Defining Efficiency in Heating Processes

Commonly Used Efficiency Definitions Overstate Efficiency

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Traditional Heating Efficiency Definitions

Most appliances utilized for heating – furnaces, boilers, and water heaters – are rated relative to their efficiency by the manufacturer according to long-established federal guidelines. A perfect score is attained if the process completely converts the chemical energy in the fuel (called the "heating value") to heat and then transfers that same amount of heat energy in to the fluid. By this definition, these products receive high marks; they are able to perform at efficiencies that are typically 85-90%. However, it is universally understood by engineers and scientists familiar with basic thermodynamics, that the conventional efficiency definition is simplistic and ignores the fact that most of the chemical energy that fuels possess has not only the ability to be converted into heat but also to be converted into work. It presumes that the device follows the traditional design approach of heating the fluid with a flame ("burner and a box") and that no better technology could be applied. Such a definition becomes incorrect when the heating appliance follows a more sophisticated design approach, one that incorporates moving parts (i.e., work) into the process. With the help of a machine that can produce work, the process can be improved many fold, an outcome that implies the impossible: a heating system that generates heat well in excess of the heating value of the fuel. In such cases the conventional definition of efficiency results in a number that exceeds 100%.

Breaking the Efficiency Barrier

We all know that energy must be conserved in any process. The traditional heater efficiency rating conforms well to this fact; a given amount of energy exists in the fuel and perfection is achieved if the entire quantity of energy in the fuel is transferred to the heated media. If an appliance is to exceed 100% efficiency, then the energy contained in the fuel must be supplemented by another source. That source is the energy that exists in our environment. Outdoor air, for example, warmed mostly by the sun is essentially a near limitless source of energy with one caveat: it is often too cool for heating. Air at 70°F can not heat 140°F water by simply bringing the two fluids into contact. In fact the opposite effect will occur – the air will be heated and the water cooled.

The indirect solar energy that exists in the local environment can only be useful if transferred to a higher temperature. This is possible with the aforementioned design approach – utilizing a machine capable of producing mechanical energy or work. As it turns out, with relatively small mechanical energy expenditure, the local ambient "solar" heat can be "lifted" from its low temperature status and "carried" to a high temperature one. Moreover, it can be proven with basic laws of thermodynamics that an idealized version of this machine is the best (most efficient) possible process that can be contemplated.

Redefining Efficiency

The proper definition for efficiency needs to compare the heating provided by an actual appliance to what is the best that the laws of nature would allow i.e. the best process possible. That "best" process is not an idealized version the "burner and box" system, but rather an ideal cycle utilizing work to extract ambient energy. For such a system, basic thermodynamic equations define the best theoretical heating appliance to be one that converts about 9 times the expended work to useful heat in the process. The important conclusion that follows is that our current appliance are not 80-90% efficient but rather one ninth that value or about 9%. Hence, the current definition not only overstates the efficiency but also masks the compelling opportunity for efficiency improvement.

Achievable Performance

In practice, using conventional vapor compression components achievable efficiencies are about 25%. Relative to the 9% efficiency of the “burner and box” design, the improvement is striking - reducing fuel usage by approximately 3 times, with proportional carbon benefit. The importance of utilizing this more sophisticated definition of efficiency becomes apparent as it reveals the shortcomings of our existing heating products while pointing the way for a new design approach for significant efficiency improvement.