SZÉKELY ENGINEERING
EXPLANATIONS & EXAMPLES

Hydraulic Calculations and Mechanical Engineering, *or*, Einstein and Electric Heat

When designing fire sprinkler systems, Codes allow such to be predicated upon pipe schedules or hydraulic calculations. The former uses tables indicating how many sprinkler heads can be fed from a given pipe size with the size increasing as the hazard ("light, "ordinary" or "extra") increases, where the hazard is defined by the amount and type of combustible materials in the space to be protected.

The pipe sizes increase because increasing hazard requires increasing water flow rates, and the tables have been generated by calculating the water pressure required to drive the needed amount of water flow through the pipe size being examined. These calculations, by the way, comprise the latter method mentioned in the beginning of this piece.

The reason hydraulic calculations may be more attractive on a given project is that the tables must be based upon the maximum permitted distance between heads and cannot account for multiple feeds to a sprinkler system. To put a point on it, if the layout allowed a somewhat reduced head spacing or you were to feed a grid of sprinkler heads from two sides, you could reduce pipe sizes as all of the required water does not have to flow through a single source pipe, and the pressure drop through a section of pipe is dependent upon its length and how much water is flowing through it.

OK, so how complicated is all of this?

It depends, but basic hydraulic calculations are fairly simple. You start with the sprinkler head which is farthest away from the water source, assume the minimum pressure required to deliver the required flow rate from that head, and calculate the pressure drop through the section of pipe feeding that head at that flow rate. For the next upstream head you flip the calculation and figure what is pushed through that head by the higher pressure required to compensate for the pressure drop in the pipe feeding the previously calculated head.

As you continue this calculation back to the source, cumulative increases in flow rate and pressure drop bump up the total pressure and flow required beyond simple addition of individual sprinkler head flow rates. That is, if we're talking about a dwelling unit where the system is calculated on the farthest of 4 heads in a room requiring 11 psi (***p**ounds per **s**quare **i**nch*) to deliver 18 gpm, (***g**allons **p**er **m**inute*) where 1 psi of that is to make up for pressure drop through the pipe, the total requirement would not be 14 psi to deliver 72 gpm, but might be more like 20 psi to deliver 74 gpm.

So what does all this have to do with Einstein, and what does Einstein have to do with electric heat?

Ah, Grasshopper, if you followed the previous paragraphs carefully, you will have understood that pressure drop in a pipe is proportional to how fast the fluid in the pipe is flowing; as more gallons (volume) per minute are flowing through a pipe, the faster (velocity) it's going and the pressure drop in the pipe (i.e. resistance to that flow) increases as the flow velocity increases.

By the way, each time the direction of flow changes, via fittings such as elbows or tees, additional resistance is imposed upon the system, which is usually expressed as an equivalent length of pipe comprised by the fitting.

All of this is also related to how smooth the inside of the pipe is, and as water pipes get older and mineral deposits coat their insides, the pipes offer more resistance to flow because they are both smaller and rougher than they were when new.

Finally, in open systems, there's the issue of gravity opposing pushing water uphill.

Einstein, in proving that the speed of light is constant informs us that electrical resistance is dependent only upon the diameter, length, and temperature of the cable carrying the current, and not upon any change in direction of the cable nor the speed of the electric current . Its speed in a vacuum, ***which is for all intents and purposes, constant***, is substantial enough a percentage of the speed of light that relativistic effects begin to take hold, and quantum mechanics begins to rear its screwy head.

These relativistic and quantum effects so overshadow any classical mechanical effects which might exist, that the latter are virtually nonexistent.

And the relationship to electric heat?

Patience, Grasshopper.

"Making" heat by burning fuel and then heating air or water or some other heat transfer fluid entails the concept of efficiency because when dealing with the coarseness of chemical reactions and classical physics, there are "friction" losses at each stage, as well as in every machine and transport mechanism involved in getting the heat from where you made it to where you need it.

When you burn something, you apply enough heat to it to break its chemical bonds, and if the reaction is exothermic the heat released by the formation of combustion products is greater than that which was applied to break the bonds, and the reaction becomes self sustaining; you only have to put a match to the kindling, and once it catches, the fire will (if you built it correctly) keep going.

If it's a fireplace, much (if not most) of that heat will go up the chimney instead of working to keep you warm.

In a boiler, much still goes up the stack and some gets lost when heating the jacket and piping. Once you've heated the water or made steam, you've lost a bit more before heating the radiators to the point where they start giving off heat that you can feel.

If it's a hot air furnace you again lose some the chimney, then lose a bit more to heat the air, and then a bit more still to heat you with the heated air.

To use an example which we all should be able to relate to, when an automobile burns fuel to get you and it from point A to point B, only about 25-30% of the input energy yielded by the combustion process moves the car down the road – the rest is given off as heat. In a high-compression racing engine this might get up as high as 35%, and in a modern hybrid this could be around 35-45%.

The point of the difference between heat of combustion and electric heat is that since electricity is a phenomenon tightly bound to quantum and relativistic effects – it acts at so small a level, i.e.; not only atomic, but subatomic – there is nothing to impede the conversion from electricity to heat, and this, boys and girls, is why a 1 kilowatt electric baseboard heater will deliver 3413 BTUH (***B**ritish **T**hermal **U**nits per **H**our*) of heat.

That is, there are no constrictions, moving parts, heat transfer fluids or other transport media to take their toll as losses, and electric resistance heating is thus virtually 100% efficient. Source to use efficiency, however, is only as efficient as the processes used to generate and transmit electricity, and at best, central power stations generate electricity at efficiencies of about 33%, and this is before transmission losses in getting the power to the point of use. By the time the electricity gets to you, only about 26% of the energy contained in the fuel used to generate the electricity has been delivered to your outlet.

Hybrid Vehicles and Electric Cars

The preceding makes electric cars, absent generation of electricity by means other than the burning of fossil fuels, look a bit less attractive. This is *not* to say that overall CO_2 emissions would not be reduced (presupposing there's some utility to same) if all cars were hybrids or electric cars, because they *would*, as indicated in the hyperlinked reference for electric cars above.

The difference, by the way, between electric cars and hybrid cars, as they are commonly known, is that in hybrid cars the internal combustion engine has adequate horsepower to drive the vehicle independently from the electric motor(s) as well as to charge batteries which power one or more electric motors which *also* have adequate power to drive the vehicle *without* the assistance of the internal combustion engine. Such a hybrid car (Toyota Prius, Ford Escape, et. al.) is actually more correctly referred to as a series-parallel hybrid, as explained in hyperlinked reference above.

In electric cars, however, the internal combustion engine is not part of the drivetrain, does not have adequate power to drive the car by itself, and serves only to charge the batteries which power the electric motor(s) which move(s) the car. Such an electric car (e.g.; Chevy Volt) is actually more correctly called a series hybrid, also as explained in the hyperlinked reference above.

The real question concerning hybrid or electric cars, however, is how to dispose of depleted batteries, and what the battery replacement cost might be.

Another newsletter, anyone?

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