters practicing their high lifts and triple axels. It seems unlikely that these three groups would not exert some kind of effect on each other, but for gases it is different. They are oblivious.

In the condenser each gas behaves as if the others were not there, and so will condense at the temperature that matches the pressure that they alone exert on the system. For R-134a in an air-cooled condenser when the air temperature is 95°F (35°C) the condensation will happen at about 120°F (about 49°C) if the condenser is reasonably sized, and liquid would come out the condenser at about 115°F (46°C). If there is no air in the system then the compressor needs to deliver the gas to the condenser at 171 psi (1179 kPa) so that it will turn to liquid at the right temperature. If 10% of the gas in the condenser is nitrogen that was left in the system after a pressure test, then the compressor still has to deliver the R-134a at 171 psi (1179 kPa), but this is only 90% of the total pressure, so the actual discharge pressure of the compressor would need to be 192 psi (1323 kPa). If you attempt to recreate this feat of calculation beware! The pressures given here are gage values but the partial pressure calculation is done with absolute values.

So for this system, where 10% of the molecules in the condenser are nitrogen, not R-134a, the pressure gage on the compressor discharge would suggest that the condensing is happening at 128°F, not 120°F (53°C, not 49°C) as intended. Usually a high condensing temperature indicates a condenser problem—dirty fins or blocked airflow or some such hindrance. However, the liquid coming out the condenser, which is always slightly colder than the actual condensing temperature, would still be about 115°F (46°C). This is the key to diagnosing excess gas in the system. The condenser is apparently underperforming and yet is still able to make the liquid as cold as before even though the pressure is higher. It helps to have figures for good performance as a comparison when checking for excess gas.

Andy Pearson, Ph.D., C.Eng., is group engineering director at Star Refrigeration in Glasgow, U.K. ■