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Simplifying the Complexities of Thermodynamics Using a Practical Application of Nuclear Energy

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1. PREFACE

In a catalog of instructional videos that I recently received there was one new topic that I had not seen before; it was a self-study program in Thermodynamics. I immediately turned to the course outline and decided to read the instructor's brief description of the program's contents. In the first sentence he summarily defined Thermodynamics as "…the movement of heat….". I was immediately deflated somewhat because I did not fully agree with this definition, not that I don't believe that the entirety of Thermodynamics is indeed inclusive of the study of and "...the movement of heat...", but it is much more than that, far more. Thermodynamics not only encompasses the study of heat and how heat and all other forms of energy [1] are transferred to and from solids, liquids and gases, but it also *is* the study of how all matter exists, co-exists and changes phase from solids to liquids, liquids to gases and back again. Further, it defines energy cycles that employ these phases of matter to generate alternate forms of energy, and to perform useful work. Practically, Thermodynamics is *so* expansive in its content and importance as an Engineering topic that it literally dwarfs many other Engineering topics. And in this expanse exists a problem. I'll elaborate…

For many years I taught a nearly year-long course in Applied Engineering to graduate Mechanical and Nuclear Engineers who were intending to sit for their Professional Engineering

[1] Such as work energy, for example

Licensing Exam. Even though my course consisted of a single 4-hour lecture each week (which frequently turned into classes six or more hours long), it *was* a very challenging course. My entire course was one of *Applied* Engineering, it was practical, real world and immediately useful to each student within his or her current job. My students possessed careers ranging from being Field Engineers in nearby Petrochemical plants, to being Senior Operators and Officers in Nuclear Power Stations [2] and Nuclear Submarines, as Systems Design Engineers in local Engineering Corporations and even as NASA Spacecraft Design Consultants. As a minimum, everyone possessed a BS Degree in Mechanical or Nuclear Engineering, while some had also continued on to complete advanced degrees. Within this amalgam of quite accomplished and learned Engineers, there was an 'issue' that persisted class after class, year after year. At the beginning of every course, after some overall introductions and a general discussion about how the course would be conducted, I asked everyone a specific and pointed question, which was, "Of all of the topics that you studied in college, which *specific* Engineering subject did you find the most difficult of all?" The overall consensus every time was Thermodynamics!

Now, why is that?

Giving this some serious thought now and again over a period of some years, in light of the reason(s) that any one or more student would venture, the answer came to me. Thermodynamics is so expansive and at times so complex and convoluted that any student listening to any professor teach what is so difficult to grasp, it is no wonder that its difficulty is all but assured. Even for myself as I recalled listening to Thermodynamics lectures immersed in raw theory without any specific examples being given, performing Integral Calculus computations for obscure reasons and making sense out of Laws of Physics that began with the 'Zeroth Law of Thermodynamics', I too found the topic a bit daunting. However, later, when I *fundamentally* realized that Thermodynamics explains:

- Why clouds form in the sky,
- Why one's glasses fog in both humid and cold weather,
- Why it takes so little time for a kettle of water to boil but it takes a seemingly endless amount of time for the water to completely vaporize,
- Why one cannot change the refrigerant in one's auto AC unit from R-12 to 134A and expect identical cooling performance,

[2] The words 'Station', 'Site', 'Plant', 'Facility' & 'Utility' may be used as interchangeable colloquial terms to describe the entirety of structures and equipment that comprise a Nuclear Power Electrical Generating Station

- How NASA knew the *precise* amount of fuel required to transport our Apollo astronauts to and from our Moon,
- How a pressure cooker can prepare one's meal in less than ½ the time of ordinary cooking methods,
- Why at 34% Nuclear Energy represents the *most* thermally efficient method of creating electricity and that one's car engine has a *maximum* thermal efficiency of a dismal 24% (contrary to the continued counterclaims of the auto industry), and
- Why Mankind is inescapably and *irrefutably* creating global warming through its indiscriminate use of carbon-based fuels, extremely inefficient and wasteful processes and associated machinery, among other facts,

I was essentially 'hooked' on Thermodynamics and all of the eye-opening facets of Engineering it exposed.

Only *after* one determines the answer to each of these aforementioned questions, and many more, is one then truly able to *begin* to realize exactly how vast Thermodynamics is. And, these previous few examples of 'Thermodynamics in action' are only the beginning; one can easily expand the list to *hundreds* more. Sorry but Thermodynamics *cannot* explain why you didn't win that $350+ million-dollar Powerball drawing; the answer is beyond Thermodynamics, but the real reason is that you didn't buy a ticket!

This all being said, this current paper is intended to provide the Engineer, novice and practiced alike, with a concise example and proof of how Thermodynamics 'works' in a real life process system, that being how in a summary fashion a Nuclear Power Station functions and why the previously stated 34% thermal efficiency can be justifiably, and definitively, claimed. In presenting the forthcoming example, when possible and practical diagrams and/or photographs of the 'inner workings' of an actual Nuclear Power Plant will be provided. It is to be noted that for a facility as immensely complex and technically 'important' as a Nuclear Power Generating Station, having *extensive* personal experience in all facets of such facilities, I assure the reader of two important issues. First, everything that I will present will be entirely truthful and accurate to the best of my knowledge, and second, at no time will any secure, classified or 'sensitive' information be divulged in any way. In this regard, what will be presented is already known by many with a similar professional background

as my own, and the documents and figures provided within are available in the public domain, but not necessarily at one source or in one easily-accessible location.

So, let's begin.