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Response to “Comment on ‘Economies of scale: The physics basis’” [J. Appl. Phys. **121**, 206101 (2017)]

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The comment is false because it is based on an elementary mistake of thermodynamics, which continues to appear in the literature even though it has been corrected in print several times.⁶

Swartz’ mistake is the view that a large or small heat input can be received (at will) from a “high temperature reservoir.” This is contrary to nature on earth, as we will explain. First, we point out the historical origin of this fundamental mistake.

In the early teachings of thermodynamics, the “high temperature reservoir” was used to be called “heat reservoir.” This notion was misleading. The only “heat reservoir” is the ambient, the atmosphere and the hydrosphere. A second heat reservoir does not exist (Fig. 1). Had there been two heat reservoirs on earth, then any (large enough) heat engine could have generated all the power needed by humanity by sucking from the high temperature heat reservoir the larger and larger heat current imagined by Swartz.

There is a high temperature side of the thermodynamic system that we defined unambiguously, as there is a low

temperature side. Entering through the hot side of the system boundary is a heat current that is proportional to the mass flow rate of the fuel burning in the combustion chamber, which is the portion of the ambient that resides on the outer side of the hot side of our system. The environment of our system consists of the fire space and the atmosphere.

The rate at which the fuel is consumed is not free to be increased at will. Fuel comes at a premium and so does the hardware of the machine. This is why in our formulation all the features of the design are described on a per-unit of heat input basis. This is standard practice, because it is reality.

The concept of efficiency proclaims the “per-unit of fuel” reality. The history of thermodynamics (Fig. 2.1 in Ref. 1) shows that the efficiency of fire-driven engines was reported as ft·lbf (of water raised from coal mines) per bushel of coal. The hardware is the physical size, the heat exchanger surfaces (boiler, condenser) and all the piping. These finite physical things belong with the finite amount of fuel.

The mistake that Swartz made had propagated earlier in the physics literature under the titles of “Curzon-Ahlnborg efficiency” (Ref. 2 in Swartz’ comment), “finite-time thermodynamics” and “maximum power.” That mistake was detected and corrected by several authors.^{2–5} This correction is being taught in a thermodynamics textbook.¹ The correction is not controversial, it is physics on earth.

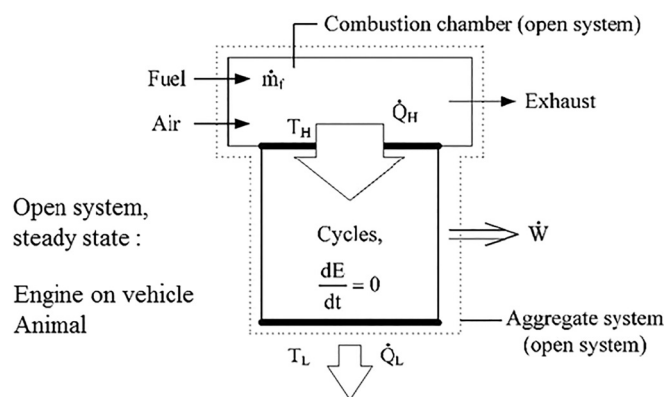


FIG. 1. The high temperature place is not a “reservoir.” The heat input to the heat engine cannot be increased at will. The heat input is proportional to the mass flow rate of fuel that is consumed.

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