Review of: "Clausius' thermodynamics, engineering thermodynamics based on the entropy principle by discarding the energy premise"

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This paper reexamines some original works of Kelvin, Gibbs and (in English translation) Planck and Clausius out of which Classical Thermodynamics emerged. The familiar thermodynamic variables energy, entropy, and heat are reported to have evolved out of the earlier caloric concept. It is observed that Clausius-Kelvin thermodynamics was no single unified theory (e.g., the same doctrine derived twice independently). Rather, it was a “blend” of two separate theories. Of these two, the Clausius Theory fostered Gibbsian thermodynamics, while the Kelvin Theory underlies orthodox engineering thermodynamics to this day. The latter is said to rely on the “energy premise”. The energy premise means that an irreversible thermodynamic process is one that “dissipates energy”. The text points out, however, that an irreversible process more generally is one that “produces entropy”, since certain irreversible processes occur without dissipation of energy. Because it retains the energy premise and thereby is dominated by a “monolithic view of energy”, this paper asserts that “engineering thermodynamics is a defective theoretical system while Gibbsian thermodynamics is a successful one”. This aspect of engineering thermodynamics is, moreover, found to be pernicious and in need of reform. In particular, engineering thermodynamics places a premium on producing work. The Second Law, in the Kelvin view, implies that dissipating energy is inevitable when producing work. Dissipation of energy frequently implies discharging waste heat into the natural environment. The latter is often regarded by engineers, at times callously and cavalierly, as an infinite heat reservoir and heat sink. These discharges, occurring worldwide daily on massive scales as they do, disrupt the local and global ecological balance. Informed by its reading of the classic texts, the paper advocates an ideological approach to solving this socio-economic problem. The paper suggests that engineering thermodynamics replace the orthodox concept of energy-conversion with the concept of “transformations” in the sense of Clausius. Motivated by Poincaré, the author has previously introduced a thermodynamic quantity called the “entropy growth potential” (EGP). The EGP appears to mean the spontaneous change in the entropy of the universe (system+surroundings) that compensates for the artificial work production that occurs during an event. I.e., through intentional effort, humans extract (or input) a quantity W of work from a thermodynamic system; the sytem+environment react to this spontaneously by increasing their combined entropy by the amount EGP. Were engineers to start talking about Clausisan transformations and EGP rather than energy-conversions and efficiencies in a widespread manner, this paper proposes that this mindset would help curb the further degradation of the natural environment (through, e.g., burning of fossil fuel) and help to preserve it (through, e.g., reliance on renewable energy sources). That summarizes the major thesis.

Let us begin with secondary, but important practical remarks. The manuscript be proofread by a native speaker of English. The author has a high familiarity with the classic source texts and inventive and well thought-out ideas. But the presentation is at times obscured by the syntactic and lexical nuances of the English language. Editing by a competent native-speaker would render it more accessible and unambiguously interpretable. Also, the typesetting of some of the equations is aesthetically off-putting. In particular, several terms are printed a line too high. Finally, some abbreviations, e.g., “NWCJ”, are left undefined in the text. All but the most common abbreviations should be defined upon first use.

Now to primary matter. A tenet of this paper can be questioned. That is the proposition that orthodox engineering thermodynamics is a defective theoretical system, enthralled to the energy premise. Mainstream engineering training in thermodynamics is not defective in this way. On the contrary, it has long included scenarios of irreversible processes without thermal discharge.

Go back, for example, to Adamson (1979), a standard text for teaching thermodynamics to engineers in its day. On pp. 318-19, this textbook derives the result that, while the entropy of mixing of an ideal solution is positive, its enthalpy (heat) of mixing is 0. The same result is arrived at on pp.453-54 of Van Wylen & Sonntag (1973), another textbook of that era. This is actually the very example cited in the worthy quotation from Planck in the manuscript. Further, on p. 438, Van Wylen & Sonntag remark profoundly:

“…the increase in entropy depends only on the number of moles of component gases, and is independent of the composition of the gas. For example, when 1 mole of oxygen and 1 mole of nitrogen are mixed, the increase of entropy is the same as when 1 mole of hydrogen and 1 mole of nitrogen are mixed. But we also know that if 1 mole of nitrogen is ‘mixed’ with another mole of nitrogen there is no increase in entropy. The question that arises is how dissimilar must the gases be in order to have an increase in entropy? The answer lies in our ability to distinguish between the two gases. The entropy increases whenever we can distinguish between the gases being mixed. When we cannot distinguish between the gases, there is no increase in entropy.”

Thus, decades ago orthodox engineering training already not only integrated scenarios of entropy production without energy exchange was integrated into, but also understood their special significance to the entropy concept. Gibbs’s contributions, mentioned in the manuscript, have also long been part of regular course materials. The same is true for the Boltzmann entropy $S=k\ln W$, a highly general formulation unrestricted to thermal effects *per se*. Regarding another point in the manuscript, conventional engineering instruction does not depict the Second Law as an indirect consequence of the First Law. Rather, the Second Law is presented as an equally ranked, fully independent axiom. Overall, in principle, there is no reliquarian energy premise from Kelvin still misguiding engineers two centuries later.

In practice, it is true that most engineers most of the time think of irreversible processes in terms of energy dissipation, as a shorthand. But that is because the most common and the most important applications involve energy dissipation. The perspective can easily be shifted should the situation demand it. But there is no need to change the formalism as the formalism already covers all possible scenarios. In particular, it is not essential to promulgate the EGP as a novel thermodynamic variable. Like the exergy, introduced as such in the 1950s, the EGP might lighten certain calculations and emphasize certain perspectives, but everything it does is already covered by other elements of standard theory.

It is true that engineering training inculcates certain habits. These include assuming infinite heat sinks or reservoirs (or concentration sinks or reservoirs, etc.) This occurs both while working academic exercises and in handling professional problems in the field. It is plausible that the routine application of these habits has abetted innumerable untoward discharges of heat and toxins into the environment. But there are remedies to this short of modifying the basic theory. For example, engineering instruction could prescribe some exercises that take the environment into account explicitly. E.g., after performing a standard calculation of the waste heat generated by a thermodynamic process, a section could be added. Maybe, “You are discharging the heat at the rate dQ/dt into Lake X, which has volume V. Species Y of fish lives in this lake. People in the villages on the shore eat the fish. The species will not lay eggs if the water temperature rises above temperature T. Can you schedule the heat discharges so that the fish never stop breeding?” Or similar. The same engineering skills and habits can be redirected to advance alternative goals without changing the formalism.

In the years since the 1970s, engineering education has only increased in theoretical depth. For example, material properties once looked-up in handbooks of empirical results are now routinely calculated from first principles. Along with theoretical sophistication, engineers on average have also risen in environmental sensitivity, owing in part to regulation and litigation. Secular changes have also occurred in the culture. Those, at least, are optimistic factors.

Adamson AW. A Textbook of Physical Chemistry, 2nd ed. Academic Press, New York (1979).

Van Wylen GJ, Sonntag RE. Fundamentals of Classical thermodynamics. Wiley, New York (1973).