Energy 101 - The Basics

Since there is a great worldwide debate going on about “energy”, some of the debate participants need to refresh their memories, or in some cases, learn something about the basic ‘Energy Laws’ (EL), associated with it’s utilization and conversion from one form to another. These have been established over centuries of study. Isaac Newton is generally given credit for first recognizing there are such natural laws and writing about them.

The debate could be of interest to the electrical power industries as a whole, because supposedly the 30 year ban on new U. S. nuclear plants has been lifted, unless it is just another political ploy.

The first of the Laws is sometimes called the Energy Conservation Law:

EL-I. Energy can neither be created nor destroyed, only converted from one form to another form.

The second has to do with separating energy into two general classes: “Available” and “Unavailable” . . . meaning some energy quantities are available to do ‘useful work’, like powering a car down the highway or turning a generator to produce electricity, while others are unavailable to do ‘work’ but are useful for things like comfort heating, cooking, or processed material drying:

EL-II. Not all energy is available to do work. Some must be discarded.

The third Law essentially says there is no way to bypass the first two laws:

EL-III. Any process involving the conversion or utilization of energy, must obey Laws I and II.

Understand that these Laws cannot be proven by mathematics and only exist because no one has ever, in the history of modern man, been able to violate them. To do so, would require the invention of a “Perpetual Motion Machine”. Patent Offices are well aware of these Laws and any machine or device, submitted for a patent, is put through an energy analysis and if it violates any of the Laws, it results

in an automatic denial of a patent.

There are two other proposed Laws that mostly concern an invented property called “Entropy”. (Was that a loud moan I heard?) Entropy is a ‘property’ like pressure or temperature and is used as a measure of Unavailable Energy in a substance. Those are called ‘proposed’ because like the other Laws, they cannot be mathematically proven and they haven’t been around long enough to be considered to be true because no one has disproved them. So it may be a long time before that happens to EL-IV and EL-V, because some scientists claim they have more to do with ‘Divine Intervention’ than Thermodynamics.

Some ‘wag’ has proposed the first three Laws are like being in a game of poker with Mother Nature, where the stakes are units of energy and her rules are:

EL-I. You can’t win.

EL-II. You can’t break even.

EL-III. You can’t get out of the game.

The Laws apply to all energy conversions, including the ‘Direct Energy’ converters like ‘fuel cells’, ‘photovoltaics’, ‘magnetohydrodynamics’, ‘thermoelectrics’, etc., or the more mundane mechanical/electric converters like electric motors and generators which have any kind of ‘friction’ or ‘resistance’, hence converting some ‘Available Energy’ (AE) to ‘Unavailable Energy’ (UE).

An example of conversions, representing a large amount of energy, is an automobile driving along a road at a constant speed on level ground. The chemical energy in the gasoline is converted by combustion to thermal energy. The thermal energy is converted by the engine into mechanical energy which is delivered to the transmission/drive train, then to the wheels which provides the force to drive the car forward.

All along the line, the energy conversions must follow the Laws. Chief among these is the energy conversion of the chemical energy to thermal energy by combustion in the cylinder, making carbon dioxide (CO_2) and water vapor (H_2O) from the combustion of the gasoline hydrocarbons. The mechanics of the piston in the cylinder of the engine is where the conversion of thermal energy (released by the combustion) to mechanical energy takes place. As the ‘working substance’, air, in the cylinder is heated, it tries to expand but being confined, the pressure rises in the cylinder and forces the piston down. Force moving through a distance is ‘Work’, and so ‘Heat’ (thermal energy) is converted to Work.

Due to some details of EL-II and the Carnot Cycle about this conversion, it is not possible to have more than about 40% of the Total Energy, ‘available’ to do work, so about 60% of the chemical energy of the gasoline (or any other fuel) is ‘unavailable’ and must be discarded as heat transferred out of the engine cylinders to the water of the cooling system, and finally from the radiator to the surrounding environment.

My Thermodynamics' class students were generally somewhat incredulous when they learned that, particularly the EEs. Yes, I was usually assigned the task of teaching basic Thermo to all EE students and a second course to the Power Option EEs., which included weekly sessions in our Heat Power Lab where they obtained some practical experience working with 150 psi/350 deg.F live steam. I think I received that assignment because though my degrees were in ME, I might be able to connect a bit with EEs because it was known from my job application that I had just ended a contract position as Data Analyst at the AC Spark Plug Inertial Guidance Div. of GM, working with electrical/electronic systems. That coupled with experience from 'Ham' radioing, and while at college, having worked as a maintenance technician in both the Electrical Power and Electronics Laboratories.

On evenings and weekends I worked as a Studio/Remote Broadcast Engineer at the campus FM radio station and summers I worked for a local sound service, installing sound systems in restaurants and motels. All of that gave me a pretty good understanding of voltage manipulation, resistors, capacitors, etc. . . . and the ability to draw analogies from the mechanical world.

But I digress. Devices like the internal combustion engine are called 'Heat Engines' because they convert thermal energy ('Heat') into mechanical or electrical energy ('Work'). It has been suggested that the heat engine you are most familiar with is your body. Think about it . . . you take in crude fuel (food) which is 'refined' in the digestive organs (the "caloric" value of food is determined exactly the same way as the 'Heating Value' of gasoline or coal). The fuel (refined food) is dissolved in the "working substance" (blood) and pumped (by the heart) to the engines (muscle cells) over a liquid (blood) supply pipeline (arterial network) along with an oxidizer (oxygen molecules) which were filtered out of the air in an intake manifold (lungs).

The engine (cells) mix the fuel, containing carbon and hydrogen compounds (food nutrients) and oxygen together, causing them to react and releasing energy for use by the muscles to do Work. Water and CO_2 are among the byproducts of the reaction, which are carried away from the cells by blood in the return pipeline (veinal network). The water goes to the urinary tract and is expelled. The CO_2 goes to the lungs and is filtered out of the blood to be mixed with excess air in the exhaust system (lungs) and exhaled . The oxidation reaction in the cells produces UE (waste Heat), which is also carried by a coolant (blood) to the radiator (skin surface) and transferred to the surrounding air, to the tune of about 400 Btu/Hr. (117 watts), for an average adult not engaged in a strenuous activity.
A unique feature of the human heat engine is it has the ability to store excess fuel (fat) if they aren't putting out very much Work.
I'll have more to say about humans as Heat Engines in a future article along with what Mr. Carnot found in his studies.

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