SZÉKELY ENGINEERING
EXPLANATIONS & EXAMPLES

Of Heat Pumps, Air Conditioners, and Geothermal Energy

If an oil pump pumps oil, and a water pump pumps water, does a heat pump pump heat?

Well, yes

It's therefore logical (and correct) to assume that if a heat pump's raison d'être is to make you warmer when it's cold out, a dedicated device you'd use to cool off when its hot out could be called a 'coolth' pump.

It could, but we know it by its more familiar name, an air conditioner, and that's the clue to the difference between a heat pump and an air conditioner. That is, while the former can "make" heat or coolth, the latter can only make coolth.

If you've ever walked by the outdoor portion of an operating window or through-wall air conditioning unit, you may have noticed the air being blown out of the back of the unit was hotter than the ambient air around it. What it's doing is taking heat from indoors and rejecting that heat, or *pumping* it to the outdoors. What if you could reverse the process?

That is, what if it were possible to take heat from outdoors and *pump* it indoors? It is, and that's why we call it a heat pump. OK, OK, "Whaddaya mean heat from outdoors??!!?? It's #$!!??@! freezing outside!" Well first, remember the difference between heat and temperature.

That is, the same amount of heat which is needed to raise the temperature of a massive object (think the interior of a Gothic Cathedral in June) a few degrees, can raise the temperature of a smaller object (say a steam locomotive's boiler) a few hundred degrees.

Once again, a British Thermal Unit (BTU) is the amount of heat it takes to raise a pound (about a pint) of water by one degree Fahrenheit. Similarly, a Calorie is the amount of heat it takes to raise the temperature of a kilogram of water (about two pints) one degree Celsius (1.8 degrees Fahrenheit).

So, if I pumped enough heat into 1000 gallons of water (8,330 pounds) to raise its temperature from 40°F to 140°F, the 833,000 BTU (100 x 8330) of heat that was required to do the job, would, if it were pumped into only 100 gallons of water therefore raise its temperature to 1,040°F, right?

Well, no.

It turns out that to change a pound of liquid water to water vapor you'd have to pump 970 BTU's into it, and its temperature stops rising while this is going on. Similarly, to change a pound of liquid water to solid water (ice), you'd have to suck 540 BTU's out of it, and again, the temperature wouldn't change.

Ice-water is just that, water at the same temperature as the ice that's floating in it. As long as ice continues to melt in the water, the latter's temperature is somewhat warmer (i.e.; its heat content is higher) than the ice, but there will come a point when enough ice is added, that any melting which may occur does so not because of the heat in the surrounding water, but because of that in the air in contact with the ice.

Ice, water, and water vapor (steam) are examples of different *states* (solid, liquid, and gas) of the same substance, as are frozen methane on the surface of Jupiter or Saturn, LNG (Liquefied Natural Gas) in fueling stations or tankers, and the gas which we cook with. The point is that *change of state* involves the addition or removal of heat energy with no change in the temperature (ergo, the term latent heat) of the substance which is undergoing the change, and the temperatures at which these occur under normal atmospheric conditions (STP or Standard Temperature and Pressure) are what we refer to as the melting and boiling points of substances.

This is a clue that these things happen at different temperatures if the pressures are different, and it's why poached or boiled eggs might be problematic in Denver, and why pressure cookers are useful devices.

This is also (finally!!!) a clue as to how air conditioners and heat pumps work. That is, temperature and pressure of a gas are related in that if you compress a gas you'll raise its temperature (operate a bicycle pump furiously as you grasp it by the cylinder) while if you let it expand, its temperature will drop (hold down the spray valve of an aerosol can with your other hand wrapped around the can).

There are certain substances, many of which we use as refrigerants, which we can compress in closed systems and then suck enough of the heat of compression out of them by blowing ambient air (or circulating ambient water) around finned coils containing the substances, to change them from a highly compressed gas like the CNG (Compressed Natural Gas) in alternate fueled automobiles, to a liquid like the LNG in their fueling stations.

If we meter a liquefied refrigerant into a finned coil at a given rate, and blow air over that coil at a given rate, the refrigerant sucks heat out of the air in order to obtain the energy to change it from a liquid to a gas, which is why the coil is called the *evaporator* coil.

The air we're blowing over that coil (which has thus cooled to 55-60°F) is what comes out of the business end of an air conditioner.

We then compress that gas, and send it to the outdoor *condenser* coil to liquefy it and start the cycle all over again.

So what would happen if you put the evaporator coil outdoors and the condenser coil indoors? Well now since you're blowing air across compressed (hot) refrigerant, what's coming out is heat from the business end of a heat pump.

While you might be able to take a standard air conditioner and mount it backwards (put the outside end indoors) to operate as a really inefficient heat pump in winter, it really makes more sense to put 4-way valves between the coils so as to reverse the flow of refrigerant.

So, all this to figure out that a heat pump is nothing more than a reversible air conditioner? Yes.

There is a limit to the operation of air source heat pumps, however, in that when it gets really cold out the evaporator coil of a heat pump can't suck enough heat out of the air to boil the compressed refrigerant. In the old days this used to be at about 30°F. Now some equipment can operate down to 5°F, but the efficiency (see COP below) goes to hell as the outdoor temperature goes down.

One more thing regarding heat pumps and air conditioners. They're kinda like amplifiers.

You put energy in (electricity) and get energy (heat or coolth) out. The ratio of output to input energy is what's referred to as the Coefficient of Performance or COP (no Wikipedia link here because the article is written in Middle Geek), but first you have to be talking in the same units.

A kilowatt (1000 watts) of electricity, converted completely to heat, will deliver 3,413 BTU's of heat. While electricity is high-quality energy (that is, energy losses in its use are negligible compared to other forms of energy), making heat directly with electricity is a lousy bargain because of the inefficiency of the fuel-burning process used to generate most of the electricity used in the U.S. in the first place – better to burn the fuel locally and make the heat where it's needed, rather than lose it as waste heat in a powerplant.

But back to COP. If, instead of using the electricity directly in an electric baseboard heater, we use it to compress a refrigerant for heat, we can get as much as 5 or more times the BTU's out ($COP \geq 5$) as are put in by the electricity. Hence the analogy to an amplifier. In passing, it should be pointed out that an incandescent lamp, in spitting out 93% of its input as heat rather than light is actually more a poor heater than a good light.

Now a distinction:

Geothermal Energy (and you thought I was never going to get to it) is hot springs, Old Faithful and the like. Geothermal heat pumps are simply using a denser medium (water, as in "water-source" heat pumps which is what they should be properly called) than air as a heat source and heat sink, and simply use wells in the place of cooling towers.

A better year 'round COP to be sure, but not Puff the Magic Furnace. As I appear to be out of space, more on this in the next issue.

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