1st and 2nd Laws of Thermodynamics: A New Approach to the Classic Theory

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Abstract *— It is probably universally observed at any undergraduate engineering program that the first and second laws of thermodynamics generate great fear among students as they prepare to take their first thermodynamics course. These students typically receive rather negative feedback from students whom have previously taken the thermodynamics course. Usually, students become confused with the sign convention used in the 1st law of thermodynamics for heat and work interactions, and struggle with how the 2nd law of thermodynamics is normally handled in a typical textbook of thermodynamics. At Embry-Riddle Aeronautical University (ERAU)'s Prescott (Arizona) campus, a new approach to the classic theory of thermodynamics (1st and 2nd laws of thermodynamics) has been conceived, formulated, and utilized for the undergraduate engineering course curriculum for over a decade. The authors of this paper strongly believe that this new approach for the classic theory is now ready to be presented after the significant accumulations of positive student responses as well as the confirmations of theoretical validity by multiple course instructors of thermodynamics at ERAU Prescott. This paper is not an attempt to fault anyone with respect to how the 1st and 2nd laws of thermodynamics are taught by that person at any undergraduate engineering program. Rather, it is an attempt to expose others to a new approach that may just be more useful to students in supporting them to understand and correctly solve engineering problems. The authors of this paper sincerely hope that the readers will give some very serious thoughts to the way they teach the undergraduate thermodynamics course.*

Index Terms *— Thermodynamics, Teaching Method, Sign Convention, Entropy Production.*

EXTENDED ABSTRACT: A NEW APPROACH TO THE FIRST LAW OF THERMODYNAMICS

Regarding the sign convention used to describe the 1st law of thermodynamics, most textbooks use the same sign convention. However, the authors have, over the years of educational experience in the subject of thermodynamics, found at least one textbook that employed the completely "reverse" sign convention of what most textbooks have. The most important issue here is why it is always required for the 1st laws of thermodynamics to use an "arbitrary" sign convention when, indeed, *no sign convention is actually necessary*. A new set of equations of the 1st law of thermodynamics, presented in this paper, was formulated that *do not require any sign convention*. The equations depend solely on common logic of what is "in" and "out."

The early version of this 1st law of thermodynamics formulation was developed by the first author (Felton) while he was teaching in the Department of Aeronautics at the U.S. Air Force Academy from 1972 to 1978. The Department Chair, Brigadier General Dan Daley (U.S. Air Force Retired), who was educated at Massachusetts Institute of Technology and spent most of his 45-year military career in the propulsion area, reviewed the formulation of this early version of alternative 1st law of thermodynamics and agreed that it was quite unique and made more sense. While the first author was not aware of anyone using such a formulation, only his colleagues were informed of this new approach to the first law of thermodynamics.

When the first author again became involved in education at the Prescott (Arizona) campus of Embry-Riddle Aeronautical University (ERAU) in 1988, he once more employed this new formulation of the 1st law of thermodynamics in his teaching. In 1992, Paul Hermann, an adjunct professor at ERAU Prescott, who was educated in Germany and had spent his entire career working in the thermodynamics/propulsion area both in Germany and in the United States, conducted a comprehensive and detailed review of the formulation to determine if it was consistent throughout the fundamental theory of thermodynamics. After this extensive review process, Professor Hermann adopted this new formulation of the 1st law of thermodynamics. In 2003, the second author (Hayashibara) joined the faculty of ERAU Prescott and again adopted this new formulation of the 1st law of thermodynamics after the careful review.

Today, it is hard for the authors to believe that almost all textbooks of thermodynamics still use the traditional "arbitrary" sign convention for the 1st law of thermodynamics. Over the long experience of course teaching at ERAU Prescott, it is very clear that the authors' students enjoy and appreciate this new approach. The authors believe that the formulation is quite beneficial to enhance the understanding level of undergraduate students in a thermodynamics-related engineering course.